Transforming Saskatchewan's Electrical Future

PART THREE

The Potential for Wind and Solar Power

By Mark Bigland-Pritchard

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This paper is written as part of an ongoing project, Green Energy Project Saskatchewan. GEPS is a civil society group, established to develop a plan for the conversion of Saskatchewan's electricity grid to sustainable renewable options by the earliest possible date. Stemming both from concern for the welfare of the human species and from a respect for the earth and all of its natural systems, we seek the attainment of sustainability, as defined by the UN-sponsored Brundtland report in 1987: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Basic principles of compassion and justice demand that we move rapidly to phase out fossil fuel usage and therefore eliminate our largest contribution to global climate change. We owe this to all the potential victims of climate change, locally, nationally and globally, in our generation and in generations to come. We therefore seek options for energy provision which are based on the following principles:

- Efficient use of resources — achieving desired results with as little energy consumption as is realistically possible.
- Use of renewable options — i.e. the energy sources which will endure for as long as possible.
- Technical viability — both innovative and traditional choices, designed and assessed according to the best available scientific and technological methods available.
- Recognition and respect for the rights of indigenous people at home and low-income people worldwide in the choice of technologies and the way in which they are implemented.
- Minimization of negative environmental impacts and respect for ecosystems.
- Optimization of opportunities for local social and economic development.

More information on GEPS and sustainable energy practices can be found at our website: *http://greenenergysask.ca*

About the Author

Mark Bigland-Pritchard operates as a consultant in energy, environmental assessment, green building and architectural physics through his company, Low Energy Design Ltd. His background includes two engineering degrees, a PhD on energy performance and moisture risk in strawbale construction, several years of teaching energy studies at the Open University and the University of Sheffield (in Britain), and a diverse range of consultancy work in the public, private and voluntary sectors, spread over two decades and three continents. He is currently a director of the Saskatchewan chapter of the Canada Green Building Council.

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Transforming Saskatchewan's Electrical Future

The Potential for Wind and Solar Power

The first paper in this series[1] set out the reasons why a radical change in Saskatchewan's electrical supply regime is both necessary and desirable, and indicated some of the potential for relatively short-term progress towards a sustainable system. The second paper[2] pointed to some of the ways in which electricity demand can be reduced through efficiency measures. Here we begin to look at supply options, starting with the sun and the wind.

Any plan for a sustainable energy future needs to take into account the renewable energy resources which are available. With the best solar profile in Canada, and the best onshore wind profile outside of the coasts and the mountaintops, this province would be foolish not to consider these two sources very seriously.

This paper addresses the opportunities and the challenges involved in developing wind and solar power for the electricity market in Saskatchewan, and answers some frequent criticisms.

Understanding the Language

Dispatchability

Some electrical generation options are able to power up and down more quickly than others. A dispatchable source is a flexible source — one which can be turned on and off rapidly at will. In the present generation mix, these include reservoir-enabled hydroelectric facilities and most gas-fired power stations. Certain sources — notably nuclear power and large coal-fired facilities — are essentially non-dispatchable: long start-up and shut-down times necessitate operation at close to constant output. Wind and photovoltaics (pv), like all natural variable sources, are not positively dispatchable (the normal output is set by the level of the natural resource at the time), though they are negatively dispatchable (i.e. their output can be rapidly switched down or off).

Baseload

In discussion of electricity futures, it is never long before someone mentions baseload. This is a much misunderstood term, and it is important to the present discussion that it be understood correctly. Baseload refers to that portion of electricity demand which is consistently present 24 hours a day, 365 days a year. It is important to note that baseload refers to electricity **demand**: the term is being used carelessly when referring to any particular **supply** option. Traditionally, however, it has been simplest to meet baseload requirements by use of one or two sources running continuously. Certain sources — notably

Figure 1: Typical characteristics (simplified) of daily power profile for a conventional generation mix, low-demand day (e.g. spring or autumn)

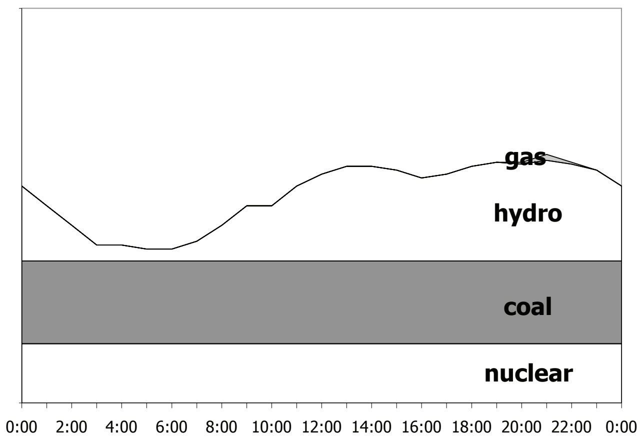
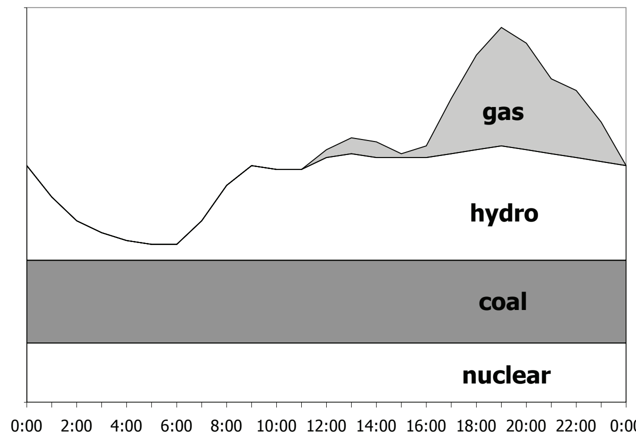


Figure 2: Typical characteristics (simplified) of daily power profile for a conventional generation mix, high-demand day (e.g. winter)



nuclear power and large coal-fired facilities — can only sensibly be used in this way because of their non-dispatchability. Hence utilities are very familiar with daily supply graphs something like Figures 1 and 2.

In these graphs, nuclear and coal provide the baseload, and hydro and gas the "intermediate" (or "load-following") and peaking power. Normal SaskPower practice to date has been to use coal for baseload, hydro for intermediate and gas for peaking.

Such an arrangement would still work well if carbon emissions and radioactive waste did not pose problems (and if nuclear power could be made affordable without subsidy). However, it is not the only way to run a grid, and indeed becomes difficult with large proportions from variable sources (such as wind and pv). The point is to supply total demand, and there is more than one way to achieve this. Wherever significant proportions of variable renewables (such as wind and photovoltaics) are used, a shift away from the old approach becomes necessary (Figures 3 and 4).

Figure 3: Typical characteristics (simplified) of daily power profile for a renewables-based generation mix, low-demand day (e.g. spring or autumn)

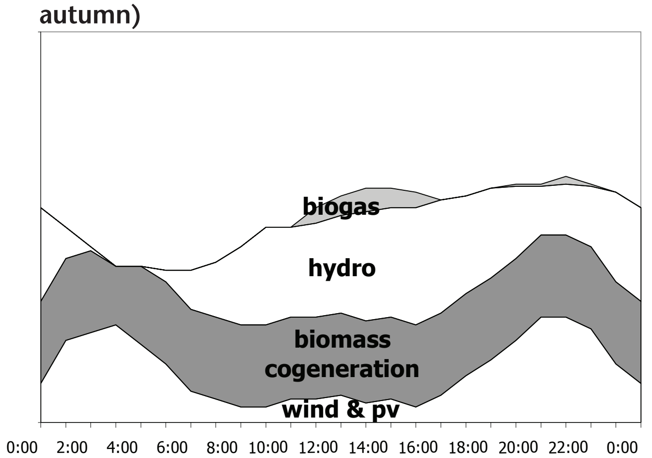
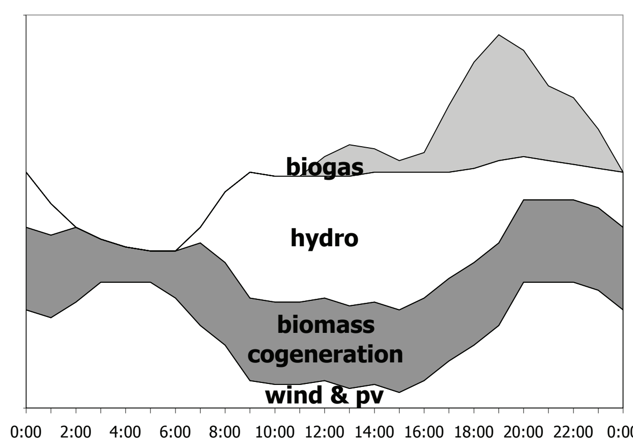


Figure 4: Typical characteristics (simplified) of daily power profile for a renewables-based generation mix, high-demand day (e.g. winter)



As the proportions of inflexible "baseload supply" sources decrease, the potential for greater flexibility increases. Even so, moving away from the old inflexible-baseload-supply-plus-dispatchable-peaking-supply approach requires careful planning. It is important to maintain security of supply, to the same degree as is achieved currently under the old system.

Capacity Factor

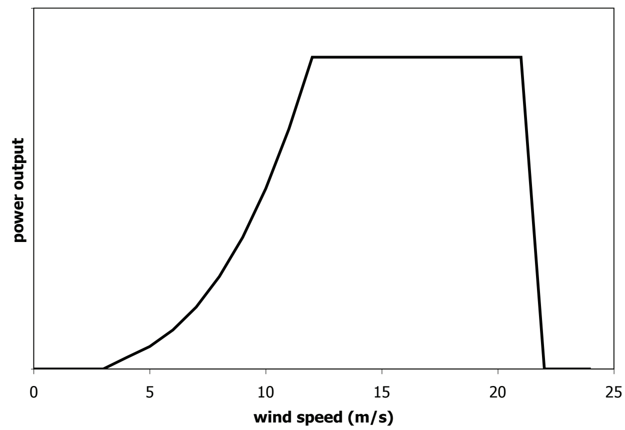
The capacity factor of a power station is the ratio of the actual power output to the theoretical maximum based on its official rating. For thermal power stations, the official rating is set by the manufacturer and the capacity factor is relatively easy to calculate. For example, the theoretical annual maximum output of a 500 MW power station is 500 MW x 365 days x 24 hrs = 4380000 MWh, or 4380 GWh. If the actual annual output amounts to 3500 GWh, then the capacity factor is 3500/4380 or about 80%.

For non-dispatchable sources such as coal or nuclear, which (as noted above) can only sensibly be operated at close to constant output, capacity factors in the region of 75% to 90% are typical. For gas-fired power stations used consistently for peaking load only, the capacity factor can be as low as 15%.

Certain conventions are used in establishing capacity factors for variable renewables.

For wind turbines, power output depends on wind speed. At low wind speeds (below about 3 or 4 metres per second — 11 to 14 kilometres per hour), friction prevents the blades from turning. At somewhat higher speeds, the output is roughly proportional to the cube of the wind speed. At still higher speeds, control mechanisms in the turbine keep the rotation speed and therefore the output constant. And at very high speeds, the wind turbine is closed down for safety reasons (see Figure 5).

Figure 5: Typical power curve for a modern wind turbine



It is normal practice to take the power output at 12 or 13 m/s wind speed — i.e. the maximum output shown by the "plateau" area of the graph in Figure 5 — as the rated capacity of the turbine. Wind turbine capacity factors depend both on the average wind speed and on the extent to which it varies during the year. Values worldwide range from about 15% in Germany to over 40% in northern Scotland. Existing windfarms in Saskatchewan achieve nearly 40%, though this figure would not be repeated in all suitable sites in the province.

For photovoltaics, power output depends upon the incident solar radiation, the sun angle relative to the panel and the panel temperature. Maximum capacity is taken as the power output which the panel can achieve at 25°C with solar radiation of 1000 watts per square metre falling perpendicularly on the panel. In Saskatchewan, an optimally-angled south-facing panel could expect a capacity factor of about 15% — a bit lower in the north, and a bit higher in the south of the province.[3]

Capacity factor should not be confused with efficiency. Efficiency is the ratio of power output to power input. Capacity factor is the ratio of power output to theoretical maximum power output.

Wind Power

This paper considers only utility-scale wind power. Typically, this would mean turbines with a nominal rating of at least 1.8 MW. There is a role for smaller units — on farms, in remote communities, etc. — but their share in the task of decarbonizing the province's electricity output is quite small, owing to their higher unit costs and lower capacity factors.

Many factors should be considered in our energy investment decisions on energy facilities, but two are of particular importance — the carbon intensity of the option and its cost. Wind power (at least in the right site) performs well on both. While some greenhouse gas production results from manufacture of the relatively small quantities of steel and concrete required to construct a wind turbine, this is currently one of the least carbon-intensive electrical generation technologies available. It is also extremely cost-effective in good sites. Its cost per kWh output, having dropped consistently for many years, is now relatively stable. With equivalent costs for fossil fuel and nuclear options steadily rising, wind power may be expected to become more cost-competitive in future, making a progressively wider range of sites viable.

In a geographically large province such as Saskatchewan there is no shortage of suitable sites. A reasonable rough guide to a suitable site (though conservative by international standards) is an average wind speed of 6 metres per second or higher at 80 metres (250 ft) above the ground: estimated wind speeds may be found in the Canadian wind atlas.[4] A more accurate test — which takes into account the variability of the local wind — is to calculate the capacity factor for a typical wind turbine with an 80 m hub height:[5] this depends both on average wind speed and on the extent to which wind speeds vary around the average (as well as on the characteristics of the turbine itself). A similarly conservative rule of thumb would be a minimum capacity factor of 24%. Either way, virtually the whole of the southern half of the province passes the test — both wind speeds and consistency are good. (These two rule-of-thumb options are, incidentally, highly conservative — on either count, virtually all of the turbines in Germany's highly successful wind programme are in locations which would be deemed to fail.) Only in the river valleys and the boreal forest is there a smaller wind resource, and every settlement of more than 4000 people in the province is easily within 50 km of reasonable sites. (In the north, wherever the forest gives way to lakes, sufficiently high wind speeds are again attained.)

Wind turbines need to be spaced such that they do not "shade" or interfere with each other. In practice that is likely to mean a power capacity density of 10 to 15 MW per square kilometre, or three to five 2 MW machines per quarter-section. If wind turbines with a 25% capacity factor were to meet a quarter of the power requirement which SaskPower projects for 2030, they would require 250 to 300 km^2. The area of the province

with an adequate resource is about 200000 km^2; even after we have eliminated all locations too distant from a low-voltage power line to be able to feed into the grid, we are still left with a far larger wind resource than we can readily use.

While 300 km^2 sounds like a lot of land, actually the vast majority of it could maintain its current use. Typically only about 2% of the land area of a wind farm is required for the foundations, associated buildings and access roads. Farming can continue under and between the turbines.

Wind turbines require relatively little maintenance to ensure reliable operation — but can still provide some local employment through this function, thereby generating economic activity in rural and remote communities, including First Nations reserves.

Unlike large-scale centralized options such as coal and nuclear, wind power is essentially a distributed resource and works best as part of a decentralized grid — this is known under a number of names, but the most common in North America is "distributed generation". Attempts to "centralize" the technology in a few chosen locations in the province miss the point. Distributed generation should be seen as an opportunity to enable rural communities to provide their own energy supply to help sustain themselves economically and socially.

Another advantage of generation based on many small units rather than a few large ones is that its development can be approached in a modular way, adding turbines to a local windfarm as finances permit.

Wind power, therefore, is not only cheaper and more environmentally sound than the large-scale options around which provincial government thinking currently revolves (nuclear, coal with carbon capture and storage, etc.), but also offers better prospects of community development in areas where it is urgently needed.

So What Are the Challenges?

Noise: It is true that modern wind turbines, in common with most machinery used by the people of Saskatchewan, create noise. However, noise levels are significantly lower than those from a major highway and can be indistinguishable from other background sounds as close as 1 km away. Some major manufacturers specialize in gearless systems, eliminating mechanical noise and so leaving only the sound of the blades "swishing" through the air. This also is being reduced by improvements in the shape of the blades. In any case, even without these improvements, maximum outdoor sound levels at a distance of between 300 m and 600 m from a wind turbine are in the 40 to 50 dBA range — similar to light traffic at 15 m, or to a typical living room. Setback distances of at least 600 m from occupied buildings not connected with the windfarm should pose no difficulty in Saskatchewan.[6] Studies on the level of "annoyance" experienced by people in the vicinity of windfarms find a correlation between this and opposition to the installation (usually on other grounds) at the outset[7] — this finding may be explained in more than one way, but it certainly casts doubt on the appropriateness of allowing such complaints to drive public policy.

Birds: In the wrong place any tall structure can result in the death of migrating birds. Wind turbines cause fewer fatalities than skyscrapers or lighthouses — or, for that matter, airports or domestic cats[8] — and careful planning of location and height minimizes the problem. In other jurisdictions, constructive relationships have been built between wind developers and avian conservation organizations, which recognize the far greater risk to birds from unmitigated climate change.[9]

Bats: There is more of an issue with certain bat species. It appears that the pressure differentials in the vicinity of the blades can result in adverse effects on bat heart function. Bat fatalities have happened in significant numbers only at a limited number of sites — especially in the eastern United States, and primarily on migration routes. It is not clear whether the same problems are likely at Saskatchewan sites. Bat activity appears to be much greater during periods of low wind speed and low barometric pressure, and studies suggest that it is possible to considerably reduce fatalities by increasing the wind turbine cut-in speed and/or closing down turbines during bat-friendly weather periods.[10]

Aesthetics: Some people think wind turbines are ugly (but at least as many find them beautiful). Debates will no doubt continue at proposed sites worldwide as to whether a windfarm would be in keeping with the local landscape — but surely this is of minor significance compared to avoidance of climate change on a scale which would devastate both the landscape and those dependent on it. And, as noted above, Saskatchewan has no shortage of suitable locations, so it is relatively easy to avoid more sensitive places.

Television, military radar, etc: Wind turbines can affect television reception and other electronic signals — but the signal can be strengthened if necessary, and a workaround has always been found in practical cases.

Local disruption: Some inconvenience to local residents may be expected during construction of service roads — but that is true of any power station or indeed any new industrial development, and for a typical wind farm it lasts for only a few months.

Alleged health problems: In addition to the noise issues noted above, some complainants have associated symptoms of sleep difficulties, headaches, dizziness, nausea, exhaustion, anxiety, depression, concentration problems and tinnitus. However, (i) the number of persons complaining of these symptoms is a tiny minority of those living in the vicinity of windfarms, (ii) the proponents of a linkage between these symptoms and windfarms are able to offer little more than a common pattern in a small collection of anecdotal reports. In scientific work evidence is not the plural of anecdote. While a properly-constructed case-control study on the subject would be welcome — as would consistent collection of epidemiological data — the theory of "wind turbine syndrome"[11] at present rests upon the testimony of a small group of self-selecting individuals (Dr Nina Pierpont's claims rest on a study of only 10 families, with no control population). The explanatory hypothesis given is that the (far from unique) infrasound and vibrations produced by the turbines have certain physiological effects (Pierpont explains a particular physiological mechanism). If this is true, then surely we should see similar problems around a wide range of industrial and mechanical equipment types. In a multidisciplinary study conducted by an expert panel of medical and acoustical specialists in 2009 for the American and Canadian Wind Energy Associations, the authors conclude that:

- *there is no evidence that the audible or sub-audible sounds emitted by wind turbines have any direct adverse physiological effects*
- *the ground-borne vibrations from wind turbines are too weak to be detected by, or to affect, humans*

- *the sounds emitted by wind turbines are not unique. There is no reason to believe, based on the levels and frequencies of the sounds and the panel's experience with sound exposures in occupational settings, that the sounds from wind turbines could plausibly have adverse health consequences.*[12]

Even if Dr Pierpont is correct, these health effects are trivial compared to those produced by the alternatives, nuclear and big coal. In any case, Dr Pierpont cites no cases more than 2 km from a windfarm. A 2 km setback distance could in most cases be readily accommodated in Saskatchewan, though not necessarily in more densely-populated jurisdictions.

Solar Photovoltaics

This is a rapidly developing area of technology, driven during the last decade in large measure by the active support of the German government through support for manufacturing facilities and through high (though declining) assured payments per kWh for generators (including the very smallest producers). PV is now (2010:Oct) supplying nearly 2% of Germany's electricity and experiencing rapid growth: this is nearly double the figure from just a year ago.[13] It is not possible to present this technology as a major alternative now, but the market is growing rapidly, and its widespread adoption will be one of the major technological changes of the next decade: there is every reason to believe that it will be cost-competitive with conventional generation methods ("grid parity") within a few years. Recent research in North Carolina[14] quotes levelized costs of 12 to 14 cents per kilowatt-hour for commercial-scale pv, and 13 to 19 cents/kWh for domestic-scale installations — already cheaper than nuclear, though there is some way to go to overtake conventional fossil fuels. (Saskatchewan's slightly smaller solar resource will result in prices a cent or two higher per kWh.) The recent entry of China into the photovoltaics market as a major player may be expected to enhance the downward pressure on prices.

Solar pv is a highly flexible technology in terms of scale — from cabin installations of a few dozen watts to solar farms of several hundred megawatts of capacity. PV panels may be fitted on the roofs or south-facing walls of buildings. They can be integrated into solar shade design. They can be placed on highway verges where they double as noise (and potentially snow) protection. Or large field-mounted arrays can coexist with grazing animals such as sheep. It functions equally efficiently in terms of electrical output at any scale (though significant cost-savings are possible with larger installations compared to smaller). It requires minimal maintenance, as there are moving parts only on solar-tracking models. It offers the potential for significant numbers of jobs in design and installation, and ultimately in recycling of rare metals and metalloids. In the last few years, technological improvements have brought down the lifecycle greenhouse gas emissions to levels comparable with other renewables and lower than any non-renewable option.[15]

In Saskatchewan there is no shortage of suitable sites. If photovoltaic panels with a 15% capacity factor were to meet 10% of the power requirement which SaskPower projects for 2030, they would require about 20 km^2, of which at least half could be on optimally-oriented buildings or beside our two major east-west trunk roads. With more complex fixing methods, a wider range of roofs and walls could be used, given appropriate municipal and provincial incentives — the city of Freiburg, in southwest Germany, with a population comparable to Saskatoon or Regina, already has 15 MW capacity installed on roofs, and a recent study identified a potential to increase this to 300 MW.[16] [For comparison, SaskPower's total generating capacity in 2009 was 3840 MW.]

So What Are the Challenges?

Price: The first is a reduction of the levelized unit price to achieve grid parity. As noted above, the industry is on target to achieve this within the coming decade.

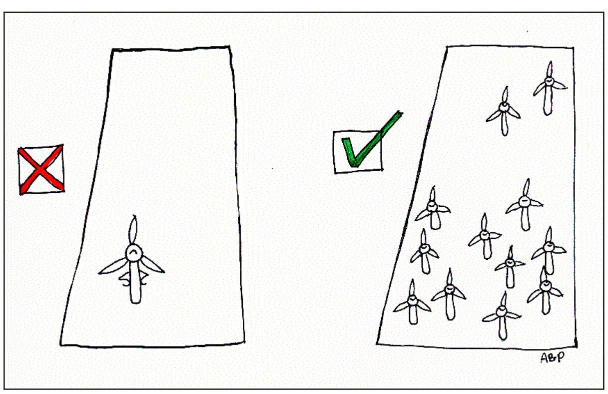
Establishing good lifecycle environmental practice: As with any industrial process, there are dangers inherent in the production and refinement process of the materials used in photovoltaic cells. Production of crystalline silicon (silicon cells are the most common option at present) involves the explosive gas silane as an intermediate; a number of chemicals with a hazard profile are used in smaller quantities. Other cell types — cadmium telluride, copper indium selenide, copper indium gallium selenide, gallium arsenide, etc. — directly involve the use of toxic metals and metalloids. In some cases — for example cadmium — the pv industry is actually providing a use for a substance which would otherwise end up in a toxic waste dump (cadmium is an impurity in zinc ores, removed in refining). Other substances require to be mined, at least until such time as they can be recovered by recycling of materials from used panels. Serious study is underway in Germany and in California into strategies for maximum safety and for enabling maximum recycling.[17]

Coping With a Variable Resource

It should first be noted that all power sources are inherently variable. Nuclear and coal plants (currently used to meet baseload) have to be taken out of service for maintenance (or for replacement of fuel rods), and sometimes they just crash without warning. Given their large size, substantial back-up arrangements are required — a 1000 MW nuclear station would require the system to have a minimum of 1000 MW of reserve capacity.

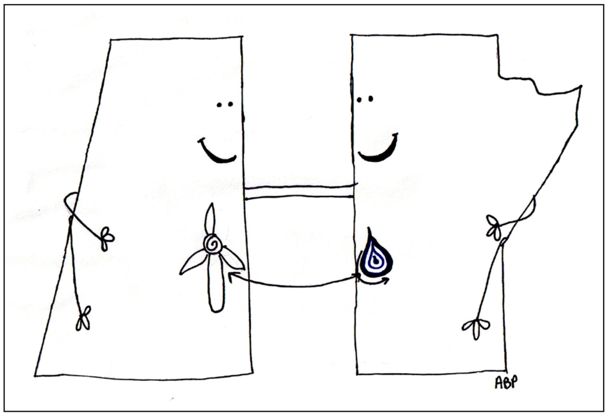
However, the natural variability of the wind and of solar radiation reaching the earth do provide new challenges. These have been met in other jurisdictions, and a set of **techniques** for addressing them is well-understood:

1. Distribute wind turbines or pv installations widely — the probability of the weather being exactly the same across the whole of the province is extremely low. SaskPower has recently somewhat adjusted its wind policy in this direction, though the reality on the ground in Denmark and Germany is still a much more distributed system than is currently planned here. The benefits of a policy of further distribution require detailed technical analysis: this will be one of the tasks of Green Energy Project Saskatchewan.



Graphic courtesy of Anna Bigland-Pritchard

2. Combine variable renewables with dispatchable renewables. In Saskatchewan, this means dammed hydro and biogas (whether from gasification or pyrolysis of solid biomass, or from anaerobic digestion). [There is still a place for other biofuels such as woodchips or straw in meeting demands which are varying relatively slowly.] The particular issues facing dispatchable renewables in Saskatchewan will be addressed in the next paper in this series.
3. As soon as the prices become right (either through a feed-in tariff or by just waiting for the cost of pv to reach grid parity), plan for an optimum mix of wind and pv — combined, they are less variable than either on its own.
4. Improve interconnections with adjoining grids — this can enable the geographical effect (technique 1) to be used more broadly, and can often also enable access to the flexibility of a more dispatchables-based grid (i.e. technique 2 — part of Denmark's methodology is to export wind-generated power to Norway and Sweden, and import hydro-generated power). The drive towards lower carbon emissions in Europe is resulting in substantial new interconnections being added in the North Sea area, to enable stabilization of wind power output, as well as massive investment in the proposed Desertec project,[18] bringing solar power into the continent from North Africa. The ultimate result could be a European/North African supergrid in which surpluses may be readily traded across national boundaries.[19] In the case of Saskatchewan, Manitoba, with its massive existing hydroelectric capacity, should be a natural partner.



Graphic courtesy of Anna Bigland-Pritchard

5. Make use of demand-side management technology. Modern electronic technology permits the development of a much "smarter" grid, in which rapid responses to changes in supply or demand are possible. Usually by means of variation in pricing according to power availability, dozens or hundreds of non-urgent (or non-time-sensitive) electrical uses can be automatically switched off (or set to a lower power setting) by remote control at times of peak demand or low supply, thus freeing up electricity for other users. (Likewise they could then be switched on to function during low demand/high supply times.) This "demand response" technology is now in use in several US states,[20] where it is generally seen as capable of saving 5% to 10% of demand at the peaks and so reducing the need for reserve capacity. In Saskatchewan, where demand is dominated by large industry, the potential could be still higher.

6. Short-term management of a renewables-rich grid is made more accurate and more efficient by improving the reliability, interconnectivity and responsiveness of weather data collection systems.

7. Make use of storage technologies. Depending on scale these may include pumped storage hydro, vanadium redox flow batteries and other advanced battery technologies, compressed air, flywheels, etc. Pumped storage stations have two reservoirs, one at high level and one at low level. Electricity is used during low demand/high supply periods to pump water into the upper reservoir; at high demand/low supply times this water can then be allowed to fall back through the turbines to generate electricity. Vanadium flow batteries store or release energy by changing the oxidation state of vanadium ions in solution at both electrodes. They can offer almost unlimited capacity simply by using larger and larger storage tanks, and can be left completely discharged for long periods with no ill effects. Electric cars can potentially provide storage opportunities — if motorists are paid a higher rate for electricity fed into the grid at high demand/low supply times, and can draw from the grid at a lower rate at low demand/high supply times, then every electric car could become in effect an electrical storage facility for the grid. Hydrogen (generated by electrolysis, consumed later in fuel cells) has been much hyped in recent years as an energy vector: it may indeed have future potential, though it currently faces considerable economic, logistical and technical obstacles.

Denmark has reached an overall figure for wind output of about 20% by using only techniques 1, 3 and 4. Even in the latest Danish energy plan,[21] which sets a target of 100% renewables-dependence for electricity, heating and transportation by 2050, with wind as the largest supply option, technique 7 is limited to electric cars — the Danish Klimacommision appears confident that they do not need to use all the tools available to meet their target. With less than one-fifth of the population in more than 12 times the land area, surely it is reasonable to expect that Saskatchewan can achieve a similar — or a more ambitious — goal.

Handling the Economics

Power from the sun and wind — like some other renewables — needs to overcome economic challenges of three different types in order to become mainstream. That it is already mainstream in several European jurisdictions is an indication that these challenges are readily surmountable:

- The unit cost of the electricity produced needs to be affordable.
- An adequate system of loans needs to be in place because the costs of these power options are heavily "front-loaded" — with no fuel costs and relatively low maintenance costs, the bulk of the cost of generation is in the initial investment in the equipment itself. Hence prices are highly sensitive to discount rates and to bank interest rates.
- In a market dominated by fossil fuels, the volatility of the cost of oil and gas can create problems for a renewables generator. A high gas price makes wind competitive, but a sudden drop in the gas price will force wind generators to accept payment lower than their outlay in loan repayments. If this comes at the wrong time in the wind company's development, it could result in economic failure. [Within a publicly owned corporation such as SaskPower, the power market does not operate in quite this way, but it is clear that this effect could disadvantage the departments responsible for renewables development. New wind farms which are privately-, cooperatively- or municipally-owned would clearly suffer directly from this market effect.]

There is an established solution to all three problems in the feed-in tariff (FiT), first introduced in a rudimentary form in Denmark in the late 1980s and developed into a powerful policy tool in Germany in the 1990s.[22] The principles of the feed-in tariff are:

- The utility or grid company is required by law to purchase all power generated by certain renewable means (the list of options varies from one jurisdiction to another).
- It must pay a certain fixed price per kWh for this power. This tariff rate is set such that the generator can realistically export to the grid.
- Typically, tariff rates for small generators will be higher than those for large generators using the same technology. This is to make community or even household scale operations viable, thus encouraging more distributed generation.
- This fixed tariff rate may in some schemes be reduced to a new fixed price after a given number of years.
- Tariff rates may be reviewed by government: as the cost of any given option drops, typically the tariff for new installations will also drop. The point of a feed-in tariff is not to enable large profits for renewables operators but to enable them to develop the industry to the point where it is self-supporting. Substantial reductions in 2010 in the German photovoltaics feed-in tariff do not appear to have interfered with the industry's ability to maintain rapid growth.

Feed-in tariffs initially provide the subsidy necessary for the industry to be able to enter the power market. By offering security, they enable the industry to build up capacity, improve efficiency and reduce costs. By establishing a fixed price, they permit easy negotiation of loans for the initial installation, and they remove the insecurity caused by the fluctuation in price of other generation options. As an industry matures, the feed-in tariff offered will reduce until at some point in the future it may become unnecessary.

Feed-in tariffs are commonly presented in the media as a subsidy. In the early years of a technology, they do function as such, but their purpose (unlike the massive subsidies still required by the nuclear industry some 60 years after its inception) is one of "pump-priming", enabling the industry to get to at point where it can stand without subsidy — "a hand up, not a handout". Furthermore, they still have an important function even after they have dropped to levels close to or lower than the overall cost of electricity — they provide security in the face of fluctuations driven by fossil fuel prices.

In practice, at least some of this investment in green technology is repaid though lower overall electricity prices — this is known as the "merit order effect". When added to the grid, wind power displaces not cheap-to-run options like hydro, but expensive-to-run options like gas turbine power stations. (The economic parameter of importance here is not the levelized cost but the marginal cost — the cost merely of running the power station, which includes fuel, operation and immediate maintenance costs only. This is low for wind and hydro because there are no fuel costs, and particularly high for low-efficiency quick-reponse options such as gas turbines.) As a result, the average price of electricity is lower than it would otherwise have been. A number of analyses of this effect have been published in several European countries (where wind normally displaces gas at times of high demand and coal at times of lower demand): overall price reductions resulting from the presence of wind power vary in these studies from 0.3 to 5.5 Euro cents (0.4 to 7.8 Canadian cents) per kWh.[23] In some cases, savings from the merit order effect were found to exceed the additional expenditure resulting from feed-in tariffs.

Other types of incentive regimes can offer some of the benefits listed above, though to a lesser extent and less efficiently. It is noticeable in Europe that the countries with thriving wind power industries are not necessarily the ones with the best wind resource, but those with a well-established FiT regime. Hence, for example, Britain, with an excellent wind resource, has lagged behind Germany, whose wind speeds outside of a narrow coastal strip are mostly indifferent. While all support for the renewables industry is welcome, the urgency of the climate crisis demands that we use the best and most efficient tools available to do so, and so the feed-in tariff is indispensible to any jurisdiction seriously wishing to pursue a credible energy policy directed towards sustainability (though by no means is it the only tool required to that end).

In Germany, FiTs (together with other supportive legislation) have resulted in the emergence of a thriving green energy sector. The renewables industry now plays a significant role in the German economy, employing about 300000 people, split roughly equally among wind, photovoltaics and biomass. The recent introduction of FiTs in Ontario is beginning to have a similar effect there. While it is possible that Saskatchewan would now be too late to capture a share of the North American market in manufacture of utility-scale wind turbines or photovoltaics, there is still plenty of scope for job creation in distribution, retail sales, installation, maintenance, consultancy, etc.

Ownership

A number of ownership models exist worldwide for wind and solar farms. The model most consistent with the distributed generation approach advocated above, and common in Scandinavia and Germany, is of local ownership of the generating capacity. This often takes the form of a cooperative, with members drawn from the local community (though in some cases a limited company is formed, with local residents as shareholders). Municipal authorities may also have an ownership stake.

This pattern is to be preferred to ownership by large private corporations. It ensures that all necessary local consultation occurs, that local complications are addressed rather than glossed over, and that local needs are heard and acted upon. It keeps any profits within the community, rather than exporting them to a remote corporate headquarters. It enables more decisions to be made locally, more jobs to be held by local people, and local strategies for job-training and job-creation to be developed. It gives people a genuine stake in the generation of their electricity, and so builds genuine local support for the scheme.

In Saskatchewan, such community enterprises would need to operate in cooperation with SaskPower. They should be bound by rules ensuring that they function in a way which puts public service before private profit, and preventing sale of assets to out-of-province operators.

Conclusions

1. Substantial expansion is justified for both wind and solar power. Both technologies can, and will need to, play a major role in the province in the creation of a sustainable electricity grid, sustainable energy use more generally, and a sustainable economy. Without these two technologies, there can be no adequate response in the province to the global crises of climate change, resource depletion and fuel security.
2. Both resources are abundantly available in Saskatchewan. Their relative unimportance in the current generation mix results from the province's consistent failure to prioritize energy sustainability. Jurisdictions with poorer resources but greater commitment to the future are currently providing the global leadership in the implementation of both technologies.
3. If efficiently managed, wind power offers considerable immediate opportunities. SaskPower should be seeking to replace a substantial proportion of its current coal-fired generation with wind at the earliest possible opportunity.
4. Solar photovoltaics are not yet an economic option, but cost trends are such that they most likely will reach cost parity before the end of the decade. However, the use of an

appropriately-set feed-in tariff to encourage their introduction earlier than this could place Saskatchewan in a strong position in the emerging global green economy: such a policy should be seen as investment in the future rather than subsidy.

5. As the proportion of wind power rises it will be important to ensure that it is accompanied by an adequate dispatchable power capacity. In the short term, this will be facilitated by existing and planned natural gas stations, but these also should ultimately be phased out in favour of dispatchable renewables.

6. In addition, the transition to a distributed generation grid will necessitate some significant changes to the province's electrical transmission system and distribution network.

Proposals for Action

1. Given the vital importance of decarbonising our economy, Saskatchewan should set a target of 120 MW new wind capacity added each year, with the specific intention of being able to displace coal-fired capacity. (Most likely, coal-fired units would not be finally closed down as a result, but — as in Denmark — maintained as reserve to be used only occasionally.) This level of investment in wind power would displace a fresh 320 to 380 GWh of coal generation each year, or 380 to 460 thousand tonnes of carbon dioxide. It would replace a 140 MW coal-fired unit in about 3 years, and would make possible the achievement of 25% grid penetration before 2030.

   This is an ambitious target, though proportionately smaller than that currently being achieved by Ireland. (Ireland's grid is about 40% larger than Saskatchewan's, and they have added an average of 200MW per year over the last 5 years.[24] Some other European countries, including Denmark, Romania and Bulgaria, have similar or even more rapid development plans.[25]) Ambitious targets are appropriate for the wind industry. It has consistently succeeded worldwide in exceeding the expectations of the majority of analysts: for example, in Europe only the European Wind Energy Association and Greenpeace have been accurate in their projections of the industry's growth.[26]

2. This target should be pursued primarily through establishment of a suitably-priced feed-in tariff regime, with administrative hurdles eliminated wherever possible, and preferential treatment for First Nations and local community initiatives.

3. New windfarms should be subject to rules ensuring democratic accountability at either a local or a provincial level, and maximizing local employment prospects.

4. Provincial incentives should be available for sourcing of towers fabricated within the province. As soon as feed-in tariff legislation is in place, negotiations should be initiated with turbine manufacturers with a view to establishing a manufacturing base for turbine blades and nacelles within the province.

5. The province should similarly establish a feed-in tariff regime for photovoltaics, in order to help build a market for this option.

6. The future importance of photovoltaics technology should be recognized by the province's education establishments. The universities should develop teaching and research programmes, and SIAST should offer training in installation. The combination of proposals 3 and 4 is necessary to attract interest from the world's leading manufacturers seeking a base in central North America. In order to achieve this, Saskatchewan institutions should be open to the idea of partnerships with their counterparts in more solar-advanced countries such as Germany.

7. The process should begin to develop Saskatchewan's dispatchable renewables. The main options are various types of biogas (from gasification or pyrolysis of solid organic material, or from anaerobic digestion) and hydro (purchased from Manitoba via an enhanced interconnection, as well as existing and planned projects within the province). The wind programme would not require this immediately for "balancing", but planning and preparation should commence as soon as possible in order to face and overcome challenges related to the technological learning curve in one case and political negotiation in the other. The size of the dispatchable capacity required to balance the growing wind fleet will need to be calculated on the basis of realistic assumptions about wind variability. (The necessary, rather complex, calculation procedure is of central importance in the development of a sustainable energy plan, and so should be available for review in detail by independent analysts, including experts from jurisdictions which have already faced the challenge of incorporating large proportions of wind power in their grid.)

8. To facilitate a shift in the direction of distributed generation, and to enable better load management, SaskPower should establish an accelerated timescale for introduction of "smart grid" technologies (increased connectivity, greater automation, load control switches, phasor measurement units, smart meters, price signalling, etc.). The result will be a grid which is not only better adapted for the sustainable technologies of the new millenium but also more reliable, less wasteful, better able to respond to sudden changes or attack, less prone to outages, and designed through price variations to enable the active participation of consumers in optimizing grid management.

These proposals, together with some modifications to SaskPower's operational practices, constitute a significant change of direction for the province and for the utility company — albeit one towards which the province has already made tentative steps by commissioning the 150 MW Centennial Wind Farm and planning for a further 175 MW.[27] A SaskPower executive referred to recommendations in the previous GEPS paper as requiring "a fundamental shift in philosophy".[28] This is indeed what is needed if SaskPower and the province are to play their part in averting global climate catastrophe and in enabling a thriving and sustainable local economy. It is not enough to "add sustainability to the mix", as the SaskPower website describes its wind operation at the time of writing[29] — the whole mix should instead be determined by principles of sustainability. As several European countries are demonstrating, it is possible to make this shift smoothly, efficiently and without ill effect.

Endnotes

1 Bigland-Pritchard M and Prebble P (2010), Transforming Saskatchewan's Electrical Future – pt 1: Sustainability is achievable, but how do we get there?, CCPA Saskatchewan

2 Bigland-Pritchard M (2010), Transforming Saskatchewan's Electrical Future – pt 2: Using Electricity more Efficiently, CCPA Saskatchewan

3 Calculated using: Natural Resources Canada, Photovoltaic potential and solar resource maps of Canada. Available online at *https://glfc.cfsnet.nfis.org/mapserver/pv/index_e.php*

4 Environment Canada (2003), Canadian Wind Energy Atlas *http://www.windatlas.ca/en/maps.php*. See in particular the map sections for Saskatchewan at: *http://www.windatlas.ca/en/gethigh.php?field=EU&height=80&season=ANU&lakes=1&cities=1&no=41* and *http://www.windatlas.ca/en/gethigh.php?field=EU&height=80&season=ANU&lakes=1&cities=1&no=42*

5 Further technical details available on request from the author: *mark@lowenergydesign.com*

6 In conjunction with its groundbreaking Green Energy and Green Economy Act of 2009, the province of Ontario amended the Environmental Protection Act to establish a setback of 550 m for 1 to 5 wind turbines, 650 m for 6 to 10 turbines, and 750 m for 11 to 25 turbines, subject to adequate acoustic performance. A noise study is required for larger windfarms. See Province of Ontario, Proposed Content for the Renewable Energy Approval Regulation under the Enviornmental Protection Act, available at *http://windconcernsontario.files.wordpress.com/2009/06/new-regs.pdf*

7 Pedersen E (2003:Aug), Noise Annoyance from Wind Turbines — a review, Naturvårdsverket, Swedish Environmental Protection Agency

8 Erickson WP, Johnson GD and Young DP (2005), A Summary and Comparison of Bird Mortality from Anthropogenic Causes with an Emphasis on Collisions, USDA Forest Service Gen. Tech. Rep. PSW-GTR-191, pp 1029-1042.

9 See, for example, the carefully thought-through position of Britain's Royal Society for the Protection of Birds as set out in: Bowyer C, Baldock D, Tucker G, Valsecchi C, Lewis M, Hjerp P and Gantioler S (2009:Mar), Positive Planning for Onshore Wind: expanding onshore wind energy capacity while conserving nature, Institute for European Environmental Policy/Royal Society for the Protection of Birds. Available online at *http://www.rspb.org.uk/Images/Positive%20Planning%20for%20Onshore%20Wind_tcm9-213280.pdf*. A summary of the RSPB's position is also available in a news article on the organization's website: RSPB (2009:Mar:23), UK can have wind power and wildlife, *http://www.rspb.org.uk/news/details.asp?id=tcm:9-213213*

10 Arnett E B, Huso M M P, Hayes J P and Schirmacher M (2010), Effectiveness of changing wind turbine cut-in speed to reduce bat fatalities at wind facilities. A final report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International. Austin, Texas, USA.

11 Pierpont N (2009), Wind Turbine Syndrome — a report on a natural experiment, K-Selected Books

12 Colby W D, Dobie R, Leventhall G, Lipscomb D M, McCunney R J, Seilo M T and Søndergaard B (2009:Dec), Wind Turbine Sound and Health Effects — an expert panel review, AWEA/CanWEA Available online at *http://www.awea.org/newsroom/releases/AWEA_CanWEA_SoundWhitePaper_12-11-09.pdf*

13 Paul Gipe (2010:Oct:04), Germany Adds Nearly 1% of Electricity Supply with Solar in Eight Months, "The Gipe Report" (online information service). *http://www.altaterra.net/members/blog_view.asp?id=511177&post=111103*
It is predicted that pv will supply between 9% and 12% of German electricity by 2020 — see: Eric Kirschbaum (2010:Dec:06), Germany to add record 8GW of solar power in 2010, Reuters, available at *http://www.reuters.com/article/idUSTRE6B53L220101206*

14 Blackburn J O and Cunningham S (2010:Jul), Solar and Nuclear Costs — the historic crossover, prepared for NC WARN. Available online at *http://www.ncwarn.org/wp-content/uploads/2010/07/NCW-SolarReport_final1.pdf*

15 Fthenakis V M, Kim H C and Alsema E S (2008), Emissions from Photovoltaic Life Cycles, Environ. Sci. Technol, 2008, 42, 2168-2174

16 Presentation by Jürgen Hartwig of Freiburg Futour, Freiburg, Germany, 2010:Sep:20

17 A summary of the potential risks, and a set of recommendations, are provided in: Silicon Valley Toxics Coalition (2009:Jan), Toward a Just and Sustainable Solar Energy Industry. Available online at *http://www.svtc.org/site/DocServer/Silicon_Valley_Toxics_Coalition_-_Toward_a_Just_and_Sust.pdf*

18 See *www.desertec.org*

19 Czisch G (2006), Low Cost but Totally Renewable Electricity Supply for a Huge Supply Area — a European/Trans-European Example. Available online at *www.fz-juelich.de/ief/ief-ste/datapool/steforum/Czisch-Text.pdf*. Also Czisch G and Giebel G (2007), Realisable Scenarios for a Future Electricity Supply Based 100% on Renewable Energies, presented at Risø 3rd International Energy Conference 2007

20 For a description of the services provided by one leading corporation in the field, see *http://www.enernoc.com/resources/files/utilitysalesbrch-web.pdf*

21 Klimacommisionen (Danish Commission on Climate Change Policy) (2010:Sep), Green Energy — the road to a Danish energy system without fossil fuels

22 For more detail on FiTs, see: Mendonça M (for World Future Council) (2007), Feed-In Tariffs — accelerating the deployment of renewable energy, Earthscan, London, England, and Mendonça M (for World Future Council), Jacobs D and Sovacool B (2010), Powering the Green Economy — the feed-in tariff handbook, Earthscan, London, England

23 Morthorst P E, Ray S, Munksgaard J and Sinner A-F for Pöyry AS and Risø National Laboratory/DTU (2010:Apr), Wind Energy and Electricity Prices — exploring the "merit order effect", European Wind Energy Association.

24 *http://www.eirgrid.com/customers/connectedandcontractedgenerators/*

25 Global Wind Energy Council / Greenpeace (2010:Oct), Global Wind Energy Outlook 2010

26 Pieprzyk, Björn and Rojas Hilje,Paula (2009:May), Renewable Energy — Predictions and Reality: Comparison of forecasts and scenarios with the actual development of renewable energy sources: Germany – Europe — the world, Agentur für Erneuerbare Energien, Berlin, Germany, p24. Available at *www.unendlich-viel-energie.de*

27 SaskPower, Power Generation Procurement: Current Projects: "Adding sustainability to the mix", *http://generationprocurement.saskpower.com/wind.shtml*, last accessed 2010:Dec:06. Note, however, that the 175 MW to be added is to be of a relatively centralized nature, and that the independent power producers deemed qualified to build and run these plants include a number of large companies from outside the province. It is difficult to see how genuine democratic control is to be achieved.

28 Johnstone, Bruce (2010:Dec:01), SaskPower should manage demand to cut energy consumption: study, Saskatoon Star Phoenix, Business pC11

29 SaskPower, ibid.