CARBON-FREE ELECTRICITY FOR SASKATCHEWAN

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April 27, 2021

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EXECUTIVE SUMMARY

In 2013, the Saskatchewan Environmental Society (SES) produced a report, *Yes They Can: A 2020 Vision for SaskPower*. The report provided basic information concerning greenhouse gas emissions in Saskatchewan and the SaskPower electricity generation system. The report went on to discuss vulnerabilities and opportunities associated with the SaskPower system. The report presented 18 recommendations covering the short, medium and long term. Short term recommendations could be achieved by 2020, medium term by 2030 and long term beyond 2050. About one-half of the recommendations had short term implications. This report examines and updates the analysis and recommendations from the 2013 report.

Since 2013, SaskPower has transitioned from being a coal-fired utility to a gas-fired utility while increasing its generating capacity by about 10 percent. Figure ES 1 shows generating capacity in 2013 and 2020. In 2018-19, SaskPower generated more electricity using natural gas rather than coal for the first time. That same year only 16 percent of SaskPower's electricity generation was from renewable sources.

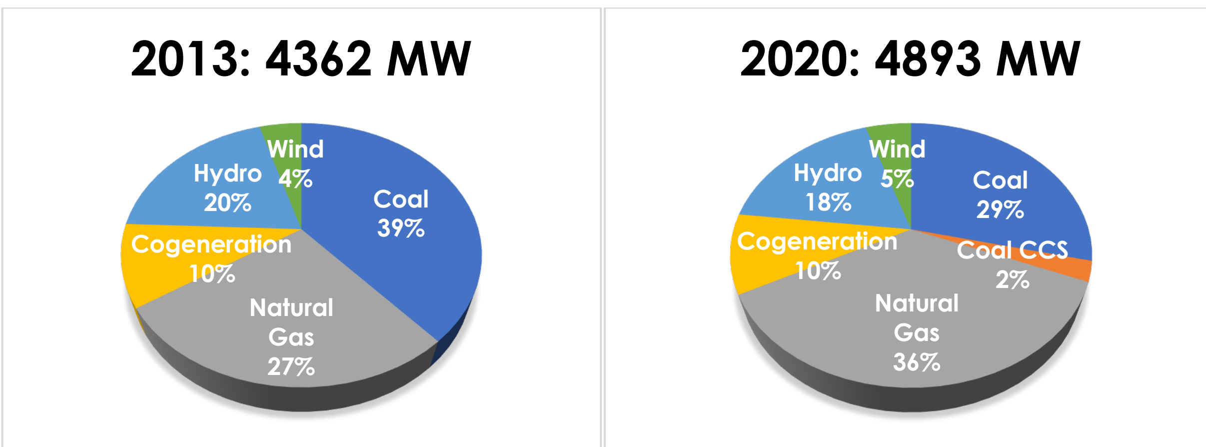


Figure ES 1. SaskPower's Generating Capacity.

Since 2013, SaskPower has committed to basing one half of its generation capacity on renewable sources by 2030, with particular emphasis on wind generation. The corporation has also committed to reducing greenhouse gas emissions to 40 percent below 2005 levels by 2030. Other developments since that time include the operation of Carbon Capture and Storage at Unit 3 of the Boundary Dam Power Station.

SaskPower has made good progress on implementing utility-scale wind generation facilities. These will come to fruition in the near future. On the other hand, there is little evidence of utility scale solar facilities. At present, only 10 MW systems are under development.

SaskPower has achieved its reduced target of 100 MW of demand side management (DSM). In 2007 the corporation had a target of 300 MW. DSM activity has also led to a small decrease in SaskPower's peak demand.

There are several challenges and opportunities in SaskPower's future. The first challenge is to get the utility off coal. While the closure of the remaining units at Boundary Dam Power Station has been announced as imminent, there have been no announcements regarding the Poplar River and Shand power stations. Presumably these also will be closed by 2030.

SaskPower has invested considerably in transitioning to becoming a gas-fired utility and plans to make additional investments in that regard. This leaves the corporation vulnerable to owning stranded assets as the world transitions to a net-zero carbon future by 2050. One opportunity for SaskPower could lie in opting for cogeneration facilities at sites such as potash mines rather that developing additional gas-fired power stations.

While SaskPower can meet its modest 2030 goal for renewable energy generation under its present course of action, meeting post-2030 targets will be very challenging. The best opportunity in this regard lies in strengthening the interconnections between SaskPower and Manitoba Hydro. Other opportunities include more aggressive action on incorporating solar power into the SaskPower grid and increasing attention to DSM.

The SES offers several recommendations for SaskPower's consideration.

1. SaskPower should commit to net-zero carbon emissions by 2040. To support this, its current 2030 goal should be enhanced to a goal of having one-half of its power generation from renewables by 2030. Being net zero by 2040 would be an ambitious target but should be viewed in the context of the planet needing to be net zero by 2050.

2. If a revised 2030 goal is to be met, SaskPower should pursue three options:
    a. Make a 1000 MW interconnection to Manitoba Hydro a high priority for completion by 2030.
    b. Continue to commission utility-scale wind farms up to the capability of the present grid. This would be in the order of 20 to 25 percent of capacity.
    c. Take the necessary steps to enable commissioning of utility scale solar stations by 2030. The target should be 500 MW of solar capacity.

3. SaskPower should formally announce its intent to decommission the Poplar River Power Station by 2030. This would remove uncertainty and allow appropriate transitional measures to be put in place at Coronach.

4. SaskPower should enhance its commitment to demand-side management to 500 MW.

5. SaskPower should continue to seek cogeneration opportunities in the order of 500 MW.

6. SaskPower should continue to investigate the feasibility of geothermal power production in the province.

7. SaskPower should continue to work on smart grid and related grid modernization technologies so that renewable power can be successfully integrated into its system.

8. SaskPower should pursue pilot projects related to energy storage using compressed air and large batteries and any other options. SaskPower should engage external expertise to develop a comprehensive plan for energy storage by 2023 and establish a pilot project by 2025.

INTRODUCTION

In 2013 the Saskatchewan Environmental Society (SES) produced a report, *Yes They Can: A 2020 Vision for SaskPower*. The report provided basic information concerning greenhouse gas emissions in Saskatchewan and the SaskPower electricity generation system. The report went on to discuss vulnerabilities and opportunities associated with the SaskPower system. The report presented 18 recommendations covering the short, medium and long term. Short term recommendations could be achieved by 2020, medium term by 2030 and long term beyond 2050. About one-half of the recommendations had short term implications. It may be useful, therefore, to consider how close SaskPower has come to meeting those recommendations. This report examines and updates the analysis and recommendations from the 2013 report. The report also reviews changes in SaskPower's generating capacity and policies in recent years.

Figure 1 shows the distribution of greenhouse gas (GHG) emissions in 2018 for Canada and Saskatchewan. From 2011 to 2018 Canadian GHG emissions have increased by two percent while those of the electricity sector have decreased by 18 percent, largely because of Ontario's closure of coal-fired power stations. In the same period, Saskatchewan's GHG emissions have increased by eight percent while those in the electricity sector have decreased by three percent. Since 2000 GHG intensity, as measured *per capita* or per unit of gross domestic product, has trended down even as actual emissions have increased.[1] Measures taken thus far to reduce GHG emissions, while useful, have been insufficient.

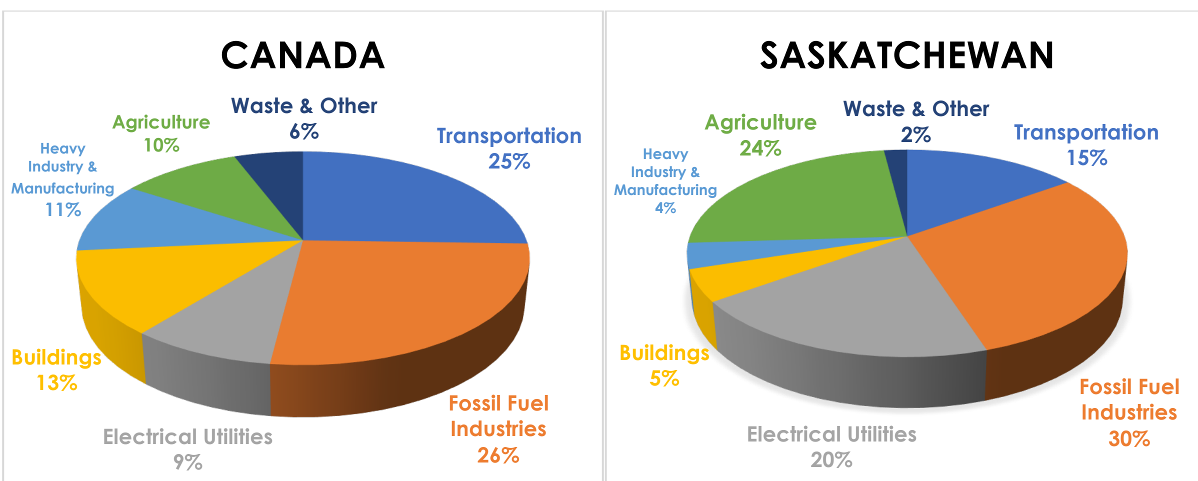


Figure 1. Greenhouse Gas Emissions – 2018.

In 2013, SaskPower produced 15.2 Mt of CO_2 equivalent and in 2020 produced about 16 Mt. While SaskPower is committed to reducing greenhouse gas emissions to 40 percent below 2005 levels by 2030, actual reductions still lie in the future. SaskPower's emissions will not attain

[1] SaskPower's GHG emissions may be levelling off as they did not increase from 2017 to 2018.

2005 levels until 2023. This places the likelihood of achieving more aggressive targets in some doubt. The corporation's modest goals and leisurely pace are a cause for concern.

CHANGES IN THE SASKPOWER SYSTEM

The current SaskPower system is shown in Figure 2, which illustrates the current SaskPower system map.

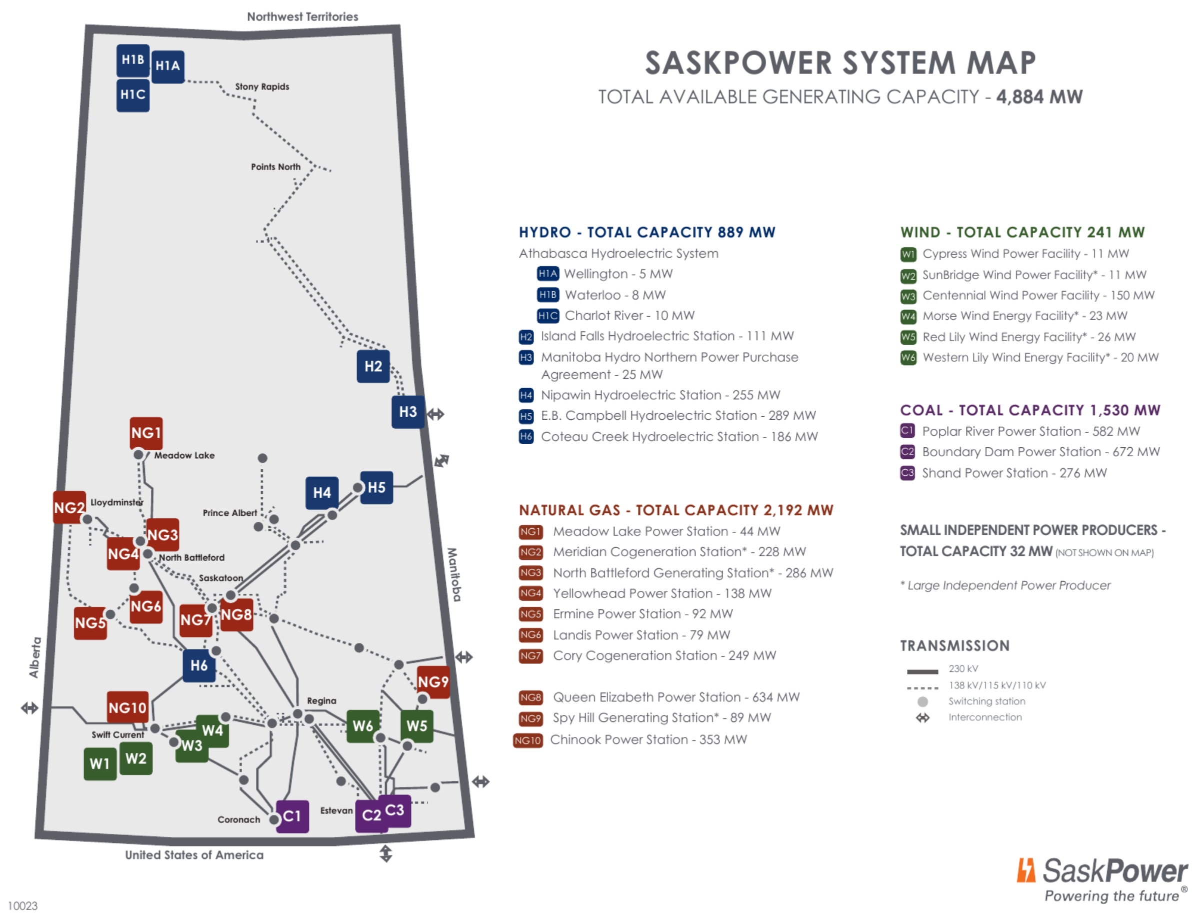


Figure 2. The SaskPower System.

Over the past several years SaskPower has transitioned from a coal-dominated utilty to a natural gas dominated utility. Figure 3 depicts the corporation's capacity in 2013 and 2020. In 2013, the installed capacity of the SaskPower system was 4362 MW. By 2020 this had increased to 4884 MW. There has been a slight decrease in conventional thermal-coal generation because of the conversion of one unit at the Boundary Generating Station to carbon capture and storage. The increase in generating capacity is made up for the most part by additional gas capacity added at the Queen Elizabeth Power Station in Saskatoon and the new Chinook Power Station at Swift Current. SaskPower has pledged to increase generating capacity from renewable sources to 50 percent by 2030. At present about 25 percent of the corporation's capacity is from renewable sources.

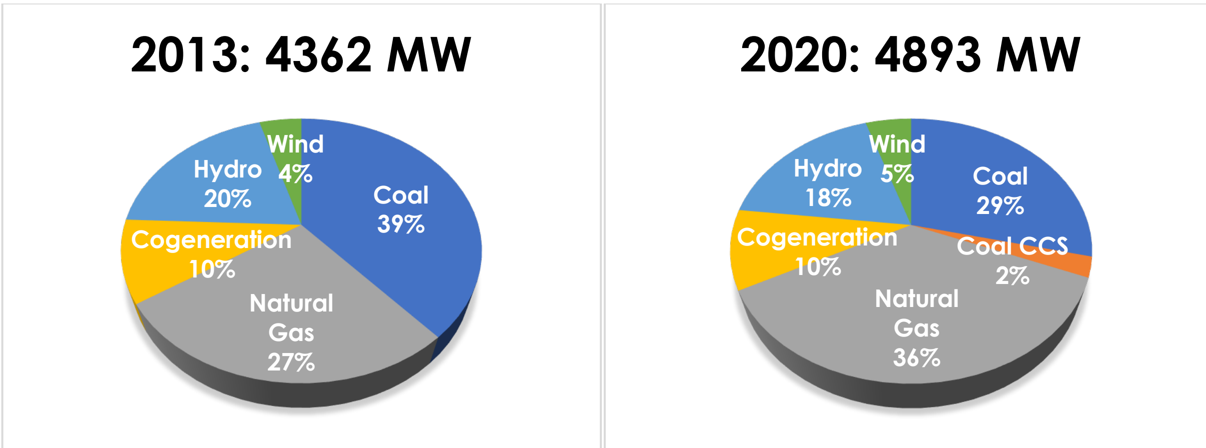


Figure 3. SaskPower's Generating Capacity.

SaskPower's installed capacity does not translate directly into power generation. It is noteworthy that 2018-19 is the first year in which the corporation generated more electricity from natural gas than from coal. In that same year only 16 percent of SaskPower's electricity generation came from renewable sources (SaskPower, 2020).

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. Saskatchewan now records all such facilities emitting more than 10,000 tonnes of CO_2 equivalent. There are now 90 such facilities in Saskatchewan. Of these, electricity generation facilities, most of them owned by SaskPower, account for 20 percent of the 77.8 Mt of CO_2 equivalent produced in Saskatchewan in 2017. Table 1 displays the facilities related to electricity generation.

Table 1. GHG Emissions at SaskPower and Related Facilities.

Facility	Organization	Location	GHG Emissions (tonnes CO2 equiv.)	
			2009	2019
Boundary Dam PS	SaskPower	Estevan	7,321,598	5,501,399
Poplar River PS	SaskPower	Coronach	4,247,967	3,936,648
Shand PS	SaskPower	Estevan	2,152,063	2,362,553
Queen Elizabeth PS	SaskPower	Saskatoon	343,376	1,366,727
Meridian Cogeneration	TransAlta	Lloydminster	821,350	888,851
North Battleford GS	Northland Power	North Battleford		740,256
Cory Cogeneration	ATCO Power	Cory	529,613	607,709
Yellowhead PS	SaskPower	North Battleford		174,756
Landis PS	SaskPower	Landis		109,098
Spy Hill GS	Northland Power	Spy Hill		90,143
Meadow Lake PS	SaskPower	Meadow Lake		49,323
Boundary Dam Mine	Prairie Mines	Estevan	50,297	45,356
Poplar River Mine	Prairie Mines	Coronach		21,387
Total Emissions				**15,894,206**

There are other significant changes since the SES report in 2013. These include the evolution of Carbon Capture and Storage (CCS) in the province, renewable power developments, Demand Side Management (DSM), Manitoba interconnections, and changes in the net metering program.

Carbon Capture and Storage

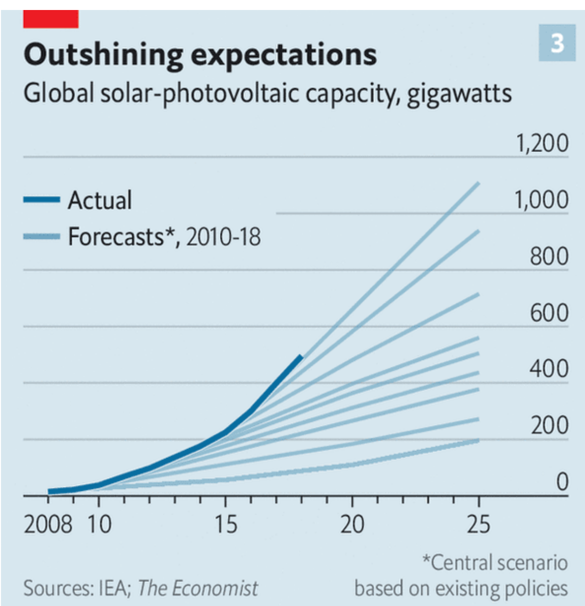
In 2014, operation began at the CCS conversion of Unit 3 at SaskPower's Boundary Dam Power Station. The unit has a capacity of 110 MW at a cost of approximately $1.5 billion (International CCS Knowledge Centre 2018). This was the world's first commercial scale CCS retrofit at a coal-fired power station. The unit uses amine solvents to strip both carbon dioxide and sulphur dioxide from the flue gas. The target is to remove 100 percent of sulphur dioxide and 90 percent of the carbon dioxide, making GHG output from the unit lower than from the equivalent natural gas station. The carbon dioxide produced is sold to Cenovas Energy for use in its enhanced oil recovery projects. There are still questions as to whether this CO_2 can be considered as permanently removed from the atmosphere. A test facility for sequestration of carbon dioxide in deep saline aquifers is also part of the project.

Although the unit has experienced problems in its early years of operation, it is becoming increasingly reliable and experiencing months-long periods of continuous operation. There is still an expectation that design carbon dioxide removal levels can be met.

Renewable Power

SaskPower has committed to reducing GHG emissions to 40 percent below 2005 levels by 2030. Part of that commitment will be met by decommissioning Units 4 and 5 at Boundary Dam Power Station and, probably, decommissioning the Poplar River Power Station. Some of that lost capacity will be made up by new gas-fired generating stations but the corporation has also committed to obtaining 50 percent of its capacity from renewable sources by 2030. The fate of the Shand Power Station is moot at this time. In 2013, SES recommended that all of SaskPower's coal-fired power stations be decommissioned at the end of their useful life.

At present, the lowest cost power available is wind power and the cost of solar power is almost as low. The dramatic decrease in the cost of wind and solar power was not anticipated in the 2013 SES report. Depending on specific situations, wind and solar costs are now just a little lower than those for natural gas-fired generation, based on what are known as levelized costs.



The Economist

Although not evident in Figure 3, SaskPower has initiated a number of wind power installations. These will come to fruition in the near future. Additions to wind power capacity in Saskatchewan tend to be in the order of 200 MW for each project. In 2013, SES recommended that 20 percent of SaskPower's generating capacity be wind by 2020 and that 20 percent of power generation be wind by 2030.

Although Saskatchewan has the greatest solar power potential of any province in Canada, SaskPower is just starting to examine those opportunities. Proposed installations are in the 10 MW range. Currently, the sum of solar power produced by individual home and business owners in Saskatchewan is greater than that produced by SaskPower. The adjacent figure shows how actual growth in the development of solar-photovoltaic power has routinely exceeded International Energy Agency forecasts. SaskPower is also supporting an 8 MW biomass plant and is exploring geothermal possibilities near Estevan.

Demand Side Management

In 2007, SaskPower's commitment to DSM was 300 MW. This was subsequently reduced to 100 MW but the corporation states that 156 MW has been achieved to a large extent through commercial lighting and industrial energy optimization. A key metric pertaining to

DSM is reduction in peak demand. In 2019-20, DSM reduced SaskPower's peak demand by 6.7 MW. In 2013, SES recommended that the 300 MW commitment be reinstated.

Another development in reducing demand was Saskatchewan's adoption of the *National Energy Code for Buildings* in January 2019. This is a national model code that can be adopted by provincial and territorial governments. The code sets out technical provisions to address energy efficiency in the design and construction of new buildings and additions to existing buildings. It helps promote consistency among provincial and territorial building codes and, as such, represents a minimum code.

Manitoba Interconnection

In 2013, SES proposed that SaskPower should purchase 1000 MW of capacity from Manitoba Hydro as a means of aggressively improving its use of renewable power. At present, the corporation purchases 125 MW from Manitoba Hydro and is in the process of improving transmission line capacity to enable a purchase of an additional 215 MW beginning in 2022 (SaskPower 2020).

Net Metering

On November 1, 2019, SaskPower revised its net metering program to eliminate capital rebates on installations and to reduce the credit for excess energy to the grid to 7.5 cents/kWh, rather than the previous 14 cents/kwh. That is, credits would be charged at wholesale, rather than retail rates. The reason ostensibly was that the program had reached an arbitrary cap of 16 MW two years early.

CHALLENGES AND OPPORTUNITIES

SaskPower is gradually moving in the right direction but lacks a sense of urgency in meeting its modest 2030 target of sourcing 50 percent of its capacity from renewable power. This target can be compared to that of the new government in the United States' plan of eliminating carbon emissions from the electricity sector by 2035. Alberta's independent power producers have recently announced that they will be off coal by 2023. SaskPower is currently considering a commitment to non-carbon electrical power by 2050. Recent events by other jurisdictions render that commitment inadequate.

The SES supports an immediate change in the SaskPower 2030 target to having 50 percent of SaskPower's annual **generation** being from renewable sources by 2030. This target would be simply a stepping-stone to ensuring that SaskPower can source all of its electricity generation from non-fossil fuel sources by 2040. There are several considerations in meeting such a target.

Carbon Capture and Storage – Coal-fired Power Stations

SaskPower is committed to closing down the remaining non-CCS units at Boundary Dam Power Station in 2021 and 2024. As stated earlier in this report, the Poplar River Power Station will be decommissioned although it is unlikely that this will happen before 2030. The only remaining opportunity for an additional coal-fired CCS facility in Saskatchewan would be the conversion of the 276 MW Shand Power Station to CCS. In the normal course of events the Shand station would reach the end of its useful life in 2042, but federal policy requires that coal-fired generating stations be closed by 2030. According to a report by the International CCS Knowledge Center (2018), it's possible that CCS at Shand could be implemented for about one-third of the cost of CCS at Unit 3 of the Boundary Power Station. Assuming this optimistic capital cost scenario is correct, parasitic load would reduce the capacity of the Shand unit to about 210 MW. This means that converting Shand to CCS would provide 210 MW capacity at a cost of about $500 million. This is high-cost power.

The cost of power generated by the CCS unit at Boundary Dam Power Station is defrayed to a considerable extent by sales of carbon dioxide to the oil industry. Enhanced oil recovery using carbon dioxide injection may increase existing oil field lifetimes by about 20 years. That is less than the anticipated lifetime of a CCS facility. The potential for sales of carbon dioxide to the oil industry for the entire anticipated life of a CCS station therefore depends on not only selling to existing fields, but also on as yet undeveloped oil fields. The viability of installing CCS at Shand will depend on the outlook for future oil field development in south-eastern Saskatchewan. In the era of the climate change crisis, future oil field developments in North America are fraught with uncertainty. SaskPower will have to make a decision concerning CCS at Shand by 2025. In general, the markets for industrial carbon dioxide are much smaller than the quantities that would be produced by significant adoption of CCS.

Gas-fired Generating Stations

SaskPower has added a number of gas-fired generating stations in recent years and two additional stations, a 353 MW station at Moose Jaw, and at least one at a location still to be determined, are under development. As stated earlier in this report, natural gas, not coal, is the current fuel of choice for SaskPower. All of SaskPower's gas-fired stations now use combined-cycle technology. Nonetheless, in the looming era of emissions-free electricity, gas-fired plants are an anachronism. SaskPower risks its proposed stations becoming stranded assets or, perhaps, being obliged to add CCS capability or pay for carbon offsets[2] to continue operation for their usual lifetimes. There are also concerns that fugitive methane emissions associated with some natural gas production makes this fuel almost as GHG-intensive as coal (Tollefson 2013, Chan *et al.* 2020).

[2] Canada's policy with respect to the sale of carbon offsets is still under development. It is unlikely, however, that a GHG emitter would be able to cover all emissions from a site through the purchase of carbon offsets.

SaskPower has power purchase arrangements for electricity from two private sector gas-fired generating stations with a total capacity of 360 MW. These stations will reach their useful life in the early 2030s. SaskPower needs to be diligent in ensuring that private sector investments in gas-fired electricity generation do not foreclose longer term objectives for producing carbon-free electricity.

There are additional opportunities related to cogeneration of electricity in the province. Experience with the 249 MW facility at the Cory Potash mine near Saskatoon and the 228 MW facility near Lloydminster has proven cogeneration to be reliable and successful. Instead of burning natural gas to produce only industrial heat, these facilities also produce electricity. Additional cogeneration capacity in the order of 500 MW could help replace decommissioned coal-fired stations. A commitment to cogeneration would reduce the risk of owning stranded gas-fired power station assets. There are potential cogeneration opportunities associated with potash mining and with the proposed Paper Excellence pulp mill at Prince Albert.

Another possibility for natural gas-fueled power stations is to re-fuel them using hydrogen. Hydrogen fuel cells have been used in transportation for decades and work is progressing related to hydrogen-fueled conversions of thermal power stations.

Generally, hydrogen fuel is defined by colours, depending on the means of production. There are four versions of hydrogen, three of which depend usually on natural gas as a feedstock and one that uses water as a feedstock. Grey hydrogen can be made from natural gas, coal or biomass and produces significant carbon dioxide emissions. Much of the hydrogen produced today is grey and is used to make ammonia, or in the oil and gas sector. If the carbon dioxide produced by making grey hydrogen is captured and stored by means of CCS technology, the hydrogen is known as blue hydrogen. Minor GHG emissions remain, however. Finally, natural gas – primarily methane, CH_4, – can be stripped of its hydrogen using a process known as molten metal pyrolysis to produce pure hydrogen and pure carbon, known as carbon black, which has a number of industrial uses. The hydrogen produced is known as turquoise hydrogen and its production is GHG-free. That said, markets for carbon black are limited and turquoise hydrogen production in the Canadian Prairies poses other challenges.

Hydrogen can also be produced using electrolysis of water. Referred to as green hydrogen, it is also GHG-free if the electricity supply used is GHG-free. It takes about nine litres of water to produce one kilogram of hydrogen. There is likely sufficient water supply from the North Saskatchewan River to enable a limited amount of green hydrogen production. One challenge, however, relates to the energy demand for low-temperature electrolysis. Renewable energy supplies do not produce waste heat that could be used to reduce power demands for electrolysis.

Salt caverns can be used for storage of hydrogen. Bulk storage of hydrogen in Saskatchewan would be quite feasible.

Today's natural gas turbines can be fueled by a mixture of natural gas with some additional hydrogen. There is an embrittlement challenge in using pure hydrogen with moving or vibrating components. It is unlikely that existing turbines can be converted to pure hydrogen fuel. A new generation of hydrogen-fueled power stations will not be available before 2030.

Renewable Power

If SaskPower is to meet its renewable capacity goal by 2030, the corporation must decommission and replace 1410 MW of coal-fired capacity with almost exclusively emissions-free capacity in the next 10 years. The need for capacity increases must also be considered. The utility has acquired experience in developing the wind energy sector and one-half of the replacement power could be from wind without necessitating significant investments in grid improvements and storage. SaskPower is on a path that would meet that target.

Another opportunity lies in the development of a 420 MW hydro-electric generating station at The Forks – 18 km downstream of the confluence of the North and South Saskatchewan rivers. Like the Nipawin generating station, this would be essentially a run-of-the river facility. This project encompasses the territory of the James Smith First Nation and could not be developed without their concurrence and support. The First Nations Power Authority could be instrumental in developing such a project.

SaskPower has designed a small-scale, low-head, 40 MW hydroelectric generating station known as Tazi Twé. It could be developed at Elizabeth Falls on the Fond du Lac River if and when electricity demand for northern mines is sufficient to justify the project. There are other small-scale hydro opportunities in the province, but these should be considered special situations, not part of the path to a renewable future.

Some of the additional renewable generating capacity could come from solar photovoltaic generating stations but SaskPower's limited experience with solar power makes this a challenge. In contrast, a 465 MW solar project is now under construction in Alberta. Saskatchewan's solar resource is unparalleled in Canada and is generally best in the area south of the TransCanada Highway. One might expect that one or two utility-scale 300 MW systems could be commissioned near Coronach or Estevan in the next decade. These locations would also facilitate connections to existing transmission lines.

Locating solar installations near Coronach and Estevan could help in the redeployment of some SaskPower workers directly affected by coal-powered station shut-downs. Decarbonizing electrical power production in the province has significant consequences for both communities. A thoughtful approach to making the transition to renewable power should benefit communities and individual workers (Carlson *et al*. 2018).

Solar power becomes increasingly attractive as SaskPower's peak demand switches from a winter peak to a summer peak. At present, the record winter peak demand is 3792 MW while the record summer peak is 3524 MW. The change in timing of peak demand will likely occur before 2030. A significant investment in solar power is warranted, in the order of 500 to 1000 MW.

The development of significant biomass or geothermal capacity is also constrained by SaskPower's lack of experience. One fairly recent biomass development is what is known as Bioenergy with Carbon Capture and Storage (BECCS). Many European companies are converting coal-fired power stations so that they can be fueled by biomass, usually wood pellets imported from the United States. While biomass fuel can be thought of as "fast coal" the carbon cycle calculations are complex. The addition of CCS to a biomass power station raises the prospect of "negative carbon". One such example is the 4000 MW Drax Power Station in England. Carbon pricing in Europe has made conversions financially attractive. Is it worth considering the Shand Power Station as a candidate for such a conversion?

In the case of geothermal power, it is not yet clear if the province has sufficient potential to make this a realistic option. The Deep Earth Energy Production (DEEP) project is investigating geothermal potential in the Deadwood Formation in the Williston Basin near Torquay. A 20 MW plant is under design. The project is supported by funding from Natural Resources Canada.

Manitoba Interconnection

The most straightforward means by which SaskPower can meet its 2030 renewable power goal is by implementing transmission lines from Manitoba Hydro to Saskatchewan (White-Crummy 2019) totaling 1000 MW capacity. The SES proposed this in 2013. The capital cost of such a line would be in the order of $1.8 billion, a little more than SaskPower paid to develop 110 MW CCS capacity at Boundary Generating Station. If development of such a transmission line were tied directly to the closure of SaskPower's coal-fired generating stations, it would be reasonable to anticipate that the federal government would pick up half the cost of the line. This could be an appropriate investment for the Canada Infrastructure Bank. Indeed, the bank has a notional allocation of $2.5 billion for interprovincial transmission lines.

Demand Side Management

Reducing power demand through conservation and energy efficiency is the least cost option in meeting current and future power demands. It would be reasonable at the very least for SaskPower to re-instate its 2007 demand side management target, thereby avoiding adding 300 MW of capacity by 2030. An overall DSM target of 500 MW appears feasible. The implementation of smart meters will also assist demand side management.

Small Modular Nuclear Reactors

Small Modular Reactors (SMRs) are generally defined as nuclear reactors with a design capacity of 300 MW or less. For a utility as small as SaskPower, 300 MW is a reasonable increment of generating capacity. In theory, an SMR uses modular technology and factory fabrication to deliver the finished reactor to a site. The idea is that many, many identical SMRs would be produced in a single factory, leading to significant cost savings. There are myriad SMR designs, none of which have been commissioned, although Ontario Power Generation is working with vendors to bring a grid-scale SMR on-line by 2028 at its Darlington Power Station. SMR proposals use various cooling methods such as pressurized water, liquid metal, molten salt, or gas. Natural Resources Canada is working with several provinces, including Saskatchewan, on an SMR Action Plan. SaskPower will evaluate the potential deployment of 900 MW of generating capacity between 2035 and 2042 using SMRs (SMR Action Plan: SaskPower 2021). The development of a 300 MW SMR is a somewhat different alternative to larger existing designs and SaskPower does not intend to be a leader in SMR development as it was with CCS.

SES has long held the view that nuclear power would not be an appropriate choice for Saskatchewan. Given the present timelines for SMR development and progress to date, it is unlikely that a financially viable unit will be available in time to play a role in SaskPower transitioning to a non-carbon future. The reality is that designing, testing, problem-solving, licensing, and commercializing an SMR product can only be realized with enormous government subsidies and will take decades. The perpetual problem of managing nuclear waste remains, irrespective of the size of the generating station. Like power produced by coal-fired power stations, power from nuclear reactors is not usually dispatchable. In addition, the nuclear industry is fraught with cost and timetable overruns.

CAPACITY REPLACEMENT AND EXPANSION OPTIONS

Table 2 summarizes the existing and proposed possibilities for adding to SaskPower's capacity by 2030. The additions include projects that are virtually certain and some that are more speculative. Two gas-fired stations will unquestionably be constructed, as will several wind generating stations, two small solar photovoltaic stations, and a 100 MW capacity connection to Manitoba Hydro. Future capacity needs, GHG reduction targets, and renewable power commitments can be met if SaskPower implements the proposed connections to Manitoba Hydro even if the Shand Generating Station is shut down.

Table 2. Capacity Replacement and Expansion Options Being Considered by SaskPower.

Project	Type	Capacity in MW	Status	Non-carbon
Shand GS	CCS Coal	220	Under Consideration	no
Great Plains GS	Natural Gas	353	Contract Awarded	no
Natural gas - Other	Natural Gas	353	Under Development	no
Blue Hill	Wind	177	Under Construction	yes
Golden South	Wind	200	Under Construction	yes
Capstone Wind	Wind	10	Under Construction	yes
Foxtail Grove	Solar	10	Under Construction	yes
Highfield	Solar	10	Under Development	yes
Birtle to Tantallon	Interconnection	100	Under Construction	yes
50-200 MW RFP	Wind	up to 400	Contract award 2021	yes
Winnipeg to Regina	Interconnection	215	Under Consideration	yes
TOTAL		2,048		

In a recent document (SaskPower 2021), SaskPower specifically states that the loss of 1400 MW of conventional coal generation will be made up by the addition of 1118 MW of natural gas generation, 685 MW of wind generation, 190 MW of hydro imports, and 183 MW of solar, geothermal and other. Comparing this statement to Table 3 implies that Shand CCS will not go ahead, nor will a major interconnection with Manitoba Hydro. The shortfall would be made up by additional natural gas power stations.

Although the path to 2030 is feasible, the significant reliance on additional natural gas power stations comes with considerable risk as outlined earlier in this report. The alternative would be for SaskPower to continue operating the stations for their lifetime while implementing CCS and purchasing carbon offsets to compensate. This would be expensive power. Other options from which non-carbon power increments could be selected are shown in Table 3. These are all alternatives identified by SES in 2013, but the capacity figures have been adjusted to meet current realities.

Table 3. Other Capacity Replacement and Expansion Options.

Project	Type	Capacity in MW	Status	Non-carbon
Cogeneration	Natural gas	500	SES Proposal	yes
The Forks	Hydro	420	Needs FN Concurrence	yes
Southern Sask.	Wind	600	SES Proposal	yes
Coronach/Estevan	Solar	500	SES Proposal	yes
Conservation	DSM	350	SES Proposal	yes
Winnipeg to Regina	Interconnection	700	SES Proposal	yes
TOTAL		3,070		

Beyond 2030, the challenge for SaskPower is considerable if carbon-free generation by 2040 becomes the goal. Matching the American goal of carbon-free by 2035 can only be achieved by implementing CCS or buying carbon offsets for 1700 MW of gas-fired generation to avoid decommissioning in the next 15 years. It should be noted that Canada's major hydropower utilities are either carbon-free already or will be by 2030. Ontario Power Generation plans to be carbon-free by 2040. Alberta plans to be off coal by 2023.

CARBON-FREE POWER BY 2040

However, SaskPower can easily meet its commitment to having 50 percent of its installed capacity in renewable power by 2030 based on decommissioning conventional coal-fired generating stations, investing in wind and solar power, and making a major connection to Manitoba Hydro. The corporation can also meet an upgraded goal of 50 percent generation from renewable power with further investments in hydro power, utility-scale solar power, and demand-side management. In effect, some 1700 MW of gas-fired power generation must be decommissioned and replaced.

There are several challenges in these next steps. Two are external to Saskatchewan and others are within the province.

Border Carbon Adjustments

Border Carbon Adjustments or Border Tax Adjustments (BAT) are taxes on imported products by countries that pay for their GHG emissions on countries or companies that do not. This concept has been discussed for at least 20 years and is very much in the thinking of the European Union (EU) (Hontelez 2007). Such a tax related to aviation fuel is already part of the EU approach. The general consensus is that a BAT will clear GATT and WTO rules (Pauwelyn, 2012). As one of the world's highest per capita producers of GHGs and a significant exporter of commodities, it is not out of the question that Saskatchewan would be vulnerable to imposition of BATs by American and EU governments that take climate change seriously. Indeed, the situation in Saskatchewan and Alberta could make Canada vulnerable to such impositions. In effect, Saskatchewan could find itself on the wrong side of a "carbon fence".

Manitoba Interconnection

There are various opportunities for SaskPower to strengthen its connection to Manitoba Hydro. At present there is a hiatus in American demand for power from Manitoba, but this could change as the United States embarks on an aggressive agenda to remove carbon from the power generation process. The benefits of a robust connection go beyond simple power purchases. The interconnections enable exchange of power generated by ephemeral sources such as wind and solar, reducing grid stability issues. A more significant interconnection also would allow both utilities to decrease distribution system energy losses by incorporating elements of grid modernization and smart grid optimization. (About 10 percent of electrical energy generated is lost in transmission and distribution systems. Power engineers speak of conservation of VARs (volt-ampere-reactive power).)

Dispatchable Power

Dispatchable power is power whose supply can be readily adjusted to meet demand. Hydroelectric and gas-fired power supplies are dispatchable while coal-fired and SMR supplies are not. Neither are intermittent supplies like wind and solar. The challenge for SaskPower in moving to a non-carbon system is to develop sufficient additional dispatchable supply in addition to present and future hydroelectric generating stations. The connection to Manitoba will help in this regard. Developing utility-scale energy storage systems is another.

Energy Storage

There are currently several opportunities for energy storage in Saskatchewan. Currently, complementary operation of hydro operations with intermittent wind power allows water to be stored in Lake Diefenbaker when the wind or solar power stations are producing and to generate hydro power when they are not. As wind and solar facilities expand this can continue.

Saskatchewan's sub-surface geology provides another energy storage opportunity, namely using Compressed Air Energy Storage (CAES). The province has a long history of using salt caverns for natural gas storage at depths of 800 to 1200 m. Caverns are created by brine washing. The quantity of brine used is about three times the cavern size. Brine is disposed of in deep groundwater formations, like the Deadwood formation. For CAES, off-peak energy is used to pump air into the cavern and when energy is required the compressed air is released through a turbine to generate electricity. Several storage methods exist with systems that have a capacity of a few hundred megawatts and the ability to store a few thousand megawatt-hours of power (B. Brunskill, personal communication 2020).

Advances in battery storage also provide opportunities for managing intermittent power sources. Tesla has introduced utility-scale energy storage based on the company's lithium-ion Megapak. A 100 MW unit was installed in South Australia at a cost of US$50 million. It was deemed to have saved US$40 million in its first year through stabilizing and balancing the grid. An expansion to 150 MW is underway. In 2013, California passed legislation requiring investor-owned utilities to provide 1325 MW of storage by 2024. That storage is currently being installed. SaskPower is currently installing a 20 MW system in Regina. Battery storage systems, whether existing or proposed, serve only to smooth daily fluctuations in power generation. They are inadequate in coping with longer-term fluctuations.

Many countries are making commitments to requiring all new vehicles to be internal combustion engine-free by 2025 to 2035. Quebec, thus far, is the only Canadian jurisdiction to make such a commitment. A large fleet of electric vehicles in Saskatchewan, combined with smart grid and related technology, would provide an opportunity for storing surplus energy.

Whether hydro, compressed air or battery, these storage options all provide dispatchable power aimed at levelising power supply. At present compressed air and battery systems will levelise supply over days, not weeks.

Grid Modernization and Smart Grids

Integrating large-scale intermittent renewable energy sources, decentralized energy supplies and bidirectional energy flows requires significant investments in the electrical grid. The end result of investments in advanced metering, communications, control systems, and computer processing is commonly described as a smart grid. These new systems tend to include advanced digital meters that give consumers better information and automatically report outages, relays that sense and recover from faults in the substation automatically, automated feeder switches that re-route power around problems, and batteries that store excess energy and make it available later to the grid to meet customer demand. Natural Resources Canada is funding smart grid projects throughout Canada and SaskPower is participating in that program (Natural Resources Canada 2020).

SES RECOMENDATIONS

In the last several years SaskPower has made very little progress on reducing GHG emissions. In its 2013 report SES offered proposals as to how carbon emissions could be significantly reduced but the slow pace of SaskPower's transition to decarbonizing its power generation leaves the 2030 goals of reducing GHG emissions to 40 percent below 2005 levels and to having one half of its generating capacity based on renewables by 2030 a challenge. The SES offers several recommendations for SaskPower's consideration.

1. SaskPower should commit to net-zero carbon emissions by 2040. To support this, its current 2030 goal should be enhanced to a goal of having one-half of its power generation from renewables by 2030. Being net zero by 2040 would be an ambitious target but should be viewed in the context of the planet needing to be net zero by 2050.

2. If a revised 2030 goal is to be met, SaskPower should pursue three options:
    d. Make a 1000 MW interconnection to Manitoba Hydro a high priority for completion by 2030.
    e. Continue to commission utility-scale wind farms up to the capability of the present grid. This would be in the order of 20 to 25 percent of capacity.
    f. Take the necessary steps to enable commissioning of utility scale solar stations by 2030. The target should be 500 MW of solar capacity.

3. SaskPower should formally announce its intent to decommission the Poplar River Power Station by 2030. This would remove uncertainty and allow appropriate transitional measures to be put in place at Coronach.

4. SaskPower should enhance its commitment to demand-side management to 500 MW.

5. SaskPower should continue to seek cogeneration opportunities in the order of 500 MW.

6. SaskPower should continue to investigate the feasibility of geothermal power production in the province.

7. SaskPower should continue to work on smart grid and related grid modernization technologies so that renewable power can be successfully integrated into its system.

8. SaskPower should pursue pilot projects related to energy storage using compressed air and large batteries and any other options. SaskPower should engage external expertise to develop a comprehensive plan for energy storage by 2023 and establish a pilot project by 2025.

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