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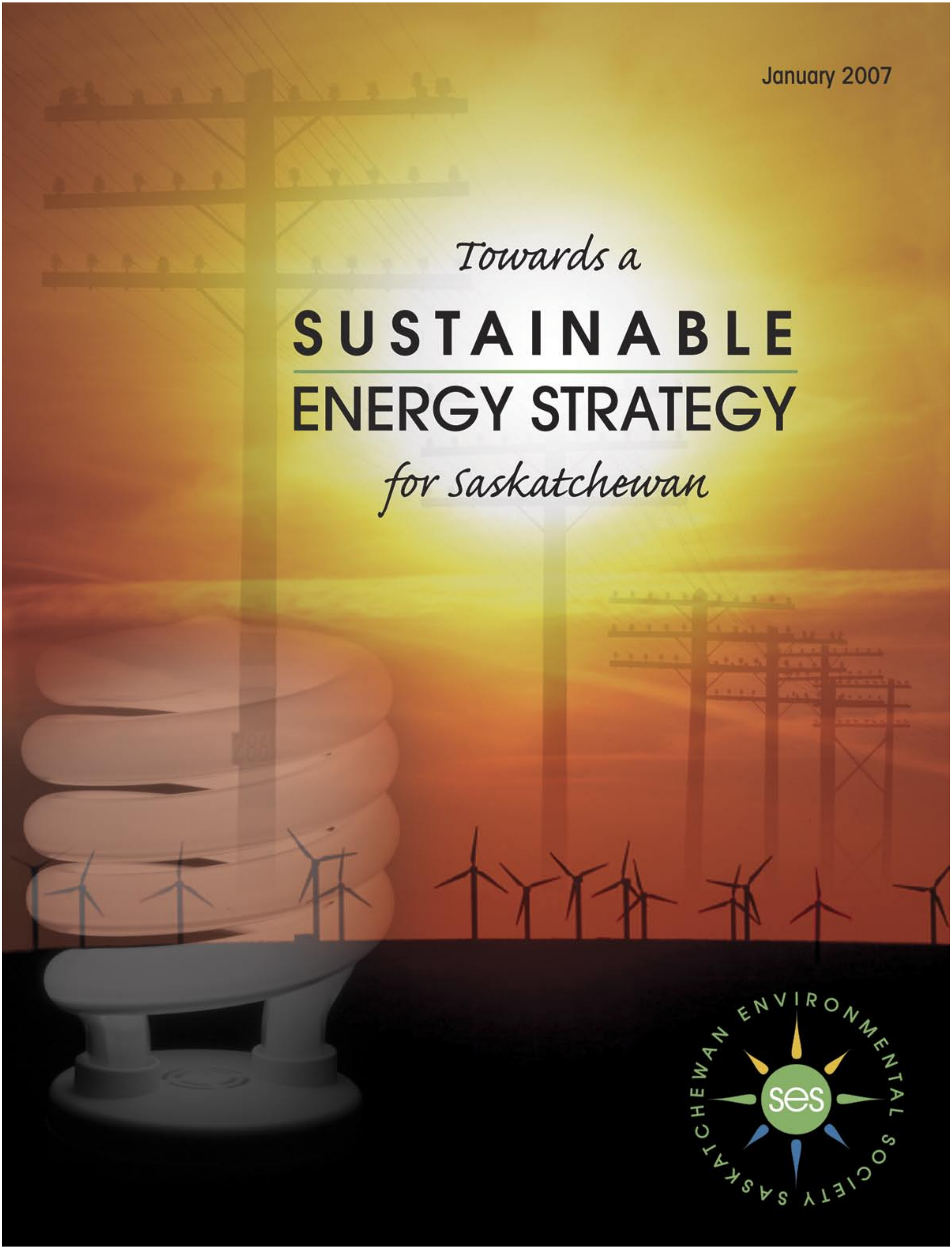

Towards a

SUSTAINABLE ENERGY STRATEGY

for Saskatchewan

SASKATCHEWAN ENVIRONMENTAL SOCIETY

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Preface

The generation and use of energy have always raised environmental concerns. Depletion of non-renewable resources, air and water pollution, management of wastes and damage of habitats—these are all energy-related issues that we have had to confront ever since the industrial age started.

More recently the over-riding concern has become the impact of greenhouse gas emissions from the burning of fossil fuels. The rate at which carbon dioxide levels in the atmosphere are increasing is completely unsustainable, and it has become urgent that we in Saskatchewan, as elsewhere, develop new approaches to meeting our energy needs. Science tells us that it will be necessary to reduce our greenhouse gas emissions by 80 per cent by the middle of this century in order to avoid the most catastrophic climate change impacts. At the same time, we will need to also address other environmental problems and avoid creating new ones as we radically transform our energy picture.

Saskatchewan's energy consumption increased 34 per cent over the 13-year period from 1990 to 2003 (the most recent figures available from Stats Canada). Most of this increase is in the form of natural gas, largely for industrial use but also in electrical generation. Our per capita energy consumption in 2003 was almost double the Canadian average, second only to Alberta's. This is due substantially to the nature of our economy, with its heavy involvement in energy-demanding resource sectors, rather than to Saskatchewan being inherently less efficient than the rest of the country. However, while recognizing the need to transform our economic base, there also is room for significant changes in the way we currently use energy and the sources from which we derive it.

This report is intended to help decision-makers to begin taking seriously the possibility of a sustainable, safe, environment- and climate-friendly energy future for Saskatchewan. We identify the nature of the resources, technologies and opportunities available to us, the barriers to their adoption, and practical steps towards a transition to an energy system based on efficiency and safe, sustainable, renewable resources.

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1

Overview of Current Saskatchewan Energy Use Trends

As of 2003, Saskatchewan's per capita energy consumption was almost double the Canadian average, second only to Alberta's.

A comparative study[1] shows that between 1990 and 2003, our province's energy consumption rose by an astonishing 34 per cent. Meanwhile our population fell by one per cent, our per capita energy consumption increased 36 per cent, and our consumption of energy per real GDP$ increased five per cent.

Seventy percent of this increase is accounted for by the rising use of natural gas. The quantity of natural gas consumed made a spectacular leap of 60 per cent in 13 years, rising from a 40 per cent share of the province's energy profile in 1990 to 48 per cent in 2003. Growth in the extraction, processing and transportation of petroleum and natural gas contributed to this surge in consumption. Use of natural gas for electricity production also greatly increased over this time period. This was coupled with a decrease in "primary electricity" production (in Saskatchewan this basically refers to hydro and wind) as river flows changed.

The proportion of Saskatchewan's total energy use that comes from refined petroleum products is lower than the national average (although our per capita consumption of these products is above the Canadian figure). Despite an increase in consumption of refined petroleum products during the 1990 to 2003 study period, the consumption share (as a percentage of our total energy use) dropped from 32 per cent in 1990 to 27 per cent in 2003. Motor gasoline consumption increased moderately, while use of diesel rose 25 per cent. Diesel fuel is widely used by oil and gas exploration and development companies in drilling and extraction as well as for transportation. Despite high coal consumption, coal's share in the province's energy profile dropped by two per cent.

Statistics Canada's summaries[2,3] show the following trends for Saskatchewan over the 1990 to 2003 study period:

1.1 Total Energy Consumption

Total energy consumption increased 34 per cent.

1.2 Refined Petroleum Products

In 2003, per capita consumption of motor gasoline, diesel fuel and heavy fuel oil in the province averaged about 129 GJ/person, about 50 per cent above the per capita average for Canada as a whole and (for further comparison) about 200 per cent above that in the UK[4] (whose transport consumption figures are reasonably typical of wealthy European countries). This high figure may be partially explained by the long travel distances required for many people in the province, including for essential purposes, and by a large agricultural machinery component. It is also compounded by limited public transit provision, poor provision for cyclists, planning strategies which permit cities to "sprawl", a growing fashion for large high-consumption vehicles, and a limited range of high-efficiency vehicles to choose from.

Consumption of refined petroleum products increased 14 per cent over the period 1990 to 2003. Within this total, consumption of motor gasoline by Saskatchewan people increased by nine per cent and diesel by 25 per cent. But because other energy use increased a great deal more than this, refined petroleum products fell from 32 to 27 per cent as a percentage of total energy consumed in the province.

In 2003, we used 61,593 Terajoules (TJ) of motor gasoline (1.76 billion litres), of which 46,466 TJ (1.27 billion litres) were for transportation and 7,410 TJ (212 million litres) for agriculture. In addition we used 58,302 TJ (1.52 billion litres) of diesel fuel oil, of which 26,839 TJ (701 million litres) were for transportation, 20,327 TJ (531 million litres) for agricultural use and 6,517 TJ (170 million litres) for industrial use.

Future consumption figures will potentially be influenced by changes in vehicle efficiency, by shifting transportation modes towards public transit and rail, by substitution of biofuels, by changes in urban design to reduce commuting distances and by changes in the nature of Saskatchewan's economy.

1.3 Natural Gas

Natural gas constituted 40 per cent of our total energy use in 1990, rising to 48 per cent in 2003. A bit less than half of this increase is attributable to electrical generation. The amount of gas used for electrical generation increased 10 fold, and by 2003 represented about 18 per cent of the total provincial natural gas use, compared to approximately three per cent in 1990. Most of the balance of the increase is a reflection of industrial use.

SaskEnergy[5] currently delivers gas to 329,000 residential, farm, commercial and industrial customers. The utility purchases gas from independent suppliers and supplies service to 92 per cent of Saskatchewan's communities. The breakdown of distribution volumes (in petajoules [PJ]: 1 PJ = 1,000 TJ) is as follows: Residential 30 PJ, Commercial 29 PJ, Farm 4 PJ, Industry 66 PJ. These figures do not include SaskPower's use of natural gas.

The majority of SaskEnergy's distribution customers consume natural gas for heating, so the volume of natural gas distributed is sensitive to weather. 2005 averaged four per cent warmer than 2004 as measured by heating degree days. So the good news is that residential customers in 2005 used 18 per cent less natural gas than in 1988, a trend resulting from adoption of energy efficiency measures as well as warmer winter weather. Customer interest in high efficiency space heating and other energy conservation efforts over the past couple of years continued to lower average consumption beyond the impact of weather. This trend is anticipated to continue. Meanwhile, however, electrical utility demand for natural gas has risen as warmer summers have increased summer power demand for air conditioning.

In trying to anticipate the future for natural gas consumption, the two big unknowns are the fuel's use in electrical generation and in industry. SaskPower is currently reviewing its options for meeting future power demand in terms of lifecycle impact assessment. Improved end-use electrical efficiency could reduce total electrical demand and thus the consumption of natural gas for power generation. Natural gas could be replaced in some applications by renewable fuels. Changes in industrial use of natural gas will depend both on price and on decisions made about the nature of future economic development strategy in Saskatchewan. A move towards use of natural gas for transportation fuel could result in seriously increased demand.

1.4 Coal

Coal consumption, almost entirely for electrical generation, has increased 27 per cent over the 1990-2003 period (the Shand power generating station came on line in 1992), but has remained fairly steady in accounting for about a quarter of our total energy use. Future coal use could fall as it is replaced by other energy sources, by improving the efficiency with which it is burned and by increasing end-use efficiency to reduce electrical demand.

1.5 Primary Electricity

"Primary electricity" (basically hydro and wind) fell 30 per cent in absolute terms over the 1990 to 2003 time period (presumably due to reduced river flow), and its contribution as a share of the total energy consumed in the province fell from three to two per cent. However, significant wind power capacity has been added to the system since then. There is room for a lot more wind capacity as well as solar power generation. New large-scale hydro development is unlikely because of environmental limitations, however there is some limited potential for small, run-of-the-river hydro generation. The amount of power delivered by existing hydro projects is expected to vary a good deal from year to year because of fluctuating river flows. SaskPower regards nuclear power as currently unsuitable for Saskatchewan because the production units available are too large to be accommodated within our grid.

1.6 Electrical Demand and Supply

As of the end of 2004, SaskPower operated 15 generating facilities with an installed capacity of 3056 MW.[6] The system included three base-load (coal) thermal stations, seven hydro stations, four gas-fired peaking stations and the Cypress wind facility. The new Centennial Wind Project adds another 150 MW of wind power capacity to raise the total wind energy capacity to 172 MW. In addition 449 MW of generation capacity is available through long-term purchase agreements with Cory Co-Gen (gas-fired), Meridian Co-Gen at Lloydminster and SunBridge Wind Power. Interconnections with Manitoba, Alberta and North Dakota allow for limited trading across borders.

Sales of electricity grew approximately one per cent in 2005 over 2004 in all customer classes except for farms. A two per cent overall increase is anticipated for 2006. Expectations are subject to significant variability as a result of weather, economic conditions, number of customers and market conditions. Hydro generation increased substantially in 2005 over 2004 as a result of higher water availability last year. However the long-term prediction is for reduced river flows as climate changes.

It is anticipated that over the next two decades most of SaskPower's fleet of thermal generating plants will need replacement or refurbishment. Meanwhile, the utility has adopted a strategy to meet new load growth over the next several years using Environmentally Preferred Power (EPP). SaskPower intends to acquire up to 45 MW of EPP through a competitive solicitation process. This strategy is intended to encourage low environmental impact power, use waste streams as a fuel source, reduce SaskPower's emissions (presumably on an intensity basis rather than in absolute terms) and add small generation units in step with SaskPower's load requirements.

2

Sustainability and the Need for Change

2.1 Defining Sustainability

Before discussing the technical, social and political choices the leaders and people of Saskatchewan can make to ensure a sustainable energy future for our province, the term "sustainable" should be defined. It is a term that is widely overused and often misunderstood. The standard definition is that of the Brundtland Commission in regards to sustainable development, which reflects behaviour that "meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition of sustainability is based on three pillars or criteria: economy, environment and equity. Any energy technology or fuel will have to satisfy all three criteria in order to be deemed truly sustainable.

The "Natural Step" model has similar foundations and can also be used to prescribe sustainable energy policies. The Natural Step (TNS) Framework provides both a science- and systems-based definition of sustainability and a process to use this definition for decision-making and planning. Using the TNS definition, a path of sustainable development must be guided by the following objectives:

- To reduce and eventually eliminate our contribution to a systematic increase in Nature of the build up of substances taken from the Earth's crust (because these substances are often foreign to life systems and exist in limited supply).
- To reduce and eventually eliminate our contribution to a systematic increase in Nature of the build up of substances produced by society (this refers to synthetic chemical compounds that are not naturally occurring).
- To reduce and eventually eliminate our contribution to a systematic degradation of natural systems by physical means (i.e., avoid damaging ecosystems and don't use renewable resources at a rate greater than that at which they are replenished).
- To reduce and eventually eliminate our contribution to systematically increasing barriers that undermine peoples' capacity to meet their needs.

In terms of energy use and energy production, these objectives lead us to consider the following issues:

- Deriving energy from the burning of fossil fuels has led to a systematic increase in greenhouse gases in the atmosphere, leading to climate change. Local air quality problems can also be attributed to the use of fossil fuels
- To produce and use energy in more sustainable ways we must use energy as efficiently as possible and develop energy from renewable sources in a way that safeguards ecosystems and the basic needs of people.
- We should reduce dependence on materials removed from underground (e.g., fossil fuels, uranium) in order to minimize the introduction of foreign substances into the biosphere.
- The chemical substances that we make to use in the products and processes of our society, or which occur as waste products, eventually end up in our air, water and land. Because these substances are foreign to Nature, there are inadequate natural mechanisms to break them down and they tend to persist. As we continue to add more of these substances at a rate faster than Nature can break them down, they increase in concentration and at some point they become toxic. Therefore the means by which we produce and use energy must avoid the release of persistent and unnatural compounds. We should use materials that are abundant or break down more easily in Nature, use them efficiently, and keep them in closed-loop cycles.
- We interfere in Nature's ability to run the sun-driven cycle that supports all life on the planet when we physically remove or degrade it (e.g., by destruction of natural landscapes) thereby systematically decreasing the capacity of Nature to harness the energy of the sun. In our production and use of energy we must take resources only from well-managed ecosystems, use resources and land most productively and efficiently, and exercise caution in all kinds of modification of Nature.
- As long as people's basic needs are not met, they cannot make ecological issues a high priority. In producing and

using energy we must use all resources efficiently, fairly and responsibly, ensure that people have safe working and living environments, make certain they have sufficient resources for a livelihood and that human rights are respected.

2.2 Sustainability and Climate Change

The link between energy and climate change is the prime and most urgent motivator for change in energy policy.

"The investment that takes place in the next 10-20 years will have a profound effect on the climate in the second half of this century and in the next. Our actions now and over the coming decades could create risks of major disruption to economic and social activity, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century. And it will be difficult or impossible to reverse these changes."[7]— *Sir Nicholas Stern, former Chief Economist at the World Bank*

Truly, any debate about the urgency for action on climate change is, or should be, over. We can no longer ignore signs such as melting ice caps in the polar regions and the opening up of the Northwest Passage. Hurricane Katrina was an example of severe weather patterns that are increasing in frequency and intensity all over the world, and which illustrate the kind of impact climate change models predict. Low-lying coastal areas are beginning to experience rising sea levels, flooding, and resulting water-borne illnesses.

While, to some, climate change may initially seem like a gift for cold areas such as Saskatchewan, in practice it is likely to mean:

- Longer and more frequent severe droughts.
- Reduced river flows as the glaciers and mountain snows which feed our rivers shrink.
- Erratic rainfall, with more frequent and more serious flooding.
- Loss of at least the southern part of the boreal forest.

In the face of these impacts, which are already beginning to appear, Saskatchewan is doing a less than adequate job of limiting its contribution to climate change. We currently lead the country in greenhouse gas (GHG) emissions per unit of GDP.[8] Over 70 per cent of our energy demand is met by fossil fuels. Yet we still lack commitment to a comprehensive provincial climate change plan.

2.3 Sustainablity and Energy Options

Over the past year or two we have seen some modest but important steps taken in Saskatchewan to foster growth of renewable energy and improvement in energy efficiency, the two major tools available for making our energy picture greener. SaskPower is currently meeting new capacity needs by addition of small, "environmentally preferred" generation units. The recent growth of the wind energy industry is significant. Programs to make energy efficient appliances and home energy audits more affordable are in place. Some tentative moves toward replacement of fossil transportation fuels with biofuels are taking place. Peter Prebble's December 2006 report to the Premier, Renewable Energy Development and Conservation in Saskatchewan, describes a wide range of potential, practical measures to support a transition to sustainability.[9]

Meanwhile, the primary focus for longer-term provincial electrical generation planning remains fixed on large scale, centralized, fossil-fuelled projects. The potential for demand-side management is only minimally exploited. Our cities are increasingly designed to accommodate cars rather than pedestrians, cyclists and bus-riders. We still have a long way to go, and clearly energy efficiency and conservation provide the most cost-effective route to sustainability.

However, even when we are efficient, we still need to use energy. The major supply options from which we have to choose are fossil fuels, wind power, hydro, solar, biomass and nuclear. None is entirely free of environmental impacts. The varying nature of the impacts often puts us in the position of having to compare apples and oranges, to determine, for example, whether we are more concerned about birds flying into windmills or mercury pollution from coal-burning.

It is unlikely that we will find any one technology that will answer all our concerns. We will need to find the best possible mix of technologies and sources to supply needed energy with the lowest possible environmental damage.

2.4 Energy Sources - Sustainability Issues

In the following paragraphs we will review the sustainability issues presented by the various energy sources.

2.4.1 Coal

The burning of coal creates airborne emissions of locally hazardous contaminants such as oxides of nitrogen and sulfur, as well as dioxins, heavy metals and particulates. Coal is also the most greenhouse gas intensive fuel. It produces more carbon dioxide per unit of energy than does any other energy source. Coal mining (strip-mining) creates massive and long-lasting landscape damage and brings toxic materials into the ecosystem.

The degree of environmental and health damage caused by the use of coal depends largely on the kind of technology that is employed. Various forms of so-called "clean coal technology" can improve the efficiency with which electricity is produced from coal and can reduce the levels of contaminants released into the atmosphere. There is also the potential to capture the carbon dioxide emissions, which can be sequestered in underground storage, potentially enhancing the extraction of oil from partially depleted reserves.

Saskatchewan has enough coal to last another 50 to 100 years at present rates of extraction, it is cheap (especially if one ignores the environmental costs) and we have a long history of using it. At present, it represents our major electricity source.

Although the concept of "clean coal" with carbon capture and storage is clearly an improvement on our present way of using coal, there remain a number of concerns. Collecting and storing the carbon dioxide emissions itself requires a lot of energy. Thus, in order to generate a given amount of usable electricity, one has to produce an additional 25 per cent or so to run the carbon capture system.

"Certainly there is no free lunch—such plants are energy intensive and burning more coal for the same electrical output and impacts to land and water bodies due to coal mining remains of concern. The technology also requires the development of expensive pipeline infrastructure to transport emissions to a suitable underground reservoir, along with further research to address potential impacts of the entire system."[10]— *Pembina Institute*

The long-term sustainability of carbon capture and sequestration systems is still questioned. There are concerns about the potential for leakage of sequestered carbon dioxide from burial sites, and the possible impacts of acidification of underground environments by the sequestered gas.

In his book Big Coal, author Jeff Goodell explores America's dependence on fossil fuel and explains his concern for industry "spinning" the concept of clean coal. He illustrates the irreparable environmental damage seen in states such as Virginia; the daily risks posed to miners (according to the US Department of Labor, coal mining is still one of the most dangerous occupations), as well as its long-term health effects like lung disease and cancers. The "clean coal" approach does not remove these problems.[11]

Environmentally speaking, therefore, clean coal is not a highly desirable path. It is important to recognize, however, that this technology is much "better than" the traditional coal plant, so there may be an appropriate role for it within the province as an interim replacement for some of our old coal plants. While coal is considered a cheap energy source, the construction of a clean coal plant is not cheap. SaskPower estimates the development of a clean coal facility of the type presently under consideration would cost $1.5 billion. Note that this is not the most efficient form of clean coal technology available. Integrated Gas Combined Cycle (IGCC) is both more efficient and more expensive.

2.4.2 Natural Gas

Greenhouse gas emissions from natural gas are significantly lower per unit of energy than those from coal or oil. However, they are by no means negligible, so the climate change impacts of this fuel source are a concern. Not only do we have to worry about the carbon dioxide produced by burning of the fuel; also the inevitable leakage of gas from pipelines releases methane, an even more potent greenhouse gas, into the atmosphere.

Readily accessible natural gas supplies appear to be diminishing, so we are increasingly moving into remote, previously unindustrialized areas in search of new supplies. This is seriously impacting wilderness areas and wildlife habitats. Extraction of coal-bed methane, a practice that has spread from the United States into Alberta (but not so far into Saskatchewan), is particularly hazardous to ecosystems. Pipelines, many thousands of kilometers in length, are being built for transmission of gas, generally from the north and west towards southern and eastern markets. The impacts on migrating animals are a concern, as is the fragmentation of habitats by roads and forest clearing, and the risk of local ground and water contamination with drilling wastes etc.

Because natural gas is a relatively simple mixture of chemicals, there is less concern about toxic emissions from controlled gas burning than there is from other fossil fuels. The cost of natural gas is unstable, making it difficult to plan economically if one is very dependent on this as a key energy source.

2.4.3 Nuclear Energy

"As far as power is concerned, all options are on the table and we shall continue to consult Atomic Energy of Canada Limited about technology updates concerning the use of nuclear power in Saskatchewan."[12]— *Larry Christie, SaskPower*

There has been a lot of discussion about the potential of nuclear energy to help meet Saskatchewan's commitment to a greener future. The debate about the appropriateness of nuclear power as an energy choice for this province is fairly polarized and often emotional. Proponents are widely viewed with skepticism, considered to be putting short-term economic interests above the safety of future generations, while opponents are accused of being ill-informed tree-huggers who would prefer to work by candlelight.

Nuclear energy is represented by the industry as a safe, economically efficient option that results in low greenhouse gas emissions. However, a major issue that cannot be ignored is that there is no satisfactorily demonstrated technology anywhere to ensure the safe confinement of the highly hazardous used fuel wastes for the extremely long time periods over which they remain an environmental threat.

Wastes from the uranium mining and milling processes also create very long-term potential ecological and human health hazards. The risk of nuclear materials being diverted into weapons use is unavoidable. There really should be no discussion beyond this point. However, even if one chose to ignore these issues, the cost of the technology is a strong deterrent.

New nuclear plants deliver electricity at far higher cost than end-use efficiency, distributed cogeneration and many renewables.[13] Any new nuclear plants will have to face the major issue of their high cost in the context of a competitive electricity market. Nowhere, according to the Rocky Mountain Institute, do market-driven utilities buy, or private investors finance, new nuclear plants. Nuclear power can compete with other options only when it is generously supported by disproportionate government subsidies.

If we were able to reconcile the cost, we would still need to determine how a nuclear plant would fit into our existing grid. At present, the smallest available plant would produce 600 MW. This would represent close to one fifth of the total provincial generating system. If such a large plant were to go out of service, there would be inadequate capacity within the system to provide back-up power. This is a weakness of all large, centralized power stations, regardless of the source.

2.4.4 Hydro-Electricity

In 2000, the World Commission on Dams released the report Dams and Development: A New Framework for Decision-Making. Within this report, significant concerns are expressed about the ecological effects that have been found across the globe with the creation of large dams:

- "The loss of forests and wildlife habitat, the loss of species populations and the degradation of upstream catchment areas…
- The loss of aquatic biodiversity, of upstream and downstream fisheries, and of the services of downstream floodplains, wetlands, and riverine, estuarine and adjacent marine ecosystems; and
- Cumulative impacts on water quality, natural flooding and species composition..."[14]

This does not mean that there is no role for new hydro-electricity projects in a sustainable energy strategy, but our focus should be on the potential for small "run-of-river" systems that harness the energy of water without flooding to create a reservoir. While they are not capable of producing as much energy as a reservoir system, they have a much smaller impact on the environment. The lack of a reservoir means lower methane and carbon dioxide emissions (from biomass decomposition in flood water), greater oxygen content in the water, and less disturbance to wildlife

2.4.5 Refined Petroleum Products

Oil and gasoline fall between coal and natural gas in greenhouse gas intensity. The huge quantities of these products that we use in transportation results in the transportation sector being responsible for over 24 per cent of our total greenhouse gas emissions in Canada.

The transportation sector is also responsible for deteriorating air and water quality. Automobile exhaust contains harmful chemicals including carbon monoxide, nitrous and nitric oxides, sulfur dioxide, benzene and formaldehyde. These chemicals are carried through the air into our lungs and are deposited onto the food we eat and water we drink. A number of recent studies have associated this pollution with health effects such as lung disease (including childhood asthma), heart disease and hypertension and certain cancers like leukemia and lymphoma.

The upstream oil industry causes significant ecological impacts (habitat fragmentation, air and water contamination, introduction of invasive plants) through exploration, development and waste disposal activities. As conventional oil supplies are depleted, there is greater dependence on the hugely destructive oil sands developments, which completely destroy landscapes, convert clean river water into contaminated waste ponds and spread air pollution into Saskatchewan. As a non-renewable and rapidly depleting resource, oil cannot be regarded as a long-term sustainable energy option.

2.4.6 Wind

With regards to the environment, the construction, erection and operation of wind turbines is a relatively benign process. Once the construction is completed, the only greenhouse gas emissions will be from vehicular traffic associated with servicing. There have been concerns expressed such as interruption of migratory bird pathways, noise, and visual disruption of the natural landscape. The first concern can be, and has been, mitigated by avoiding siting wind farms along migration paths. According to the National Wind Coordinating Committee, "Wind plant related avian collision fatalities probably represent from 0.01 to 0.02 per cent of the annual avian collision fatalities in the United States."[15] It seems birds are far more likely to meet their demise on our windshields, skyscrapers and radio towers than they are on our wind turbines.

In terms of noise, with modern turbines, one should be able to stand directly under a moving turbine and carry on a normal conversation. One study found that at a distance of 350 m, (which is standard between wind farms and residential property) the typical wind farm produces about the same decibels to the listener as their own air-conditioner or gas-powered fireplace.

The argument that turbines spoil the view is really quite subjective, depending upon a personal definition of beauty. To be fair, this concern has been voiced by German citizens, some of whom feel that their limited landmass is being overtaken by turbines. In Saskatchewan, blessed with abundant wide-open spaces, this will be less of an issue.

It has been pointed out that a very large conglomeration of wind power units has the potential to impact local wind movement. It is unclear yet whether this could create any significant problem.

Problems with the intermittency of wind-power are discussed in Section 4.2.1 of this report.

2.4.7 Solar

Like wind, solar systems produce no GHG emissions in their operation. Any environmental concerns will stem from the energy intensive production and disposal of photovoltaic cells, which may contain harmful chemicals. They also use resources that are becoming increasingly scarce, such as indium and silver. Continual improvements in technology are resulting in cells becoming thinner and more efficient, the use of different materials, and rapid drops in cost. Use of solar energy for heating (space-heating, hot-water) has minimal environmental impact.

2.4.8 Biomass

Biomass constitutes a broad range of plant and animal-based materials. Biomass fuel can come from wood waste, deliberately planted trees, agricultural residues, fast-growing energy crops or animal waste. Sometimes domestic refuse is also included in this category for convenience. If plant material is grown sustainably there is theoretically no net change in atmospheric carbon dioxide levels when it is burned. In practice, however, there is some use of fossil fuel involved in the production, harvesting and processing of the biomass material. The degree to which biomass fuels approach climate-neutrality therefore varies.

Cellulose-based biofuels (wood, straw, etc) may be burned in solid form, or subjected to pyrolysis to give a mix of liquid and gaseous fuels, or to gasification to produce a gas rich in carbon monoxide and hydrogen. Putrescible waste (both agricultural and domestic) may be subjected to anaerobic digestion, in which bacterial action produces a combustible gas (mostly methane) and leaves behind a nutrient-rich residue which can be used as a soil improver or fertiliser. Ethanol may be produced from cellulose by an integrated gasification—catalytic conversion process, by steam or dilute acid pretreatment followed by enzymatic hydrolysis of cellulose, or by simple fermentation of starchy crops. Oil from canola (and other) seeds may be transesterified to produce biodiesel. Other processes may be used to generate hydrogen, or methanol, or butanol.

Thus a wide range of raw feedstocks may be used to make an equally wide range of fuels, each with its own advantages, disadvantages and sustainability issues. Criteria for evaluating bio-energy projects must include net greenhouse gas impacts, forest and wildland ecosystem impacts, competition for land-use between food and fuel production, soil conservation, and impacts on traditional users of land, as well as all the usual factors included in an environmental impact assessment. These impacts will be found to vary greatly among different locations and different types of project. This has given rise to a lot of controversy as people have tried to generalize about impacts. It is important to ensure that each potential project is individually reviewed to assess its potential impacts.

Currently in Saskatchewan we are particularly interested in the use of ethanol and biodiesel as transportation fuels. The environmental impacts of such renewable fuels differ depending upon the source material and the production process used. If a crop is grown specifically for fuel production, the fossil fuels and energy used to grow that crop must be taken into account in calculating the greenhouse gas benefits. This would be significant in the case of growing corn or wheat for ethanol. The greenhouse gas costs and benefits have to be calculated in terms of energy consumed and emissions produced. The financial and environmental costs of fertilizers and pesticides used in growing the fuel also have to be accounted for. With these factors in mind, the derivation of ethanol from cellulosic materials such as straw or woody waste material is preferable to using grains.

There has been controversy about the amount of greenhouse gas reduction that results from substituting ethanol produced from grain for gasoline. Some analyses of American plants based on corn grain suggested that the greenhouse reduction was quite low. The amount of greenhouse gas emissions reduction from plants in western Canada based on wheat grain as the raw material was investigated recently by $(S\&T)^2$(2006)[16]. All the analyses assumed that ethanol was blended in gasoline at the 10 per cent level. The amount of greenhouse gas savings in these 10 per cent blends was compared to using gasoline without any ethanol (See Table 1).

These results and others in the $(S\&T)^2$ report, suggest that there are possible changes in the way farmers grow the grain for processing and in which the processing plant saves energy or uses renewable energy in the operation of the plant, which could significantly increase the greenhouse gas reduction achievable by using ethanol in blends with gasoline.

Table 1.

Effects of changing how ethanol is produced from wheat grain or wheat straw on the total greenhouse gas emissions of a 10 per cent blend of ethanol in gasoline. Comparisons to gasoline without any ethanol added.

Method of producing ethanol used in the blend	Reduction in total greenhouse gas emissions of a blend of 10% ethanol and 90% gasoline compared to pure gasoline (%)
Conventional plant to produce ethanol from wheat grain.	3.9
Capture waste heat from another industrial operation to meet 50% of the thermal energy needs of the ethanol plant (e.g., Lloydminster ethanol plant).	4.9
Plant using waste wood or surplus straw as an energy source for thermal energy needs, plus capture carbon dioxide from fermentation and sequester underground, plus grow the grain using zero tillage or after forages in the rotation to increase soil organic matter.	9.7
Produce ethanol from wheat straw using the Iogen process.	6.3

Source: (S&T)[2]

Although biomass is a renewable resource, and thus has inherent sustainability advantages over fossil fuels, the following cautions, in addition to those described above, need to be recognized. Ethanol, on a volume for volume basis, delivers less energy than gasoline. This needs to be taken into account in making cost comparisons. Most air emissions from combustion of ethanol (carbon monoxide, nitrogen oxides, volatile organics etc) are lower than those from gasoline. Emissions of acetaldehyde are slightly higher. Any system that involves combustion of solid biomass, especially municipal solid wastes, has the potential to release toxic gases, so would need to be approached with caution. Simple wood-burning for heating homes can result in the release of particulates and other emissions hazardous to health unless the combustion takes place in an efficient stove. Obviously the rate of use of firewood must not exceed the rate of replacement of wood growth

2.4.9 Ground Source Heat

The relative constancy of the temperature of the earth a few metres below the surface can provide a source of low-level heating in winter and cooling in summer. A heat transfer agent is pumped through piping in an underground field. In Saskatchewan, the fact that the pumping requires the use of electricity that is mainly produced by burning coal seriously undermines the potential reduction in greenhouse gas emissions associated with this energy source.

2.5 Moving Towards Sustainability

The debate about whether or not climate change is occurring is over. Indeed, many academics and writers are already moving on beyond preventative measures and solutions towards policies of adaptation and environmental security. There is considerable concern that we may have already missed the boat. We must now take responsibility for our excessive greenhouse gas emissions and use the solutions that we already know exist that will protect not only our environment, but also our economy and way of life.

Saskatchewan has the capacity to innovate and adapt to change. What remains to be seen is who is willing to take the leadership in making these changes happen? The following sections will further explain our options and illustrate the opportunities that are available to the provincial government, urban and rural municipalities and every individual or organization in the province.

Readers will find useful background information in a series of reputable national studies, published in the past year, which deal with methods to improve the sustainability of Canada's energy systems.[17,18,19,20,21]

3

Energy Efficiency Improvement and Conservation Opportunities

Over the past 30 years, it has been consistently shown that it is generally cheaper to reduce end-use energy consumption through efficiency savings than to produce more energy to achieve the same result in terms of energy services. Throughout the world, as developed industrial economies have continued to grow, their energy consumption has not kept pace: energy intensity has generally consistently dropped. We believe that in a free market this process is inevitable; however, the urgency of the task of global warming mitigation is such that it needs to be helped on its way, partly by removing obstacles to the process, and partly by direct incentives.

With oil and gas prices unstable and on a long-term upward trend, more and more energy efficiency options are becoming economically favourable. If consumers were expected to pay the full environmental cost of fossil fuel consumption (i.e., if externalities were accounted for in the price through taxation or some other mechanism), the economic case for efficiency and conservation would become even more starkly obvious.

In this section, we identify the areas in which the energy intensity of Saskatchewan's economy can be further reduced.

3.1 Energy Efficiency in Buildings

Levels of insulation in walls, attics and basements or floors in Saskatchewan buildings are highly variable – depending largely on the age of the property. With the exception of a few recent superinsulated buildings, however, standards could be substantially increased. When comparing with current European standards, it is noticeable that similar insulation levels are used in Saskatchewan although we have a much more severe winter climate and generally our buildings are larger. The result is unnecessarily high energy consumption for heating. We therefore believe that there is a need to provide enabling mechanisms for building owners to retrofit additional insulation, and for all new buildings to meet more exacting specifications.

The Canadian building industry has shown itself able to meet high specifications for windows. The best quality, low heat loss types (double or triple pane, with argon fill and low emissivity coating) should become the norm in all new building work. Further savings may be made by using glazing in passive solar design: this is discussed further in Section 4. The Canadian building industry has also shown itself able to meet high specifications for airtightness and ventilation control. Best practice should become the norm in all new building work. Ventilation heat losses may be reduced further through use of heat recovery ventilation systems and solar inlet air preheat systems.

Furnace and boiler efficiencies of over 90 per cent are now common. The province's existing programmes enabling replacement of old units with modern efficient ones should continue, as should provincial support to enable upgrading of domestic heating controls, which can make a significant difference to overall fuel consumption. In larger buildings, the same concerns apply, and more sophisticated control mechanisms become practical

Hydronic systems of heat delivery, especially those using underfloor piping, have some advantages over blown-air heating. They enable more consistent heat distribution, with no serious hot or cold spots. By operating at a low temperature they enable condensing boilers to run at maximum efficiency for much of the time. Perhaps most significantly, in the absence of continuous forced air flow, residents/occupants feel comfortable at lower temperatures, enabling the thermostat to be turned down.

Air conditioning should not be necessary in any home or small business facility, except where unusually high concentrations of electronic equipment make other means of controlling summer temperatures ineffective. The first recourse in designing summer cooling should be to pursue strategies based on shading, ventilation and thermal mass. When these strategies are inadequate, the most efficient available systems should be utilised, and immediately after installation should be subject to a commissioning process including proper balancing of air flows.

Electrical loads may be reduced in a number of other ways. Purchasing policies should specify low-consumption models of white goods, electronic equipment, etc. Incandescent tungsten light bulbs should be replaced with compact fluorescent and light emitting diode units; T5 and T8 fluorescent tubes should increasingly replace the more common T12s.

One factor that sometimes discourages home-owners from making major energy improvements to older homes is the recognition that, after incurring the cost of the retrofit, they may not live in the house long enough to benefit from the reduced energy costs. An interesting model for dealing with this disincentive is to cover the retrofit costs through a municipal Local Improvement Charge that is paid off through the annual tax bill on the house. Thus the cost is shared with the new owners of the property.

3.2 Energy Efficiency in Industry

In countries that have made the greatest gains in energy efficiency over the past 20 years, it has generally been the industrial sector that has led the way. It is here that many of the largest savings can be made on a cost-effective basis. The options available for energy saving are numerous and diverse, and vary considerably from one industry to another. Much can usually be achieved at no cost or low cost. Examples in this category include proper setting of temperature controls, regular maintenance of burners, avoidance of unnecessary ventilation, and elimination of leaks in pneumatic lines, steam pipes, etc.

Many fans and motors are running at a non-optimal speed for most of their period of use. Significant efficiency gains may often be achieved by variable-speed motors with appropriate controls.

In many processes, it is possible to recycle heat by means of heat exchangers. This has been common practice in the chemical industry for many years; however, it is by no means universal in other industries.

For high temperature processes, conventional shell-and-tube heat exchangers are no longer practical, but savings can be achieved by means of regenerators, in which heat is collected from the process and stored in refractory materials and released to preheat the input materials.

Techniques to optimise process design from an energy point of view may be applied to any process, from a pizza parlour to a major mining and refining operation. Because each situation is different, an accessible consultation service is required in order to help businesses and industries plan appropriately.

3.3 Efficient Use of Energy in Electrical Generation

One benefit of local power production on a distributed generation model (see Section 4.2.1) is the opportunity for local use of waste heat from thermal power stations.

Thermal power stations (i.e., those in which electricity is generated from the heat given off by combustion of a fuel), are inherently inefficient. The second law of thermodynamics sets maximum theoretical achievable efficiencies (Carnot efficiencies) for such a process; in practice it is not technically possible to come even close to these. Hence a traditional fossil fuel plant using steam turbines is between 30 and 40 per cent efficient; combined cycle gas turbine plants can reach 50 per cent. The remainder of the energy released from the fuel is lost as low-temperature heat into the environment (usually via cooling towers).

In a combined heat and power (CHP) station, this heat is recovered and used for appropriate purposes—mostly space and water heating in local buildings. While the situations most financially suitable for CHP are those in which there is a significant year-round heating load (e.g., indoor sports/leisure centres, hotels and airports), it can also be used for district heating of housing and offices.

This is a mature technology: it is in widespread use in northern Europe, on all scales from single buildings to whole cities.

Co-generation plants are similar in that they also use both heat and electricity derived from the same fuel supply. Generally waste heat from an industrial process creates steam to drive a turbine that produces electricity.

The principal problem with CHP or co-generation plants is the matching of loads—the heat and electricity requirements do not necessarily rise and fall at the same time. While technology is available to vary the ratio of power to heat output, this can only be done within certain limits. One way of reducing this problem is to use electrical surpluses to electrolyse water, producing hydrogen which may be used either for direct combustion or in fuel cells. (see Section 4.2.1) As noted above, this approach would also be of benefit for grid stabilisation.

3.4 Energy Efficiency in Transport

Greater energy efficiency in transport requires three different approaches, which should be seen as part of a package, not as alternatives to each other:

3.4.1 Technological Development

While policy makers in Saskatchewan are unable to directly influence the direction in which vehicle manufacturers direct their research and development, they are able to create policy favouring the uptake of more energy-efficient vehicles and more carbon-efficient fuels. The following factors are relevant:

- Smaller cars are more energy-efficient than larger cars.
- Lighter-weight vehicles are more energy-efficient than heavier vehicles of the same size.

- Diesel vehicles are usually more energy-efficient than gasoline vehicles of the same size
- Hybrid gasoline-electric vehicles, such as the Toyota Prius, have both an internal combustion engine (as in a conventional vehicle) and a large battery system coupled with electric motors which can also directly drive the wheels of the vehicle. Whenever the vehicle applies the brakes to slow down or stop, the electrical motors operate in reverse as generators, and recharge the battery. Through this and other mechanisms, the hybrid vehicles have considerably greater fuel efficiency than a conventional internal combustion engine powered vehicle. Within the next few years, the first hybrid diesel-electric cars will become available. We can expect the fuel efficiency of these models to be even better.
- Electric vehicles and plug-in hybrids: Long travel distances make Saskatchewan a difficult testing ground for purely electric vehicles. The existing range of hybrid vehicles (e.g., Toyota Prius, Honda Civic Hybrid, etc) enable higher energy efficiency, but not fuel substitution—the electrical motive power still results from gasoline combustion. However, there are vehicle designs in development intermediate between these two options. Known as "plug-in hybrids", this type of vehicle will still have a small gasoline or diesel engine, but will rely on a larger electrical battery capacity than a conventional hybrid; it will be possible to charge these batteries from an external electrical source as well as from the engine. When they enter the market, plug-in hybrids will thus offer the option of fuel substitution with locally-generated renewable electricity, either through overnight charging or through incorporation of photovoltaic panels on the body of the vehicle.

Lester Brown of the Earth Policy Institute in the United States has proposed that this plug-in hybrid system be coupled with use of wind power electricity to provide a means to store wind energy electricity from overnight winds for use during the day, and greatly reduce the consumption of liquid fuels.[22] He estimates that a total reduction of liquid fuel use, in urban driving, could be as high as 70 per cent.

Two companies are now offering conversion packages to change a conventional hybrid vehicle into a plug-in hybrid (PHEV). These companies are Hymotion[23] of Toronto, Ontario, and EDrive Systems[24] of California. Both companies offer systems employing lithium ion batteries which have higher power density than the nickel-hydride batteries used in conventional hybrid vehicles.

Manitoba Hydro is testing the EDrive system from EnergyCS in a converted Toyota Prius.[25] Manitoba generates most of its electricity from hydro; thus using more electricity to power vehicles, and using less gasoline, would reduce overall greenhouse gas emissions. The benefits in provinces which generate much of their electricity from coal would be less clear. The American Council for an Energy-Efficient Economy (ACEEE) cautions in a recent report[26] that plug-in hybrids' benefits to the environment depend greatly on how electricity is generated. In places where most electricity is now generated from coal burning only small reductions in greenhouse gas emissions would result compared to burning gasoline in a conventional hybrid vehicle. The present extra cost of the batteries ($10,000) could not be recovered in net savings in gasoline consumption cost in the lifetime of the vehicle. Improvements in lithium ion batteries with time could improve the economic situation.

- **Fuel Cells**

  In a fuel cell, hydrogen and oxygen are reacted to form water; the energy output is electrical rather than heat, enabling greater efficiency than with a conventional engine. However, in order to achieve lifecycle savings in carbon dioxide emissions, it is necessary that:

  a) The hydrogen be produced by electrolysis of water (or reformation of methane of biological origin), rather than reformation of fossil fuels.

  b) The electricity used be generated from renewable sources.

  Fuel cell technology still faces a number of challenges in becoming viable on a mass scale, and the infrastructure for hydrogen provision needs to be put in place before it becomes logistically viable. However, it could play an important part in the short to medium term for institutional vehicles which carry out regular short journeys, and in particular for public transit vehicles. In these cases, hydrogen could in principle be generated locally.

  This option is currently being explored by a number of city public transport utilities in Europe, following a successful trial in ten major cities in Europe and one in Australia in 2003–2005.[27] The European trial found that fuel cell buses could already compare well on cost with modern high-efficiency diesel models; the most economic source of hydrogen depends on the relative costs of natural gas and renewable electricity.[28]

- **Lower-CO2 fuel options** are not discussed here, but will be considered in Section 4 under renewable energy.

3.4.2 Transport Policy Measures

The private automobile may be a necessary convenience for many rural residents of the province, but not all journeys need to be by car. Policies which encourage the use of public transit systems, both within cities and on well-used intercity and commuter routes, will enable a reduction in energy use and in net carbon output. The same applies for policies to encourage cycling and walking, not just as a means of exercise but also to travel to work, to do errands etc. A policy portfolio which takes the problem of global warming seriously will, therefore, include inducements to encourage modal shift towards these less energy-intensive modes of travel.

An energy-aware approach to transport policy however, is not just about encouraging people to use buses or to cycle, but also must consider whether there are means of shortening necessary journeys, reducing their number, optimising load factors, etc. Planning policies which permit urban sprawl, and which locate services at a distance from residential areas, add to energy wastage. Commuter journeys with a single occupant in the car are also wasteful: this can be addressed by incentives for car-pooling schemes.

In order to analyse possible policy options to encourage modal shift, it is necessary to break down journey types into different categories—for journeys up to one or two kilometres, the best alternative to the automobile is likely to be walking, for journeys from two to 10 km it could be cycling or local public transport, and for longer distances it is likely to be a quality rail or bus service. Policy should drafted in a way that recognises these differences.

Policies to shift the mix away from private cars towards less energy-intensive modes include:

- A requirement that all road-building proposals be submitted to a stringent environmental assessment that includes consideration of alternatives.
- Investment in, and subsidy for, public and non-motorised modes of transport.
- Redistribution of transport taxes to promote fuel economy, alternative fuels and public/non-motorised transport.
- Introduction of a carbon tax.
- Introduction of a "feebate" scheme (i.e., a revenue-neutral redistribution measure whereby purchasers of energy-efficient vehicles are given rebates, and purchasers of "gas-guzzlers" are charged fees).
- Increases in fuel taxes.
- Fuel economy labelling for cars and regulations on the content of car advertisements.
- Introduction of measures to encourage employers to reduce the travel requirements of their workforce.
- Fiscal and practical limitations on parking in urban areas.
- Introduction of area licensing to discourage use of cars in urban areas. Such schemes may be regulatory (i.e., only certain vehicles allowed in) or financially-driven (i.e., a permit must be purchased to enter the restricted area), or some combination of the two. Examples are already in operation in Singapore, Milan, Stockholm and the Randstad in Holland; the congestion zone introduced in 2001 in London, England has been a significant success.
- Extensive introduction of urban traffic calming measures (combined, where possible, with bus and cycle lanes).
- Enforcement of road speed limits, and in some instances reduction of those limits.
- Discrimination in favour of vehicle-sharing (e.g., in Greater Vancouver a number of main routes operate lanes for the exclusive use of vehicles carrying five persons or more).

Not all of these options would work effectively in Saskatchewan; they are listed here to open up debate and encourage thought as to what could be effective both in urban and in rural areas.

3.4.3 Personal Choices

The role of the individual in mitigating global warming cannot be underestimated. Opinion polls frequently indicate that a majority of the population are willing to make changes to their lifestyle for environmental reasons. However, they need to have realistic choices at their disposal. In a society in which citizens have no alternative to the private automobile for necessary journeys, or farmers have no alternative to hauling grain long distances by truck in order to be able to sell it, no amount of goodwill can substitute for effective government incentives.

3.5 The Role of Government in Promoting Energy Efficiency

Governments need to act by example, by incentive, by social marketing and by regulation. The recent Prebble report, Renewable Energy Development and Conservation in Saskatchewan, provides an excellent menu of suggestions.

4

Renewable Energy Opportunities

We use energy in a number of different ways—principally, to heat buildings, in transport fuel, to generate electricity, and to provide high temperature heat for industrial processes. While there is a small element of crossover among these categories (e.g., electrical heating of furnaces or homes), they are best addressed separately.

Different renewable options are suited for different energy end-uses. Passive solar house design provides only space heating, and so can displace natural gas usage but not (for the most part) coal-fired power stations. Photovoltaic cells and wind turbines provide only electricity: hence they can in principle displace fossil fuel power stations, but do little to reduce demand for heating or motor fuels. Therefore an important ground rule in developing a sustainable energy policy for Saskatchewan is to match the source with the end-use in terms of the energy supplied.

Our second ground rule for any programme to replace existing energy sources with renewables is implicit in the structure of this report: work first to reduce the end-use requirement (through energy efficiency measures, and in some cases also by enabling voluntary lifestyle change), before making a substitution. Energy efficiency measures are nearly always more cost-effective, and nearly always have a smaller environmental impact, than energy provision measures.

Discussion follows on the suitability, viability and potential contribution of each of the main renewables options in Saskatchewan. It should be borne in mind that, while they may provide a technical solution to the global crisis of anthropogenic climate change, renewable energy technologies have environmental impacts of their own, and these should be addressed and minimised in any plan to use them.

4.1 Bio-Energy

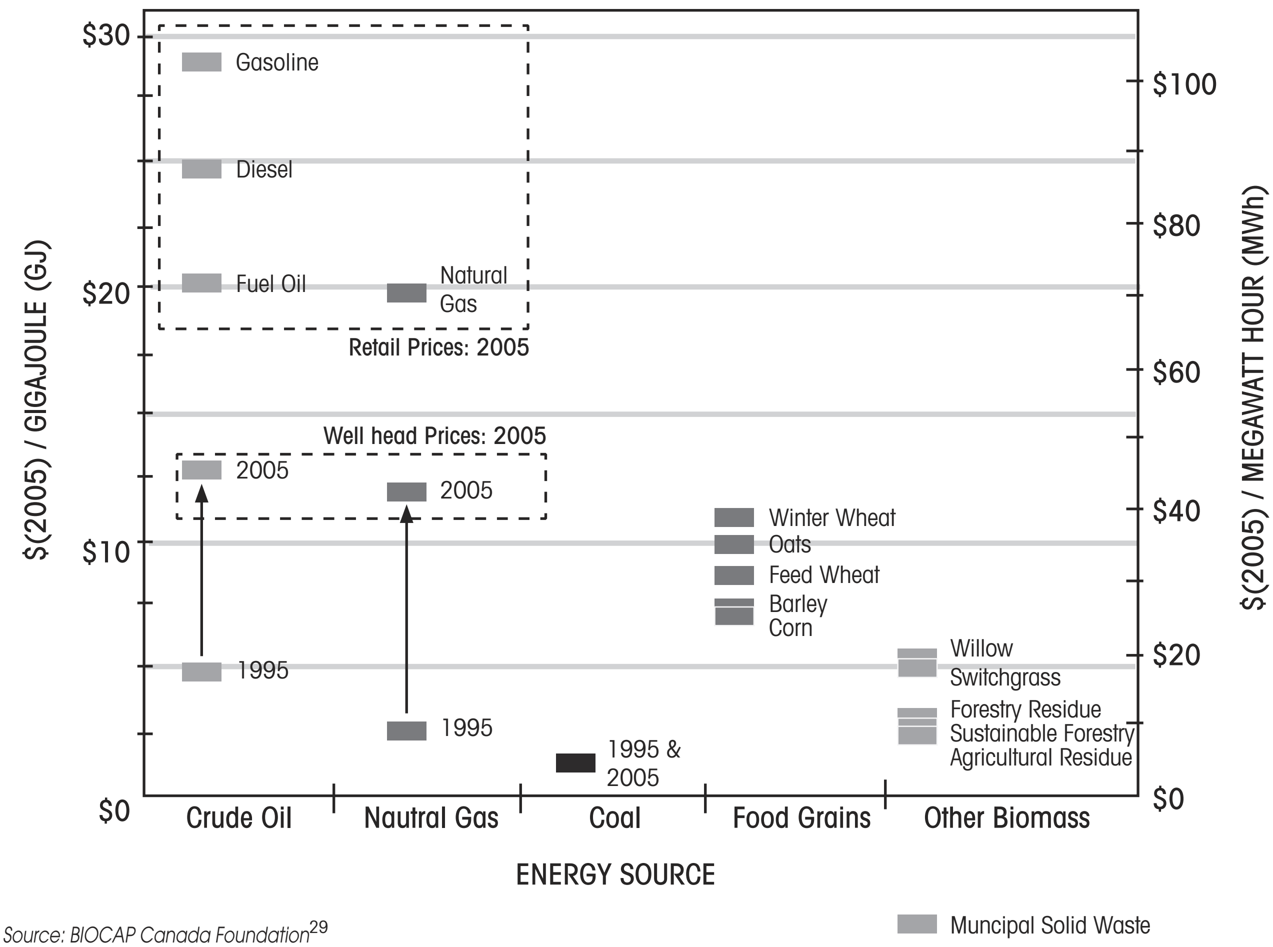
Biomass constitutes a broad range of plant and animal-based materials. Biomass fuel can come from wood waste, deliberately planted trees, agricultural residues, fast-growing energy crops or animal waste. Sometimes domestic refuse is also included in this category for convenience. Cellulose-based biofuels (e.g., wood, straw, etc) may be burned in solid form, or subjected to pyrolysis to give a mix of liquid and gaseous fuels, or to gasification to produce a gas rich in carbon monoxide and hydrogen. Putrescible waste (both agricultural and domestic) may be subjected to anaerobic digestion, in which bacterial action produces a combustible gas (mostly methane) and leaves behind a nutrient-rich residue which can be used as a soil improver or fertiliser. Ethanol may be produced from cellulose by an integrated gasification–catalytic conversion process, by steam or dilute acid pretreatment followed by enzymatic hydrolysis of cellulose, or by simple fermentation of starchy crops. Oil from canola (and other) seeds may be transesterified to produce biodiesel. Other processes may be used to generate hydrogen, or methanol, or butanol.

Solid biomass fuels, being bulky to transport, are best used locally to the place where they are grown, or else used to produce methane and other gaseous fuels by use of gasification or digestion processes. The biofuel energy sources available in the province fall into five main categories: forestry residues and thinnings; forestry energy crops; agricultural crop residues (straw and chaff); agricultural energy crops; and post-consumer waste.

Biomass fuel prices are in principle already able to compete well with those for most fossil fuels, as shown in the graph below. Competing with natural gas for direct space and water heating, several biomass options prove to be cheaper. Competing with coal for electricity generation, the picture is less clear. Coal remains less expensive as a fuel, however, costs of plant and machinery also need to be considered. When compared on more equal environmental terms (i.e., with flue emission controls, carbon capture and sequestration included in the price of a coal-fired station), coal's price advantage is at the very least cut drastically, and probably reversed. Furthermore, the relative ease with which small local biofuel plants may be adapted for combined heat and power gives them an efficiency advantage. Transportation biofuels remain somewhat more expensive than their mineral counterparts in Canada. In some jurisdictions, including Saskatchewan, tax adjustments allow ethanol to compete with gasoline. While some incentive mechanisms may prove to be necessary for biofuels to begin to fulfil their potential, the principal obstacles to growth of the industry lie in logistics, in lack of investment, and in a general resistance to change.

Figure 1.

Comparison of fossil and biomass energy prices in Canada. All prices in 2005 Canadian dollars, and apply to 2005 unless otherwise indicated.



Source: BIOCAP Canada Foundation[29]

4.1.1 Bio-Energy Sources

- **Agroforestry and Agricultural Lignocellulosic Energy Crops**

  A recent success story in parts of Europe has been the development of short rotation coppicing schemes, usually willow or poplar. In other parts of the world, fast-growing species such as eucalyptus provide a significant energy resource. While rainfall is lower in Saskatchewan than in many other places where such agroforestry-based bioenergy systems are being considered, there still may be potential for fast growing hybrid poplars and willow production in the northern agricultural zone. Some of this hybrid poplar production could be used for various bioenergy applications.

  To give an idea of the magnitude of bioenergy production that might be achieved from bioenergy crops or multipurpose crops in Saskatchewan, an estimate was made of the total potential ethanol production from hybrid poplar grown on all the highly suitable land available. Data from the Saskatchewan Forest Centre indicates that 1.29 million hectares of land are highly suitable for hybrid poplar production in the northern agricultural zone.[30] The mean annual increment (wood yield) was estimated at 15.2 m^3/ha/year. This is equivalent to about 3.7 tonnes of wood dry matter/ha/year. Data from the Saskatchewan Research Council (M. Wismer, SRC, personal communication, December 18, 2006) estimates yields, with tops and main branches included, from short rotation hybrid poplar for bioenergy applications of 4.0 tonnes of wood dry matter/ha/year. If all the potential land highly suitable for fast growing poplar grew poplar at this annual growth rate of 4.0 tonnes/ha, the total production of poplar wood would be 5.16 million tonnes per year. This could be converted into 2.74 billion litres (64 PJ) of ethanol per year. Recognizing that landowners may well choose to use only part of this land for bioenergy production, we note that if 20 per cent of the total highly suitable land were used for poplar bioenergy production, the total production would be 1.03 million tonnes per year.

One method to convert this poplar wood into liquid biofuels would be gasification to produce synthesis gas (a mixture of hydrogen and carbon monoxide) followed by catalytic conversion of the synthesis gas to ethanol. A processing centre using this gasification process to produce ethanol from poplar wood and flax straw is being planned for the Nipawin area of eastern Saskatchewan. Estimates of yields of ethanol from this process are in the range of 530 L/tonne of poplar wood dry matter (M. Wismer, SRC, personal communication, December 18, 2006). Total production of ethanol from 1.03 million tonnes of poplar wood dry matter would then be 546 million litres (12.8 PJ) per year. (For comparison, the total consumption of gasoline and diesel fuel in Saskatchewan in 2003 was 120 PJ).

The potential may be larger than this. Bioenergy production might be integrated in the future with production of higher value products, such as veneer or wood pulp, in regional processing centres. Co-products or waste products from such processing centres might be used for bioenergy. Other bioenergy raw materials, such as annual or perennial forage crops, might also be developed over time. Switchgrass, often recommended as an energy crop in other places, will probably not do well in our dry climate.

Grain and oil-seed crops used for fuel production are discussed in Section 4.1.2.

- **Forestry Residues**

Residues from the province's extensive forest harvest (e.g., logging slash, sawdust and shavings, bark, other mill waste, woodland debris, etc.), constitute a significant energy source as well. Surplus mill residue production alone in the province was estimated to be the equivalent of about 3.2 PJ per year. Logging slash would, at a conservative estimate, add another 1.7 PJ/year. In addition, stockpiles amounting to a total of over 40 PJ energy content exist in the province. We may therefore assume that forestry wastes could provide about 5.0 PJ of primary energy annually. This estimate needs to be accompanied by a caution about the requirement to ensure that the sustainability of the forest ecosystem is given first priority.

- **Agricultural Crop Residues and Manure**

There are many options for energy recovery from agricultural by-products, but they can be thought of in two basic categories: straw (and other crop stems), to be burned directly or subjected to pyrolysis, gasification or enzymatic conversion to ethanol via the Iogen or related processes, and putrescibles (e.g., animal waste, vegetable tops, etc.), which may be used for anaerobic digestion to produce biogas (mainly methane).

Crop Residues

While total crop residue production in Saskatchewan is large, some of it is already used for cattle feed and bedding. This leaves more that 10.4 million tonnes available for, firstly, soil protection and then, secondly, industrial uses.[31] Based on present knowledge of the effects of crop residue removal on crop yields, soil protection and soil organic matter, about two million tonnes might be available for bioenergy and other industrial applications. This represents 32.0 PJ/year. Total amounts available might be less than this in a drought year.[32]

Wheat straw is one of the materials being investigated by Iogen as a raw material for conversion into fuel ethanol. The majority of the crop residue material available for bioenergy applications in Saskatchewan is wheat straw. A recent study estimated that the yield of ethanol by the Iogen process would be 400 litres per dry tonne in 2010, as the process was improved.[33] If one million tonnes (dry basis) of wheat straw were available each year, this could result in production of 400 million litres of ethanol (9.4 PJ).

Manure

The scope for anaerobic digestion of manure to produce biogas in the province is more difficult to assess. Collecting the faeces of free-roaming cattle has frequently proved non-viable even with much smaller field sizes in England and Wales; the technology is, however, more viable for intensive operations. It is also an option at food processing plants and for sewage works. We assume, for the purposes of this report, however, that manure methane digestion will make only a small contribution to future energy provision in the province. (One possible problem is that the need for strict temperature regulation may seriously impact the net energy output of all but the largest digestors in the Saskatchewan climate.)

- **Post-Consumer Waste**

Most European countries have for some time been opting for incineration in preference to landfill when planning new disposal capacity for domestic, commercial and industrial waste. Tight pollution controls are required for both gaseous emissions and solid residue from such incinerators, and need to be enforced

Waste from Saskatoon, Regina, Prince Albert and Moose Jaw could—assuming a production rate of one tonne/person/year—generate about four PJ of energy by this means: smaller settlements may also find this approach worth considering.

Small modular plants using pyrolysis and gasification reactions rather than direct combustion are now beginning to be available on the world market.[34] These enable small scale operation and strategies of phased introduction; they also perform particularly well with regard to emissions control.

4.1.2 Biofuels for Transportation

As well as approaching bio-energy potential from the perspective of sources, as we have above, it is useful to examine the potential of various transportation bio-fuel products.

- **Ethanol Potential from Starch Sources**

  Bioethanol is at present mostly produced by fermentation from crops high in sugar (e.g., sugar beet, corn). Alternative processes are under development, in which cellulose from wood or crop stalks is broken down into sugars and fermented, or gasified to methane and oxidised. In principle, any gasoline engine should be able to run on ethanol with some adaptations; however, most motor manufacturers discourage this. Vehicles guaranteed to run without adaptation on a mixture of 85 per cent ethanol and 15 per cent gasoline (E85), as well as on pure gasoline or any intermediate proportions, are becoming more common, and are known as flex cars. This development is largely the result of the requirements of the Brazilian market, where ethanol distilled from sugar cane plays a major role. Saskatchewan is moving towards a 7.5 per cent ethanol requirement in all gasoline sold in the province. The main limiting factor until recently has been the lack of sufficient manufacturing plant producing ethanol. By the end of 2007, several new plants will be in operation and the province will have more than enough ethanol production capacity to meet the 7.5 per cent blend mandate.

  In the short term, the main production of ethanol will come from fermentation of grains, particularly wheat in western Canada. O'Connor has estimated that Saskatchewan might be able to produce 666 million litres of ethanol from wheat grain, particularly using the higher starch content varieties.[35] This would require about 1.8 million tonnes of wheat. This represents some 13 per cent of Saskatchewan's typical annual wheat production.

  Small additional amounts of ethanol might be produced from barley grain. The total potential for Saskatchewan would be 726 million litres (17.1 PJ). Saskatchewan would then contribute 35.8 per cent of total Canadian production of 2025.5 million litres needed to meet an initial goal of five per cent (V:V) substitution of ethanol into all Canadian gasoline requirements.

  Total production of ethanol in Saskatchewan by the end of 2007 is shown in Table 2.

  See Section 2.3.8 for discussion of estimates of greenhouse gas reduction resulting from substitution of grain-based ethanol for gasoline.

- **Biodiesel from Canola**

  In Saskatchewan, biodiesel will mostly mean canola methyl ester (CME), a product formed by reacting clean dry canola oil with methanol using a sodium hydroxide catalyst. Any diesel engine can function on 100 per cent biodiesel (B100), or on a mixture of petrodiesel and biodiesel. At the time of writing, some Saskatoon buses are run on a five per cent biodiesel fuel (B5).[36] While recent tests show that this small proportion also results in more efficient combustion, and hence in a carbon emissions saving of some seven or eight per cent, use (and general availability) of B100 would clearly result in much greater savings.

Table 2.

Ethanol production in Saskatchewan. Production capacity when all plants are in full production by the end of 2007. All plants use wheat grain as raw material.

Location	Company	Capacity (millions of litres per year)	Comments
Lloydminster	Husky Energy	130	Construction completed, now nearing full production
Belle Plaine	Terra Grain Fuels	150	Under construction
Weyburn	NorAmera Bioenergy Corporation	25	Started production in June 2006
Lanigan	Pound Maker AgVentures	12	Has been in operation for a number of years. Integrated with a feedlot.

Source: L. Moskal, Saskatchewan Industry and Resources

A recent estimate of the amounts of vegetable oils and animals fats that might be available in Canada for conversion into biodiesel concluded that 699,992 tonnes of oils might be available by 2015.[37] This would produce about 750 million litres of biodiesel. This would be sufficient biodiesel to substitute for three per cent of Canada's diesel fuel requirements.

Of the total vegetable oils required, Saskatchewan might produce 160,080 tonnes of canola oil, enough to provide 173 million litres (6.17 PJ) of biodiesel.

In Saskatchewan, one study estimated the amount of crop land and crop production that a typical farm would need to divert to growing canola which would be converted into biodiesel (via conversion of the vegetable oil) to provide all the farm's liquid fuel requirements.

This short study estimated the amount of canola needed to be diverted from present oil seed markets to provide the biodiesel needed to replace all the diesel fuel used on the farm.[38] The study looked at a farm in the Indian Head area of Saskatchewan. A four year rotation of spring wheat-peas-CPS wheat-canola was used in the model. For a conventional tillage system on the farm, 38.5 per cent of the canola production would be required for biodiesel production, or 9.6 per cent of the whole farm crop acreage. If zero tillage was used for crop production, 27.8 per cent of the canola production would need to be diverted to biodiesel production, or 7.0 per cent of the whole farm acreage. However, the canola oilseed meal from the oilseed used for biodiesel production is still available for feed use. Thus the percent of the total food and feed production on the farm diverted to biodiesel production was calculated to be only 2.0 per cent to 2.8 per cent, depending on the tillage system used.

Canola is a valuable crop. It may be unlikely that biodiesel produced from good quality canola oil would be cheaper than diesel fuel. However, significant amounts of poor quality canola are produced some years depending on growing conditions. This poorer quality canola might be a first choice for more limited use of canola for conversion to biodiesel for meeting a portion of farm diesel fuel requirements.

- **Methane (Biogas)**

Cars adapted to run on methane (whether of mineral or biological origin) have been commercially available for decades. Difficulty in accessing the fuel has, however, limited take-up of this option. It is, however, becoming more popular in Sweden. In West Sweden and Göteborg (with a combined population of about two million), the number of methane-powered cars has risen from zero to 4,500 in the last 10 years[39] and is set to continue to rise rapidly as a result of the local price differential and of government policies to wean the country off petroleum-based fuels. The majority of the fuel used is from anaerobic digestion of putrescible waste (though some is from natural gas and some from gasification of timber or agricultural waste).

- **Butanol**

Butanol is another alternative to gasoline. A new process has been developed by DuPont and will be marketed by British Petroleum.[40] An advantage claimed by proponents of the fuel is that it requires a lesser degree of engine adaptation for use in high proportions.

- **Straight Vegetable Oil and Waste Vegetable Oil**

Clean, water-free vegetable oil can be used in (usually modified) diesel engines in place of petrodiesel. In the Saskatchewan winter, however, this presents some problems: the viscosity of unprocessed vegetable oil is inadequate at low temperatures. Kits are available to overcome this problem by means of an additional fuel tank, pipes and switching gear, and a fuel heater. In this system the vehicle is started on petrodiesel, while the vegetable oil is heated up; once it reaches a suitable temperature the fuel line is switched to receive from the vegetable oil tank. This approach has, however, been criticised by biodiesel specialists in the province as liable to increase wear and tear on the engine. The successful alternative of engine modifications, widely used in Germany, Denmark and France,[41] is more expensive, and does not in itself address the issue of fuel temperature in a prairie winter. This is a field in which little scientific research has been done, so many of the opinions expressed both for and against the two-tank system may be backed up with little more than anecdotal evidence: in these circumstances drivers are likely to treat this technology with caution.

4.1.3 Bio-Fuels: The Total Resource

The total potential amounts of biofuels which might be produced in the future in Saskatchewan are summarized in Table 3. All liquid fuels from lignocellulosic sources such as wood or straw were calculated as ethanol. However, other liquid fuels such as synthetic biomass-based gasoline or synthetic biomass-based diesel fuel might also be produced, via production of synthesis gas followed by Fischer-Tropsch catalysis conversion to hydrocarbon fuels.

- **Global Potential for Bio-Energy**

Monique Hoogwijk and her colleagues at Utrecht University in The Netherlands have calculated the global potential for bio-energy for liquid fuels or electricity, after taking into account future needs for food, feed and wild areas to be left intact.[42] Most biofuels would be produced from high-

Table 3.

Total potential annual bio-fuels in production in Saskatchewan.

Bio-fuel type	Amounts (millions of litres)	Energy production (PJ)
Ethanol from grain	726	17.1
Biodiesel from canola	173	6.2
Ethanol from straw	400	9.4
Ethanol from agroforestry hybrid poplar	546 – 2,740	12.8 – 64.0
Total potential liquid fuels		45.5 – 96.7
(a) Ethanol	1,672 – 3,866	39.3 – 90.5
(b) Biodiesel	173	6.2
Present fossil liquid fuels consumption (2003)		
Saskatchewan:		
Gasoline	1,760	61.6
Diesel fuel	1,520	58.3
Canada:		
Gasoline	40,230	1,408
Diesel fuel	23,580	903
Solid bio-fuels from Saskatchewan forestry		5.0 (plus stockpiles of about 40 PJ)

Source: Saskatchewan Environmental Society

yielding, fast-growing trees or forage crops rather than grains or oil seeds. Four scenarios were considered, which varied in how intensively food was produced. Different estimates of world population for 2050 and 2100 were tested in the various scenarios. The potential of biomass energy crops for producing either electricity or transportation fuels was evaluated. In the worst case, the amount of electricity which could be produced from biomass was 63 PWh/year in 2050, increasing to 91 PWh/year in 2100. The present (2000) production of electricity from all sources in the world is 15 PWh/year. The amount of biomass potentially available to produce heat or liquid fuels was 171 EJ in 2050, increasing to 217 EJ in 2100. Total crude oil production in 1998 was 142 EJ/year.

4.2 Electrical Generation

Four renewable options have significant potential for electricity generation in the province: wind, hydroelectric, photovoltaics and thermal power stations fuelled by biomass.

4.2.1 Incorporating Renewables into the System

- **Integration and Grid Stability Concerns**

Maintenance of security of electrical supply requires that a second-by-second balance between generation and demand be achieved. The intermittent nature of renewables such as wind energy has caused concern in some quarters that levels of generation would fluctuate such that excessive levels of back-up capacity would be required. We understand, for example, that SaskPower's current policy is to require one-to-one back-up capacity for the Saskatchewan wind farms. Intermittency certainly presents a challenge which needs to be addressed; however, it is also possible to exaggerate the problem. As British grid integration expert David Milborrow puts it:

"The idea, sometimes advanced, that every MW of intermittent plant must be backed up by an equivalent amount of standby thermal plant is incorrect. The central issue is that additional standby plant will need to be provided, but the amount is a function of the additional uncertainty introduced by the intermittent source."

There are always uncertainties in balancing supply and demand, but an integrated electricity system only needs to be able to respond to the aggregated uncertainty. Short-term variations (on timescales up to a couple of minutes) in renewables supply are likely to be of less concern than variations in demand over a similar timescale; it is highly unlikely that a provincial intermittent renewables portfolio would give rise to instantaneous changes of the same scale as those currently managed (e.g, when a large power station "trips").

For levels of generation up to about 20 per cent of total demand, studies in Germany, Denmark and Finland show that the additional reserves required on the system due to wind variability amount to only a few percent of the installed wind capacity; these figures are confirmed by recent work in North America.[43,44,45]

Variability over still longer timescales (of the order of a day) is of significance only if the risks of power shortfall (through low wind speeds, etc) are highest on days of peak demand. We have seen no evidence that this is the case in Saskatchewan. There is therefore reason for confidence that any additional cost involved in managing variable sources will be small. Furthermore, the main strategies necessary to ensure consistent supply are familiar to the worldwide electricity generation industry:

a) Quick-response back-up provision—principally appropriately-sized hydroelectric generation and gas-fired power stations. Stronger links with the Manitoba grid, which makes greater use of hydroelectric stations, would enable this, as would the building of large numbers of small (probably locally-owned) biogas-fired thermal stations.

b) Electricity storage options (see below)

c) To these conventional approaches may be added a shift towards distributed generation especially for variable sources such as wind. Wide distribution of wind turbines throughout the province would reduce the risk factor: when the wind is weak in one place it may be strong in others. Diversity of types of variable source can also be of benefit when costs permit: wind and photovoltaics together represent a source with less variability than either on its own.

For higher levels of renewable energy generation in the grid and eventual transition to a mostly renewable energy-based power system, new storage and grid control technologies are needed, such as electricity storage (see below) and smart grid control technologies that can manage large numbers of distributed generation and storage systems.

- **New Technologies for Large-Scale Electricity Storage**

There is probably no suitable site in Saskatchewan for the best-tested option pursued in other jurisdictions, namely pumped storage; but battery storage and distributed generation of hydrogen may be included in this category as promising future technologies.

Vanadium Flow Batteries

A Vancouver, BC-based company called VRB Power Systems Inc. has started commercial manufacture of large scale electricity power storage units based on "flow" batteries.[46] The technology involves pumping an electrolyte containing salts of the metal vanadium through a membrane into another tank of vanadium salts with a different valence state. This causes a chemical reaction that releases electricity. The flow can be reversed to store electrical power. This new Vanadium Redox Battery Energy Storage System ("VRB-ESS") technology is described in some detail on the company's web site. A unit the size of a refrigerator can hold enough electricity (as chemical charge potential) to power a cellphone transmission tower. A unit array the size of a football field could store power from a mid-size wind farm (up to 10 MW).

A recent sales agreement in Ireland calls for VRB to supply $6.3 million worth of the electricity storage units to the Sorne Hill wind farm. The batteries will store electrical power generated from wind during the night when the wind blows hardest but when electricity use and rates are low. The VRB units will deliver power during the day, when it is needed and when the farm can make more money from higher daytime electricity rates.

The sales agreement is conditional on a feasibility study that is looking at whether the system makes economic sense. This study is expected to be completed by the end of 2006.

An environmental assessment of the vanadium redox battery system compared to conventional lead-acid battery systems concluded that the vanadium battery system had much lower environmental impact.[47]

Storing Wind Energy Generated Electricity as Hydrogen and Subsequent Conversion Back to Electricity

Electricity generated from wind energy can be used to electrolyze water to generate hydrogen gas.[48] While this is not the cheapest way to produce hydrogen, it results in almost no greenhouse gas emissions. Cheaper methods to produce hydrogen create higher greenhouse gas emissions. If methods could be developed to store the hydrogen over a long period, the hydrogen could subsequently be run through a fuel cell to generate electricity.

A recent study in Italy describes an electricity generating system being planned for a small island off the coast west of Naples.[49] The island has to generate its own electricity at present by use of diesel powered generators. The electricity demand peaks in the summer when there are many tourists on the island. The wind energy potential peaks in the winter, when wind speeds are the highest. The model demonstrated how electricity generated by wind in the winter would be used to electrolyze water to produce hydrogen, which would be stored as compressed gas in tanks (500 m^3 storage capacity). The hydrogen would then be used in the summer to generate electricity by conversion in a fuel cell system. The hydrogen-based electricity production system is to be coupled with demand side management to reduce electricity demand, introduction of solar water heating, installation of photovoltaic systems, plus back up diesel powered generators (smaller need than the present system) to provide all the island's electricity requirements.

The renewable energy system and the demand side management actions would provide 85.9 per cent of the total electricity services supply. They reduce the greenhouse gas emissions by 62 per cent compared to the present situation. The next stage will be to calculate the cost of the new system and the pay-back time. A new Transient Simulation Model was vital for calculating how the new system would work to integrate the various renewable energy sources into the overall electrical supply.

- **Distributed Generation**

It is already practical to connect large power stations using renewables to the Saskatchewan grid as it currently stands. However, the current centralised model of electricity distribution is not well adapted to take advantage of the full benefits of the renewable options available in Saskatchewan.

The path taken by many northern European countries, partially in response to the growth of the wind energy industry, has been to shift towards a more local approach to generation. In this model, electricity is generated primarily for the local community and any excess exported to a wider grid. This approach is known by a number of names (e.g., embedded generation, decentralised generation, microgrids, etc.), but the most commonly used terminology is distributed generation. In Denmark, over 50 per cent of generation is now decentralised in this way; the Netherlands and Finland are close to 40 per cent; and Germany has, despite a strong tradition of power centralisation, reached 20 per cent.[50] Canada as a whole stands at present at about 12 per cent, and the current figure for Saskatchewan is similar (though the "distributed" element of the SaskPower grid is almost entirely provided by the two industry-based facilities at the Cory potash mine and the Meridian oil refinery: a truly decentralised approach would include large numbers of smaller, more local generators).[51]

Distributed generation is becoming attractive to decision-makers for other reasons. Recent reports by Ceres Insurance,[52] the US Department of Energy[53] and the New Zealand Ministry of Economic Development[54] have cited it as a desirable strategy for reducing the risk of widespread power outages in the case of terrorist attack or natural disaster. Where truly distributed generation is in place, significant savings are possible on grid losses. By enabling more small businesses to enter the market, it is seen as encouraging efficiency through competition. In northern Europe it has become an important element in the local regeneration of the rural economy. The rapid growth of the decentralised energy sector in virtually all parts of the developed world over the past 20 years indicates sound economics,[55,56] wherever local utilities do not discriminate against small generators in their pricing structures. With modest government support and price stabilisation policies, even the least economically favourable renewable options can compete on cost in this context.[57] There is also some evidence that bringing generation closer to consumers, and giving them a stake in it, raises their awareness of energy-related issues and prompts voluntary reductions in consumption through both efficiency and lifestyle changes.[58]

In this report, we do not advocate a target of 100 per cent distributed generation. Some large power stations will always be needed. However, with the use of modern electronic switching systems, a more flexible and more locally self-reliant system is possible, and, as indicated above, able to give many benefits in addition to those inherent in the use of renewables.

- **Encouraging Small Producers**

A Small Power Producers Policy has been in place in Saskatchewan since 1998. It is intended for producers who wish to generate small amounts of power to offset their consumption needs. The generator first uses his/her own power, then draws any extra needed from the grid. If the small producer is generating surplus power, it is sold to the grid at the marginal wholesale price (currently 6.26 cents per kWh).[59] This differs from "net-metering" systems in that the latter programs generally purchase surplus at the retail rate (currently around 9 cents in Saskatchewan). There are a few users of this Small Power Producers program, including both wind and solar projects, for a total of less than 130 kW. At present the policy is not restricted to renewable power. As all the set-up costs are the responsibility of the small producer, this program is not particularly attractive economically under the present financial arrangement.

This approach can be contrasted with that of Germany. Within 15 years, Germany has become a world leader in the production of wind energy, which currently supplies the country with six percent of its total energy supply.[60] In 2005, wind provided over 18,000 MW of power. The industry was spurred in 1990 by the passing of "The Electricity Feed in Law" that required utilities to purchase renewable energy created in their geographic region, at or near the market cost.[61]

Banks provided low interest start-up loans to cover the capital costs of renewable technologies that were then refinanced by the German government.[62] Significant funding has been given to research and development of the technology, into training for operators, and for public education campaigns. In 2005, an amendment to the German Renewable Energy Sources Act created further growth through a more favorable pricing mechanism.

4.2.2 Windpower

Currently there is approximately 172 MW of grid-connected windpower capacity in Saskatchewan, generated by SaskPower and Independent Power Producers. The addition of a further 28 MW is under discussion.

- **Windpower potential**

Saskatchewan has a good, though not outstanding, wind resource through most of the area south of Prince Albert and Lloydminster. Wind speeds compare well with those of northern Germany, where this technology has made major inroads over the past decade. They are more consistent than in many of the successful European locations, especially at height: hence relatively high capacity factors are achievable in the province. If government provides an adequate framework within which to function, there is no reason why a successful, prosperous and diversified wind industry should not develop in the province. Unlike fossil fuels, this is also an industry able to add prosperity to the local rural economy, through stable rental payments to farmers and through provision of local employment in construction and maintenance. A target of 20 per cent of total electrical demand being supplied by wind power is a conservative and achievable target.

Although the costs of manufacture of wind turbines are still dropping, and the average size of units being ordered is still rising, this is a technology which is close to maturity. Denmark already produces 20 per cent of its electricity from the wind. Germany will use the wind to generate 10 per cent of its demand when currently planned windfarms come online, and is expected to reach 25 per cent in the first half of the next decade. Other European countries, notably Spain, Portugal, Ireland and the Netherlands, are taking the same fast track of wind development. Even Britain, where government support is less efficiently targeted, is expected to exceed 10 per cent by about 2011.

For comparison, Canada as a whole currently has about 1200 MW installed capacity for wind generation[63]: this can provide about 0.4 per cent of the current national electricity demand. When projects currently under construction or given final approval are added, the figure still barely reaches one per cent of electricity demand.

Thanks to the Centennial windfarm at Rushlake Creek, Saskatchewan is now able to produce about two per cent of its electricity from the wind. [Readers should distinguish between this more useful figure and that for nominal generating capacity, which stands at about five per cent.] The currently approved plans for further capacity will make little change to this figure.

It is clear that Canada has been slow to adopt this particular technology. However, as there is no shortage of suitable sites in the country, there is no reason why Canada in general, and Saskatchewan in particular, should not be able to catch up with Europe. The European experience has been generally one of rapid growth. For example, Germany has reached its current capacity from almost nothing in 15 years, with only moderate levels of government support. With a similar commitment by the provincial government to invest in a safe clean energy future, Saskatchewan could do the same. (See Section 4.2.1 for discussion of integration of intermittent power into the supply system).

- **Capacity**

Because wind is an intermittent resource, we suggest an appropriate target is to provide 20 per cent of total electrical generation (i.e., six TWh), from wind. Assuming (somewhat conservatively) a capacity factor of 25.5 per cent, a wind turbine with a rating of 1.8 MW may be expected to generate four GWh/yr: hence 1500 turbines of this size would be required to hit the 20 per cent target. This works out at about three turbines per 2000 people.

- **Location**

  Two factors determine the optimal location for windfarms in a distributed generation network. On the one hand, transmission losses may be minimised by siting the turbines as close as possible to demand; on the other, more power may be obtained from a given turbine model if it is located in an area of high wind speeds. SaskPower has, thus far, treated the latter consideration as definitive: hence the location of all of the province's large scale wind turbines in the south-west. A more extensive use of wind power would need to follow the example of successful pioneers such as Denmark, Germany and Spain, where to a large extent locally-generated electricity meets local needs. As noted previously, this would also reduce the problems associated with intermittency.

  The majority of the prairie and parkland areas of the province experience reasonable, and reasonably consistent, wind speeds, enabling viable electricity generation.[64] Hence local generation is possible for most of the more-populated parts of the province. There are, however, some areas in which a low average wind speed would make this more difficult. For example, it is unlikely that viable turbines could be placed between the North and South Saskatchewan Rivers north of Saskatoon; but the towns in this part of the province could be served by wind farms located to the north and west of the North Saskatchewan, and to the east of the South Saskatchewan.

  A policy of distributed generation opens up the possibility of community ownership of wind farms, through cooperatives. The success of the pioneering Danish wind industry is due in large measure to the leadership of the agricultural cooperative movement; this pattern of ownership has continued to be important as the growth of the industry in Europe has moved to northern Germany, Spain, Sweden and the Netherlands. A distributed network does not, however, depend on one ownership model. Ownership of wind farms could be in the hands of conventional limited companies, crown corporations, municipalities, cooperatives, wealthy individuals or more likely some combination of the above. Power provision would, however, need to be in full cooperation with SaskPower.

- **Land Area Required**

  When placed in windfarms, turbines need to be spaced such as to minimise interference from their neighbours. In practice this means that turbines in the 1.8 to 2 MW range require a land area of about 16 ha (just over 40 acres) each.[65] Only about one to two per cent of this area, however, is typically required for the tower foundations, control and distribution gear and access roads. The remainder of the land may continue to be used for crops or grazing, with no productivity losses.

- **Costs**

  Typical all-in costs in Canada for a windfarm using large turbines (over 400 kW nominal capacity) currently work out at about Cdn$2000/kW. Smaller turbines tend to cost more per rated kW.

  Hence the total bill for plant to achieve 20 per cent market penetration (as set out above) would be about Cdn$5.5 billion.

  Operating costs, are, however, substantially lower than those incurred by fossil fuel plants.

4.2.3 Electricity from Biomass

In a renewables-based scenario for Saskatchewan's electricity supply, there will still be a need for some power stations to function as effective baseload, and for others to switch in and out rapidly to supply peak demand. Solid fuel biomass stations could readily fill the former role, but only biogas stations would be flexible enough to handle the latter; they also permit higher efficiency values. We would therefore expect the majority of cellulosic biomass for electricity generation (whether timber, agricultural waste or other) to be gasified.

Because of transportation costs, solid biomass fuels are best used close to their source. It is important to note that the availability of biomass for electricity generation will be in competition with other energy-related uses of these resources (e.g., transportation fuel, cellulose insulation). Decisions will be needed about how to prioritize these different demands on a resource that must be managed sustainably.

SaskPower currently obtains power from a 120 kW capacity power station which uses methane derived from a pilot hog manure facility in Cudworth. This represents only a tiny fraction of the potential for manure-sourced power. Pulp mill waste ("black liquor") was successfully used for electrical generation at the Weyerhaeuser mill in Prince Albert. There is a large supply of sawdust, otherwise treated as a waste product, currently available from various lumber operations in the forest area of the province. However, there are questions about the long-term sustainability of supply of this material. We hope that, in a move to biofuels, the norm will be the small local (and locally-fuelled) Combined Heat and Power station, enabling overall conversion efficiencies above 70 per cent. However, larger power stations are possible; conversion of existing coal-fired stations to chipped solid biomass should be actively investigated. It should also ultimately be possible—following the Swedish precedent—to pipe excess gas into the main gas distribution network.

4.2.4. Photovoltaic power

SaskPower reports that 14.9 kW of solar electricity capacity is provided by themselves and independent power producers in Saskatchewan.

Saskatchewan is blessed with plentiful sunshine. The annual solar gain in the southern part of the province is:

- 4.9 GJ/m^2/yr on a vertical south-facing wall
- 5.8 GJ/m^2/yr on a south-facing wall at 60° to the horizontal
- 4.9 GJ/m^2/yr on a horizontal surface

These are unusually high figures for the latitude. Furthermore, when compared with European locations at the same latitude (including the Netherlands and north Germany, where photovoltaic panels are much more common than in Saskatchewan), the winter figures are particularly favourable.

- **Capacity and Appropriate Size**

  Large scale photovoltaic arrays are unlikely to become economically viable in Saskatchewan without significant government subsidy. The world leader in implementation of the technology, Germany, still produces only about 0.1 per cent of its electricity in this way. However, this is an industry which is still developing, with panel efficiencies steadily rising and costs steadily dropping, especially where economies of scale become possible through mass production.

  In order to generate one per cent of Saskatchewan's current electricity consumption through photovoltaics, about 1.4 km^2 of panel area would be required. This is equivalent to about 30,000 south-facing roofs on average-sized homes.

- **Cost Issues**

  At present, the obvious market for photovoltaic panels is remote locations lacking access to the grid; a simple installation can often compete on cost with a diesel engine in such locations. The future potential of the technology, however, is such that some financial encouragement of its development in the province would be justified at this stage, following the example of Germany, California and Japan in particular, but also most recently Ontario.

  The feed-in tariff laws (mandated, temporary, high purchase price to support introduction of renewable electricity) in operation in Germany guarantee to wind generators a price of between €0.06 (Cdn $0.09) and €0.09 (Cdn $0.14) per kWh, depending on location. For comparison, the tariff guaranteed for photovoltaic supply is still as high as €0.50 (Cdn $0.77) per kWh.

  The total cost of the 1.4 km^2 of panels alluded to above would be about Cdn$600 million at current prices. However, maintenance costs are virtually zero.

4.2.5 Hydroelectricity

Hydroelectric sources provide approximately 15 to 25 per cent of our electricity supply, varying from year to year with water flow in the rivers. Power supply from hydroelectricity depends on the flowrate of the water, which is reasonably stable on a short-term basis, so there is less hour-to-hour variability in supply than with some other renewables. Although the water used in the generation of power is returned to the ecosystem, large hydro dams are not generally regarded as sustainable (see Section 2.4.4). SaskPower does not currently generate or purchase power from micro-hydro (run-of-the-river) sources.

While there is some scope for expansion of the province's hydroelectric generation, the potential exists mostly in the north, far from centres of population. There are serious environmental concerns about any further damming of our rivers. This option is therefore not explored here. While it is unlikely that much additional capacity could be usefully added to the SaskPower grid, the potential exists for small-scale, run-of-the-river installations to supply individual villages, reserves or settlements in the North.

4.3 Heating with Renewables

At present, in most parts of the province, low-temperature heating (e.g., air and water heating in homes, farms, offices, etc) is supplied by gas furnaces and boilers. Existing renewable alternatives include stoves to burn wood or agricultural waste, and ground source or air source heat pumps.

Except for the most energy-efficient buildings, basic energy conservation measures (see Section 3) provide the easiest and more cost-effective means of reducing carbon dioxide emissions from this source. However, solar water heating, solar preheat of furnace inlet air, and especially passive solar design methods all have an important role to play.

4.3.1 Wood Heating

We have no way of quantifying the amount of wood energy used in stoves, fireplaces and campfires in Saskatchewan homes, cabins and camps. It is probably safe to assume that while it makes a significant local contribution to meeting of heating needs, in total it is small enough that it does not constitute an unsustainable demand on a renewable resource. It should be noted that fireplaces are generally a very inefficient way of heating; a given amount of fuel provides much more heat if it is used in a modern high-efficiency woodstove.

4.3.2 Solar Heating

Passive solar is of course our main source of heat energy. It is a basic requirement for all life except for those odd species that survive deep in the ocean or deep underground. Depending on how our homes are designed, a significant part of our winter heating needs are met by using solar heat entering the home through high-efficiency, south-facing windows.

- **Solar Hot Water Heating**

  A typical household in Canada uses about 25 GJ annually on domestic hot water heating: to meet 80 per cent of this load from solar heat would require six to 10 m^2 of panels (i.e., three or four typical-sized panels). The options include high-efficiency evacuated tubes, more conventional manufactured fluid-filled panels, or self-assembled panels. Solar water heating has proven to be cost-effective in situations where economies of manufacturing scale are possible. For example, studies carried out in Britain in the 1990s found that the cost of complete systems (i.e., panels, tank, piping and controls), was typically over twice that in Greece and five or six times that in Israel, where a large market had enabled mass production and manufacturers' promotional costs were lower. Reasonable prices have been achieved in some parts of Europe—notably in Austria—through establishment of solar clubs in which people band together to order and install the equipment.

  Once installed, ongoing costs are low as solar heating panels require little maintenance.

  An increasing number of Saskatchewan residents are displacing a good deal of their natural gas requirements by installing solar hot water panels on their roofs. For example, one Saskatoon resident writes:

  "Our house has a hydronic radiant floor heating system. Hot water is circulated through plastic pipes that are encased in a concrete slab floor, making the floor a giant radiator. The warm air is at the floor where we want it, giving us very even, comfortable heat and reducing heat loss through the ceiling and walls. Water for the system comes from the natural gas-fired water heater that provides us with hot water for our domestic needs. By installing a solar hot water system on the roof this summer, we can now take advantage of the sun's energy to pre-heat cold water before it goes into the water heater. This reduces the amount of gas needed to both heat the house and meet our other needs for hot water....Since the solar panels went onto the roof in early July until the gloomy, wet weather began in mid-September the sun provided us with more hot water than we could use. By midday on a sunny day in early November we had water heated to 54 C while the outside temperature was at a chilly -11 C."[66]

- **Solar Air Preheating**

  Another mature technology is the solar air heater. This uses darkened tubes or darkened profiled sheeting, attached to the south wall of a building. The air which passes through these panels is heated by several degrees Celsius by the sun, reducing the heating requirement from the furnace or boiler.

- **Passive Solar Design**

  Passive solar design describes an architectural approach in which the benefits of solar gain are maximised in a building. Given the intermittent nature of sunshine, three things need to be achieved in a heating climate:

  a) As much energy as possible should be absorbed from the sun by the building—this is achieved by appropriately located glazing.

  b) This energy is then stored within the building—in heavy building materials ("thermal mass") such as bricks, concrete or rammed earth, or in storage media such as water stores or phase change materials.

  c) The energy is released at the times when it is most needed.

  The simplest form of passive solar design is to place as many as possible of the building's windows on the south side, where solar gain is greater, and to minimise glazing on the north side. Other design options are almost always variants of either the conservatory or the mass wall. A conservatory is a seasonally-used room on the south side, which functions as a "solar collector" for the building and as a buffer space. In a solar wall, heat is collected in a masonry wall behind glazing.

  Passive solar methods vary according to the climate: in the case of Saskatchewan, a design strategy is necessary which maximises winter gain, damps down diurnal temperature variation in spring and autumn, and controls temperature rise in summer within acceptable bounds. Established mechanisms exist to do all of these things: how effectively they are introduced into a building is, however, a measure of the skill of the designer.

- **Passive Solar and Superinsulation**

  Through the 1970s and 1980s, many designers saw passive solar techniques as in competition with a strategy of heavy insulation and minimal ventilation. The latter approach, known as "superinsulation", provided the basic design philosophy behind Canada's groundbreaking R2000 programme.

More recently, it has become clearer that the two approaches can be complementary. Heavily insulated walls can coexist with high-specification glazing; the airtight buildings required by the superinsulation approach enable better control of passive ventilation when appropriate. Hence a modern approach to low energy building design will incorporate the best of both approaches.

- **"Net Zero" Buildings**

  The extent of savings possible through a hybrid low energy design method depends on the building, the site, and the expectations of the occupants. A house built this year in Regina is designed to reduce the heating load by 90 per cent compared to a typical 1970s dwelling of the same size.[67] It is at least theoretically possible even in the prairie climate to go even further than this: to bring the heating requirement down so low that a conventional furnace or boiler is no longer necessary. Occasional space heating requirements may then be supplied by a single wood-burning stove, for example, which would also be used for cooking, with any shortfall being made up from solar panels supplying hot water. Electricity can be generated on-site, using small wind turbines and/or photovoltaics. This approach enables net zero import of energy for use in the building, and (more importantly in our view) net zero carbon dioxide emissions.

  While the Saskatchewan climate presents something of a challenge for such a strategy, near-net-zero buildings have existed in Europe, functioning at the comfort standards expected for modern living, for over a decade. Good recent examples include projects in Göteborg, Sweden, and Hannover/Kronsberg, Germany, under the European Commission's CEPHEUS programme,[68] and the BEDZED development in south London, England.[69] Perhaps more relevant to the prairie climate is a very recent building in Denver, Colorado.[70]

  For some, such a design would enable a dream of living "off-grid", free from dependency on government- or industry-run electricity and gas supply systems. In contrast to the rugged individualism of the off-grid approach, most European projects are multi-unit developments with district heating; and, rather than being off the electricity grid, the scheme will be set up as a participant in a distributed generation system, exporting to the grid at some times, importing from it at others. (Legislative change would be required to enable this type of arrangement for electricity for a multi-unit development in Saskatchewan.)

4.3.3 Geo-Exchange

True geothermal energy (i.e., extracting energy from hot rocks at depth) is, for geological reasons, unlikely to become a serious option in Saskatchewan.

In common parlance, however, the term "geothermal heating" has also come to mean a heating system based on ground-source heat pumps. In such a system, most of the heat is "pumped" from a lower to a higher temperature (from the ground to the house), but the laws of thermodynamics require that in order to do this a certain minimum electrical input is required. A good ground source heat pump typically has a coefficient of performance of about three in a prairie climate—this means that each kWh of electricity used achieves a heating effect of three kWh. As using electricity from the (highly coal-intensive) SaskPower grid results at present in nearly four times the carbon dioxide emissions per kWh compared with natural gas, the result is that typically in this province ground source heat pumps have a greater greenhouse gas impact than a high-quality natural gas heating system.

However, the Craik EcoCentre models an interesting development of this technology. Part of the heating for the EcoCentre is provided through an in-floor radiant heating system similar to that described above in Section 4.3.2. In this case, though, the warm liquid for the in-floor system comes from tubing buried three metres deep in an area extending 300 metres in front of the building. An antifreeze solution is circulated through the buried plastic loops, where it absorbs heat from the constant 11 C at that depth. Electric heat pumps upgrade the energy in this fluid to an appropriate heating temperature. To increase the efficiency of the system, any excess solar-heated liquid from the roof panels is pumped back into the earth through a separate loop.

Hence this is a hybrid solar/heat pump system, using ground storage. The solar component reduces the required electrical load, both directly by substitution, and indirectly by increasing the heat pump coefficient of performance.

4.4 Prospects for a Renewables-Fuelled Saskatchewan

Saskatchewan is well placed to make a rapid transition away from fossil fuels to a fully renewables-based energy supply. Its good wind, solar and biomass resources, combined with a low population density, put it in an excellent position to make the changes necessary to combat climate change without resorting to nuclear power or large-scale hydro development.

5

The Role of Energy in a Green Economic Development Strategy

One need look no further than the development of the Alberta tar sands for an example of an economic undertaking that is unsustainable. This venture has been heavily subsidized, with royalties set at a mere one per cent. The extraction of one barrel of oil requires the use of three barrels of water, drawn from the Athabasca River. The continued operation is expected to produce 70 million tonnes of greenhouse gases by 2010 making it the most highly polluting region in Canada.[71] The nearby town of Fort McMurray is struggling to keep up with its population explosion, the resulting demand on infrastructure and healthcare services, as well as increasing drug use and criminal activity. This is a picture of development based solely on economic growth, on fast profit, with no regard for the environmental or social implications it brings.

This is not the kind of development we need in Saskatchewan. While our two major cities grow, our total population continues to decrease. To counteract this increasing urbanization, we must meet the needs of our rural people for meaningful employment. We should work to draw people back to smaller centres by illustrating how they can be revitalized, by showing that they can again be sources of opportunity, while continuing to offer social and environmental goods that meet or exceed those of the urban centres. Drawing people back to smaller towns and cities will also work to reduce the stress on the cities' infrastructure and their continuing propensity for sprawl.

A sustainable development strategy must address all of these social issues. It is not enough to suggest our problems will be solved by increasing our population, nor by increasing business and industry investment. What matters more is the type of investment we seek out and how we meet the needs of the people who have chosen to remain here.

The Government of Saskatchewan has echoed these ideals, perhaps most concretely within the recent release of Saskatchewan's Green Strategy: For a Green and Prosperous Economy. In this framework, the government shares the following:

"The vision for Saskatchewan is one of strong economic growth, vibrant communities and a healthy environment. Saskatchewan people are acting together to achieve improved human health and education, and a thriving sustainable economy, all supported by a diverse and enduring environment."[72]

Along with this vision, a promise is made in the document to pursue the creation of "a society that is economically, socially, culturally and environmentally sustainable."[73] It is time to bring government to focus on this promise and for us all to work together to achieve such a vision.

It is also clear that major economic benefits to Saskatchewan residents and communities will result from improved energy efficiency. Wasted energy represents money down the drain.

Renewable energy technologies present a unique opportunity to individuals living in rural Saskatchewan and to their communities. While traditional energy systems are centralized, wind, solar, biomass, geothermal and small hydro systems can be placed in close proximity to the end users. This means that landowners and communities in rural Saskatchewan may be able to provide their own energy, be it for electricity or liquid fuel, and sell the surplus for profit. A recent statement by the Prairie Policy Institute supports this concept:

"Most of the money for these (wind) turbines can come from investment by the private sector. For instance, a community or rural municipality erects a turbine, which pays for itself in seven or eight years. After which, for the rest of its rated life (around 20 to 25 years), the community shareholders (the property taxpayer) receive a dividend cheque. It is easy to imagine the spin-off benefits of so many turbines located in rural Saskatchewan."[74]

The Canadian Renewable Energy Alliance notes "locally-owned wind generation in particular creates five to fifteen times more economic activity in the local community than typical commercial developments, particularly in rural economies."[75]

On a grander scale, operations such as wind farms and biofuel processing plants will also require a labour force. Instead of young people leaving the province, or moving out of their communities to find jobs in the oil patch, they may be able to stay closer to home, working in an industry that will benefit the province for years to come. There would not be the same concerns as with a boom and bust industry; just as the source is renewable, so too would be the resulting economic, environmental and social benefits.

The St. Leon 99 MW wind farm in southwestern Manitoba is expected to create six to 10 permanent jobs at the maintenance facility and around $9 million of extra revenue for the 50 farmers whose land will be occupied by the 36 square miles of the wind farm.[76] Most present farming activities will continue as usual. The Canadian Wind Energy Association provides information on their web site on the considerable economic benefits to the Pincher Creek area of southern Alberta of the Summerview Wind Farm (68.4 MW) constructed there recently.[77]

In the United States, the Rocky Mountain Institute calculated that farmers in the American mid-west might get $50-80/acre/year new net income from their land occupied by a wind farm.[78] Assuming an area of 640 acres in the wind farm—most of this land is still farmable for crops—an individual farmer might receive $32,000 new net income per year.

Additional economic benefits to rural communities can be expected to occur through provision of new markets for bio-energy, by development of biomass processing facilities, and through further decentralization of electrical generation.

6

Barriers to Progress

Further development of renewable energy technologies in Saskatchewan is hindered by a number of factors. These are particularly problematic for small scale production of energy, and relate to infrastructure, technology, financial cost and the nature of the market, as well as political and social issues.

6.1 Technical Barriers

6.1.1 The Energy Grid

Different renewable technologies for electrical generation all have their respective challenges; they are also faced with the limitations of the delivery system. Over the past 60 years, SaskPower has created and reinforced a centralized grid, mostly dependent on and designed for fairly large central generating facilities. While this has enhanced service delivery, it has virtually eliminated the opportunity for inputs to the grid from small suppliers in rural areas. Contrast this concept to that of Sweden, where farmers have purchased wind turbines, connected to the grid and are able to sell their surplus energy back to the state at an attractive price.

6.1.2 Wind Energy

Critics of wind energy are quick to point out that there are times, even in Saskatchewan, when the wind does not blow. This is an issue of supply intermittency. We cannot depend upon an energy system that shuts off and on according to the weather. We have come to expect a constant supply that meets our needs 24 hours a day and to whatever level of excess we might like. Thus, wind has been suggested as an appropriate technology to partner with a more dependable source, like hydro, nuclear or coal. It is important to note, however, that a number of studies have demonstrated that peak wind flows correlate with peak demand times. This suggests that while wind energy may need to be partnered, it has the potential to be a greater contributor than its critics care to admit. See Section 4.2.1 for discussion of methods of accommodating intermittent sources such as wind in the grid.

6.1.3 Solar Energy

Solar energy is the earth's most abundant and consistent renewable source of energy. However, the strength of the solar energy available at any point on the earth depends on the day of the year, the time of day, and the latitude of the collection point. The amount of energy collected depends on the orientation and shape of the object doing the collecting. In addition, the amount of solar energy that reaches the surface of the earth depends upon the angle of the sun, the amount of dust and water vapour in the air, and the amount of cloud cover. Because of this, technology to date requires a fairly large surface area to collect useful amounts of solar energy for electricity generation.

Solar technologies are, as well, susceptible to intermittency, necessitating the use of battery storage and retrieval (see Section 4.2.1).

6.1.4 Biomass

The technological challenges associated with biomass are dependant upon the material being used and the scale of production (see Section 4.1) There is a growing interest in Saskatchewan farmers producing crops to be used as biofuel. However, uncertainty persists about the implications for farmers if the demand for energy crops expands significantly. Some fear that prices may fall because the demand for lower-grade crops will dominate the market. At the same time, some livestock operators fear that competition for crops will result in higher feed prices. Differences of opinion on the impact for a hungry world of growing energy crops on land that could be used for growing food continue (see Section 4.1.3). Ongoing arguments about the net energy balance and greenhouse gas benefits of substituting biofuels for mineral gasoline (see Section 2.4.8) add to an atmosphere of uncertainty.

6.2 Economic Barriers

The greatest costs in the development and use of renewables are the capital costs of the equipment. However, once the initial investment is made, the ongoing cost can be competitive with traditional sources.[79]

It is important to note that it is impossible to make a true comparison with fossil fuels unless externalities are entered into the equation. Externalities in this case refer to issues such as health effects of pollution, damage to ecosystems caused by the exploration for and the extraction of fossil

Table 4.

Capital and ongoing cost of renewable energy sources.

Source	Wind	Solar (PV)	Geothermal	Biomass	S. Hydro
Capital	$1000-4000	$5000-20000	$900/kW		$1500-7000
Ongoing	.05-.20c/Kwh	.37-4.50/kWh	.03-.075/kWh	$1.85 -2.90/MBtu	.05-.20/kWh

fuels, as well as more generalized costs associated with climate change. This "full-cost accounting" is necessary to reveal the high cost of traditional energy sources, which will in turn illustrate the actual competitiveness of renewables. Thus, one of the most challenging barriers to the adoption of renewable technologies is that at present, government and industry do not take these externalities into account.

The subsidization of traditional technologies further distorts the comparison. Federal and provincial governments offer direct payments, tax breaks and fiscal incentives to fossil fuel industries and its consumers. In 2000-2001, over $1.3 billion was paid to Canadian consumers "to offset the rising price of natural gas, reducing the incentive for Canadians to conserve energy". In the winter of 2005-2006, a similar pay out was initiated again in Saskatchewan to soften the blow of a natural gas rate hike, while in the spring, the federal government phased out the successful Energuide program.

The continued exploration, development and use of oil and gas clearly benefits the province financially, when the externalities are not considered.

The mining and use of coal presents a somewhat different picture. While the province doesn't make the same income from coal as it does from oil and gas, it does enable it to offer residents a relatively cheap source of electricity. Coal currently provides about 70 per cent of all electricity to consumers and its reserves exceed 30 billion tonnes.[81] It is estimated that coal may be able to supply us with electricity for another 50 years, but at what cost to the environment?

Coal is also heavily subsidized by the government, further enhancing its appearance as a low cost source. Current subsidies include:

- Mineral exploration tax credit.
- Prospector and Corporation mineral exploration incentive programs.
- Fuel tax rebate for mineral exploration.
- Competitive royalty regimes.[82]

6.2.1 Market Access

At present, independent power producers cannot be assured access to SaskPower's energy grid. The Small Power Producers Program provides little incentive to encourage participation. For those producers of less than 100 kW, a caution is given:

"SaskPower's experience shows that smaller power projects can be costly to set up and operate. Customers are encouraged to evaluate the amount of energy you expect to produce and the economics of the project to determine your overall cost of electricity."

This is sound advice and is very telling for the future of renewables in this province.

"The Generator Owner is responsible for the total cost of the Interconnection Facilities required to integrate the Generation Facilities into the SaskPower distribution system. The Generator Owner is also responsible for the costs of future changes to the Generation Facilities as may be required by SaskPower."[83]

Table 5.

Revenue from oil and gas producation in Saskatchewan, 1995–2002 in million 2000$.[80]

Revenue Source	1995	1996	1997	1998	1999	2000	2001	2002
Oil Royalty	577	479	731	510	313	640	775	524
Natural Gas Royalty	67	44	56	46	68	92	232	122
Income Taxes	101	233	103	95	100	247	307	520
TOTAL	745	757	890	651	480	979	1314	1166

So not only is there no support for capital costs, there is little to no incentive for providing power to the grid. This is evidenced in the current rate of compensation and was an issue with the Crown Corporations's transactions with Weyerhaeuser. The mill burned pulp mill waste, thus was capable of meeting almost all of its own electricity requirements. It did remain connected to the grid, but found when it needed to purchase power, it did so at the highest industrial rate.[84]

6.2.2 Transportation

Special attention must be paid the transportation sector, as it is responsible for 25 per cent of our greenhouse gas emissions in Canada. Our goal should be to decrease the number of private vehicles on the road, especially those with poor fuel economy. There are a number of challenges to this goal, some of which are particular to Saskatchewan. We have a large landmass that is primarily rural. We lack the density, even in our cities, to support adequate public transit. We are deeply entrenched in agriculture—45 per cent of our land mass is involved in agricultural activities, all of which requires some use of fossil fuels for transport. The majority of cargo is carried by large trucks, while we continue to reduce the amount of railway traffic. These scenarios culminate in a society dependent upon fossil fuels, people and producers who find it hard to imagine any other way of being.

Barriers to alternative transportation methods include cost of and access to new technologies and insufficient incentives to do so. For diesel vehicles in Saskatchewan, there is still no biodiesel available for individual consumer purchase. While some in urban centers are able to cycle, walk, or bus to their destinations, rural residents, who comprise over 40 per cent of our population, are far more constrained by their lack of options.

6.3 Political Barriers

The Government of Saskatchewan has taken a number of promising steps towards a sustainable energy future. These steps include technical developments such as the increasing number of installed wind turbines, research and development into biomass technologies and ethanol production, and solar demonstration projects. Politically, we have a commitment from the 2006 Throne Speech that states "by the third decade of this century, the children of our Centennial will live in a province where one-third of their energy needs are met by renewable energy sources, and Saskatchewan will lead the country in energy conservation practices." In addition we have seen the appointment of a Legislative Secretary to the Premier for Renewable Energy and Conservation and the continued investment in the Environmentally Preferred Power (EPP) Program. What remains to be seen is how aggressively this government will work to promote conservation, if they actually act upon the findings of the legislative secretary and if they take the necessary steps to make renewables a realistic solution for the people of Saskatchewan.

Energy efficiency and conservation clearly represent the most effective route towards a sustainable energy system, but they appear to be the least glamorous. Utilities have limited interest in them because "utilities delivering electricity and gas often view efficiency in terms of loss of market share. As a result, when trying to meet a growing demand for energy, utilities tend to think first of new energy supply options."[85]

A major impediment to political change in any case is whether or not the issue is of concern to voters. If elected representatives never hear from the voters and are never encouraged or pressured to take action towards a specific goal, they have little motivation to pursue it. Political will seems to stem from public interest and will. It is difficult to blame inaction on any level of government, when the general public is apathetic.

Conversely, we do expect leadership from politicians. There are times when difficult choices have to be made, including some that may be unpopular in the short term, for the common good. This requires a government to think past the next election, to have a long-term vision for the sustainability of our energy solutions. The people of Saskatchewan can hope that this is, and will be the case, but we must also do our part as citizens and encourage the political will necessary to make real change.

6.4 Social Barriers: The Concept of Change

It is difficult for the general public to embrace change, especially when it is viewed as a sacrifice or a loss. The use of renewable energy alone will not be enough to build a truly sustainable energy system; it must be coupled with conservation measures. This represents a challenge to any real progress—not only will people have to accept and adapt to new technologies, but they will have to address what continues to be an excessive demand on energy resources.

Much has been written by social movement theorists as to how significant change occurs in society. A popular theory is Malcolm Gladwell's "tipping point", in which a critical mass is formed. The Tipping Point plots the steps of change and the measures we can take to make it happen. Innovators are necessary to present new ideas and technologies, to test the water and take risks. From there, salespeople then need to spread the message of possibility and success. Saskatchewan has innovators and salespeople of renewables and sustainable energy paths in general, but we appear to be stalled in our attempt to motivate the general public.

Conservation of energy faces other challenges, as people tend to resist this concept of "sacrifice". Economists know this and can measure it by what people are willing to pay for a service, compared to what they are willing to accept as compensation if they agree to sacrifice it. What we are willing to accept tends to exceed what we are willing to pay, unless we see a suitable alternative on the horizon. This is why efficiency measures are easier to sell than conservation. We are more likely to pay a few extra dollars to get Energy Star appliances. We are not apt to cut back on how much energy service we use. People in Saskatchewan like to be warm in the winter and cool in the summer. We like to have electric lighting available 24 hours a day, to be able to power the TV, washing machine and vacuum cleaner simultaneously. Anything less than this is seen as an inconvenience and the officials responsible for depriving us of it would be unpopular.

However, throughout history the general public has been known to sacrifice for the greater good. This has been most commonly seen in war time, when we rationed, and even in the OPEC crises when we reconsidered our modes of transport. It was understood by the populace that we were in a time of crisis. This was a message repeated by every mode of media and every public official. The message trickled down to cities, towns and neighbourhoods. It became a general understanding.

A similar message of crisis is currently being passed around the margins. What is now necessary is to make it widespread and pervasive. We are in a time of crisis. People in Saskatchewan may not see this now. Our air looks fairly clear, we've not experienced a major blackout, the majority of us can still afford to live in relative comfort, but the crisis still looms. We already feel the pressure from the rising prices of oil and natural gas, we are beginning to make the connections between our changing weather patterns and climate change and we will soon be faced with making decisions on nuclear power. The world around us is changing—the question is whether or not we will be able to successfully change with it. The key to success may be the timing. If our province waits, and is merely reactive to rising fossil fuel prices, pollution, climate change and energy shortages we will forever play catch up. If, however, we become proactive in our legislation and conservation practices, acting on scientific and market evidence of resource scarcity, we should have every opportunity to benefit from a sustainable energy path.

7

Recommendations

In June 2006, the Canadian Renewable Energy Alliance (CanREA), of which SES is a founding member, published a Framework for a Model National Renewable Energy Strategy for Canada (www.canrea.ca). The Framework includes recommendations for provincial/territorial renewable energy and energy efficiency policies and actions. Of these, we have selected out those that are particularly appropriate for Saskatchewan and have described them in the context of our own provincial situation. Some additional specific examples of programs and policies to support the recommendations are provided. These are, for the most part, consistent with the recommendations in the recent Prebble report to the Premier.

1. Energy Efficiency and Conservation

Energy efficiency and conservation must form the cornerstone of a sustainable energy future for Saskatchewan. Experience has shown that these are the lowest-cost options for meeting energy needs while simultaneously avoiding greenhouse gas emissions and providing much needed local economic development opportunities. In order to overcome the barriers to adoption of these obviously desirable options, governments need to put in place policies and programs that encourage investment in energy efficiency and conservation and transform markets towards energy efficiency products and practices.

1.1 Saskatchewan should set a goal of meeting all new growth in energy demand over the next two decades through energy efficiency and conservation. To meet this goal, legally enforced efficiency and demand-side management (DSM) targets are needed for each power and gas utility along with appropriate intermediate milestones.

1.2 Legally enforceable energy efficiency targets are needed for each major energy-user, along with appropriate intermediate milestones. A tradable permit system would facilitate achievement of required targets for those users who are unable to make the necessary technological transitions in time.

1.3 SaskPower and SaskEnergy should be provided with a shared savings DSM incentive mechanism through the rate structure so that they are rewarded for delivering conservation and efficiency as well as for selling energy.

1.4 Provided with stable funding, the provincial Office of Energy Conservation (OEC) should become the coordinating agency for design and delivery of energy conservation and efficiency policies and programs. A public benefits charge on all utility and fuel energy sales should be considered to provide this stable funding and to finance efficiency incentives.

1.5 A comprehensive, well-staffed, easily accessible "sustainable energy information service" should be established by the OEC. This will provide a commercial-free, reliable, credible source of advice for Saskatchewan energy users who are seeking information about energy efficiency products, practices, programs, contractors, etc.

1.6 Market barriers to adoption of energy efficient practices and products by Saskatchewan residents should be identified and remediated. The following policies (1.7-1.8) would start this process.

1.7 Building on SaskEnergy's support for purchase of energy efficient residential heating systems, more targeted financial incentives should be offered to help kick-start market transformation in consumer areas such as housing, appliances and vehicles. These may in the form of low-interest loans, grants or tax relief.

1.8 A provincial business energy efficiency tax credit would help offset expenditures undertaken by businesses to improve the energy efficiency of their operations. This tax credit would be applicable also to owners of new buildings who incur additional upfront costs by building to LEED standards.

1.9 Grants for homeowners to improve the energy efficiency of homes should be continued after the projected March 2007 expiry date, and should be expanded to include non-profit and municipal buildings.

1.10 The government of Saskatchewan should adopt Energy for New Houses 80 (EGH 80) as the minimum building code for all new residential construction, and 30 per cent better than the national model energy code for all new buildings. The provincial building code should also require that all new homes and buildings be designed "solar ready" for future addition of solar electric and solar heating systems.

1.11 Training and certification of trades and technical people in energy efficiency design, construction and renovation is required in order to upgrade the skills of Saskatchewan people.

1.12 A vehicle registration re-bate/fee-bate system should be developed to lower costs for owners of efficient vehicles at the expense of those owning gas-guzzlers.

1.13 Public investment in public transit and other energy-efficient transportation modes should be increased. Temporary financial and social marketing incentives will be needed in order to encourage use of these transportation modes rather than private vehicles.

1.14 Government should provide leadership by expanding its own "house-in-order" program, ensuring that the buildings which its departments and agencies occupy are operated in a highly energy efficient manner. (At present there appears to be little if any incentive to Departmental managers to save energy as they are not responsible for the cost of their buildings' energy use). Similarly, government vehicle fleets should set an example of energy efficiency.

1.15 Saskatchewan should actively participate in collaborative energy efficiency work with other provinces and the federal government under the Council of Energy Ministers DSM working group. In particular Saskatchewan should participate in collaboratives on a national lighting efficiency strategy, low income housing, and building code upgrading—implementing provincial initiatives as part of national action plans.

2. Electricity Generation

We are recommending a transition from the large central power station system that has served Saskatchewan for the past several decades to one based on smaller, decentralized, distributed generation units interconnected by a smart network. Increasingly these generation units will be based on renewable energy resources. Distributed generation encourages community economic development by allowing for local control and ownership, offering opportunities for substantial job creation. A distributed approach can improve reliability of power systems and reduce the risk of system-wide failures. Producing electricity close to its location of use also reduces transmission losses Use of renewable resources minimizes ghg emissions and other environmental impacts of energy production, and helps to ensure long-term sustainability.

2.1 Access to development capital and adequate financing through innovative loan, grant and tax-based incentive programs will enable participation of individuals and communities in distributed generation initiatives.

2.1 A skilled labour and technician base capable of supporting integrated, renewable energy power systems and distributed technologies must be developed through schools, post-secondary training programs and unions.

2.3 SaskPower must guarantee a streamlined interconnection process for distributed generation to connect to the grid to enable community participation in a fair energy market.

2.4 Saskatchewan should establish a Renewable Energy Portfolio Standard for Sask Power, requiring that by 2025, 50 per cent of our electrical load will be met from sustainable renewable energy sources such as windpower, solar, small scale hydro, biomass, methane gas recovery etc. A plan for reaching this standard, with milestones for achievement along the way, should be developed over the next two years, with a process defined for updating the plan as technology evolves.

2.5 A feed-in tariff and standard offer contract system offering premium prices should be established for distributed power sources including wind, solar and biomass. For those not participating in the standard offer contract system, a system of net metering should be introduced to allow individuals who generate their own power to supply excess power to the grid for the same price as they are charged to buy power from the grid.

2.6 Because of the continuing failure to solve the problems associated with long-term management of nuclear fuel waste and with diversion of nuclear materials to military use, nuclear power should be ruled out as a potential component of Saskatchewan's electrical supply system in the foreseeable future.

2.7 "Cleaner" coal power generation should be seen only as a replacement for existing "dirty coal" generation, not as an addition to it. So any "cleaner coal" plants that are commissioned should be accompanied by the closure of an equivalent capacity of "dirty coal" generation.

2.8 Sustainability criteria should be established for all sources of biomass used to generate power in the Province. These criteria would ensure that only biomass sources with low life cycle environmental and social impacts would be eligible for power generation.

3. Transportation

Actions to reduce the amount of energy used for transportation generally fall into three categories: using energy more efficiently (i.e., improved vehicle design), shifting transportation modes (e.g., public transit and active transportation to replace private cars; trains to replace trucks) and improving urban design to minimize commuting distances. Renewable fuels (e.g., ethanol, bio-diesel), appropriately produced, have a role to play in reducing ghg emissions.

3.1 Economic subsidies of various transportation modes must be consistent with their full economic, social and environmental cost. The clear ecological and societal benefits of active transportation, public transit and rail freight must be taken into account in decision-making about public expenditures on transport-related programs and infrastructure. Commuting between Saskatoon and Regina by energy efficient buses or by a restored rail service should be made convenient and less expensive than driving. Public subsidy of such service is justified by the resulting social and environmental benefits

3.2 In order to minimize commuting distance within cities, compact mixed-use urban development should be encouraged rather than suburban sprawl.

3.3 Financial instruments (e.g., congestion charges, parking fees, road tolls) should be used to discourage unsustainable transportation.

3.4 A vehicle registration re-bate/fee-bate system should be developed to lower licensing costs for owners of efficient vehicles at the expense of those owning gas-guzzlers.

3.5 Development of facilities to produce ethanol and bio-diesel should be supported in order to permit an orderly increase in the amount of petroleum product replaced by biofuel. However, the focus should be on production technologies which result in the lowest life-cycle emissions of ghg's and criteria air contaminants. Government should encourage the development of locally owned and managed cooperatives or partnerships to build, operate and supply raw material to bio-fuel facilities in order to keep the profits in Saskatchewan communities and the management under Saskatchewan control.

3.6 Sustainability criteria should be established for all sources of biomass used to produce biofuels in the Province. These criteria would ensure that only biomass sources with low life cycle environmental and social impacts would be eligible for conversion to ethanol and bio-diesel. (see also Electricity Generation)

4. Heating and Cooling

Energy requirements for heating and cooling of buildings can be most fruitfully addressed by improving the energy efficiency of both new and older buildings (see recommendations 1.2 through 1.10). In addition, the following measures will encourage a transition to sustainable energy use as we strive to maintain our homes and public and commercial buildings at comfortable temperatures.

4.1 A grant program should be introduced to assist building owners in the purchase and installation of approved renewable energy systems. These would include solar water-heating systems, photovoltaic systems and small wind-power systems.

4.2 Municipalities should be required to control new building in such a way that solar access for existing buildings is protected. New subdivision design should be required to provide for future solar access by all homes.

4.3 New buildings receiving provincial government funding should be built to a minimum LEED silver standard.

4.4 Government should identify and support opportunities to design and build a model residential neighborhood using seasonal solar storage (modeled on the Okotoks, Alberta project) and other affordable, low and renewable-energy-use housing projects in order to demonstrate their practicability.

4.5 SaskEnergy's mandate should be changed to include renewable energy heat supply. Saskatchewan should establish a Renewable Energy Portfolio Standard for Sask Energy, requiring that by 2025, 30 per cent of space and water heating loads currently met with gas will be met from sustainable renewable energy sources such as solar water heating, earth energy and biomass. A plan for reaching this standard, with milestones for achievement along the way, should be developed over the next two years, with a process defined for updating the plan as technology evolves.

5. Industry

The growing demand for energy by Saskatchewan industry must be addressed if we are to move towards sustainability. This demand should be approached in two ways:

5.1 First, the province's economic development strategy must take into account the environmental costs, globally as well as locally, associated with various development options. Incentives in the form of tax relief, grants and loans to leverage investment, infrastructure support, royalty rate adjustments, etc. should be provided in such a way as to favour those forms of development and job-creation that are ecologically and socially sustainable.

5.2 Secondly, because every industry is unique, it is not possible to define specific changes and practices that should be universally applied in order to improve industry efficiency and sustainability. Rather, required standards of achievement should be defined, and the infrastructure established to support industries with information and advice as they work towards meeting these standards. A national cap-and-trade system for greenhouse gas emissions would be very helpful for dealing with these large industrial emitters. Saskatchewan should support the adoption of such a system.

5.3 Saskatchewan should refrain from developing any oil sands energy projects in Northern Saskatchewan without full consultation among provincial stakeholders and a frank discussion of the environmental, health and land use impacts such a development would cause.

6. Financing Change

Renewable energy and energy efficiency systems are unique in that they require higher initial investment than conventional energy sources, while at the same time providing multiple benefits that are not reflected in their cost. Innovative strategies and policies are therefore needed to increase investment, spread the cost over the system's lifecycle, and reflect the benefits of sustainable energy. While government commitment and policies to leverage investment are key, investments will need to come from both public and private sectors, and will have to take many forms including financial incentives from governments, loans and capital investments from banks, private investors, venture capital funds and communities. Energy bill charges, community development funds and general tax revenues will all be needed.

8

References

[1] From www.statcan.ca "Canada, A Big Energy Consumer: A Regional Perspective" 2003

[2] Table 7: Primary energy consumption and selected indicators, Saskatchewan, 1990 and 2003. in ref. above

[3] Report on Energy Supply-Demand in Canada 2003 (StatsCanada)

[4] Department of Trade and Industry (2004:07), UK Energy in Brief, London, England.

[5] www.saskenergy.com/about_saskenergy

[6] www.saskpower.com

[7] Stern, N. (2006). Stern Review Report: The Economics of Climate Change. pp.1. http://www.hm-treasury.gov.uk/media/8A8/C1/Summary_of_Conclusions.pdf

[8] Marshall, D. (2006) "All Over the Map: Status Report of Provincial Climate Change Plans." David Suzuki Foundation.

[9] Prebble, Peter, MLA: Renewable Energy Development and Conservation in Saskatchewan, December 2006)

[10] Raynolds, M. (2006). "Clean Coal by what Definition?" Calgary Herald Feb. 24, 2006. http://www.pembina.org/media/op-ed.php?id=1222

[11] Goodell, J. (2006). Big Coal: The Dirty Secret behind America's Energy Future. Houghton Mifflin Company.

[12] Molnar, R. (2006) "Debating nuclear energy in Saskatchewan" The Carillon (48)17 Found online: http://www.carillon.uregina.ca/02.09.06/news5.html

[13] Rocky Mountain Institute, RMI Solutions, summer 2005

[14] World Commission on Dams. (2000). "Dams and Development: A New Framework for Decision-Making". Earthscan Publications. Also found online at: http://www.dams.org/report/wcd_overview.htm

[15] National Wind Coordinating Committee. (2001). Avian Collisions with Wind Turbines: A Summary of Existing Studies and Comparisons to Other Sources of Avian Collision Mortality in the United States. Found online at: http://www.nationalwind.org/publications/wildlife/avian_collisions.pdf

[16] $(S\&T)^2$ (2006). Sensitivity Analyses of GHG Emissions from Biofuels in Canada. See www.ghgenius.ca.

[17] SDTC (2006a). Renewable Fuel – Biofuels. SD Business CaseTM. Sustainable Development Technology CanadaTM. Canada Foundation for Sustainable Development Technology (SDTC). Web site address: www.sdtc.ca.

[18] SDTC (2006b). Renewable Fuel – Hydrogen. SD Business CaseTM. Sustainable Development Technology CanadaTM. Canada Foundation for Sustainable Development Technology (SDTC). Web site address: www.sdtc.ca.

[19] NRCan (2006a). CCSTRM. Canada's CO2 Capture & Storage Technology Roadmap. Natural Resources Canada. Web site address: www.co2trm.gc.ca.

[20] NRCan (2006b). Powerful Connections: Priorities and Directions in Energy Science and Technology in Canada. Office of Energy Research and Development, Natural Resources Canada, Ottawa, Ontario K1A 0E4.

[21] CAE (2006). Energy Pathways Report: Phase 1. Canadian Academy of Engineering. Web site address: www.acad-eng-gen.ca.

[22] Brown, L.R. (2004). The Short Path to Oil Independence: Gas-electric Hybrids and Wind Power Offer Winning Combination. See www.earth-policy.org.

[23] www.hymotion.com

[24] www.edrivesystems.com

[25] www.greencarcongress.com/2006/11/manitoba_hydro_.html

[26] ACEEE (2006). Plug-in Hybrids: An Environmental and Economic Performance Outlook. J. Kliesch and T. Langer, American Council for an Energy-Efficient Economy. See www.aceee.org.

[27] The project was a collaboration among Clean Urban Transport for Europe (European Union), Ecological City Transport System (Reykjavik, Iceland) and Sustainable Transport Energy Program (Western Australia), and is documented at http://www.fuel-cell-bus-club.com : including final reports by all three of the organisations involved. In ongoing collaboration, they have been joined by MOST (Beijing) and BC Transit (Vancouver).

[28] Clean Urban Transport for Europe (2006), CUTE: Detailed Summary of Achievements – a hydrogen fuel cell bus project in Europe 2001-2006, EvoBus GmBH, Ulm, Germany

[29] Layzell, David B; Stephen, Jamie; & Wood, Susan M, (2006:02), Exploring the Potential for Biomass Power in Ontario: a response to the OPA supply mix advice report, BIOCAP Canada Foundation, Queens University, Kingston, Ontario

[30] Saskatchewan Forest Centre (2006). Agroforestry maps and data from S. Poppy, Agroforestry Unit, Saskatchewan Forest Centre, Prince Albert, Sask.

[31] SECDA (1994). Assessment of the Potential Use of Biomass Resources as a Sustainable Energy Source in Saskatchewan. Saskatchewan Energy Conservation and Development Authority (SECDA) Report No. T800-94-P-008.

[32] Stumborg, M., Townley-Smith, L. and Coxworth, E. (1996). Sustainability and economic issues for cereal crop residue export. Can. J. Plant Sci. 76: 669-673.

[33] Levelton and (S&T)2(2000) Assessment of the Net Emissions of Greenhouse Gases from Ethanol-blended Gasolines in Canada: Lignocellulosic Feedstocks. Report R-20000-2 Agriculture and Agri-Food Canada

[34] See British-based company Compact Power's description of the process at http://www.compactpower.co.uk/pages/technology_overview.php

[35] O'Connor, D. (2000). Wheat: The Fuel Ethanol Feedstock for Canada. Proceedings of the bio-logical futures III conference, Saskatoon, Sask., October 16. CD available from Ag-West Bio, Inc., Saskatoon, SK S7N 3R2

[36] See the Saskatoon Transit Services website: http://www.city.saskatoon.sk.ca/org/transit/biobus.asp

[37] SDTC (2006a). Renewable Fuel – Biofuels. SD Business CaseTM. Sustainable Development Technology CanadaTM. Canada Foundation for Sustainable Development technology (SDTC). Web site address: www.sdtc.ca

[38] Coxworth, E. (2006). Providing the Farm Fuel Supply with Farm-Grown Biodiesel. Available from the author at ewen.coxworth@sasktel.net

[39] Biogas Cities (2006), promotional brochure available at http://www.businessregiongoteborg.com/download/18.7b9ef41d1098c3fc06580002718/Biogas_8sid+eng+2.pdf (last accessed 2006:Oct:29) Biogas Cities is an international partnership led by Swedish organisations including the city of Göteborg and the Volvo Corporation.

[40] Pratt, S. (2006). Biobutanol eyes ethanol's crown. Western Producer, Octover 26, p. 3.

[41] See, for example, the following websites:

The German company Elsbett Technologie has been supplying single-tank svo systems (including modified injector nozzles and glowplugs) since 1979: http://www.elsbett.de

In Denmark, the Folkecenter for Vedvarende Energi (Peoples Centre for Renewable Energy) has for several years been testing both the effectiveness of the fuel and the potential for economic benefit in the agricultural community: a number of documents are posted at http://www.folkecenter.dk/plant-oil/plant-oil_en.html

There is useful general discussion on the issue at the Journey to Forever website: http://journeytoforever.org/biodiesel_svo.html#problem

The 2-tank system with unmodified engine is defended by Ed Beggs, of Neoteric Biofuels in British Columbia. His company website, which includes his masters dissertation on the subject, is at http://www.plantdrive.com

[42] Hoogwijk, M., Faaij, A., Eickhout, B., de Vries, B. and Turkenburg, W. (2005). Potential of biomass energy out to 2100, for four IPCC SRES land-use scenarios. Biomass and Bioenergy 29: 225-257

[43] Holttinen H (2003), Hourly wind power variations and their impact on the Nordic power system operation, Helsinki University of Technology (Department of Engineering Physics and Mathematics), available at http://lib.tkk.fi/Diss/2004/isbn9513864278/ (last accessed 2006:Nov:01)

[44] British Wind Energy Association (2005:09), BWEA Briefing Sheet - Wind Power and Intermittency: the facts, BWEA, London, England. Available online at http://www.bwea.com (last accessed 2006:Nov:01)

[45] Milborrow, David J (2004:07), Impacts of Wind on Electricity Systems with Particular Reference to Alberta. Available online at http://www.canwea.ca/Grid_interconnection_interconnection.cfm (last accessed 2006:Nov:01)

[46] VRB (2006). The VRB Energy Storage System (VRB-ESSTM). An Introduction to Wind & the Integration of a VRB-ESS. Available on the web site: www.vrbpower.com.

[47] Rydh, C.J. (1999). Environmental assessment of vanadium redox and lead-acid batteries for stationary energy storage. J. Power Sources 80: 21-29

[48] SDTC (2006b). Renewable Fuel – Hydrogen. SD Business CaseTM. Sustainable Development Technology CanadaTM. Canada Foundation for Sustainable Development Technology (SDTC). Web site address: www.sdtc.ca.

[49] Corsini, A., Gamberale, M. and Rispoli, F. (2006). Assessment of Renewable Energy Solutions in a Small Island Energy System Using a Transient Simulation Model. J. Solar Energy Eng. 128: 237-244

[50] World Alliance for Decentralized Energy (2006:05), World Survey of Decentralized Energy 2006, WADE, Edinburgh, Scotland

[51] Based on calculations using figures from:

SaskPower (2006), Our Changing Environmental Landscape: Environment Report 2005, SaskPower, Regina, Saskatchewan, and

SaskPower (2006), Regeneration: Annual Report 2005, SaskPower, Regina, Saskatchewan

[52] Mills, E & Lecomte, E (2006:08), From Risk to Opportunity: How Insurers Can Proactively and Profitably Manage Climate Change, Ceres / Investor Network on Climate Risk, Boston, MA, USA

[53] Department of Energy (2006:09), Strategic Plan, Draft W 08/25/06, Washington DC, USA: p.11

[54] Resources and Networks Branch, Ministry of Economic Development (2006:09), Facilitating Distributed Generation, Wellington, New Zealand

[55] Lovins, Amory B (2005:09, updated 2006:01), Nuclear Power: economics and climate-protection potential, Rocky Mountain Institute, Snowmass, CO, USA

[56] Greenpeace / World Alliance for Decentralized Energy (2006:03), Decentralising UK Energy: cleaner, cheaper, more secure energy for the 21st century – application of the WADE economic model to the UK, Greenpeace, London, England

[57] Abu-Sharkh S, Arnold RJ, Kohler J, Li R, Markvart T, Ross J N, Steemers K, Wilson P & Yao R (2006:04), Can Microgrids Make a Major Contribution to the UK Energy Supply?, Renewable and Sustainable Energy Review, Vol 10 issue 2, 2006:Apr, pp 78-127, Elsevier Science, Oxford, England

[58] The Hub Research Consultants (for Sustainable Consumption Roundtable) (2005:10), Seeing the Light – the impact of microgeneration on the way we use energy, The Hub, London, England

[59] Personal communication, Doug Opseth, SaskPower, December 2006

[60] German Wind Energy Association. (2006) A clean issue – Wind energy in Germany. Can be found online: http://www.wind-energie.de/en/wind-energy-in-germany

[61] Sawin, J. (2004). World Watch Paper 169. Mainstreaming Renewable Energy in the 21st Century. State of the World Library 2004.

[62] Sawin, op.cit.

[63] Data for Canadian wind generation capacity from: Canadian Wind Energy Association, Wind Energy Industry: Installed Capacity: online tables at: http://www.canwea.ca/production_stats.cfm (last accessed 2006:Nov:01)

[64] Environment Canada (2003), Canadian Wind Energy Atlas, available online at http://www.windatlas.ca/en/ (last accessed 2006:Oct:25)

[65] This figure is based on a rule of thumb, common in the wind industry, of a spacing of 5 turbine diameters between turbines, and an assumption of 80m turbine diameter for a 1.8MW machine (as is the case for the V80 units marketed by Vestas as suitable for onshore North American locations: technical details may be downloaded from the Vestas website at http://www.vestas.com/vestas/global/en/Products/Wind_turbines/V80_1.8MW.htm). The resulting figure of 9 hectares per MW capacity compares with a range from 6 to 10 ha/MW capacity indicated on the British Wind Energy Association website (http://www.bwea.com/ref/faq.html).

[66] H. Trueman in Saskatchewan Environmental Society Newsletter, nov/dec. 2006

[67] A description of the Factor 9 house in Regina is given at the SRC website, at: http://www.src.sk.ca/html/research_technology/manufacturing/build_perform/Factor_9/index.cfm

[68] A general description of the programme, plus links to all the projects involved, may be found at:

http://www.cepheus.de/eng/index.html .

Further information on the Göteborg project, and a plan to replicate the design in Ireland, may be found at:

http://abridesign.com/lowimpact/housing/action.lasso?-Response=search05.lasso&ID=1481, and http://www.scanhome.ie/passive.php .

[69] See the BEDZED website at http://www.zedfactory.com/bedzed/bedzed.html

[70] Norton, Paul & Christensen, Craig (2006), A Cold-Climate Case Study for Affordable Zero Energy Homes, National Renewable Energy Laboratory, Golden, Colorado, USA

[71] Sierra Club of Canada. April 26, 2005. Feds and GNWT Urged to Come Clean. Sierra Club of Canada, Arctic Indigenous Youth Alliance, Ecology North News Release. Found online at: http://www.sierraclub.ca/national/media/item.shtml?x=824

[72] Saskatchewan Environment (2006) "Saskatchewan's Green Strategy: For a Green and Prosperous Economy", p.13 www.se.gov..sk.ca/green

[73] ibid p.17

[74] Jessie, D. (2006) Who has seen the wind? Part 3: Wind energy alternative. Prairie Policy Institute www.prairiecentre.com

[75] www.canrea.ca

[76] Lovell, A. (2004). Man. wind energy project proceeds. Western Producer, December 9, p. 61.

[77] www.canwea.ca

[78] RMI (2004). Winning the Oil End Game: Innovations for Profits, Jobs, and Security (see page 164). Rocky Mountain Institute, Snowmass Colorado, USA 81654-9199 (see also www.rmi.org).

[79] Natural Resources Canada (Aware ppt) http://cetc-varennes.nrcan.gc.ca/fichier/41695/aware_02.ppt "Renewable Energy Technologies". Natural Resources Canada. (2006).

[80] http://www.pembina.org/pdf/publications/Regional%20Details_Saskatchewan.pdf

[81] Lyons, M. "Clean coal venture a burning issue" Star Phoenix, Saskatoon August 11th 2006, p.C8

[82] http://www.ir.gov.sk.ca/Default.aspx?DN=4736,3066,3038,2936,Documents

[83] http://www.saskpower.com/powerandenvironment/transmission/NUG345kV.pdf

[84] Lyons, M. "Clean coal venture a burning issue: Things may get heated when cost hits home". Star Phoenix. Saskatoon, Saskatchewan. Aug 11, 2006. pp.C.8.

[85] Canadian Renewable Energy Alliance. (2006). Energy Efficiency and Conservation:

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