Saskatchewan Environmental Society

YES THEY CAN: A 2020 VISION FOR SASKPOWER

Prepared for submission to Saskatchewan Power Corporation

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EXECUTIVE SUMMARY

Greenhouse gas (GHG) emissions produced through the combustion of fossil fuels are the primary anthropogenic contributors to global climate change. Only two of seventeen Organization for Economic Co-operation and Development (OECD) countries have higher per capita GHG emissions than Canada. Within Canada, GHG emissions from the electricity generation sector accounted for 99 megatonnes (Mt) of the nation's 692 Mt GHG emissions in 2010. Coal-fired thermal generating stations are responsible for 80 Mt of those GHG emissions.

In 2010 Saskatchewan's GHG emissions were 69.8 tonnes/capita (t/c), about 3.5 times the national average. The electricity sector comprises 22 percent of the province's GHG emissions. Thus, the fact that Saskatchewan's electricity sector accounts for significant emissions must be viewed in the context that Saskatchewan's total greenhouse gas emissions are unacceptably high.

SaskPower manages an electrical power generation system of some 4100 MW capacity, either as an owner or through power purchase and other arrangements. Three conventional coal-fired power stations comprise 1682 MW of this capacity. Because these stations are used to meet baseload needs, they account for about 60 percent of power generated in a typical year. These power stations pose two challenges for SaskPower: they are very significant GHG emitters and, in two cases, they are reaching the end of their useful life. The decisions required of SaskPower by 2020 concerning investments in replacement generating facilities while, at the same time, meeting burgeoning demand for additional power will set the course for the corporation for decades to come. These decisions can be taken in the context of both vulnerabilities and opportunities.

Vulnerabilities

SaskPower has taken a strategic decision to implement a Boundary Dam Integrated Carbon Capture and Storage Demonstration Project for one unit at the Boundary Dam Power Station. This unique project will allow the corporation to assess both technical and financial aspects of carbon capture and storage (CCS) in a Saskatchewan context. If the demonstration project meets requirements following its completion in 2014, other units at this station can be converted to CCS. While there appears to be an industry consensus that CCS can meet technical requirements, observers are not as sanguine concerning financial aspects. A failure to meet both tests would leave SaskPower vulnerable to financial and other pressures in replacing coal-fired power stations.

At present the lowest cost opportunity for providing new generating capacity is through natural gas-fired power stations, even if combined cycle technology is used. This advantage is driven for the most part by the current low cost of fuel as North America experiences a natural gas "bubble". Natural gas-fuelled generating capacity now comprises one-third of SaskPower's generating capacity and this share could increase in the future if CCS projects do not move ahead as planned or as more generating capacity is required. While meeting near-term needs, reliance on natural gas could lead to a future price shock as natural gas prices rise in response to increased demand.

There are several pressures that could lead to future price increases. The current natural gas supply bubble is driven by success with hydraulic fracturing technology in developing new natural gas supplies in North America. The depletion rate of these supplies, however, appears to be higher than originally anticipated. Price pressures could also develop if Canada becomes a supplier of liquefied natural gas to world markets, as thermal coal-fired power stations in the United States are converted to natural gas fuel, and if natural gas becomes a transportation fuel.

Use of natural gas in power generation can be considered, at best, as a stepping-stone to the future. Continued reliance on fossil fuels like natural gas beyond the 2032 time horizon of this report is problematic. Certainly by the middle of this century fossil fuelled power stations will be obliged to cease operations.

SaskPower's coal-fired stations are all dependent on cooling water from prairie streams and the corporation's hydroelectric stations, for the most part, are dependent on runoff from the eastern slopes of the Rocky Mountains. Future climate change promises to exacerbate already variable prairie water supplies while the nature of usually reliable mountain supplies could be affected by climate change and increased upstream consumption in Alberta. Thermal power stations are also subject to de-rating as cooling water temperatures increase. Experience with make-up water supplies from groundwater at the Boundary Dam Power Station in the 1980s drought indicates that the pumping rate used was not sustainable.

As the global struggle with GHG reductions starts to take hold, carbon taxes are inevitable. These could take the form of a direct tax or some sort of cap-and-trade system. SaskPower's GHG emissions will doubtless be caught by whatever system is implemented. It is also likely that whatever system of GHG reduction is put in place, it will become enveloped in global trade relations. Operating as it does in a province that is highly dependent on trade, SaskPower could be sideswiped by international trade actions or by extra-territorial application of United States law.

Opportunities

There are many options for reducing GHG emissions in the power sector and several of them are applicable to SaskPower operations. The options of particular value to SaskPower include demand side management (DSM) through increased efficiency and conservation, renewable power, and carbon capture and storage.

The least cost power that can be provided to customers is that achieved through reductions in demand through conservation and energy efficiency. DSM can best be accomplished through two measures: ensuring appropriate economic incentives are in place and through technological improvements. Just as capital investments are required to increase power supply, investments are equally important to ensuring demand management. DSM opportunities for SaskPower are equivalent to two to four units of a conventional coal-fired power station.

Previously identified as a vulnerability for SaskPower, CCS may also provide an opportunity. If the demonstration project now under construction proves the technical and economic viability of CCS in a Saskatchewan setting, conversion of some or all of the existing coal-fired stations to CCS may be possible as long as markets exist for CO_2 and other by-products of the process. The demonstration project may also lead to exportable technologies. As noted earlier, however, all power stations requiring the combustion of fossil fuels will likely have to be phased out in a post-2050 era.

Although natural gas power stations are currently a least cost option and opportunities for cogeneration should be pursued, renewable power sources provide sustainable benefits for SaskPower. Renewable power options, such as hydro and wind are now price competitive with any option other than natural gas, while other renewable options such as solar and biomass will achieve that status over the medium to long term. This is in consideration of only capital and operating costs. When a price is placed on carbon production, the balance swings even more heavily towards renewable power.

The southern half of the province offers considerable potential for development of wind generation facilities. There is no reason why Saskatchewan cannot join the leading Great Plains states in the United States in sourcing more than twenty percent of its power supply from wind.

Saskatchewan's geography provides opportunities for the development of solar power in the southern extremities of the province that are unique in Canada. This could include both photovoltaic and concentrated solar power options. These possibilities become even more attractive as the peak power demand switches from a winter peak demand to a summer peak demand.

If SaskPower chooses to include solar and biomass power stations in its generation mix through power purchase arrangements, this will require a carefully designed feed-in tariff regime to provide appropriate incentives to vendors. Of necessity the tariff would have to include both pricing and supply considerations.

Power sources such as wind and solar are not dispatchable, that is, supply cannot be easily adjusted to meet demand. However, complementary operation of these options with hydro allows considerable operating flexibility. In effect Lake Diefenbaker can act as a giant battery, storing water when other supply options are available and releasing it through turbines when they are not. Wind and solar power can also contribute to a drought contingency plan as neither entails major water demands.

One further opportunity for SaskPower lies in strengthening its transmission links with Manitoba Hydro and, indeed, purchasing power on a firm basis from that utility. A sizable power purchase or a joint venture on the development of a new hydro project on the Nelson River could easily replace one of SaskPower's coal-fired power stations. Improved linkages with Manitoba would also enable better integration of non-dispatchable supplies.

Recommendations

The following recommendations cover the short, medium and long term. Short term recommendations should be accomplished by 2020, medium term by 2030 and long term beyond 2030. The recommendations can be addressed by SaskPower but some would require policy direction from the Province itself. The recommendations represent a suite of options that would enable Saskatchewan to move to sustainable power production without conventional coal. Depending on the extent of implementation and the results of initial investigations, not all may prove to be needed or, indeed, to be feasible.

1. In the short term SaskPower should commit to a 300 MW saving driven by efficiency and conservation. The focus of this program should be on major power accounts. This could be accomplished through SaskPower bringing

industrial electrical engineering expertise to the problems of large consumers. Based on experience in other jurisdictions, increasing this commitment to 450 MW and then 800 MW in the medium to long term seems feasible.

2. Given the major capital costs associated with SaskPower's scenario of doubling electrical generation capacity in Saskatchewan over the next 20 years, SaskPower should gradually adjust its rate structure to encourage efficient use of electricity and to remove pricing incentives that offer customers lower rates when larger amounts of electricity are consumed. This transition to conservation pricing is an important component of demand side management and should be initiated in the short term.

3. In a clear statement of public policy the Province should state that existing conventional coal-fired generating stations (1700 MW) will be decommissioned at the end of their useful life. This implies that, unless they are equipped with carbon capture and storage (CCS), the Boundary Dam Generating Station would be decommissioned in the short term, the Poplar River Station in the medium term and the Shand Station in the long term.

4. SaskPower should continue to pursue its current 110 MW carbon capture and storage project at the Boundary Dam Generating Station. The results achieved with this project would help inform future expenditures on carbon capture and storage. Decisions regarding the role of CCS in SaskPower's generation mix are required in the short term. Given the uncertainties associated with this technology, however, SaskPower cannot count on CCS as the primary vehicle for resolving its carbon emission problem. SaskPower needs to invest in the short and medium term in other proven cost effective ways of reducing GHG emissions.

5. SaskPower should be prepared to implement time-of-day power rates in the short term, or as load profiles make this useful.

6. While gas-fired thermal generating stations are widely seen as the least cost short term option for SaskPower expanding its generating capacity, SaskPower should ensure that any such facilities be specified as natural gas combined cycle rather than simple cycle. This would apply to both power purchase arrangements and to stations owned by the corporation. This commitment should be made in the short term.

7. SaskPower should ensure that 20 percent (1200 MW) of its generating capacity is wind-powered in the short term and that 20 percent of its net electricity production is wind-powered in the medium term.

Complementary operation with hydro should be diligently pursued. It is understood that meeting the target level of wind power production may also require enhancement to the transmission and control systems of the electrical grid.

8. In the short term SaskPower should commit to the construction of up to 100 MW of small scale, run of the river hydropower generation. This increment of hydro could include the Elizabeth Falls project and other small-scale opportunities.

9. The province of Saskatchewan should enter into discussions with Manitoba for the provision of 1000 MW of firm hydropower. This could be achieved through construction in the medium term of the 1485 MW Conawapa generating station on the Nelson River. The arrangement could be a simple power purchase or a risk-sharing arrangement that would see SaskPower invest in a project. The power purchase decision can be made in the short term with power availability being in the mid-2020s.

10. In the short and medium term SaskPower should continue to strengthen its transmission ties to Manitoba. This would enhance power purchase opportunities and help strengthen the stability of the transmission system. A connection to Manitoba's Bipole III line should be investigated.

11. SaskPower should commit to 300 MW of generating capacity from biomass. Such projects would be implemented in the short and medium term. These developments could be supported by application of a feed-in tariff or a direct power purchase arrangement.

12. SaskPower should investigate the construction of a 300 MW concentrated solar power facility near Coronach as a potential replacement of the Poplar River Generating Station. If the costs associated with such a project do not allow it to be feasible as a Poplar River Generating Station replacement, the technology could be considered as a Shand Generating Station replacement.

13. SaskPower should carefully monitor solar photovoltaic developments with a view to introducing 300 MW into the generation mix over the next decade. This could involve introduction of a feed-in tariff to support this development.

14. SaskPower should strongly support the adoption of an ambitious energy efficiency code for new construction in the residential, commercial, and institutional sectors.

15. SaskPower should follow the lead of more than 60 other countries and adopt feed-in tariffs – particularly for the purpose of advancing renewable electricity production using biomass and solar technologies.

16. SaskPower should make more use of cogeneration, including entering into agreements that would see the installation of additional cogeneration plants at Saskatchewan potash mines.

17. SaskPower should promote renewable energy projects that are community based, including the development of wind farm co-ops, solar power co-operatives, and renewable energy ventures that are jointly owned by municipal governments and SaskPower.

18. SaskPower should adjust its net metering policy to facilitate the establishment of renewable energy co-operatives.

If these recommendations were implemented it will be possible for SaskPower to continue to supply safe, reliable and sustainable power while significantly reducing GHG emissions in the province. Many of the decisions required to transition to environmentally sustainable power production are required in the short term. The next few years will therefore be critical from a power planning perspective.

Table ES1 shows one possible scenario for making the required transition. This table assumes SaskPower's forecasts for increased electrical generating capacity and demonstrates what is, in the Saskatchewan Environmental Society's judgement, a more environmentally acceptable way of achieving them. The GHG intensity for various power sources is shown in kilograms of CO_2 equivalent for 1000 kWh of production.

The table accepts SaskPower's assumptions and targets with respect to doubling generating capacity over the next two decades. These assumptions slow the ability of SaskPower to phase out coal and replace it with conservation, renewable energy and co-generation. A more moderate growth scenario would allow an accelerated coal phase out.

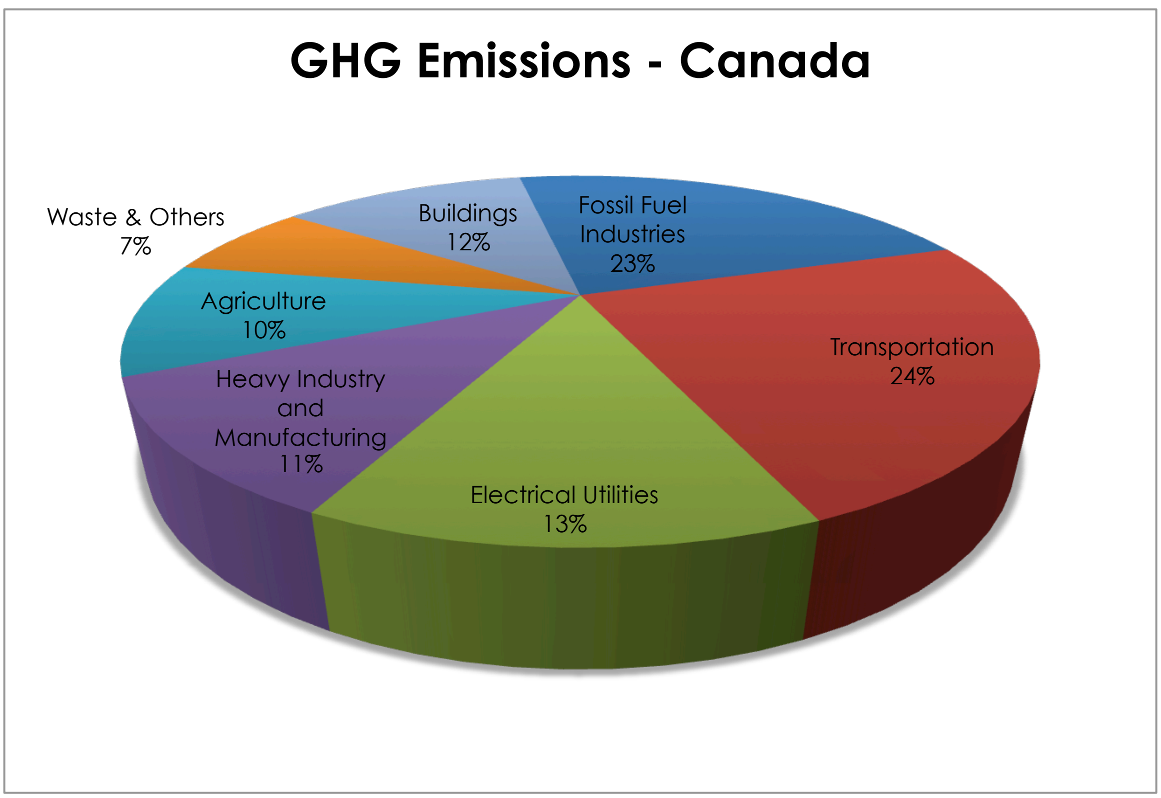
Table ES1. Transition to Sustainable Power. (Capacity in MW)

Power Source/Year	**2012**	**2014**	**2022**	**2032**	**GHG Intensity**	**Remarks**
Conventional Coal	1686	1486	1146	276	>1000	Shand closes in 2038
CCS Coal	0	110	110	110	<450	
Natural Gas	899	1160	1360	1620	450	
Cogeneration	438	438	800	1100	varies	
Hydro	853	853	1100	1100	4	
Hydro purchase	0	0	1000	1000	4	Conawapa or equivalent
Wind	198	198	1200	1500	13	
Biomass	10	10	200	600	18	from forest/agriculture waste
Photovoltaic	0	0	300	650	46	
Concentrated Solar	0	0	0	300	22	Poplar River replacement
Heat Recovery / Geothermal / Other	21	21	40	100	low	
Total Capacity	4105	4276	7256	8356		
New Conservation (includes new demand response)			(450)	(800)		
Effective Capacity	4105	4354	7706	9156		

INTRODUCTION

Greenhouse gas (GHG) emissions produced through the combustion of fossil fuels are the primary anthropogenic contributors to global climate change. Only two of seventeen Organization for Economic Co-operation and Development (OECD) countries have higher per capita GHG emissions than Canada. In 2010 Canada's GHG emissions were 20.3 tonnes/capita compared to the OECD average of 15.3 t/c (Environment Canada 2012). Figure 1 shows the distribution of GHGs produced from various sources for Canada and Saskatchewan. Within Canada, GHG emissions from the electricity generation sector accounted for 90 Mt of the nation's 702 Mt GHG emissions in 2011. Coal-fired thermal generating stations are responsible for 81 Mt of those GHG emissions. (Appendix 1 contains a list of symbols, abbreviations and acronyms used in this report.)

In 2010 Saskatchewan's GHG emissions were 69.8 t/c, about 3.5 times the national average. The electricity sector accounts for 22 percent of the province's GHG emissions. Thus, the fact that Saskatchewan's electricity sector accounts for significant emissions must be viewed in the context that Saskatchewan's total greenhouse gas emissions are unacceptably high. The per capita GHG emissions from Saskatchewan's electricity sector alone is equivalent to that for all sectors of the provincial economy in other Canadian provinces, with the notable exception of Alberta.



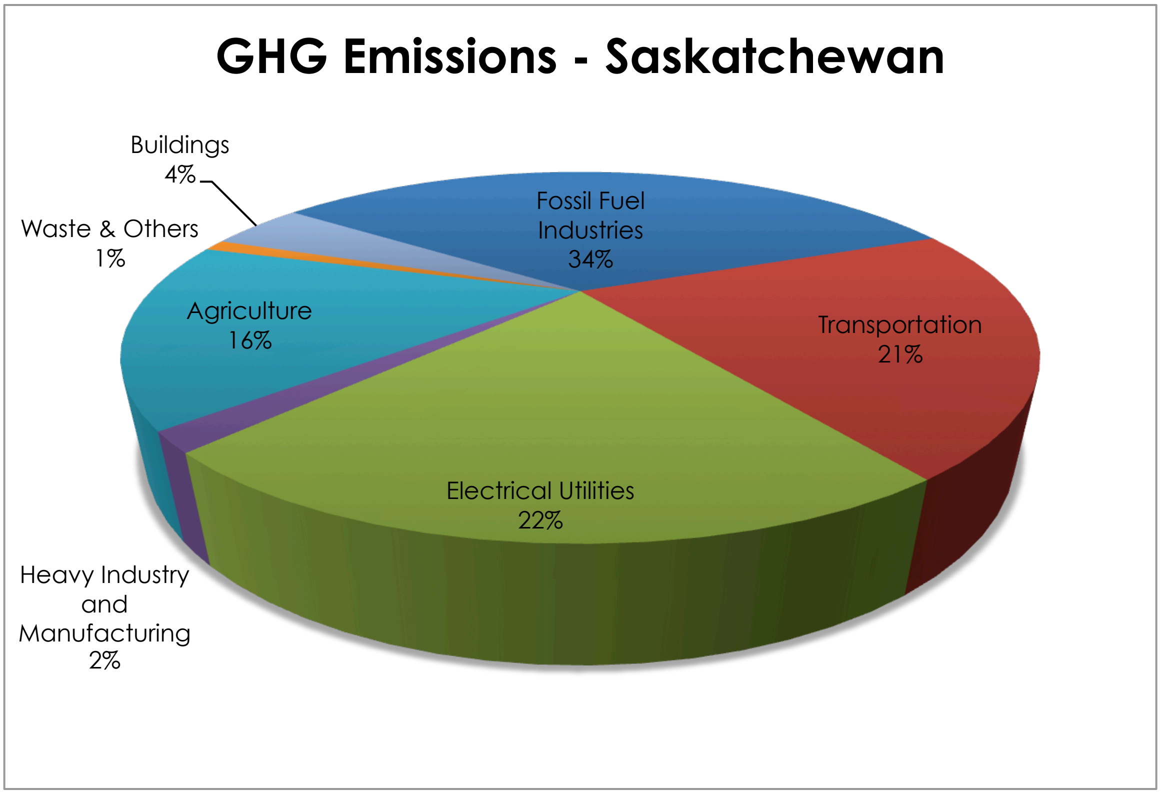


Figure 1. Greenhouse Gas Emissions from Canadian and Saskatchewan Sources.

(Sources: Sources: The first chart in Figure 1 is from: Environment Canada, National Inventory Report 1990-2011: Greenhouse Gas Sources and Sinks in Canada - Executive Summary. Refer to Figure S-6: Canada's Emissions Breakdown 2011, by Economic Sector (Total = 702 Mt). The second chart in Figure 1 is based on a compilation of Saskatchewan based data in Table A11-16, Part 3 of Environment Canada's National Inventory Report 1990-2011: Greenhouse Gas Sources and Sinks in Canada.)

A very large number of utilities throughout the world use coal-fired power stations to generate electricity. Although several Canadian provinces generate electricity using coal-fired power stations, only in Nova Scotia, Alberta and Saskatchewan is this the dominant form of power generation. Reducing GHG emissions will require a significant effort in all three provinces. This is an emissions reduction challenge that Ontario is successfully facing. That province phased out 6 of its 15 coal-fired power units in 2010 and 2011, and plans to phase coal out entirely by 2014.

Environment Canada maintains a database of GHG emissions from large industrial sources. Any facility emitting more than 50,000 tonnes of CO_2 equivalent annually is entered into the database. As shown in Appendix 2, there are 29 such facilities in Saskatchewan. Of these, electricity generation facilities, most of them owned by

SaskPower, account for 70 percent of the 15.8 Mt of CO_2 equivalent produced in 2009 by the large emitters listed in Appendix 2.

As the principal producer, distributer and marketer of electrical power in Saskatchewan, SaskPower has a number of complex tasks to perform in one of the largest service areas in Canada. The corporation, a provincial crown corporation, is regulated under *The Power Corporation Act.* The purpose and powers of the corporation as specified in the act are very sweeping and allow for a broad range of activities. The act does not provide any guidance that would affect the nature of SaskPower operations. That is, there is no "power at cost" statement or direction with regard to renewable power, for example. SaskPower states its mission is to provide "safe, reliable and sustainable power" for its customers.

The SaskPower board is appointed by the province. The corporation is also subject to *The Crown Corporations Act, 1993*. Under this act, the Crown Investments Corporation (CIC), the holding company for Saskatchewan's commercial crown corporations, has the broad authority to direct SaskPower. Rates and other charges are regulated by the CIC. As a CIC crown, SaskPower has operating flexibilities that Saskatchewan Treasury Board crowns do not.

SaskPower operates in the second largest service area in Canada and has the lowest customer density of any Canadian utility. Like any electrical utility, the corporation faces many challenges, not the least of which is adapting to a future that includes significant changes in climate and international, as well as local, responses to those changes. At the same time, SaskPower has adaptation opportunities that could benefit the province, both from economic and environmental perspectives. This discussion paper is aimed at reviewing the SaskPower system, identifying specific challenges and identifying opportunities. It closes with some specific recommendations.

THE SASKPOWER SYSTEM

SaskPower was formed in 1929 and manages a net generating capacity of 4100 MW that includes hydro (21 percent), thermal coal (41 percent), thermal gas (33 percent), and wind (5 percent). Independent power producers have a net capacity of 14 percent of the system; most of that capacity consists of thermal gas generation. The system is illustrated in Figure 2. SaskPower operates three coal-fired power stations, seven hydroelectric stations, six natural gas stations, and two wind facilities comprising a net capacity of 3519 MW. The utility manages generation, transmission and distribution assets having an initial cost of $5.3 billion.

The challenge for any electrical utility is to ensure that the supply of electricity to the grid closely matches the demand. Utilities operate some power stations continuously to supply baseload. Other facilities are operated as intermediate load to meet daytime power demands, which tend to be predictably higher than overnight demands. Finally, some facilities are operated as peak load to meet actual demand. Balancing loads to supply is a complex task. Power stations that can be ramped up and down quickly to meet near instantaneous needs are said to supply dispatchable power. Hydroelectric and gas-fired power supplies are considered as dispatchable. Wind or solar and, in some cases small-scale hydro, supplies are considered intermittent sources and are not dispatchable. Saskatchewan power demand within a day can vary as much as 500 to 1000 MW.

Figure 2. The SaskPower System

SaskPower operates three coal-fired generating stations that provide 1682 MW of baseload capacity for the system. Boundary Dam Power Station near Estevan has a total net generating capacity of 824 MW. It is comprised of six units; units one and two comprising 62 and 61 MW, respectively were commissioned in 1959. They will be decommissioned in 2013 and 2015, respectively, at the end of their useful lives. Units three and four, each 139 MW, were commissioned in 1970 and unit five, also 139 MW, was commissioned in 1973. The sixth unit, 284 MW, was added in 1978. The station consumes locally mined lignite and depends on Boundary Reservoir on Long Creek for cooling water. The power station is considered the largest lignite-fired station in Canada. Barring a major capital injection, the retirement date for the plant is considered to be 2025.

Poplar River Power Station near Coronach has a total net generating capacity of 582 MW. Two 291 MW units were commissioned in 1981 and 1983. The station is home to SaskPower's Emissions Control Research Facility. The station consumes locally mined lignite and depends on Cookson Reservoir on the East Poplar River for cooling water. The retirement date is considered to be 2026 to 2028.

The Shand Power Station near Estevan consists of one 276 MW unit. It was commissioned in 1992. The station consumes locally mined lignite and depends on Rafferty Reservoir on the Souris River for cooling water. The retirement date is considered to be 2038.

SaskPower has seven hydroelectric plants in three different watersheds – the Saskatchewan, Churchill, and Lake Athabasca – that provide 853 MW of installed capacity. Most of SaskPower's hydroelectric generating stations are essentially run-of river with the exception of significant annual storage on the South Saskatchewan River at Lake Diefenbaker. In terms of installed capacity, the Saskatchewan River, Churchill River, and Lake Athabasca systems represent 85%, 12%, and 3%, respectively. Some of the hydro facilities in the SaskPower system can be considered as spinning reserve. That is, they can be ramped up to meet increased power demands in ten minutes or less.

The Coteau Creek Hydroelectric Station on the South Saskatchewan River comprising three units totalling 186 MW was commissioned in 1968. The station will require a significant capital injection or retirement in 2035 to 2039. The station depends on storage in Lake Diefenbaker for its water supply. There are two hydroelectric stations on the Saskatchewan River with a total capacity of 543 MW. The E.B. Campbell Hydroelectric Station consists of eight units totalling 288 MW. The first six units (204 MW) were commissioned in 1963-64 while the last two (84 MW) were commissioned in 1966. The station will require a significant capital injection or retirement in 2035 to 2043. Nipawin Hydroelectric Station consists of three units with a combined net capacity of 255 MW. The first unit was commissioned in 1985 and the final two in 1986. Nipawin will require a significant capital injection or retirement in the years 2021 to 2023. The stations on the Saskatchewan River system are used mainly to serve peaking load and intermediate load.

Effective operation of SaskPower's principal hydroelectric stations is highly dependent on operation of Lake Diefenbaker. For example the flow regulation provided at Lake Diefenbaker allows significant increased winter power production at the plants downstream on the Saskatchewan River. The reservoir is operated as a multipurpose facility by the Water Security Agency (WSA) and is replenished and drawn down over an annual cycle. SaskPower's preference is to have all releases to the South Saskatchewan River pass through its turbines and to enter the winter power production season with the reservoir as close to full supply level as possible. The winter period is the time when demand for energy and the fuel costs to meet that demand tend to be the highest. The turbines at Coteau Creek Hydroelectric Station will only handle a maximum flow of 360 m^3/s, however, so during high flow years such as 1995, 2005 and 2011 water must be spilled from the reservoir. Reservoir operations must also take into account a need for stable levels during the late spring-early summer nesting and brooding season of the piping plover, an endangered species, and for minimum flow releases at various locations on the Saskatchewan River system to protect fish, particularly sturgeon. (According to Johnson and Gerhart 2005, Lake Diefenbaker has, at times, supported the largest single-site population of piping plover in the world.) In addition, stable flows are needed in the late fall to encourage solid ice cover formation and therefore reduce risk of downstream ice jams.

Under normal operating conditions, releases from Lake Diefenbaker are about 60 to 150 m^3/s, all of that water passing through SaskPower's turbines. There is insufficient flow in the South Saskatchewan River to operate the turbines continuously at full capacity. If this were done, the available storage of Lake Diefenbaker would be depleted in about four months. This water availability situation provides an opportunity that will be discussed later in this report.

The Island Falls Hydroelectric Station on the Churchill River near the Saskatchewan-Manitoba boundary consists of seven units with a total net capacity of 101 MW. The station was initially constructed in 1929-30 and the last unit installed in 1959. The station was built by the Churchill River Power Company, a subsidiary of Hudson's Bay Mining and Smelting to provide power to Flin Flon. SaskPower acquired the station in 1981 and assumed operations in 1985. This station is essentially baseloaded. The station will require a significant capital injection or retirement in 2024 to 2043.

The installed net capacity in the Lake Athabasca watershed consists of 23 MW from three small-scale plants, Wellington, Waterloo and Charlot. The Wellington and Waterloo stations will require significant capital injections or retirement in 2041. The stations are essentially baseloaded. The Athabasca plants wheel their power through Manitoba, under an agreement with Manitoba Hydro, and then back into Saskatchewan.

In addition to providing energy, the hydroelectric plants on the Saskatchewan River system are also used to provide important ancillary services. Without ancillary services, power could not be delivered across the transmission grid. For example, EB Campbell units one to six are used to provide Automatic Generation Control (AGC) and Nipawin and Coteau Creek provide spinning reserve. AGC is used to instantaneously follow the load swings and spinning reserve is used to meet the load quickly. Additionally, Coteau Creek is often used to provide voltage support during the night by operating in synchronous condense mode. E.B. Campbell also provides black start capability. That is, if the entire system goes down, E.B. Campbell provides the energy required to start up all other generating units.

The six natural gas-fired stations operated by SaskPower have a total net capacity of 813 MW and are used to meet peak power demands. The stations' gas turbines can be started and shut down quickly as demands require. Like hydroelectricity, gas turbine generation is considered as dispatchable power. A recent news release, for example, indicates that a new General Electric turbine can ramp up at a rate of 50 MW a minute.

The Yellowhead Power Station at North Battleford was commissioned in 2010. The station consists of three gas turbines having a net capacity of 138 MW. The Landis Power Station was commissioned in 1975 and refurbished in 1999. It has a net capacity of 79 MW. The Meadow Lake Power Station was commissioned in 1984. It has a net capacity of 44 MW. The Success Power Station near Swift Current was commissioned in 1967-68. It has a net capacity of 30 MW. The Ermine Power Station near Kerrobert was commissioned in 2009. It has a net capacity of 92 MW. These plants all contain simple cycle turbines, akin to jet engines for aircraft. The older stations will require significant capital injections for refurbishment or retirement in the next few years.

The Queen Elizabeth Power Station in Saskatoon was commissioned in 1959 and currently has a total capacity of 430 MW. The three original turbines have a combined capacity of 218 MW. Six 25-MW units along with heat recovery equipment were added in 2002. These combined-cycle systems reduce greenhouse gas production. An additional three turbines having a capacity of 108 MW were added in 2010.

A provincial announcement on September 22, 2011 indicated that three 35 MW turbines will be added to the Queen Elizabeth Power Station by 2015 at a cost of $550 million. The expansion also features the addition of steam generators to three existing units plus the new units. These will drive a steam turbine that will generate 95 MW. The total additional capacity will therefore be 200 MW. When this work is complete the entire Queen Elizabeth station can be considered a natural gas combined cycle (NGCC) operation.

SaskPower has signed a 25-year power purchase agreement with Northland Power for the supply of power from a 261 MW gas-fired station at North Battleford. The facility will be operational in 2013.

SaskPower operates two wind power facilities having a total net capacity of 161 MW and has power purchase arrangements for an additional 37.4 MW. The Centennial Wind Power Facility near Swift Current was commissioned in 2006. The 83 turbines have a total net capacity of 150 MW. The Cypress Wind Power Facility near Gull Lake was commissioned in 2002. Its 16 turbines have a total capacity of 11 MW. These stations will require significant capital injections or retirement in 2022 to 2026. The SunBridge Wind Power Project near Gull Lake, operated by an independent power producer (Suncor Energy and Enbridge), was commissioned in 2002. Its 17 turbines also have a net capacity of 11 MW. The power purchase agreement expires in 2022. The 26.4 MW Red Lily Wind Power Project near Moosomin became operational in 2011. The project is operated by Algonquin Power. SaskPower has a 25-year power purchase agreement with the Red Lily Wind Energy Partnership, which is owned by Concord Pacific.

SaskPower signed a power purchase agreement with Algonquin Power Co. in March, 2012 that will enable the construction of a 177 MW wind farm near Chaplin. A further 30 MW from three projects will be added through the Green Options Partners Program. The total capacity of existing and proposed wind farms represents about ten percent of SaskPower's installed capacity.

There are two cogeneration stations in the province having a net capacity of 438 MW. Cogeneration is the simultaneous production of electricity and steam from a single fuel source using combustion gas turbines, heat-recovery steam generators and steam turbine technology. In effect waste gases from a gas turbine are captured to produce steam that can be used in industrial processes and to generate additional electricity.

The Cory Cogeneration Station at the PCS Cory potash mine, a joint venture between SaskPower and ATCO Power, was commissioned in 2003. It has two gas turbines and one steam turbine for a total net capacity of 228 MW. The power purchase agreement expires in 2028. The 215 MW Meridian Cogeneration Station near Lloydminister, owned by TransAlta and Husky Oil, was commissioned in 1999. SaskPower has a 25-year purchase agreement for 210 MW, that is, almost all of the station's capacity. (SaskPower is also a financial partner with ATCO Power in the MRM Cogeneration Station near Fort McMurray.)

Heat recovery projects at Kerrobert, Loreburn, Estlin, and Alameda, owned by independent power producers, comprise an additional 20 MW of net capacity. These were commissioned in 2006 to 2008 and the power purchase agreements expire in 2016 to 2018. Such projects capture heat from flue gases, using that heat to drive a turbine and generator. SaskEnergy's pipeline subsidiary, TransGas, has a 1 MW heat recovery project at its compressor stations at Rosetown and is developing a 0.1 MW project at Coleville. The power produced annually will be greater than that consumed by SaskEnergy.

Saskatchewan's total net generation capacity of 4100 MW, showing the capacity by power generation sector, is illustrated in Figure 3. This is only part of the picture, however. Coal-fired power stations are used to meet baseload requirements and are operated continuously except during scheduled maintenance shutdowns. On the other hand, other power stations such as gas-fired ones operate intermittently to meet peak power demands. Wind systems are dependant on available wind. Because of this situation, the mix of power supplied in a typical year is quite different from the distribution of installed capacity. The annual power production in Saskatchewan by various sectors is shown in Figure 4. It can be seen that coal-fired generation dominates.

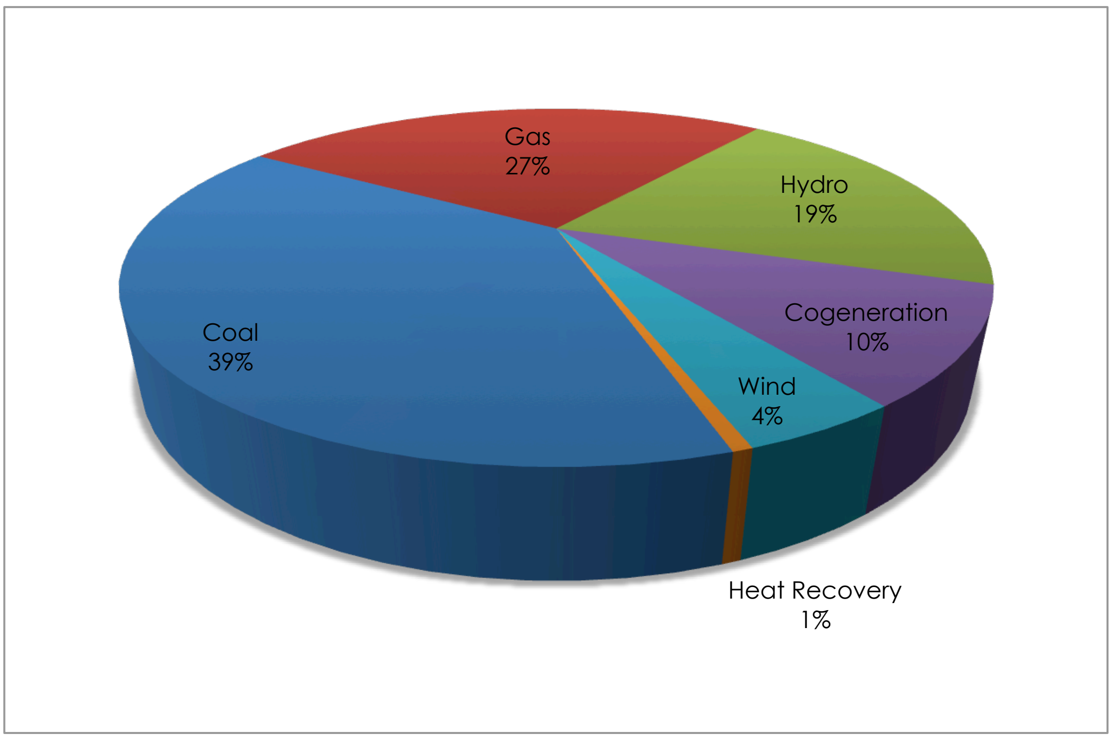


Figure 3. Net Power Generation Capacity in Saskatchewan

Power utilities calculate the percent of time for which the installed capacity of a power station is in use. This will vary from a very high percentage for stations that meet baseload requirements to a relatively low percentage for stations that meet peak load requirements. In 2009 Saskatchewan thermal coal facilities had a collective capacity factor of 86.5 percent; hydro stations, 39.5 percent; wind facilities 38.5 percent; and gas-fired facilities, 18 percent (Pineau 2012). The year 2009 was a fairly typical year for streamflow in the Saskatchewan River system.

The distribution of annual power generation by source shown in Figure 4 for Saskatchewan is much different from that for Canada as a whole. In Canada hydro dominates the picture with 62 percent of annual generation followed by coal and nuclear both with 16 percent of annual generation. No other source exceeds three percent. Canada's reliance on hydroelectricity is somewhat unusual in a global context, where thermal coal dominates.

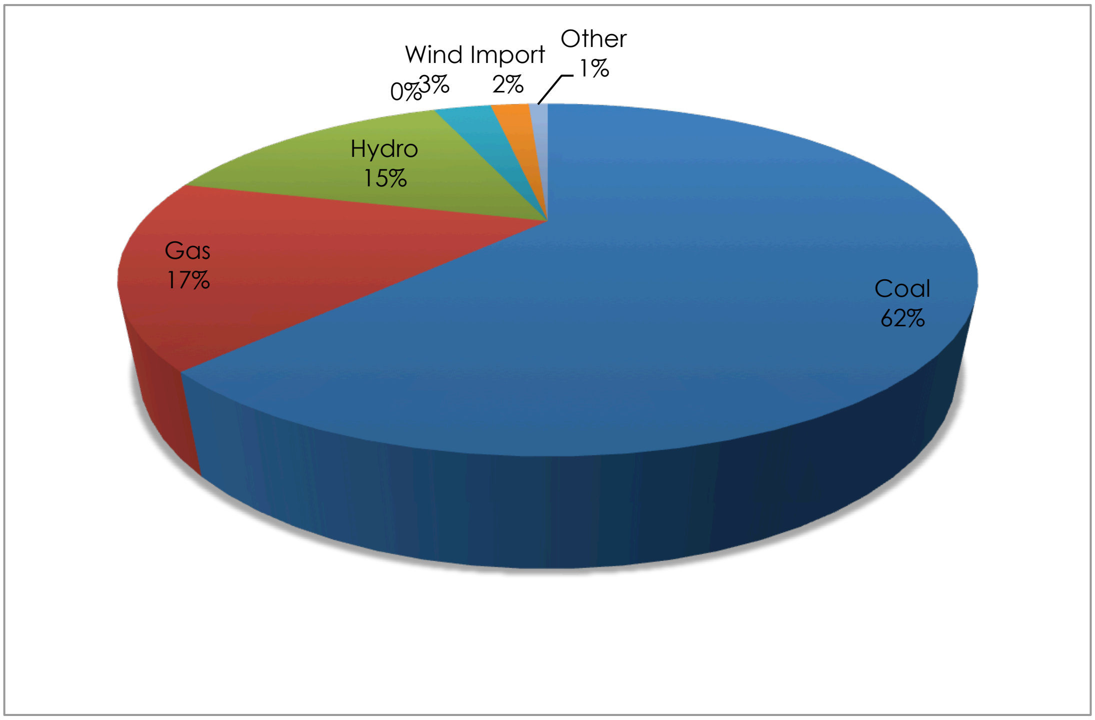


Figure 4. Typical Annual Power Production in Saskatchewan by Source.

Because of Saskatchewan's reliance on fossil-fuel combustion, in particular coal-fired power generation, to meet its electricity needs, the province is a very large per-capita greenhouse gas emitter. For Canada as a whole, the electricity sector accounts for 17 percent of all greenhouse gas emissions. Coal-fired generation was responsible for most of Canada's electricity-related GHG emissions in 2011. Of Canada's 99 Mt of CO_2 equivalent, coal-fired electricity accounted for 80 Mt. Saskatchewan accounted for 14.8 Mt of that total.

In Saskatchewan, SaskPower-owned facilities alone accounted for approximately 14 Mt of CO_2 equivalent in 2010 (Environment Canada 2010). This figure does not include emissions from private power producers. For instance, Cory Cogeneration Station and

Meridian Cogeneration Plant together accounted for over 1.2 Mt of CO_2 equivalent in 2010 (SaskPower 2010). It is unsustainable for Saskatchewan – with only 3% of Canada's population – to account for 19% of Canada's electricity-related greenhouse gas pollution.

SaskPower has indicated that, even with conservation, it will need to rebuild, replace or acquire 4100 MW of capacity by 2030. That is similar to the present system capacity. Current increased demand is about 110 MW a year. The supply increments identified by SaskPower are: 2009-2014 – 1091 MW, 2015-2022 – 1017 MW, and 2023-2032 – 1985 MW (SaskPower 2009). Forecasting power needs is fraught with uncertainties but it is noteworthy that in 1986, when SaskPower's peak load was about 2100 MW the corporation forecast a need for generation to meet a peak load of 3500 MW in 2006. As it turned out this figure was about 10 percent higher than the actual 2006 demand.

The mix of electrical power sources varies considerably across western Canada. British Columbia and Manitoba depend on hydroelectricity almost exclusively (Manitoba 98 percent and British Columbia 92 percent of generation) while Alberta's installed capacity is somewhat the same mix as Saskatchewan's. That is, 46 percent is coal-fired, 39 percent gas-fired, 7 percent hydro and 6 percent wind. Ninety-three percent of Alberta's electricity generation is from thermal sources. (Similarly, 59 percent of Nova Scotia's capacity is coal-fired and 80 percent is from thermal sources.) In the neighboring states, North Dakota uses coal for 95 percent of its electricity generation while Montana uses coal for 65 percent and hydro for 31 percent.

In addition to examining sources of electrical generation in the province, one can also examine the factors that drive power demand. Table 1shows the demand mix determined by SaskPower.

Table 1. Demand Mix for SaskPower

Demand Drivers	Number of Clients	Percent
Power Accounts	78	34.5
Oil Field	13,932	15.3
Commercial	54,563	19.1
Residential	328,719	16.5
Farm	62,712	7.5
Reseller	2	7.1
SaskPower		0.6

Power accounts comprise the power purchases by large industrial customers such as mines. These are a relatively small number of SaskPower's largest customers. They tend to receive preferential rates, in part because the cost of servicing them is lower than that for individual small consumers. At present, 35 customers account for 45 percent of the electrical power used in the province. (The figure 50 customers accounting for 60 percent of power generated has also been used.) In some cases, major power accounts purchase power at less than SaskPower's cost of production. The incentive to reduce power consumption is therefore lower than if other pricing models were used.

Resellers include the cities of Swift Current and Saskatoon who purchase from SaskPower as required. The resellers tend not to be power producers, although Saskatoon has examined some small-scale opportunities.

SaskPower's peak demand almost inevitably takes place during a cold, dark day in December or January. Summer air-conditioning demands are continuing to increase, however, so it is probable that summer peak demands will overtake winter demands in the medium to long term.

SaskPower's distribution system is linked to Alberta, Manitoba, and North Dakota by seven tie lines. The Alberta connection is modest – a 150 MW capacity link near the TransCanada highway. The link to North Dakota is south of Estevan while there are several links to Manitoba with a total capacity of 450 MW. Saskatchewan, Manitoba and North Dakota are members of the Midwest Area Power Pool (MAPP). The MAPP also includes Minnesota and a small portion of Montana.

VULNERABILITIES

SaskPower's generation system has several vulnerabilities that will require attention immediately or in the longer term. These relate to the long-term viability of coal-fired power stations in the context of global climate change, natural gas prices and water supply. SaskPower's system, as the largest emitter in the province, is also vulnerable to future provincial, federal or international efforts to reduce greenhouse gas emissions.

CCS for Thermal Coal Power Stations

Coal-fired power stations are major producers of greenhouse gases and those currently operated by Saskatchewan are no exception. Preferably such stations would be decommissioned as they reach the end of their usable life and be replaced with stations that produce reduced or minimal greenhouse gases. (Natural gas-fired stations produce about one-half of the GHGs of the equivalent coal-fired station.) This is, in fact, the current policy of the provinces of Ontario and Nova Scotia. Alberta operators, who are heavily dependent on coal-fired stations, have decommissioned some 600 MW of capacity in the last 15 years. A recent example is TransAlta's closure of the Wabamun 4 unit – a 279 MW facility – in 2010.

For planning purposes the useful life of a coal-fired power station is taken to be 30 years. Well-maintained systems will continue to perform beyond that time period. Indeed most units at the Boundary Dam Power Station are about 40 years old. Those at the Poplar River Power Station are almost 30 years old. On the basis of the age of these facilities, SaskPower will need to carefully consider the future viability of both of these stations, both from an ongoing operational perspective and from a greenhouse gas reduction perspective. SaskPower must move quickly on the replacement of these two power stations with environmentally sustainable power stations within the next few years.

The challenge for SaskPower will be to either incorporate Carbon Capture and Storage (CCS) technology at its coal-fired plants as they reach the end of their useful life or to develop another source of generation capacity. The challenges related to CCS include the extent of carbon capture achieved, the cost of constructing and operating the CCS facility, sourcing the make-up power to account for parasitic load, and the feasibility and cost of permanently storing CO_2 underground.

SaskPower is aiming for 90 percent carbon removal at its initial Boundary Dam CCS demonstration project. Industry observers appear confident that a CO_2 capture rate of 70 to 90 percent is achievable.

The greater challenge for SaskPower will be to retrofit CCS facilities at existing power stations at reasonable cost. The current demonstration project will produce exceptionally expensive power. The test will be to determine if costs can be lowered for subsequent conversions. Britain recently scrapped a CCS project at Scottish Power's Longannet Power Station on the basis of concerns over both construction costs and operating costs. The United States federal government shelved plans for a new CCS thermal coal power station on cost grounds. CCS projects in Italy and Germany have also been suspended. Closer to home, Transalta Utilities in April 2012 abandoned work on a CCS facility at its Keephills 3 station near Edmonton on economic grounds.

Parasitic load is the term used to describe the energy requirements related to CCS. That energy is not available for distribution to customers. At present, parasitic load for CCS is about 30 percent. Some industry observers indicate that it may be possible with technological development to reduce parasitic load to ten percent (California Council 2011). A common means of meeting parasitic load at CCS facilities is through the use of natural gas power generation. While this provides a short-term solution, it must be kept in mind that in the long term, and certainly by 2050, gas-fired power stations will also require CCS. Industry experts assume that by that time, CCS will be a mature technology.

In general, the quantity of CO_2 required for enhanced oil recovery is much less than the total emissions from coal-fired power stations. In the specific case of the Boundary Dam Power Station, the current CO_2 demand by the oil industry in southeast Saskatchewan is roughly equal to that produced by the generating station. Demand by the oil industry will drop as the oil field is depleted. It should also be noted that some of the CO_2 used in enhanced oil recovery returns to the surface with the recovered oil. It must be captured and re-injected.

Natural Gas Prices

Natural gas-fired power stations often are the least expensive stations that can be constructed. The relative simplicity of these systems means that they can be constructed quickly and with relatively little environmental review. Further, the systems lend themselves to meeting peak power demands so the return on investment is attractive for power station developers. For these reasons, natural gas-fired power stations are becoming an increasing proportion of installed capacity in many jurisdictions. In Alberta, for example, the installed capacity fuelled by natural gas is similar to that fuelled by coal. The situation in Saskatchewan is becoming similar; as shown in Figure 2, natural gas now accounts for one-third of Saskatchewan's installed generation capacity.

As SaskPower increases power generation using natural gas, the corporation will become increasingly subject to market fluctuations in the cost of that fuel. There is a very close correlation between wholesale electricity prices during peak load periods and the price of natural gas. The costs or prices of imports of electricity from other jurisdictions will therefore be vulnerable to natural gas prices. The price of natural gas is expected to remain low for a considerable period. Price projections through 2035 call for a price increase of only 2.3 percent a year (EIA 2011). This forecast is based on rapidly increasing shale gas production through hydraulic fracturing (fracking).

In the short and, perhaps, medium term it does not appear likely that SaskPower (and other North American electrical utilities) could experience a natural gas price shock. It should be noted nevertheless, that the depletion rate of shale gas sources is relatively high so the longevity of the current natural gas bubble is in some doubt. Overseas sales of liquefied natural gas will tend to lead to increases in domestic prices towards levels seen in the international markets. Natural gas prices could also be influenced by large increases in natural gas use in the North American market. Adoption of natural gas as a vehicle fuel or as a replacement fuel for coal-fired power stations are two examples of situations that could lead to much increased natural gas demand and hence, higher prices.

The United States Environmental Protection Agency is currently proposing a limit on GHG emissions from new power plants of 453 kg CO_2 equivalent per MWh. This will curtail new conventional thermal coal power stations with the expectation that gas-fired plants can be constructed to meet the standard. Taking into account the market forces identified together with the likelihood of some form of carbon-related pricing, the notion of stable natural gas prices through 2035 may be optimistic.

Water Supply

SaskPower uses water in two significant ways: as a means of wet cooling its thermal power stations and to generate hydroelectricity. Under climate change scenarios one can assume that water supplies may change and that extreme hydrological events will become more common. It is important as well to keep the geographic context in mind. SaskPower's coal fired power stations in the Souris River basin near Estevan and the Poplar River basin near Coronach are dependent on prairie streams for their cooling water while the hydroelectric stations on the Saskatchewan River system depend on flows from rivers originating in the Rocky Mountains. (Even if climate change is not considered, streamflow of prairie streams is much less dependable that that of mountain streams.) While the likelihood of increased temperatures is almost certain, scenarios tend to show both annual increases and decreases in prairie precipitation and increases in mountain precipitation. The scenarios also show seasonal variations. Translating the uncertainties in future climate into water availability is fraught with uncertainties (Pomeroy *et al*. 2009). It is difficult therefore to draw conclusions concerning climate change effects on water supplies of interest to SaskPower, other than that it would be wise to design the system for increased resilience in the face of almost certain increased variability in water supplies.

Precipitation decreases from east to west in southern Saskatchewan, making Coronach, on average, a little drier than Estevan and average runoff a little lower. The two communities, however, are only 200 km apart. Despite slight differences in climate, it is safe to assume that under most circumstances weather and available water supplies in any given year will be similar. That is, year-to-year availability of cooling water supplies for SaskPower's stations that meet much of Saskatchewan's baseload needs will be roughly equivalent. Low water supplies for all three power stations will likely occur at the same time.

As the reservoirs that supply cooling water are drawn down the power stations are de-rated as water temperatures increase. Generation output therefore decreases. In the case of both the Boundary Dam and Poplar River Power Stations, low water supplies in the 1980s were mitigated by pumping water from groundwater to augment the surface water supply. In the Boundary Dam case the sustainable yield of the aquifer was exceeded and a significant drawdown cone extended into North Dakota (Maathuis and van der Kamp 2011). Pumping took place from 1988 to 1994 and the aquifer still has not recovered. SaskPower is currently considering the installation of permanent supplementary groundwater wells for the Poplar River station.

In the absence of sufficient surface water supplies or sustainable groundwater supplies, air-cooling (dry cooling) of power stations is an option. Examples of such stations are rare and the additional cost is significant. Retrofitting dry cooling into an existing thermal power station is likely uneconomic, even if it is feasible for a new plant. In any case, the time required to retrofit dry cooling makes it unlikely that such an option exists during a drought. Like the situation with wet cooling, thermal power stations are subject to de-rating as the ambient air temperature increases. To sum up, SaskPower's supply of baseloaded power is extremely vulnerable to a protracted drought in the central plains of North America.

Turning now to hydroelectric facilities, there are three potential problems. First, with the exception of the generating station at Island Falls, most of Saskatchewan's present hydroelectric capacity is on the Saskatchewan River system. When natural flows are high there is a system-wide benefit and when flows are low there is a system-wide penalty. Available water supplies are also affected by upstream water use. Although the annual quantity of water in the North Saskatchewan River system has been largely unaffected by human activity, the annual flows in the South Saskatchewan River are depleted by about a third on account of upstream water consumption, primarily in irrigated agriculture. Increasing water consumption in Alberta and Saskatchewan will reduce the available supply for most of SaskPower's hydroelectric stations as well as for those downstream in Manitoba.

Natural supplies of water in the North and South Saskatchewan rivers for the most part originate in the mountains and foothills of Alberta and to a much smaller extent, Montana. These supplies will be affected by land use change in the foothills and by climate change. As an example, increased timber harvesting in the foothills, perhaps in response to mountain pine beetle infestations, will lead to increased water supplies. On the other hand, under some climate change scenarios annual flows could decrease and extreme flows (both highs and lows) could increase (PFSRB 2009).

Although it is impossible to be definitive, SaskPower should take into account increased water use upstream of its hydro facilities, reduced average natural flows, and persistent drought in its long-term planning. In the short and perhaps the medium term, increasing upstream water consumption rather than climate change itself will dominate the planning scenario.

Greenhouse Gas Reduction Actions

> *The best time to begin reducing greenhouse gas emissions was 30 years ago; the second best time is today.*

Although every Canadian government beginning with the Mulroney government in the mid-1980s has made commitments to reduce GHG emissions, none have made any significant progress in doing so. The developed countries that signed the Kyoto Protocol have, with the exception of Canada and Australia, stabilized or reduced their GHG emissions. The United States, which did not sign Kyoto, has only experienced modest increases in energy-related GHG emissions.

Saskatchewan has passed Bill 126, *The Management and Reduction of Greenhouse Gases Act*, aimed at reducing the province's contribution to GHG emissions. Proclamation is expected soon. The legislation defines a regulated emitter as one that produces over 50,000 t CO_2 equivalent a year. (This is also the federal definition.) The regulated emitters in Saskatchewan are shown in Appendix 2; it can be noted that SaskPower facilities represent a significant proportion of those emitters. A 20 percent reduction in GHG emissions by 2020 from a 2006 baseline is seen as a desirable reduction target (Meyers Norris Penny 2010). (It should be noted that this target is scientifically insufficient for stabilizing global GHG emissions (UNEP 2010)). Much deeper cuts than those currently proposed by either the federal or the provincial government are required if Canada wishes to join other jurisdictions in trying to prevent the worst consequences of climate change from occurring.)

On September 5, 2012 the federal government announced regulations that will come into effect on July 1, 2015. Coal fired units that were commissioned before 1975 will be either limited to 50 years of operation or required to terminate operations by the end of 2019 - whichever comes sooner. Units commissioned between 1975 and 1985 will be either limited to 50 years of operation or required to terminate operations by 2029, whichever comes sooner. The performance standard for new coal fired electricity generation units in Canada is to be set at 420 t/GWh. New and end-of-life units that incorporate technology for carbon capture and storage may apply for an exemption from the performance standard until 2025 (Environment Canada 2012).

In the opinion of the Saskatchewan Environmental Society, it would be prudent for SaskPower to plan on all of its conventional coal generating stations being decommissioned well before the 50-year mark at which time they would be replaced by renewable energy generation or converted to CCS.

The conventional coal-fired stations are financially vulnerable to whatever GHG-reduction scheme based on carbon pricing is eventually implemented in Canada, whether it be a carbon tax or cap-and-trade system. In addition to any actions pertaining to greenhouse gas reduction at a provincial or national level, it is increasingly evident that Canadian producers of GHGs could be caught by environmental actions taken internationally. Initially such actions may be industry specific such as the European Union's carbon tax related to the aviation industry. In the longer term, however, the likelihood of environmental tariffs is increasingly possible. An American environmental tariff aimed at coal-fired power stations in China and India could easily catch Canadian power producers. Since 70 percent of Saskatchewan's exports go to the United States, GHG initiatives taken in that country and potential extraterritorial application of those initiatives are particularly important to the province.

Other emissions from coal-fired power stations are also becoming the subject of regulations. Reductions in sulphur dioxide (SO_2), nitrogen oxides (NO_x), heavy metals such as mercury, and particulate emissions are examples. Such regulations will add additional costs to operators, like SaskPower, of coal-fired power stations.

OPPORTUNITIES

There are many options for reducing GHG emissions in the power sector and several of them are applicable to SaskPower operations. These options can be considered under four broad headings: demand side management through increased efficiency and conservation, carbon capture and storage, nuclear power, and renewable power. For the purpose of this report, renewable power options will be considered under hydroelectricity and non- hydroelectricity headings.

Capturing green energy opportunities will require significant investments. These should be considered in the context of business as usual investments to meet increasing power demands. There are several sources of cost comparisons of new generating facilities. One such example is shown in Table 2 (Energy Information Administration 2010). The costs given may not apply directly to SaskPower but the relative costs of various options could be taken as generally indicative. (There is some evidence that costs of solar photovoltaic systems are dropping more quickly than the cited report anticipated.) These costs do not include carbon pricing considerations.

While Table 2 does not include costs associated with demand side management (DSM), such costs are generally much lower than those associated with provision of new generation. DSM will be discussed in the next section of this report.

Table 2. Estimated Levelized Cost of New Generation Resources, 2016.

Plant Type	Capacity Factor (%)	U.S. Average Levelized Costs (2009 $/MWh) for Plants Entering Service in 2016				
		Capital Cost	Fixed O&M	Variable O&M	Trans-mission Investment	Total System Cost
Conventional Coal	85	66.3	3.9	24.3	1.2	94.8
Advanced Coal	85	74.6	7.9	25.7	1.2	109.4
Advanced (CCS)	85	92.7	9.2	33.1	1.2	136.2
Natural Gas-fired						
NGCC	87	17.5	1.9	45.6	1.2	66.1
Advanced NGCC	87	17.9	1.9	42.1	1.2	63.1
With CCS	87	34.6	3.9	49.6	1.2	89.3
Combustion Turbine (CT)	30	45.8	3.7	71.5	1.2	124.5
Advanced CT	30	31.6	5.5	62.9	3.5	103.5
Advanced Nuclear	90	90.1	11.1	11.7	1.0	113.9
Wind	34	83.9	9.6	0.0	3.5	97.0
Wind – Offshore	34	209.3	28.1	0.0	5.9	243.2
Solar PV*	25	194.6	12.1	0.0	4.0	210.7
Solar Thermal	18	259.4	46.6	0.0	5.8	311.4
Geothermal	92	79.3	11.9	9.5	1.0	101.7
Biomass	83	55.3	13.7	42.3	1.3	112.5
Hydro	52	74.5	3.8	6.3	1.9	86.4

* Costs are expressed in terms of net AC power available to the grid for the installed capacity.

Demand Side Management

Almost inevitably, the most cost-effective approach to reducing power requirements is through demand side management (DSM). This implies both energy conservation and efficiency improvements. Reducing consumption results in lower consumer costs and reduces the need for new generation facilities. It has been stated that each dollar invested in conservation leads to savings of two or three dollars. Electrical utilities in other jurisdictions tend to invest much more in energy conservation programs than does SaskPower. This is a business decision that helps utilities reduce the large costs associated with building new electrical generating capacity, and also helps utilities reduce long term fuel, operation and maintenance costs. In the case of electricity exporters such as BC Hydro, Manitoba Hydro and Hydro Quebec consumption reductions in the domestic market allow increased power sales into the lucrative American market.

From a SaskPower perspective one component of conservation would be to reduce peak demand. One strategy is load shifting. That is using economic instruments or other means to encourage users to reduce demand at peak times. In some cases SaskPower has implemented load-shedding mechanisms with major power accounts to reduce peak demand. Figures 5 and 6 show typical SaskPower load profiles in winter and summer. Based on these profiles, there appear to be greater opportunities for load shifting in the summer than in the winter.

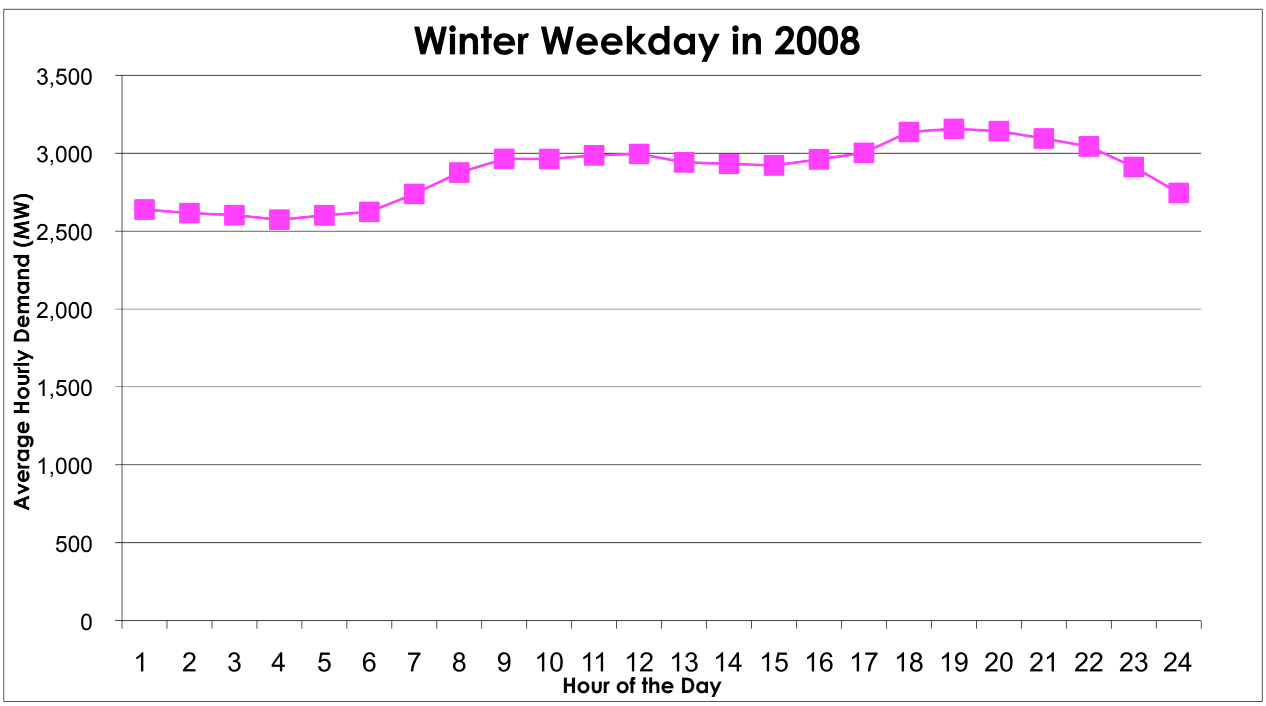


Figure 5. Winter Weekday Load Profile (courtesy SaskPower)

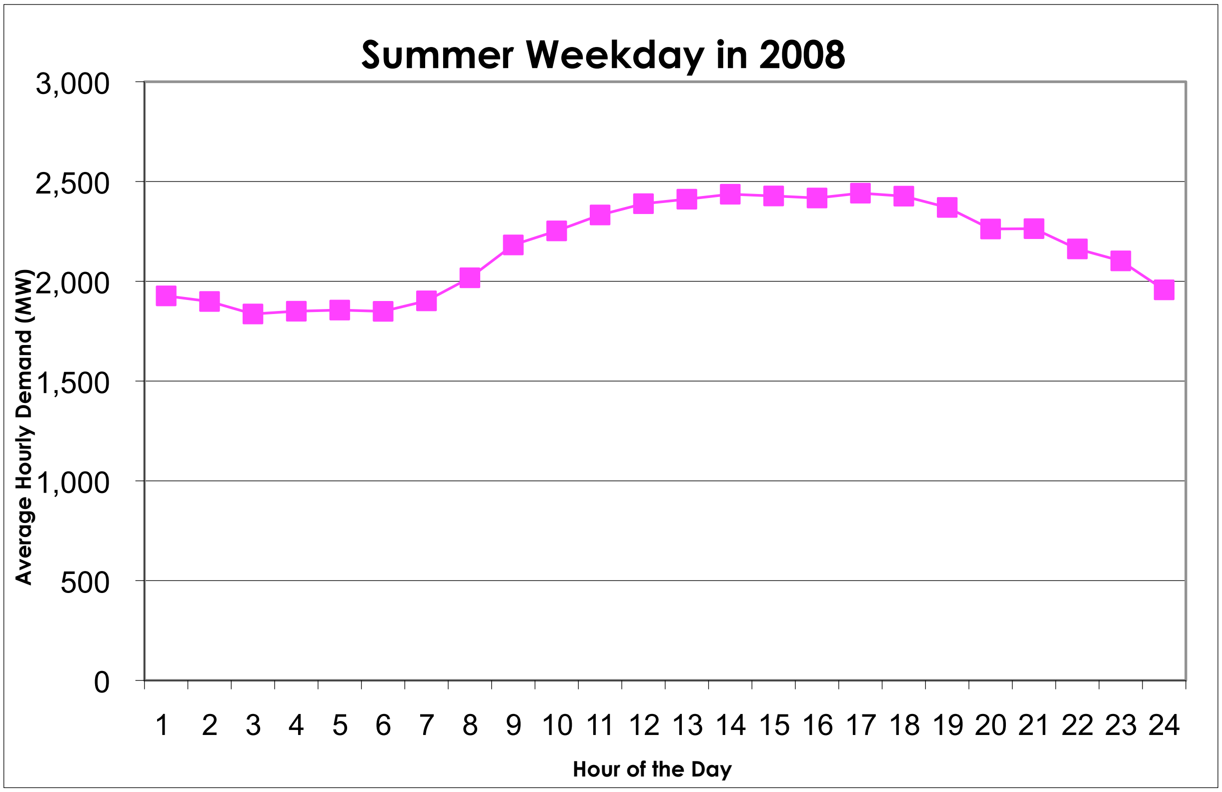


Figure 6. Summer Weekday Load Profile (courtesy SaskPower)

On September 17, 2007 SaskPower made a commitment to reduce energy demand by 300 MW by 2017. This target was later reduced to 100 MW. The distribution of these savings is 10-15 percent industrial, 50-60 percent commercial, 30-35 percent residential, and 10 percent from customer self-generation from renewables. (SaskPower allows net metering.) The 300 MW commitment is now seen as a long term commitment (SaskPower 2009). That said, SaskPower estimates that some 450 MW might be available through DSM.

Encouraging purchase of energy efficient appliances and projects such as refrigerator recycling are aimed at reducing householder power consumption. SaskPower's Advanced Metering Infrastructure (AMI) initiative will provide direct feedback to consumers on electricity use and would allow for client initiated load shifting. The program will also reduce SaskPower's own energy costs. The program started in 2012 and will be completed in 2014. For the present SaskPower will use the smart meters as a means of providing consumer information. One measure that would allow clients to act on the information they receive, and that would enhance client-centered load shifting, is time-of-day metering. While SaskPower currently has no plans to institute time of day rates, SaskPower should reconsider this policy decision. Offering customers lower rates during non-peak periods of the day, while charging higher rates during peak periods, can be a sound way of shifting electricity use patterns for tasks that are not time sensitive.

On January 1, 2012 Ontario joined British Columbia in requiring new house construction to meet an EnerGuide 80 (E80) standard under its building code. This is equivalent to 3.1 air exchanges per hour (3.1 ACH). Under this standard E100 is considered as a zero net energy house. Current new house construction in Saskatchewan and elsewhere achieves about E65 to E72. Houses with ratings of E90 are feasible with current practices. One weakness in the Ontario approach is that builders will be allowed to use a "construction recipe" for E 80 rather than verify performance with a blower test.

Another significant consumer initiative would be to adopt strong energy conservation measures in the Saskatchewan Building Code. The current code, based on the federal model code, has no energy conservation content. The 2011 federal model National Energy Code for Buildings for commercial and institutional buildings for the first time includes energy efficiency provisions for lighting, air conditioning, ventilation, motors, electric power systems and the building envelope. Although some provinces have adopted the federal model energy codes for houses and for other buildings, Saskatchewan is still considering this. Saskatchewan does have standards related to energy management of government owned buildings.

As noted earlier in this report, residential power consumption is a relatively small portion of annual power sales. Opportunities exist for reducing demand from major industrial clients. There is an opportunity for SaskPower to work with major clients to institute both energy efficiency and energy conservation measures.

In Saskatchewan power rates are developed based on a cost of service methodology. Each customer's rate is based on the cost of service to that class of user. For that reason rural residential rates are more than such rates for urban areas. As well, residential rates are greater than industrial rates on account of the distribution infrastructure associated with residential systems. Industrial rates are lower because industrial facilities are most often fed directly off high voltage transmission lines and industrial operations very often own their own transformation facilities. For residential customers SaskPower owns all the transformation hardware.

That said, the key change that could be made to SaskPower's rate structure would be to move from a declining block rate structure to a level block and ultimately to an increasing block. The effect would be to encourage efficiency and conservation by initially ceasing to reward excess power consumption and eventually penalizing such consumption.

One of the important opportunities for future efficiency gains is in the area of equipment replacement. Whenever equipment breaks down – whether it be in a small business, large business, farm, or industrial facility – SaskPower should take advantage of the immediate opportunity that arises to see that equipment replaced with the most energy efficient option on the market. (Prebble, 2011) A good example of that approach can be found in the work of the non-profit organization Efficiency Vermont, which actively works with local wholesalers and retailers to encourage them to carry high efficiency products, and at the same time provides same-day assistance to businesses to replace equipment that has broken down. Efficiency Vermont combines this service with financial incentives aimed at encouraging the highest electricity efficiency choices that are available in the market place. It would be exciting to see that kind of service offered by SaskPower DSM staff.

The Efficiency Vermont example is one of many. Experience in other jurisdictions has shown that a more proactive approach in Saskatchewan is necessary. Utilities such as Manitoba Hydro spend tens of millions of dollars each year in helping their customers to reduce power costs. Manitoba Hydro's demand management targets are in the order of 1000 MW. BC Hydro has been directed by the provincial government to meet 66 percent of its future load growth through conservation and efficiency measures. Making major strides in energy efficiency and energy conservation will require expertise that is generally unavailable in Saskatchewan. SaskPower leadership in this area could also lead to new business opportunities. The advantage to SaskPower would be reduced costs associated with deferring new generating capacity. The U.S. Energy Information Administration estimates that the cost of implementing energy efficiency measures is about one-quarter the cost of building the equivalent additional lowest cost supply.

Carbon Capture and Storage

SaskPower has embarked on a CCS project involving Unit 3 at the Boundary Dam Power Station. The project is known as the Boundary Dam Integrated Carbon Capture and Storage Demonstration Project and completion is anticipated in 2014. Because of the energy use associated with CCS – parasitic load – the rated capacity of the unit will drop from 139 MW to 110 MW. That capacity loss will have to be made up by new generation. The project cost is given as $1.24 billion with $240 million provided from federal sources. SaskPower plans to sell the CO_2 captured by the project to the oil industry for oil recovery operations and the captured SO_2 to manufacturers of sulphuric acid. SaskPower can be considered an early adopter of commercial-scale CCS technology and will doubtless face many technological and financial challenges as the project develops. This project and CCS projects elsewhere in the world are rightfully considered as demonstration projects. The results will guide future developments. If the present project at Boundary Dam Power Station meets expectations, both technical and financial, this will provide a significant opportunity for SaskPower.

Nuclear

Although nuclear power is fraught with environmental, economic and public policy issues, it does represent a low GHG emitting means of meeting baseload requirements by replacing conventional coal-fired power stations. Standard nuclear power units tend to have a capacity of 1000-1200 MW, however, and this is too large an increment for a utility like SaskPower. As well, the time line for placing a nuclear power station in service is likely beyond the service life of both the Boundary Dam and Poplar River coal-fired stations. Cooling water requirements mean that a nuclear plant would most likely be located somewhere on the North Saskatchewan River system.

For over 20 years, the board of the Saskatchewan Environmental Society has taken the position that nuclear power would not be an appropriate choice for Saskatchewan. Issues of economics, long-lived radioactive wastes, routine and accidental radioactive emissions, weapons and security, and efficiency in reducing greenhouse gas emissions together make this option unacceptable. Recent events have reaffirmed the SES view in this regard. These include the exceptionally high cost of repairing the Point Lepreau reactor in New Brunswick, the large cost overruns on reactor construction projects around the world, the decision by the U.S. government to abandon the Yucca Mountain nuclear waste repository, and the terrible consequences of the Fukushima nuclear power plant meltdown in Japan. Germany – the third largest economy in the world – is currently committed to phasing out nuclear power, while Japan is cautiously restarting only a few of the reactors shut down after the Fukushima disaster.

Hydroelectricity

There are now three hydroelectric projects being considered by SaskPower, one at Elizabeth Falls on the Fond du Lac River, another on the Saskatchewan River downstream of The Forks and the redevelopment at Island Falls on the Churchill River. The Saskatchewan River project would be similar in size to two other power stations on the river, that is, about 250 MW. Like the Nipawin power station, it is essentially run-of-the river as it would depend on water storage in Lake Diefenbaker. The Island Falls redevelopment would produce 150 MW of additional power by adding to existing infrastructure. The Island Falls redevelopment is an example of what's known as "supply side enhancement". That is, an existing facility is upgraded in some manner to generate more power. If local interests, including First Nations, were supportive these hydro projects could proceed in the short to medium term.

There are opportunities in Saskatchewan for the development of low-head or small-scale hydro. In general this implies development of hydroelectric potential when the head is 15 m or less. Ultra low-head is usually taken to mean a head of less than 5 m. Often small-scale or low head hydro capability may be added to existing structures developed for irrigation, water management or flood control. It has been estimated that the low head hydro potential in Canada is about 5000 MW. A report prepared for Natural Resources Canada indicates that Saskatchewan has 28 low-head hydro sites with a potential of 178 MW. Almost all of the sites are in the northern half of the province. Seventeen of these sites are ultra-low head sites having a total of 25 MW capacity (Hatch Energy 2008). SaskPower has identified 30 potential sites in the north that are within 25 km of a market. Of these, 13 have potential installed capacity of 10 MW or more, 7 have potential installed capacity of 2 to 10 MW, and the remainder have under 2 MW capacity. Generally such sites have little water storage and may have smaller environmental impacts than large-scale hydro projects. Costs tend to be somewhat higher than for large facilities.

The Elizabeth Falls project is a small-scale, low head, 40 MW proposal for the Fond du Lac River that would service communities in the north. Other low-head hydro sites in the north will provide alternatives to generation using diesel generators. Proximity to a load centre like a community or mine is an important aspect of evaluating the economic feasibility of a project. One low head opportunity in the southern part of the province would be at the Qu'Appelle diversion from Lake Diefenbaker.

Another important hydroelectric opportunity for SaskPower lies in importing power from Manitoba. This could involve direct purchase or an investment in a new facility. Nelson River generating stations are typically in the order of 1200 MW capacity (made up by several turbines). If SaskPower wished to replace coal-fired stations with much lower GHG emitting systems, this would be one alternative. Historically Canadian provinces have usually met power needs through developments within the province. Closer power production integration with Manitoba would require significant political leadership.

As mentioned earlier, hydroelectricity is dispatchable so the supply can be adjusted to meet demand. This attribute is important as it provides an opportunity for complementary operation with wind and solar. This will be discussed further in the next section.

Non-Hydro Renewable

Renewable power includes a broad suite of opportunities. These include wind, biomass, solar photovoltaic, concentrated solar, and geothermal. Other more esoteric sources of power are being investigated. In an international context, wind power and biomass power have drawn the most attention. Solar electricity production also provides opportunities for SaskPower.

Wind

Wind energy technology is still evolving but has made enormous strides in the last 40 years. The total installed capacity of wind generation in Canada now exceeds Saskatchewan's installed capacity from all sources. Generally, large-scale terrestrial wind farms are now price competitive with other generation sources, at least on an installed MW basis. Experience with the existing large-scale Saskatchewan facilities shows that they attain capacity factors of 40 percent. Although the best sites for wind generation appear to be in southwest Saskatchewan, wind farms must be geographically distributed so that power supply can be more dependable. Each utility has to carry out its own calculations, but there are studies indicating that about 20 to 30 percent of installed wind capacity could be considered as an addition to baseload. Wind energy resource maps show opportunities at many locations in southern Saskatchewan. One current limitation of wind systems is that, despite the use of heating plus special lubricants and metallurgy, they automatically shut down at about -33° and restart at -30° (personal communications, Rick Halas and Doug Daverne 2011).

For the present electrical grid in Saskatchewan a reasonable target for wind generation is 20 percent of annual power production (US Department of Energy 2008). As the wind systems become more significant, activities such as wind forecasting become increasingly important. There also can be issues with grid stability leading to the need to improve the system. This stability issue has been observed in Germany, which uses intermittent solar power to a considerable extent. With current technology, sourcing power from variable renewables like wind and solar appears to be limited to about one-third of demand. This limitation can be overcome as storage opportunities improve and as electrical grids become "smarter".

Wind systems and the solar systems described below lend themselves to complementary operation with hydro or gas turbines. (Although wind and solar are both intermittent power sources, there are complementary operation opportunities between them as well.) In Saskatchewan the flow of the South Saskatchewan River is insufficient to run the turbines at Gardiner Dam and downstream on the Saskatchewan River at maximum capacity continuously. This is one reason why the hydropower is used to meet only intermediate and peak loads in this province. There is therefore considerable scope for complementary operation. In effect, a complementary operation system would function in such a manner that when wind (or solar) generation is available, hydro generation would be curtailed and water would be stored in Lake Diefenbaker. When wind generation is not available hydro would be used to meet needs (Scorah *et al.* 2010). As noted earlier in this report, both hydro and wind generating facilities in Saskatchewan operate at a capacity factor of about 40 percent. Complementary operation between wind and hydro therefore appears very feasible. Industry practitioners speak of the need to "firm and shape" the wind generation.

Biomass

For the most part biomass power systems depend on the processing of plant material or other waste to produce steam, liquid biofuel, or biogas, all of which can be used to produce power. There are many sources of biomass, among them agricultural and wood waste. (So-called "black liquor" from pulp mill operations is a significant fuel source in some areas.) These wastes can be pelletized and used as a feedstock for biomass-fuelled generators. Biomass power plants do produce greenhouse gases, but conceptually the fuel source can be considered as "fast coal". That is, the GHGs produced had been sequestered only a few years previously. The assumption is that the harvested biomass is always replaced by growing new vegetation that fixes carbon as it photosynthesizes.

The carbon footprint of a biomass generator depends on the source material and the way in which it is processed, but appropriate technologies may be considered carbon neutral. Biomass is an attractive option because it may provide dispatchable power (depending on the process) and is cost effective. The challenge often relates to obtaining sufficient sustainable feedstock within a reasonable distance from the power station. Concerns can be raised as well, at least in some cases, with energy production replacing food production.

The European Union implemented a Biomass Action Plan in 2005 aiming to double the use of biomass to produce electricity and heat. Thus far the plan has met with modest success. There is some experience in Europe with large co-fired biomass stations that burn biomass with coal or gas. In general large plants have been found to be more cost effective than small ones but the smaller ones have environmental and rural development advantages.

There are currently 35 biomass generating stations in Canada having an installed capacity of 893 MW. SaskPower has signed a power purchase agreement with the Meadow Lake Tribal Council for the production of 36 MW from wood waste. The station will cost $150 million and is expected to be operational in 2014.

Solar

Given remarkable solar resources, Saskatchewan people have long been interested in the idea of applying solar energy for electricity production. Solar photovoltaic power systems are ubiquitous in Saskatchewan, but they are almost inevitably used in special situations to charge battery-operated systems that operate off the grid. In the past 5 years, over one hundred small solar systems have been installed under SaskPower's net metering program. Even with the current cost structure, many small-scale solar photovoltaic systems have been installed, particularly during periods when some financial assistance for up-front installation costs has been available. In general, stand-alone small-scale systems meet the power needs of individual homeowners or farmers (backed up by the grid), or those in special situations. They do not add much capacity to the grid.

There are several aspects of Saskatchewan's geographic situation that are supportive of solar power. Solar intensity in the southern part of the province – roughly south of the TransCanada Highway – is the highest in Canada. As well, that solar intensity tends not to be attenuated by smog and other particulates. Finally there are significant energy demands adjacent to the geographic area with high solar potential. With rapidly improving energy conversion rates and decreasing manufacturing costs solar opportunities are expanding rapidly. Industry observers indicate that it is reasonable to expect competitively priced large installations in the medium term. China has made great strides in lowering the cost of photovoltaic systems.

There are examples in Germany and Ontario of significant developments assisted by the use of feed-in tariffs that permit the operator a return on investment. In jurisdictions that are willing to maintain financial support and that are willing to support larger solar installations, there has been rapid growth. For example, using feed-in tariffs as a policy tool, Ontario installed more than 46 MW of solar capacity in 2009 and 168 MW of solar capacity in 2010. Ontario has now reached 500 MW of installed solar electric capacity. Germany currently has 28,000 MW of solar capacity. In the first 6 months of 2012, in a geographical area smaller than the size of Saskatchewan, and with a sunlight resource that is much less impressive than Saskatchewan's, that country has increased solar installations by another 4,300 MW. There are several utility-scale installations in the United States. The state of New Jersey added 450 MW of capacity in 2012 alone – the largest total of any state (SEIA 2013).

Concentrated solar power (CSP) thermal installations capture solar radiation and focus it to provide heat, which is used to drive a steam turbine connected to a generator. Further work is needed to improve the concentrators and to lower manufacturing costs. Concentrator efficiencies are only in the 30 percent range at present. Large-scale units in the order of several hundred megawatts are currently in operation, although the costs are double that of gas-fired stations. Two approximately 300 MW stations will come on-line in the United States this year. It will take another decade for costs to come down. CSP presents an additional renewable energy opportunity as some designs use liquefied salt as the heat transfer mechanism. This liquefied salt can also serve to store energy for use when the sun doesn't shine. Unlike photovoltaic systems, CSP systems do exhibit some thermal inertia. Nonetheless, more work is needed on system integration requirements.

This technology could have some interest for SaskPower because it can be developed on a large scale and because of that organization's expertise with steam turbine and generator systems. Using existing thermal coal generating sites as locations for new solar generation is attractive. Solar energy availability maps show the potential in southern Saskatchewan is the highest in Canada. Development of a CSP power station would also have to consider the water requirements for the station. The annual supply required would be less than that needed for the present thermal coal stations.

The only Canadian jurisdiction thus far to invest in solar systems is Ontario. The province is proving support for research and development through use of a feed-in tariff that is high enough to support the development.

Saskatchewan's peak power demand inevitably occurs in deep mid-winter. It is noteworthy that peak summer demand is increasing with each passing year and it is not inconceivable that within the time frame of replacing either the Poplar River or Shand generating stations CSP generation will be economically feasible. Having peak power demand in the summer would bring a significant re-think of SaskPower's opportunities for future developments.

Geothermal

Although other jurisdictions, notably British Columbia, have opportunities for generating electricity using geothermal sources, the stable geology in Saskatchewan does not provide significant opportunities (Grasby *et al*. 2011). Some special situations may exist, such as the opportunity now being studied to locate a 5 MW binary geothermal plant near Estevan.

This power generation option should not be confused with the use of geothermal resources for space heating. (High efficiency geothermal electrical power production requires higher subsurface temperatures than geothermal space heating.)

Other Power Generation Possibilities

There are possibilities for exotic technologies to eventually replace fossil fuelled power production in the 2050s and beyond. These might include artificial photosynthesis or laser fusion. While SaskPower needs to monitor such possibilities, for the next 20 years, the power production options previously mentioned in this report would appear to be a more likely source of commercial-scale power.

That said, there are some local power opportunities such as farm-scale wind turbines, small-scale heat recovery units, or fuel cells that can meet some power demands. Users of such systems would require energy storage or grid connections, or both, to meet their needs.

Renewable Energy Co-operatives and Net Metering

The Saskatchewan Environmental Society believes there are opportunities across Saskatchewan for the development of community-based initiatives around wind, solar and biomass power. These community-based initiatives could take many different forms. One model might include joint ventures between SaskPower and local municipalities. Another model could be the development of renewable energy co-operatives that own a wind farm or a solar power plant facility. SaskPower should encourage the emergence of these types of community-based initiatives, which would be powerful vehicles for community engagement, economic development and a more decentralized approach to renewable energy development.

For this kind of approach to renewable energy development to move forward in Saskatchewan, SaskPower would need to either enhance its Green Options Program or modify its Net Metering Policy to allow for larger scale projects. The Saskatchewan Environmental Society is submitting a separate brief to SaskPower specifically on recommended changes to net metering policy.

Transmission Systems

SaskPower operates 13,500 km of high voltage transmission lines at 72,000 V, 138,000 V and 230,000 V. There are 52 high-voltage switching stations. The system is monitored and controlled through a single Grid Control Centre. The distribution system consists of 144,400 km of 25,000 V and 14,400 V lines, 182 substations and 150,000 transformers. A power distribution grid is a sophisticated enterprise because of the need to match supply and demand continuously. That said, innovations in electrical grids are usually discussed in the context of smart grids.

The first step in development of smart grids is the use of advanced meters that provide clients with information on an hour-by-hour or even minute-by-minute basis. This allows consumer choice as to when power will be used and, together with time of day metering, encourages decreased consumption or at least load shifting. A further development in smart grids is the use of grid-enabled appliances that allow the grid to command operation of appliances such as water heaters, refrigerators and air conditioners. Turning these off for a few minutes an hour may be imperceptible to the consumer, but result in SaskPower being able to shed load during peak times.

SaskPower has four connections to Manitoba Hydro with a total capacity of 450 MW. There is a proposal for an additional 230 kV Tantallon-Birtle connection. These connections enable power sales and purchases between the two utilities thereby enhancing reliability of supply. By conserving reactive power, the connections have the added benefit of reducing line losses in both systems. Enhancing connections between the Saskatchewan and Manitoba grids would improve overall system reliability and reduce costs. In addition, it would improve SaskPower's and Manitoba Hydro's ability to accommodate power generation from wind and solar systems.

A more robust connection would also permit the purchase of firm hydropower from Manitoba as a means of reducing GHG emissions in Saskatchewan. There is a particular possible opportunity in the construction of Manitoba Hydro's new HVDC Bipole III transmission line from the north (Manitoba Hydro 2008). This line, which will pass down the west side of that province could, with the addition of a converter station near The Pas, provide a robust connection to SaskPower's grid. The technical and economic feasibility of such a connection warrants investigation. Manitoba will be making key decisions concerning this project soon.

As mentioned earlier, Alberta operates in a different power pool from Saskatchewan. Power can be transmitted to and from Alberta by first converting it to direct current then converting it back to alternating current. This adds to the cost of Alberta interconnections and makes such interconnections less desirable than those to Manitoba.

Increasing dependence in Saskatchewan on non-hydroelectric renewable power could require significant changes in the electrical grid (Milligan and Kirby 2009). One consequence of the shift to renewables is that renewable power sources tend to be located near the fuel rather than near the load. The current Saskatchewan grid is a blend. Thermal coal and hydroelectric power stations are located near the resource while gas-fired stations are located near the load. Wind systems, widely distributed to enhance the contribution to baseload, would lead to grid modifications, as would the addition of biomass systems. On the other hand, the present thermal coal stations are perfectly situated for solar power options, so effects on the grid would be relatively small. Under a sustainable power future, grid modifications would be carried out in concert with regional interconnections, robust transmission systems, and adoption of smart grid approaches, including controllable loads such as smart appliances.

Energy Storage

Making the transition from thermal coal power stations that provide baseload for the province to renewable power sources that may provide intermittent power means that energy storage options must be considered. As mentioned earlier in this report, SaskPower has a unique storage option in the use of Lake Diefenbaker. Storing energy as hydraulic head is so normal that it is rarely thought of in that light by power consumers.

One additional aspect of water storage is the use of pumped storage. In effect water is pumped into a reservoir when power needs are low so that it can be used to generate electricity when demand is high. Pumped storage has been used in many jurisdictions, including the Sir Adam Beck Station on the Niagara River in Ontario. Opportunities for use of pumped storage in Saskatchewan, however, are very limited.

Several other energy storage options are in some stage of development. One possible variant on CCS, for example, would be to use an intermittent power source such as wind or solar to electrolyze water producing hydrogen, which can be combined with CO_2 to produce methanol, a liquid fuel. Other energy storage options include special batteries, compressed air, salt liquefaction, flywheels, and even the batteries of electric cars. All of these technologies have particular problems. Compressed air, for example, is subject to adiabatic cooling when it is released. Energy must be added to the system to avoid this problem thereby decreasing efficiency. In general, energy storage options need further development and do come at a cost.

RECOMMENDATIONS

The following recommendations cover the short, medium and long term. Short term recommendations should be accomplished by 2020, medium term by 2030 and long term beyond 2030. The recommendations can be addressed by SaskPower but some would require policy direction from the province itself. The recommendations represent a suite of options that would enable the province to move to sustainable power production without conventional coal. Depending on the extent of implementation and the results of initial investigations, not all may prove to be needed or, indeed, to be feasible.

1. In the short term SaskPower should commit to a 300 MW saving driven by efficiency and conservation. The focus on this program should be major power accounts. This could be accomplished through SaskPower bringing industrial electrical engineering expertise to the problems of large consumers. Based on experience in other jurisdictions, increasing this commitment to 450 MW and then 800 MW in the medium to long term seems feasible.

2. Given the major capital costs associated with SaskPower's scenario of doubling electrical generation capacity in Saskatchewan over the next 20 years, SaskPower should gradually adjust its rate structure to encourage efficient use of electricity and to remove pricing incentives that offer customers lower rates when larger amounts of electricity are consumed. This transition to conservation pricing is an important component of demand side management and should be initiated in the short term.

3. In a clear statement of public policy the Province should state that existing conventional coal-fired generating stations (1700 MW) will be decommissioned at the end of their useful life. This implies that, unless they are equipped with carbon capture and storage (CCS), the Boundary Dam Generating Station would be

decommissioned in the short term, the Poplar River Station in the medium term and the Shand Station in the long term.

4. SaskPower should continue to pursue its current 110 MW carbon capture and storage project at the Boundary Dam Generating Station. The results achieved with this project would help inform future expenditures on carbon capture and storage. Decisions regarding the role of CCS in SaskPower's generation mix are required in the short term. Given the uncertainties associated with this technology, however, SaskPower cannot count on CCS as the primary vehicle for resolving its carbon emission problem. SaskPower needs to invest in the short and medium term in other proven cost effective ways of reducing GHG emissions.

5. SaskPower should be prepared to implement time-of-day power rates in the short term, or as load profiles make this useful.

6. While gas-fired thermal generating stations are widely seen as the least cost short term option for SaskPower expanding its generating capacity, SaskPower should ensure that any such facilities be specified as natural gas combined cycle (NGCC) rather than simple cycle. This would apply to both power purchase arrangements and to stations owned by the corporation. This commitment should be made in the short term.

7. SaskPower should ensure that 20 percent (1200 MW) of its generating capacity is wind-powered in the short term and that 20 percent of its net electricity production is wind-powered in the medium term. Complementary operation with hydro should be diligently pursued. It is understood that meeting the target level of wind power production may also require enhancement to the transmission and control systems of the electrical grid.

8. In the short term SaskPower should commit to the construction of up to 100 MW of small scale, run of the river hydropower generation. This increment of hydro could include the Elizabeth Falls project and other small-scale opportunities.

9. The province of Saskatchewan should enter into discussions with Manitoba for the provision of 1000 MW of firm hydropower. This could be achieved through construction in the medium term of the 1485 MW Conawapa generating station on the Nelson River. The arrangement could be a simple power purchase or a risk-sharing arrangement that would see SaskPower invest in a project. The power purchase decision can be made in the short term with power availability being in the mid-2020s.

10. In the short and medium term SaskPower should continue to strengthen its transmission ties to Manitoba. This would enhance power purchase opportunities

and help strengthen the stability of the transmission system. A connection to Manitoba's Bipole III line should be investigated.

11. SaskPower should commit to 300 MW of generating capacity from biomass. Such projects would be implemented in the short and medium term. These developments could be supported by application of a feed-in tariff or a direct power purchase arrangement.

12. SaskPower should investigate the construction of a 300 MW concentrated solar power facility near Coronach as a potential replacement of the Poplar River Generating Station. If the costs associated with such a project do not allow it to be feasible as a Poplar River Generating Station replacement, the technology could be considered as a Shand Generating Station replacement.

13. SaskPower should carefully monitor photovoltaic developments with a view to introducing 300 MW into the generation mix over the next decade. This could involve introduction of a feed-in tariff to support this development.

14. SaskPower should strongly support the adoption of an energy efficiency code for new construction in the residential, commercial, and institutional sectors.

15. SaskPower should follow the lead of more than 60 other countries and adopt feed-in tariffs – particularly for the purpose of advancing renewable electricity production using biomass and solar technologies.

16. SaskPower should make more use of co-generation, including entering into agreements that would see the installation of additional co-generation plants at Saskatchewan potash mines.

17. SaskPower should promote renewable energy projects that are community based, including the development of wind farm co-ops, solar power co-operatives, and renewable energy ventures that are jointly owned by municipal governments and SaskPower.

18. SaskPower should adjust its net metering policy to facilitate the establishment of renewable energy co-operatives.

If these recommendations were implemented it should be possible for SaskPower to continue to supply safe, reliable and sustainable power while significantly reducing GHG emissions in the province. Many of the decisions required to transition to environmentally sustainable power production are required in the short term. The next few years will therefore be critical from a power planning perspective.

Table 3 shows possible scenarios for making the required transition. This table assumes SaskPower's forecasts for increased electrical demand and demonstrates what is, in our judgement, a more environmentally acceptable way of achieving them. The GHG intensity for various power sources is shown in kilograms of CO_2 equivalent for 1000 kWh of production (Moomaw *et al*. 2011, McCulloch *et al.* 2000).

Table 3. Transition to Sustainable Power. Capacity in MW.

Power Source/Year	**2012**	**2014**	**2022**	**2032**	**GHG Intensity**	**Remarks**
Conventional Coal	1686	1486	1146	276	>1000	Shand closes in 2038
CCS Coal	0	110	110	110	<450	
Natural Gas	899	1160	1360	1620	450	
Cogeneration	438	438	800	1100	varies	
Hydro	853	853	1100	1100	4	
Hydro purchase	0	0	1000	1000	4	Conawapa or equivalent
Wind	198	198	1200	1500	13	
Biomass	10	10	200	600	18	from forest/agriculture waste
Photovoltaic	0	0	300	650	46	
Concentrated Solar	0	0	0	300	22	Poplar River replacement
Heat Recovery / Geothermal / Other	21	21	40	100	low	
Total Capacity	4105	4276	7256	8356		
New Conservation (includes new demand response)			(450)	(800)		
Effective Capacity	4105	4354	7706	9156		

Acknowledgement: I wish to thank Ann Coxworth and Peter Prebble of the Saskatchewan Environmental Society for their advice in the development of Table ES1.

The transition is not without risk, whether technical, financial or political. CCS coal faces both technical and cost challenges that will not be resolved for another five years. (Table 3 assumes that only Unit 3 at Boundary Power Station is converted to CCS.) In the best-case scenario, the GHG target reduction of 90 percent will be achieved at reasonable cost, including having a market for the produced CO_2. In a worst case scenario, the GHG reduction could be less than anticipated or the costs of achieving that reduction much higher than anticipated. There will also be a need for drought contingency planning related to cooling water supplies for the CCS power stations.

The risks associated with natural gas and cogeneration relate almost entirely to the future price of natural gas. At some point natural gas shortages or carbon taxes will make this option uneconomic. The latter certainly will take place by the 2050s, a time horizon beyond the anticipated life of existing facilities.

The technical and financial risks related to supply side augmentation at existing hydro facilities are small. However, there are some environmental risks associated with small-scale hydro that could have cost implications for mitigation. The risks associated with a purchase of firm power from Manitoba relate primarily to public policy. With any scenario involving hydro, there will be a need for drought contingency planning.

Wind power, even now, can be considered as a maturing technology. Technical and financial risks are modest, especially as smart grid requirements are implemented. Complementary operation between wind and hydro is important and, indeed, can become part of SaskPower's drought contingency plan. Complementary operation with natural gas power stations can also be used to reduce technical risk. Technical risk with wind power is also reduced as peak power demands transition to summer rather than winter, and as low temperature shut-downs become less significant.

SaskPower's other energy options, biomass, photovoltaic and concentrated solar, all have some technical and financial risks at present. In the case of biomass, there are risks associated with scaling up pilot plants and with timely supply of feedstock. Photovoltaic power appears to be on the cusp of economic viability and Saskatchewan is, in a Canadian context, uniquely positioned to consider that option. At the present state of development, concentrated solar stations would require payment of a feed-in tariff if developed under power purchase arrangements. If developed by SaskPower the higher costs could be absorbed across the entire system.

It should be noted that by 2050, the climate change crisis will be more fully felt around the world and stringent international GHG reductions are more likely to be in effect. These will make generation from natural gas unlikely thus leading to additional GHG reduction challenges for SaskPower.

CONCLUDING NOTE

This report has been written based on Saskatchewan Environmental Society's willingness to assume SaskPower's forecasts with respect to a doubling of electrical consumption in Saskatchewan over the next two decades. We believe it is clear that by focussing on a strategy of wind power, solar and biomass energy development, carbon capture and storage, co-generation of electricity and electricity efficiency, SaskPower can phase out the greenhouse gas emissions associated with conventional coal, reduce financial risks of over-reliance on natural gas, avoid the dangers of nuclear power, and move forward without large scale damming of our river systems.

It should be noted in conclusion, however, that the Saskatchewan Environmental Society does not accept the notion that per capita electricity consumption in Saskatchewan should be allowed to double. On a per capita basis, the electricity consumption for our province is already amongst the very highest of all jurisdictions on Earth. To assume ever increasing per capita power consumption is not environmentally sustainable.

The Earth's natural capital is being rapidly eroded. Biodiversity across our home planet is in steady decline. Our Earth's climate system is showing clear signs of disruption. There is widespread scientific agreement that a very large reduction in greenhouse gas pollution must urgently be achieved. Every electrical utility on Earth must take account of these global realities and act within their context.

By way of example, the international scientific community is advising the United Nations that greenhouse gas emissions – which now average approximately 7 tonnes per capita on a worldwide basis – must be reduced to 2 tonnes per capita over the next 25-30 years, if our home planet is to avoid the most dangerous consequences of climate change. Given that SaskPower's electrical generation system currently emits approximately 16 tonnes of greenhouse gas pollution per capita, and given that Saskatchewan as a whole emits over 69 tonnes of greenhouse gas pollution per capita, a planned doubling of electrical generation under these circumstances seems to us to be an unwise and unrealistic assumption.

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APPENDIX 1 – SYMBOLS, ACCRONYMS AND ABBREVIATIONS

ACH – Air Exchanges an Hour

AGC – Automatic Generation Control

AMI – Advanced Metering Infrastructure

CCS – Carbon Capture and Storage

CSP – Concentrated Solar Power

DSM – Demand Side Management

GHG – Greenhouse Gas

HVDC – High Voltage Direct Current

MAPP – Midwest Area Power Pool

Mt - megatonne

MW – megawatt

NGCC – Natural Gas Combined Cycle

OECD – Organization for Economic Cooperation and Development

PCS – Potash Corporation of Saskatchewan

t/c – tonnes per capita

WSA – Water Security Agency

APPENDIX 2 – LARGE EMITTERS IN SASKATCHEWAN

Facility	Organization	Location	GHG Emissions (tonnes CO_2 equivalent)
Boundary Dam Power Station	SaskPower	Estevan	7,321,598
Poplar River Power Station	SaskPower	Coronach	4,247,967
Shand Power Station	SaskPower	Estevan	2,152,063
CCRL Refinery Complex	Consumers Co-operative Refineries Ltd.	Regina	1,549,212
Lloydminster Upgrader	Husky Oil Operations Ltd.	Lloydminster	956,027
Meridian Cogeneration Plant	TransAlta Generation Partnership	Lloydmister	821,350
TransCanada Pipeline, Sask.	TransCanada Pipelines Ltd.	Burstall	720,720
Cory Cogeneration Station	ATCO Power Canada Ltd.	Saskatoon	529,615
Yara Belle Plaine Inc.	Yara Belle Blaine Inc.	Belle Plaine	518,301
Saskatchewan Pipeline System	Alliance Pipeline Ltd.	n/a	414,140
Mosaic Potash Belle Plaine	Mosaic Canada ULC	Belle Plaine	414,051
TransGas Ltd.	TransGas Ltd.	Regina	358,827
Bolney Thermal	Husky Oil Operations Ltd.	Lloydminster	343,729
Queen Elizabeth Power Station	SaskPower	Saskatoon	343,376
Pikes Peak	Husky Oil Operations Ltd.	Lloydminster	236,977
Foothills Pipeline, Saskatchewan	Foothills Pipe Lines Inc.	Richmond	207,181
SaskEnergy Inc.	SaskEnergy Inc.	Regina	194,107

EVRAZ Inc. NA Canada	EVRAZ Inc. NA Canada	Regina	170,318
North Tangleflags In-situ Facility	Canadian Natural Resources Ltd.	Lloydminster	135,258
Bienfait Mine – Char Plant	Prairie Mines & Royalty Ltd.	Estevan	126,474
Lloydminster Ethanol Plant	Husky Oil Operations Ltd.	Lloydminster	116,500
City of Saskatoon Landfill	City of Saskatoon	Saskatoon	95,150
Weyburn Oil Battery	Cenovus Energy Inc.	Weyburn	87,740
Senlac Thermal Oil Battery	Southern Pacific Resource Partnership	n/a	74,585
Potash Corporation – Allan Division	Potash Corporation of Saskatchewan	Allan	61,925
Terra Grain Fuels Inc.	Terra Grain Fuels Inc.	n/a	59,895
Vanscoy Potash Operations	Agrium Inc.	Vanscoy	58,081
Meadow Lake Mechanical Pulp	Meadow Lake Mechanical Pulp	Meadow Lake	57,951
Boundary Dam Mine	Prairie Mines & Royalty	Estevan	50,297
		Total	22,427,870

Source: Environment Canada, National Pollutant Release Inventory, 2009