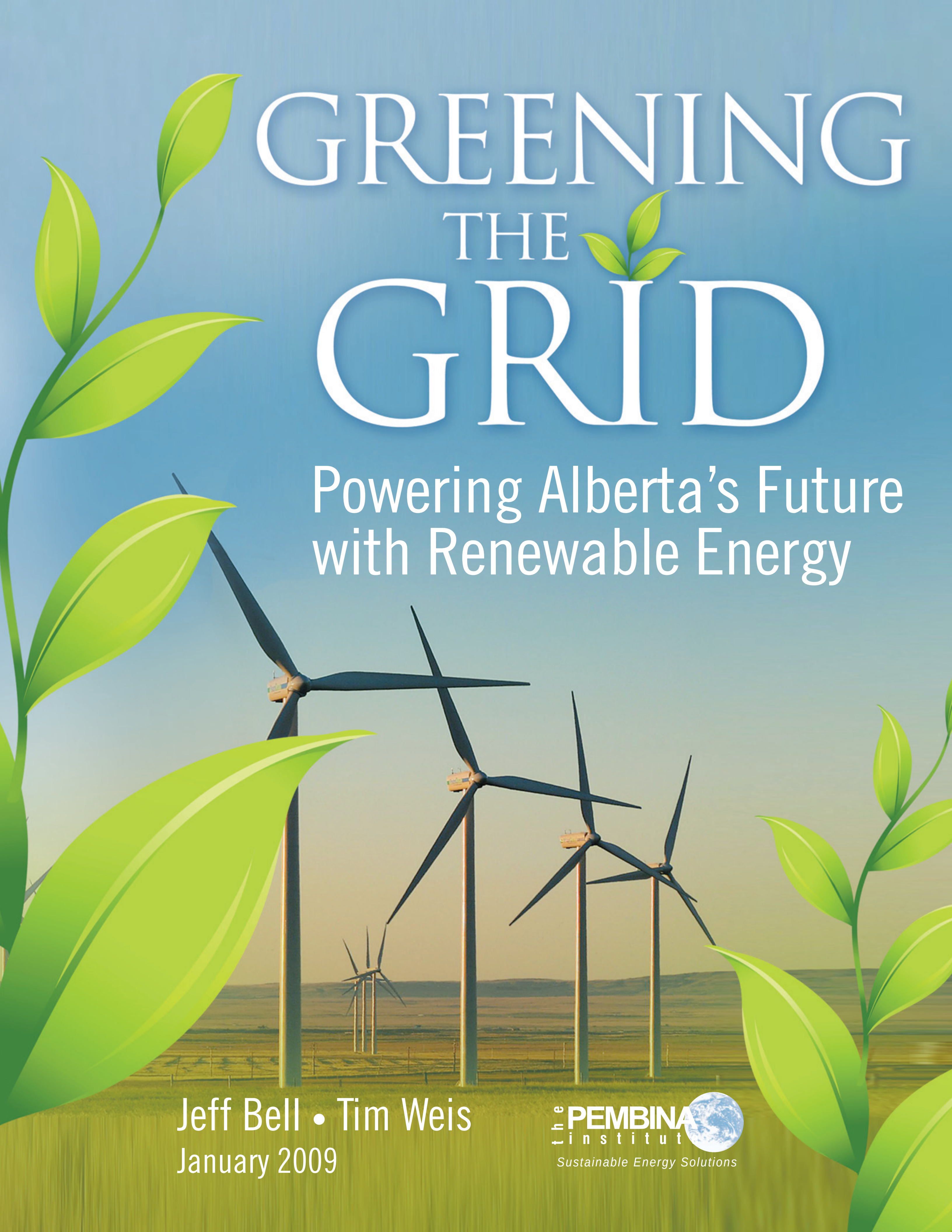
GREENING THE GRID

Powering Alberta's Future with Renewable Energy



Jeff Bell • Tim Weis

January 2009

the PEMBINA institute
Sustainable Energy Solutions

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Revised Edition

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About the Pembina Institute

The Pembina Institute is a national non-profit think tank that advances sustainable energy solutions through research, education, consulting and advocacy. It promotes environmental, social and economic sustainability in the public interest by developing practical solutions for communities, individuals, governments and businesses. The Pembina Institute provides policy research leadership and education on climate change, energy issues, green economics, energy efficiency and conservation, renewable energy, and environmental governance. More information about the Pembina Institute is available at www.pembina.org or by contacting info@pembina.org.

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Greening the Grid

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Sustainable electricity resources could replace coal in 20 years

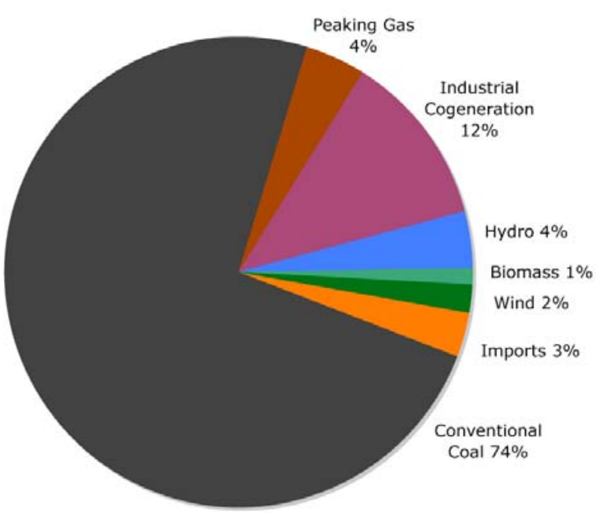
Clean renewable and transitional energy resources in Alberta are more than capable of meeting future demand, even if electricity consumption doubles over the next 20 years. Alberta can harness this energy with proven technologies already in use in Alberta and elsewhere.

Alberta's future: green or brown?

Albertans face a choice: build a future with clean, efficient, sustainable electricity or continue using the old, wasteful, polluting systems that are increasingly obsolete?

Changing Alberta's electricity system will be challenging, but renewable and transitional energy options offer a phenomenal business opportunity for Albertans. Markets will increasingly favour renewable energy as society forces existing companies to bear the full cost of their pollution.

Current electricity mix relies on dirty, wasteful technology



David Dodge, The Pembina Institute

Although Alberta was Canada's leading wind energy producer for many years, in 2008 both Ontario and Quebec surpassed it. In spite of 15 years of wind development, Alberta still takes advantage of less than 1% of the estimated total wind energy potential in the province.

1. One-quarter of Alberta's greenhouse gas emissions come from electricity generation.
2. Electricity generation produces 80% of Alberta's airborne mercury and 30% of its acid rain–causing sulphur oxide emissions.
3. Power plants draw the second highest volume of water in Alberta after irrigation. About 4% of the water allocated for cooling is never returned to watersheds.
4. Coal-based electricity generation is forcing Alberta taxpayers to bear the costs of pollution. For example, the Government of Alberta recently promised $2 billion to help industry cover the costs of capturing and storing carbon pollution.
5. Coal plants are inefficient: almost two-thirds of the energy found in the coal they burn is lost out the smoke stack.
6. If Alberta continues to rely on coal for most of its electricity, total greenhouse gas emissions will continue to increase, even if all new coal plants use unproven carbon capture and storage.

Menu of Ways to Green Alberta's Electricity Grid

Alberta can transform its electricity supply from a system based on coal to one based entirely on a diverse menu of cleaner options.

Efficiency

Decreasing energy use is the smartest, cheapest and cleanest way to meet electricity demand.

Wind

Alberta has one of Canada's best wind resources, but it still only gets about 2% of its electricity supply from wind. Denmark, by comparison, has generated close to 20% of its supply from wind since 2004.

Hydro

The untapped hydro potential in Alberta is thought to be greater than total existing coal capacity.

Biomass

Energy from agriculture and forest waste could become a sustainable fuel source for generating electricity in Alberta's rural areas.

Geothermal

Natural heat deep under the earth's surface could provide a sustainable source of electricity and play into an existing Alberta strength: drilling.

Micropower

A diversity of small technologies, such as solar, wind and cogeneration, could allow farms, homes and businesses to become energy independent while reducing their environmental footprint.

Cogeneration

Capturing the heat produced during electricity generation can more than double the useful energy from each unit of fuel. This cogeneration of electricity and heat from a single fuel could play a transitional role in supplying industrial heat and power and neighborhood district energy.

Recovered Industrial Energy

Every year the energy equivalent of millions of barrels of oil is wasted as heat that escapes up smokestacks in Alberta industrial facilities. In many cases, this heat is of sufficient temperature to generate electricity.

Virtual Power Plants

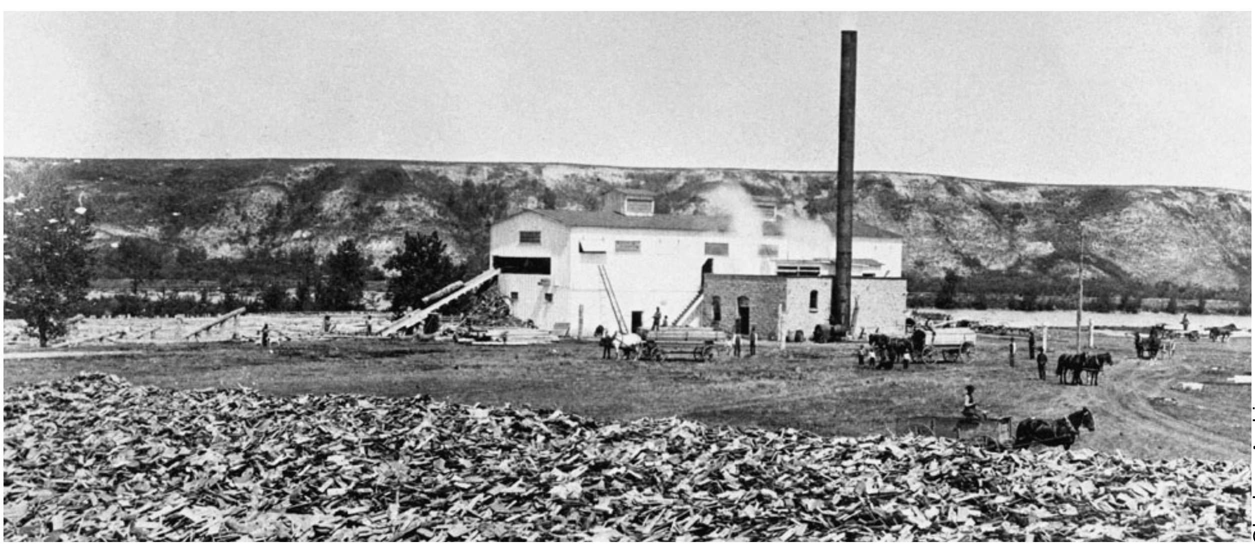
Remote communication technology could allow the strategic control of large numbers of small machines or appliances. Temporarily slowing or shutting down such resources could displace the need for up to 10% of electricity at peak times.

Power Storage

Technologies that allow electricity to be stored (including pumped water, compressed air and batteries) will facilitate the integration of large amounts of wind power and other variable electricity sources to meet demand.

Carbon Capture and Storage

Although the costs are still unknown, carbon capture and storage technologies are likely to play some role in cleaning up Alberta's coal plants.



Glenbow Archives

Alberta's first power plant, built in Calgary in 1889, burned lumber sawdust to generate electricity for street lighting. Waste heat from the steam-driven generator supplied process heat in the mill.

Getting to Green: Two Scenarios

Greening the Grid looks at different scenarios for Alberta's future electricity generating mix that will get the province away from its "business as usual" reliance on dirty coal-fired power plants. The scenarios use conservative estimates of adoption rates for existing technologies that have been proven in Alberta or elsewhere.

Under the Pale Green scenario, investments in a diversity of cleaner options, mainly efficiency, wind and natural gas cogeneration, could meet Alberta's anticipated demand without having to resort to building new coal or nuclear plants.

The Green scenario showed that if Albertans set their sights higher, the province could generate so much energy from renewable and transitional technologies that it could begin to phase out existing coal generation.

Alberta's government can take the following four steps to help reduce pollution and green the grid:

1. Establish a Renewable Electricity Task Force

Alberta has already appointed expert panels to examine the potential role of nuclear power and carbon capture and storage. It must now also appoint a panel to examine renewable energy.

2. Develop a Comprehensive Energy Efficiency and Conservation Strategy

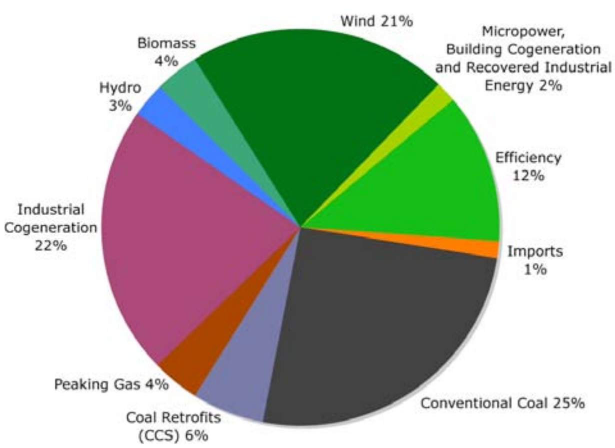
The Alberta government committed to passing an Energy Efficiency Act, which is an opportunity for it to show bold leadership in making energy use more cost effective. Alberta could also promote a culture of smart energy users through training and outreach, loans and updated efficiency regulations.

3. Conduct an Assessment of Renewable Energy for Alberta

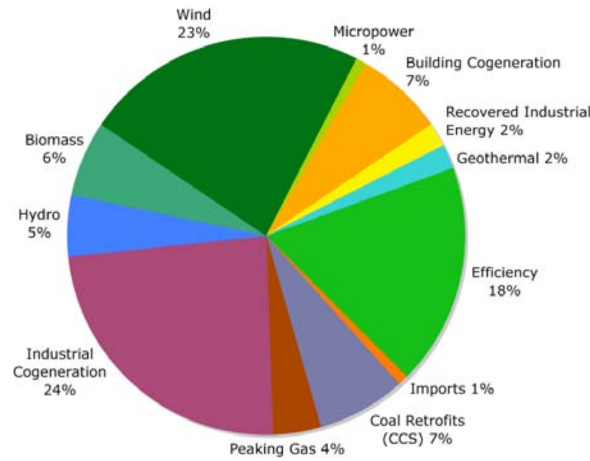
To understand how to best plan for and strategically develop its renewable resources, Alberta needs to determine the full potential for the various technologies. A Renewable Energy Assessment for Alberta would provide detailed information for public and private decision-makers about the quantity, quality and location of the province's renewable resources.

4. Earmark Funds for Renewable Energy

Alaska is using its fossil fuel revenues to create a quarter billion dollar "Renewable Energy Fund". With over five times the population, a comparable investment in renewables in Alberta would still be less than the money allocated to carbon capture and storage. In addition, investment in research is needed to drive technologies such as power integration, management and storage. This investment would not only help Alberta green its grid at home, but enable it to export products and skills to the booming global renewable energy industry.



Alberta's electricity generation in 2028 under the Pale Green scenario.



Alberta's electricity generation in 2028 under the Green scenario.

1. Introduction

Canada is an emerging energy superpower. But our real challenge and our real responsibility is to become a clean energy superpower. … We want to be a world leader in the fight against global warming and the development of clean energy.[1]

— Prime Minister Stephen Harper, Sydney, Australia, September 7, 2007

Alberta's development and use of renewables will help in reducing greenhouse gas emissions, enhance Alberta's diversity of energy supply, stimulate regional activity, and fortify collaboration across industry sectors.[2]

— Alberta Provincial Energy Strategy, December 11, 2008

1.1 About This Report

The objective of this report is to put into the public sphere an analysis that illustrates not only that renewable energy and energy efficiency need to play a major role in Alberta's electricity future, but that they can — and in the very near future.

The analysis contained in this report refutes the statement that "alternative and renewable energy sources will play a growing role in Alberta energy's future, but they cannot match the importance to Alberta of 'clean' fossil fuels."[3] The Government of Alberta made that statement in the Provincial Energy Strategy it released in December 2008, but to date, no public analysis supports that conclusion. In fact, the research in this report illustrates that Alberta can move from an electricity system based on coal, to one based on clean alternatives in the next 20 years. Given that electricity accounts for approximately one-quarter of the province's greenhouse gas pollution (GHG) and over 80% of all of airborne mercury emissions in the province, the urgency of making a transition is acute.

The province's energy strategy states: "Assuming that carbon costs continue to rise, and assuming that coal will require gasification-with-CCS, we project that generation sources such as wind, run-of-river hydro, geothermal and biomass will become more competitive, and that renewables' proportion of Alberta's generation will therefore increase."[4]

The purpose of this report is to determine to what extent cleaner alternatives to coal, nuclear and other non-renewable resources can be deployed to meet Alberta's electricity consumption over the next 20 years, which is expected to be almost twice the current levels of consumption. Findings show that it is possible to meet all future requirements for electricity in the province using a combination of renewable plus cleaner transitional technologies. "Renewable" technologies include low-impact hydro, wind, solar, biomass and geothermal.[5] "Transitional" technologies include high-efficiency cogeneration and the recovery of industrial waste energy. Figure 1 illustrates the Pembina Institute's vision of progress from the present to a clean, sustainable energy future. The introduction of more

> Alberta's electricity system, currently based on coal, emits GHGs at a rate almost five times worse than the national average.

low-impact renewables and transitional technologies is viewed as a sign of progress, whereas more fossil-fuelled technologies (especially coal) and nuclear, are a setback. This report looks at three possible alternative scenarios: the "Business-As-Usual" scenario, the "Pale Green" scenario and the "Green" scenario.

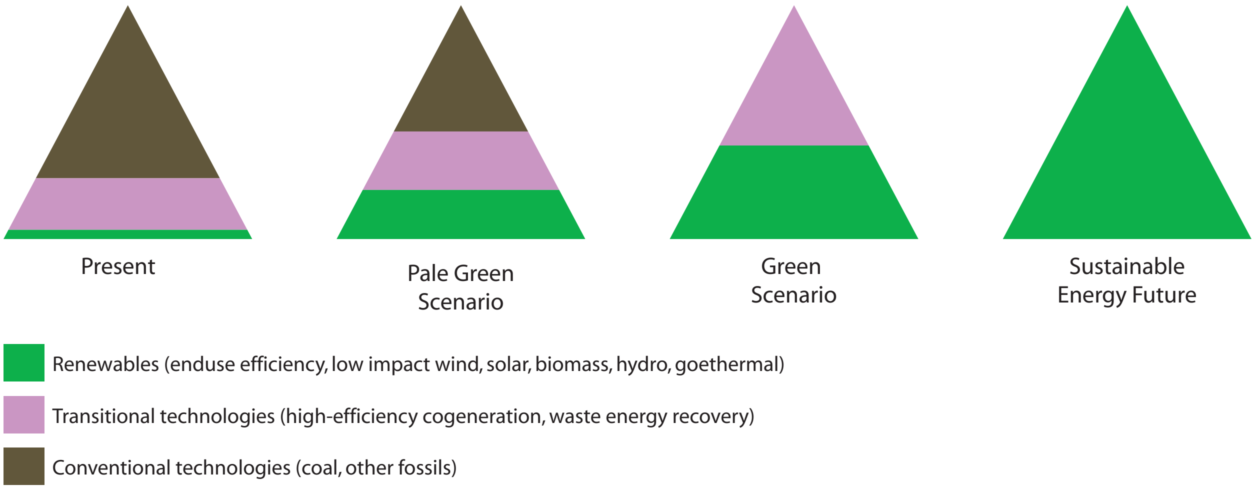


Figure 1. Progress toward a clean energy future

> Carbon capture and storage may or may not need to play a role in reducing the environmental impact of electricity in the most cost-effective way.

In light of technological advances in clean energy technology and the increasing willingness of both the federal and provincial governments to start taking action to combat climate change, 20 years from now Alberta's electricity grid will be very different than it is today. Nonetheless, major infrastructure decisions, such as the make up of the electricity system, need to be planned with such long horizons in mind. This report puts very conservative restrictions on renewable energy by assuming that no technological advances will occur in the next two decades. Despite this restriction, we still determined that a much cleaner future is possible using technology that is available off the shelf today.

Such a future will not happen without significant government leadership, however, and the required changes will no doubt have associated costs. The Government of Alberta's allocation of $2 billion to carbon capture and storage research illustrates that any change in the system will require both leadership and investment.

A doubling of electrical demand, combined with aging coal infrastructure, means that massive investment will inevitably be required over the next 20 years, regardless of the specific mix of technologies that will be put in place to satisfy these demands. Which required grid upgrade investments are made and where new lines are built will have cost implications for the various technologies and portfolios. A detailed analysis of various policies and actions that will be required to make progress is also needed. Although this report touches on both costs and policies, future work will need to look at these issues in much more detail.

It is also important to be clear that the intent of this report is not to say that the proposed scenarios are necessarily the right portfolios. Although both the Pale Green and Green scenarios described in this report indicate progress from a business-as-usual approach, other mixes of technologies may in fact be able to clean up the grid cheaper. The point of this report is to show that, at least from a technical standpoint, it is possible to make significant progress in cleaning up Alberta's electricity using renewable technologies. The preferred approach of the Government of Alberta to date — carbon capture and storage — may or may not need to play a role in reducing the environmental impact of the electricity sector in the most cost-effective way.

1.2 Electricity Basics

The primary goals of the electricity industry have so far been to provide electricity safely, reliably and cheaply, although environmental stewardship is of increasing priority. Policies designed to balance these goals and compromises are unavoidable.

> Electric system planners must ensure not only that enough electricity is generated but also that it is available when required.

In planning the development and production of any commodity in any sector of society the future requirement of two distinct but related concepts needs to be evaluated: the volume of the commodity and the ability to produce, store and deliver that commodity when it is required. In the electricity sector, the commodity is electrical energy, the ability to produce it is known as generation capacity, and the ability to deliver it is known as transmission capacity. Closely connected to these concepts are a number of other very technical concepts that ensure system reliability and electrical quality, and reduce system inefficiencies.

The concepts of energy and capacity are often confused with each other. Electrical energy is what most people think of when they think of electricity. Electrical energy is determined by multiplying electrical power by time. Electrical energy is usually expressed in units of kilowatt hours (kWh), megawatt hours (MWh) or gigawatt hours (GWh). The price of generated, transmitted and delivered electrical energy in electricity bills is measured in dollars per megawatt hour ($/MWh) for industrial customers or cents per kilowatt hour (¢/kWh) for residential customers. Electrical capacity, on the other hand, is a measure of the maximum power a plant can produce or a transmission line can carry. It is usually expressed in kilowatts (kW) or megawatts (MW). Electrical energy and capacity are closely linked. For example, if a 2 MW wind turbine operates at full capacity for one hour, it produces 2 MWh of electricity.

There are many terms used to describe capacity, including "demand," "capacity factor," and "peak capacity." Capacity is the ability to generate, store, transmit or deliver the energy when it is needed. Peak capacity is the maximum amount required in any single time period (for example a day or a year). Electric system planners must therefore not only ensure that electricity is generated in sufficient quantities but also that it is immediately generated and delivered when required. "Electrical generation" is the amount of electrical energy that is generated during any given period of time; "electrical load" is the amount of electrical energy that is consumed during that same period.

1.3 Electricity Generation in Alberta

The electricity sector is the single largest source of Alberta's total GHG pollution, accounting for approximately 25% of the province's annual emissions.[6] Alberta has relied on coal for the majority its electricity supply for much of the province's history. Coal is not only a non-renewable resource, it also releases more GHG pollution than any other fossil fuel, and many other air pollutants, such as acid rain precursors (nitrogen oxides and sulphur dioxide) and mercury, into the atmosphere. In addition to being very polluting, large electricity plants such as coal are also highly inflexible because they can not quickly be turned on and off as consumption changes. They require costly backup plants.

Electricity generation in Alberta emits more air pollution than in any other province in Canada, both in absolute terms and on a per kilowatt hour basis (see Table 1). Alberta has one of the dirtiest electricity portfolios in the world.[7] In 2006 Alberta's GHG grid intensity was 0.93 kgCO_2e/kWh (kilograms of carbon dioxide equivalent per kilowatt hour). Saskatchewan is the only other province close to Alberta's GHG pollution intensity; both provinces are almost double the next closest province in emissions intensity and almost five times the national average. In the same year Alberta's electricity plants emitted 50,130 ktCO_2e, representing 45% of Canada's total emissions from the electricity sector and almost twice as much as the next closest province, Ontario, which has almost three times the population. In addition to being extremely dirty, Alberta's electricity system relies almost exclusively on non-renewable resources. Consuming these resources makes them unavailable for future generations and is ultimately unsustainable in the long run.

Table 1. Electricity grid portfolios by province and average GHG intensity (2006)

		BC	AB	SK	MB	ON	QC	NB	NS	PE	NL	NT/NU YT
Generation (GWh)	Coal	0	**45,500**	10,940	360	25,600	0	2,770	7,010	0	0	0
	Refined Petroleum Products	50	**40**	40	10	30	160	3,130	600	1	790	240
	Natural Gas	3,570	**6,750**	2,720	40	10,400	990	3,060	360	0	0	0
	Nuclear	0	**0**	0	0	83,460	4,600	4,370	0	0	0	0
	Hydro	44,450	**880**	3,950	33,500	35,270	151,360	3,660	950	0	41,020	590
	Biomass	700	**870***	0	0	630*	270*	0	210	1	0	0
	Other Renewables	0	**920**	590	150	44	500	0	130	50	0	1
	Other	0	**70**	0	0	320*	0	450	1,930	0	0	0
	Total	48,770	**55,030**	18,240	34,060	155,754	157,880	17,440	11,190	52	41,810	831
GHG Intensity (kgCO_2e/MWh)		20	**930**	810	10	180	6	366	549	192	15	80

* 2005 data. Source: Based on Environment Canada data[8]

Most of Alberta's coal plants still only use one third of the energy in the coal they burn, just as they did more than 50 years ago;[9] the other two thirds is wasted, emitted into the environment as heat. Figure 2 illustrates the flow of energy in Alberta's electricity system in 2007. About 143,000 GWh of fuel energy enters the system. It is mostly in the form of potential energy in trapped in fossil fuels, but some of it is clean renewable energy. About 60% of the total primary energy used by the electricity

Over 60% of the energy in fossil fuels used to generate electricity in Alberta is lost by the time the electricity is delivered to its end users.

system is wasted in the form of heat going up the stacks of coal and natural gas plants and into the nearby lakes for cooling. An additional 3.3% of the original fuel energy (about 5% of the electricity generated[10]) is lost in transmission lines. This energy is unavoidably lost when the electricity is carried through long transmission and distribution lines. As a result of this combined waste, only 37.2% of the original fuel energy makes it to consumers in the form of useable electricity. The many clean and renewable options available for meeting Alberta's electricity consumption can reduce this enormous waste of energy. Additional energy waste occurs once the electricity arrives on the customer premises, both in the residential and industrial sectors, but this waste is not illustrated in the figure because insufficient information exists to document its extent.

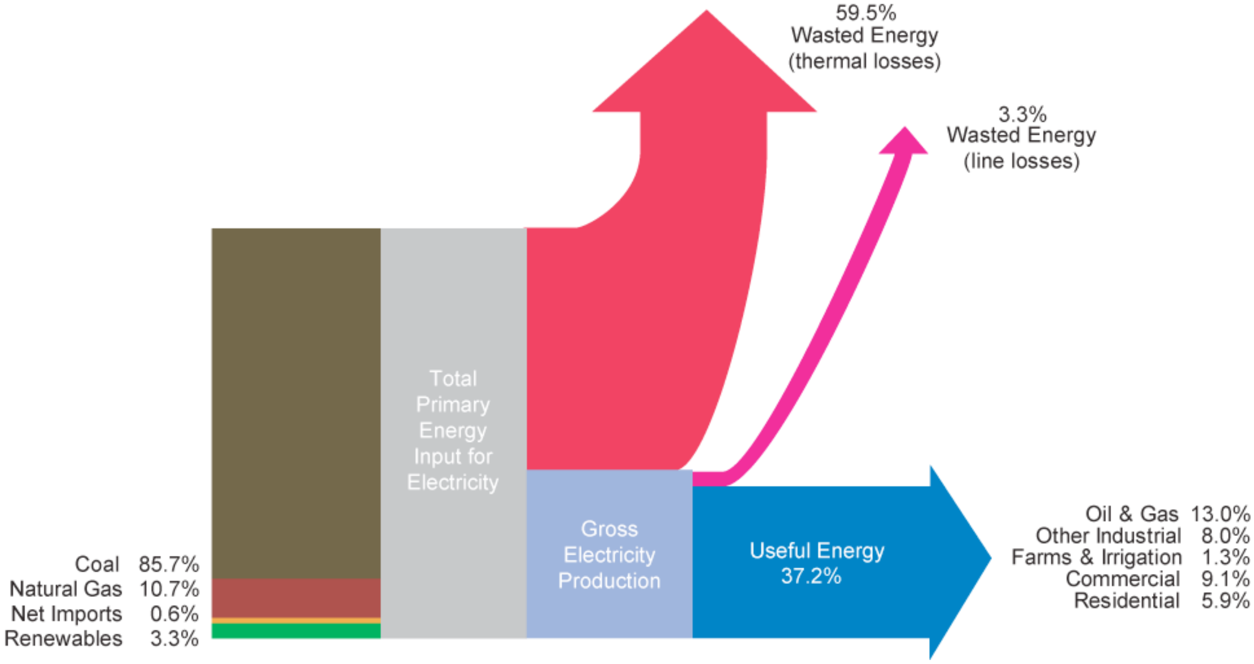


Figure 2. Total Alberta fuel energy used for electricity generation and energy delivered to customers by end use in 2007

Source: Based on data from AESO and EDC Associates Ltd.

1.4 History of Electricity in Alberta

The first major electricity generating plant constructed in Alberta in many ways exemplified what needs to be replicated to make the province's electricity supply more sustainable. It was a renewable-fuelled cogeneration plant, making efficient use of heat as well as generating electricity (see Figure 3). Built in 1889 by Calgary entrepreneur Peter Prince, the plant provided street lighting via a 75 kW steam-driven generator fuelled by burning waste sawdust from the lumber yard he managed.[11] Waste heat was also used for process heat in the mill.[12] A coal-fired steam driven plant soon followed in downtown Edmonton in 1891.[13]

Most of the new capacity built in the first half of the 20th century was hydro capacity. Some of these plants are the oldest generating plants still in operation. The vast majority of generating plant capacity installed since then has been coal fired. Two main forces moved the construction of subsequent electricity generating plants outside of the cities and to larger scales:

1. As more and more electricity was generated in cities to meet the consumption of the city-dwellers, pollution became a problem and there was public pressure to relocate plants away from population centres.[14]

2. Investors' desire for improved return on their investments made them look toward the economies of scale that large plants offered, especially those sited immediately adjacent to a coal mine.

Figure 3. Alberta's first electricity plant was a cogeneration plant powered by sawdust from Eau Claire Lumber Company

Source: Glenbow Archives

> The average power plant has been getting smaller and smaller in Alberta since 1985.

Alberta has an abundance of coal. The enormous reserves west of Edmonton near Lake Wabamun made for an ideal location to site larger coal plants. For almost the next 85 years the tendency in Alberta, like most the rest of the world, was to build increasingly large, remote generating plants.

In the late 1970s the general trend around the world toward bigger and bigger centralized plants was reversed, and the average generating plant size has been shrinking ever since. A combination of affordable natural gas along with newly available gas turbine technologies resulted in an increase in smaller gas-fired plants, while concerns about pollution slowed investment in large coal-fired plants, and concerns about cost overruns, safety and weapons proliferation cooled global interest in new nuclear facilities. Gas-fired plants also offer locational flexibility, in that they can be built close to where the electricity is used, rather than at the fuel source.

A similar trend toward smaller plant sizes happened in Alberta, as can be seen in Figure 4. The rate of growth of overall capacity (blue line) has increased despite the fact that the average plant size peaked in 1985 (red trend-line).

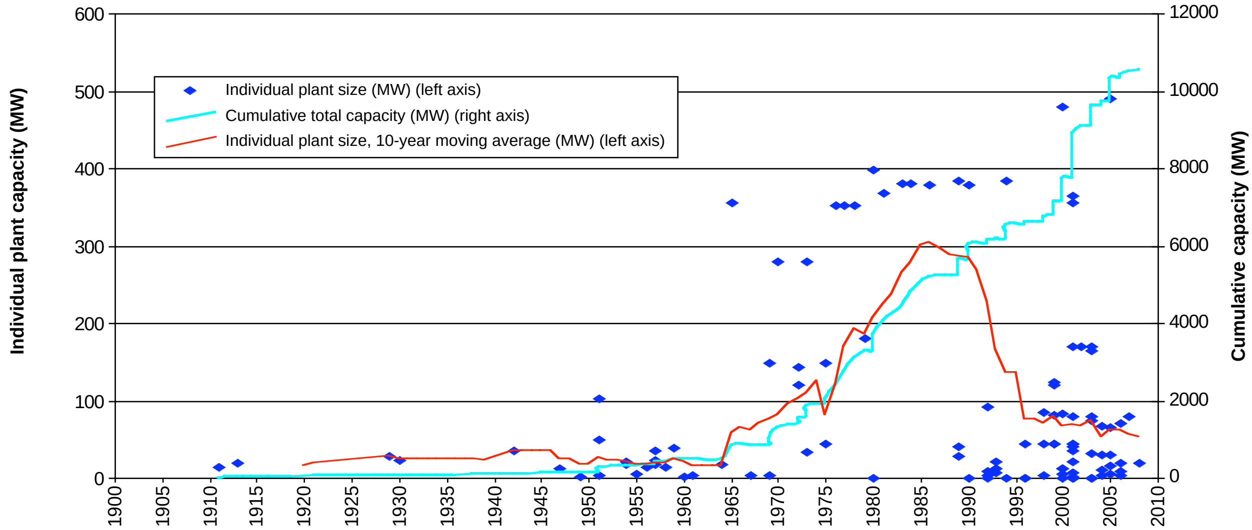


Figure 4. New Alberta generating plant sizes by start date

Source: Based on data compiled by the Pembina Institute from various sources[15]

In the 1980s transmission lines built between Alberta and British Columbia and Alberta and Saskatchewan allowed, for the first time, the trade of electricity outside the province. In 1995 the Government of Alberta decided to follow the example of California and the U.K. (among others) and introduce competition into the Alberta electricity sector. The move from a government-regulated monopoly system to a system where new generators are allowed to enter the market is usually referred to as "deregulation."[16] The goal of the initiative was to spur innovation and efficiency, drive down price (via competition) and offer consumers more choice.[17,18] The new wholesale market system was introduced in 1996, with retail competition unveiled four years later on January 1, 2001. The rules are still evolving today. Smaller generating plants, such as wind energy systems in southern Alberta and natural gas cogeneration in the oil sands, have sprung up in Alberta since deregulation. At the same time average electricity prices have increased from around $15/MWh in 1996 to close to $80/MWh by 2008, with some dramatic spikes in between, as can be seen in Figure 5.

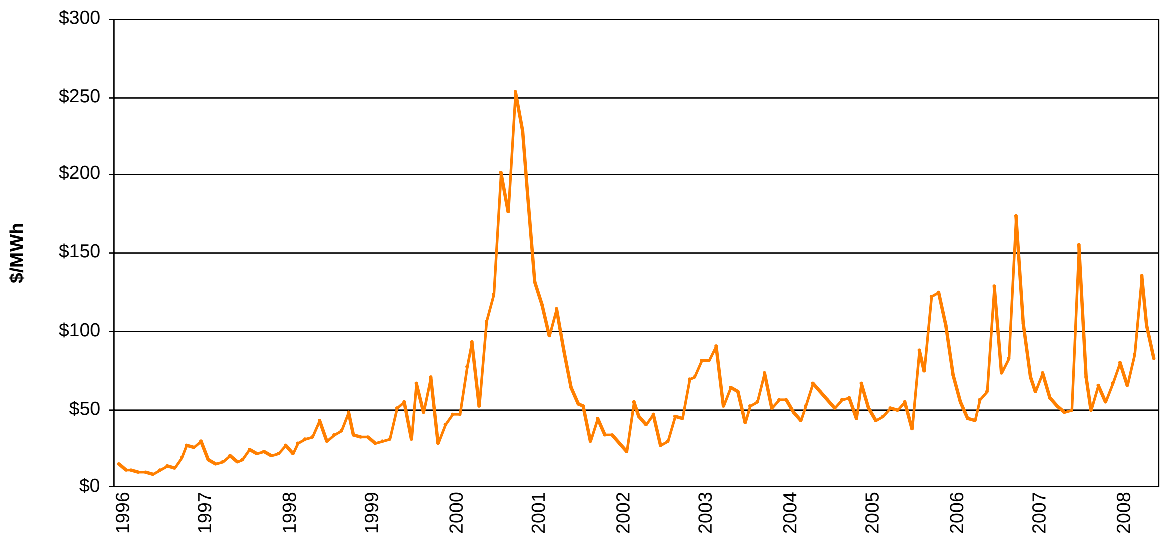
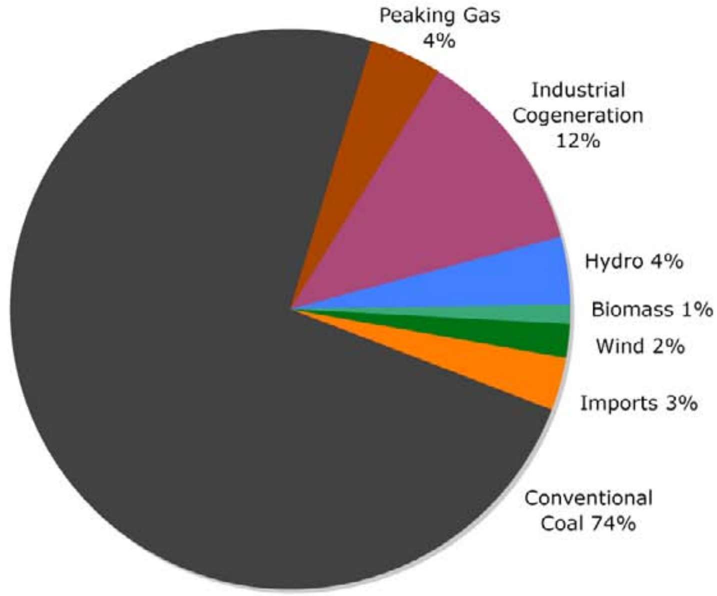


Figure 5. Monthly average Alberta power pool price 1996–2008

Source: Based on data from AESO

Figure 6. Electricity generated in 2007 in Alberta by source (total: 57,295 GWh)

Source: Based on AESO data



1.5 Electricity in Alberta Today

1.5.1 Supply

Alberta relies mainly on coal and natural gas (through a combination of "peaking" and "cogeneration") to generate its electricity, as illustrated in Figure 6. Figure 7 shows the historic trends in Alberta's grid mix. Renewable energy sources currently represent 7% of Alberta's electricity generation even though Alberta has more wind energy capacity than any other province in Canada (524 MW in 2007[19]). Wind still represents a small fraction of total provincial generation and an equally small fraction of the wind energy resource potential in the province. Alberta has never employed nuclear energy to generate electricity. The province has recently commissioned an appointed panel to draft a report examining the potential for nuclear generators in Alberta, whose report is due by the end of 2008.[20] With a diverse portfolio of clean options, such as wind, solar, biomass, hydro, geothermal and cogeneration systems,[21] there remains considerable scope for cleaning up the Alberta grid with low-risk technology that can be deployed quickly.

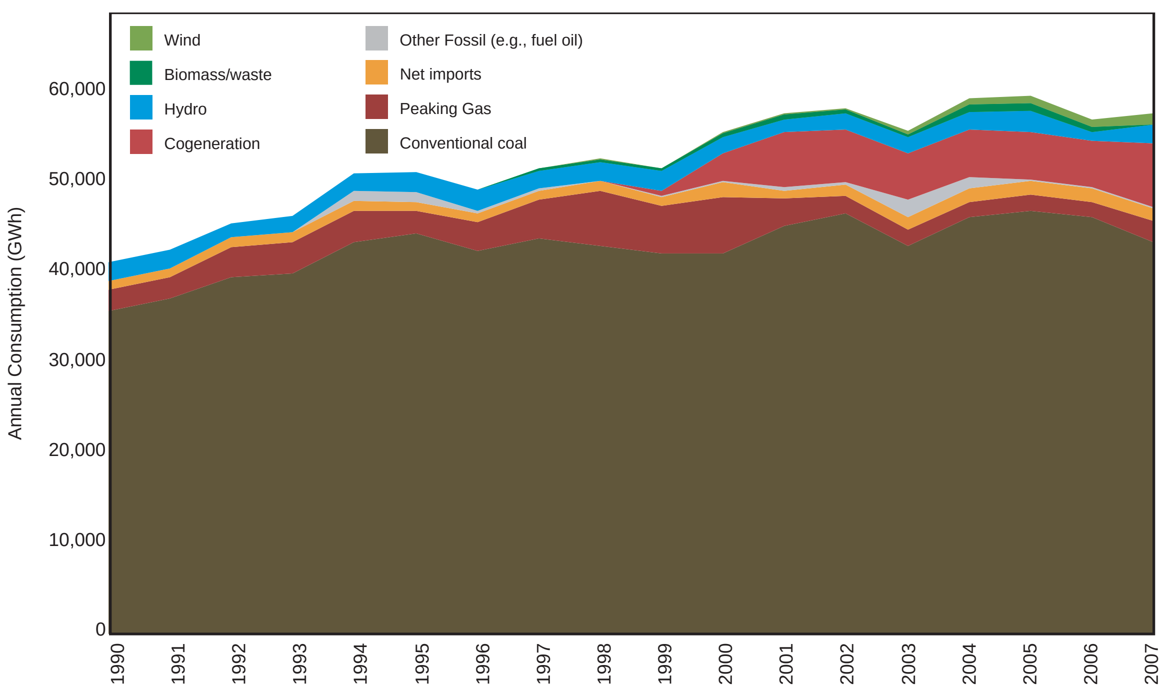


Figure 7. Historic electricity generated in Alberta, 1990–2007, by source (GWh)

Source: Based on AESO data

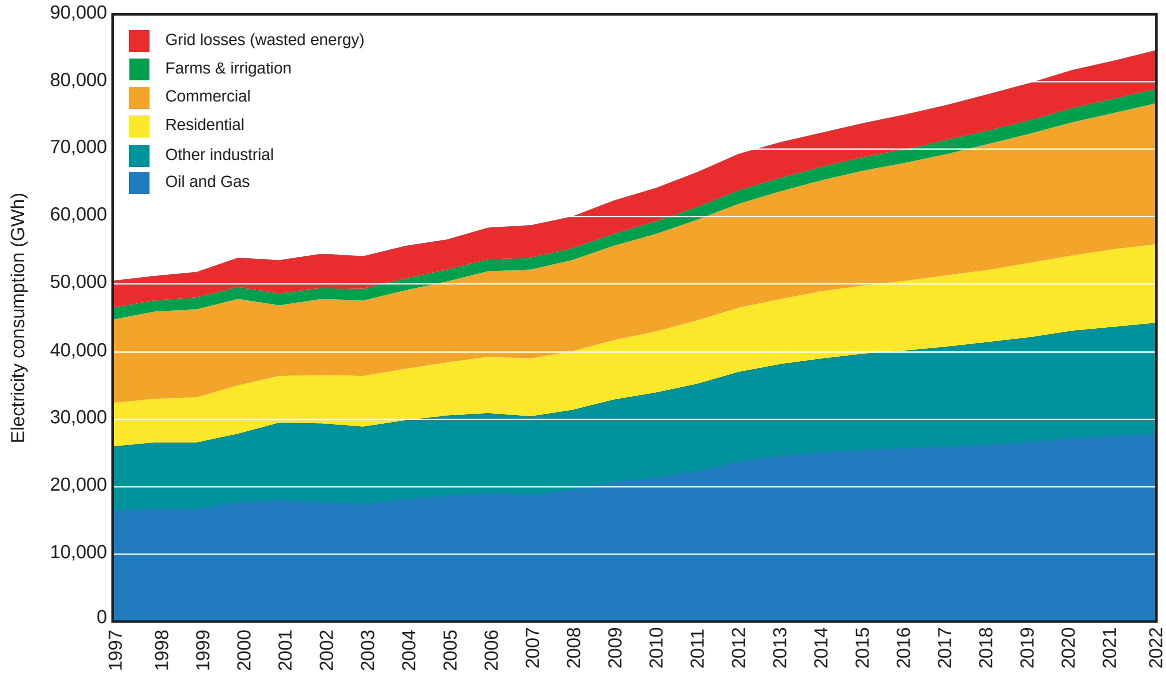


Figure 8. Historic and projected total Alberta electricity usage by sector

Source: Based on data from EDC Associates Ltd.[22]

1.5.2 Consumption

In 2007, about 35% of Alberta's total electricity was used in the oil and gas sector.

Alberta's industrial sectors use the vast majority of Alberta's electricity, as illustrated in Figure 8. In 2007, about 35% of Alberta's total grid electricity consumption was estimated to have been used in the oil and gas sector,[23] much of it for pumping fluids and compressing gases at well sites, oil batteries and gas plants.[24] Oil sands operations also use large amounts of electricity, but the majority of it is not purchased from the grid; rather, it is generated from onsite gas-fired cogeneration systems, often owned or partially owned by the oil sands companies themselves. Such electricity generated on the premises of a (usually) industrial operation, often referred to as "behind-the-fence generation" or "self-generation" in industry jargon, is not included in this report. Figure 8 also illustrates transmission and distribution line losses in the province.

1.5.3 System Planning

As a result of deregulation of the electricity market, the industry is broken down into various categories or subsectors: generators, transmission and distribution, and providers/retailers. Before deregulation, regulated monopolies owned both generating plants and grid infrastructure. When companies wanted to develop new infrastructure they presented their case before the government regulator: the Alberta Energy and Utilities Board. If the case was convincing and was deemed to fit with the Government of Alberta's electricity supply policy, the proposal was approved. Costs were subsequently recovered by electricity rates that were guaranteed by the regulator and that included amortization costs and a return on investment. Deregulation brought competition to the Alberta grid and created more space for the private sector in deciding what generation plants to invest in. Prior to deregulation there were five major regulated utilities in the province;[25] as of September 2008 there were 214 participants on the official list, including electricity generators, major consumers and marketers.[26] Compared to other jurisdictions in North America, most of which still operate in regulated frameworks, Alberta uses a system that relies more on market forces to decide what generating assets need to be built, where they need to be built and when.

> Even with a deregulated market, the Government of Alberta still wields the power to clean up Alberta's electricity supply.

Because natural resources are under provincial jurisdiction the Alberta premier wields ultimate power over the electricity industry. There is no direct intervention on behalf of government regulators about what projects are built and where. Investment decisions are nevertheless influenced by the policy framework and government decisions. As illustrated in Figure 9, the premier's office sets the general policy direction and tone of discourse and can also provide specific guidance on policy development. The figure shows the hierarchy of the organizations influencing the way the Alberta electricity grid and fuel portfolio are developed. Like governments in other provinces, the Government of Alberta has the power to make decisions that influence what technologies are used. For instance, in Ontario, the only other Canadian province with a deregulated electricity market, the government has committed to phasing out coal altogether and has issued request for proposals for clean renewable energy and cogeneration. In British Columbia, the government has stated that carbon emissions from new electricity generating capacity are prohibited.[27] The Government of Alberta wields similar influence on investment decisions. Direction could come in the form of new legislation or revisions to existing legislation.

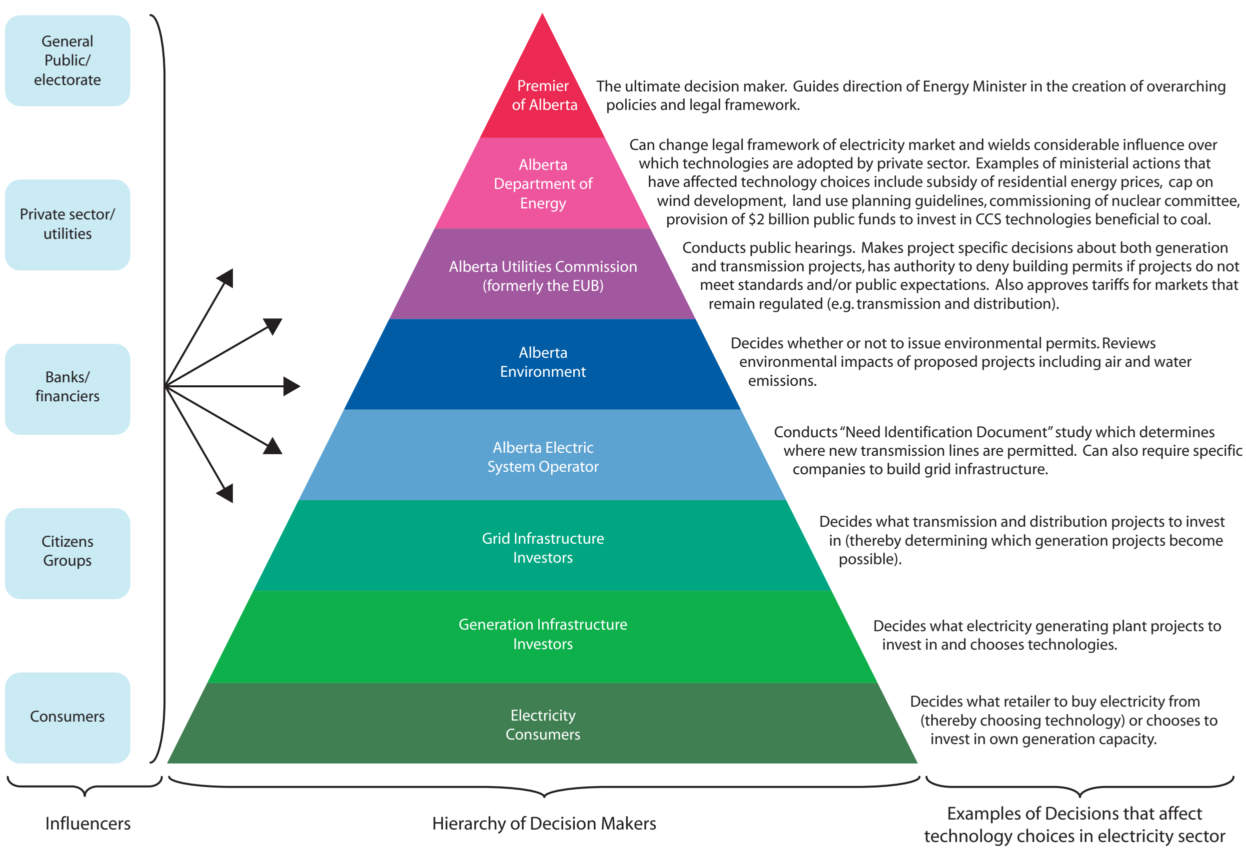


Figure 9. Decision-making hierarchy in the Alberta electricity sector

Ministry decisions can also affect the choice of technology directly. Examples of actions previously taken by Alberta Energy or Alberta Environment include mandating a cap on wind power development (subsequently rescinded), allocating $2 billion of public funds toward CCS (effectively a subsidy to fossil fuels such as coal) and assembling an expert panel to look at nuclear power. The provincial energy strategy states: "We defer to the market to determine what mix and proportion of energy sources Alberta will ultimately use for electricity,"[28] but it singles out coal quite explicitly as the favoured technology to receive research and development funding and general policy support.

In the current deregulated system companies are encouraged to build generation infrastructure if they think the economics are attractive enough to make a business case. The Alberta Utilities Commission must approve any proposed generating plants or grid infrastructure projects. In the case of transmission and distribution projects, costs are for the most part still recovered by a regulated rate charged to all customers. As a result, grid infrastructure private sector companies, such as Altalink (serving about 85% of the Alberta customers[29]), bear little risk because their profit is guaranteed through the rate payers.[30] In some cases, new grid infrastructure, notably interconnections, can be deemed the responsibility of the generation proponent, adding to their project costs.

Another agency that affects investment decisions is the arms length, not-for-profit government corporation known as the Alberta Electric System Operator (AESO). AESO was created in 2003 under the authority of the Electric Utilities Act and assigned the responsibility of "the safe, reliable and economic planning and operation of the Alberta Interconnected Electric System."

> Over the next 20 years, annual electricity consumption is expected to almost double as a result of rapidly expanding oil sands development. Alberta will need large amounts of new capacity to meet demand.

An important aspect of AESO's current work is to ensure transmission infrastructure is in place in advance of projected generation. The process for deciding where grid investments are required comes from an assessment of needs. Needs assessments are undertaken informally on an ongoing basis in the form 10- and 20-year transmission system outlook reports. AESO develops projections of future transmission needs based on internal research and public consultation to determine where new generating projects are expected, where existing infrastructure requires upgrading, where the load is growing, etc. If there is evidence that transmission may be required, AESO commissions a detailed technical study called a "Need Identification Study." AESO then puts the study to the Alberta Utilities Commission, which decides whether or not transmission is indeed required. If it is decided that transmission is required, AESO then assigns the project to the incumbent company in the area spelling out its technical requirements. The company must then make an application to the Alberta Utilities Commission to have the proposal approved, including the routing of the lines.

Because generators need transmission lines to move their power to the market, the choice of where a transmission line is built automatically precludes some generation projects in favour of others. The Alberta Utilities Commission's decisions therefore affect the ability of potential generators and generation technologies that are employed and when they are employed.

The challenge going forward in Alberta is to ensure environmental performance criteria are met while continuing to allow the market to drive generation investments. The provincial energy strategy released in December 2008 does not provide either a framework for renewables to compete fairly in the market or a clear strategy of how environmental performance will be guaranteed.

1.6 Projecting Future Needs

Planning for future needs in any sector of society is by its nature a challenging exercise. It is especially so for electricity because decisions and large infrastructure investments have very long time horizons, in some cases often up to 10 years in advance. Planning for electricity production is not possible without estimating future electricity consumption.

1.6.1 Projecting Alberta's Electric Demands

Because it often takes a long time (in many cases more than 10 years) to develop and construct transmission and large centralized generation plants, estimating future consumption demands and prices for electricity are key driving forces for the industry. Various organizations have provided estimates of Alberta's future electrical consumption. Figure 10 shows projections by the consulting company, EDC Associates Ltd., the National Energy Board and AESO. AESO releases its electricity consumption projections every few years. AESO's projections are the industry standard and are often cited by developers to help justify need for proposed plants.[31] While the consumption of electricity is expected to continue to grow in Alberta, in large part because of a rapidly expanding oil sands industry,[32] there are many factors that influence the predictions of this future consumption most notably the pace of this industrial expansion. Figure 10 illustrates how in a span of only four years AESO's forecast for the year 2028 rose by over 25% — from 88,000 GWh to 111,000 GWh — while the EDC Associates Ltd. prediction roughly splits the difference. Because the oil and gas industry is the largest driver for growth in Alberta, the price of oil, decisions on bitumen upgraders and development approvals will all affect the actual rate of electricity consumption in 20 years' time. In any case, the overall annual consumption is expected to almost double in the next two decades, and Alberta will need large amounts of new capacity to meet these demands.

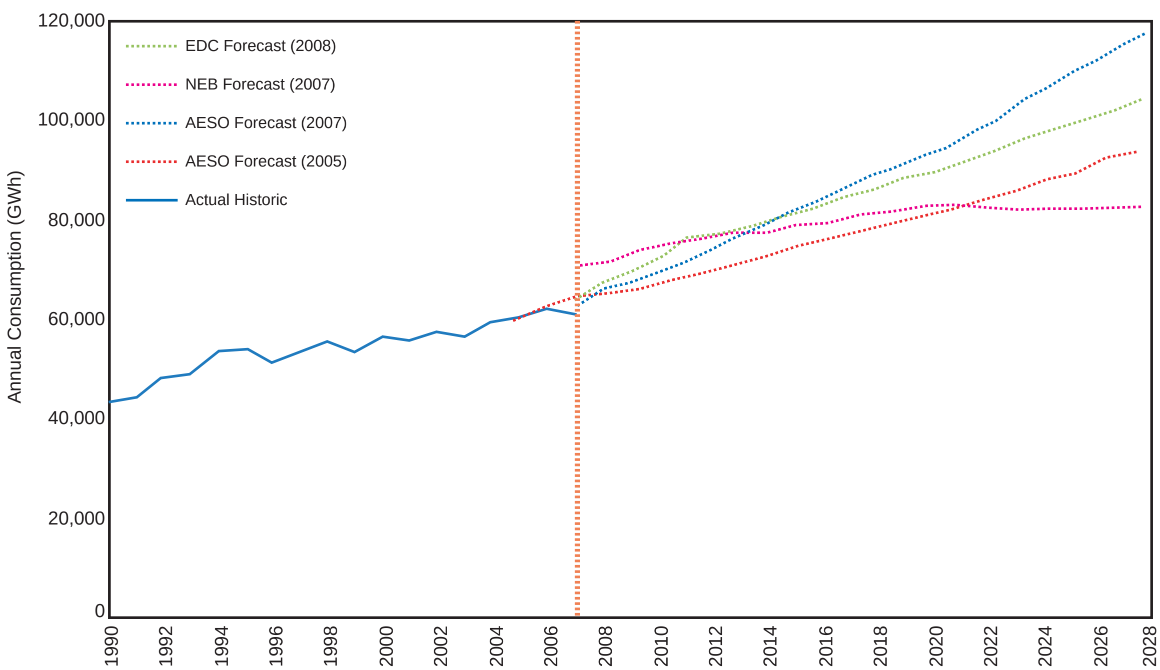


Figure 10. Comparison of various projections for future electricity annual demand in Alberta

Source: Based on AESO, EDC and NEB data

In spite of this significant revision in the space of only a few years, AESO's most recent projections are used in this report as the reference point for meeting future consumption requirements. Because it is AESO's mandate to ensure that the electric system will adequately serve Alberta's needs, AESO's projections need to be conservative; that is to say they represent the upper bound of likely future consumption. This can be seen by comparing AESO's 2005 forecast (red line in Figure 10), which predicted a linear increase in consumption on an average of 1,500 GWh per year, to the actual consumption (dark blue line) between 2005 and 2007, which in fact remained almost constant.

The recent global economic slowdown and the falling price of oil in the second half of 2008, combined with rising project costs in Alberta, have led many companies to delay large development projects. These recent significant economic changes were not foreseen at the time any of the most recent forecasts were made, and as a result the forecasts are very likely overshoots, and potentially by significant margins. Nonetheless, in order to ensure very conservative assumptions for this analysis, the dotted blue line in Figure 10, which represents AESO's most recent projection at the time of the analysis done for this report, is used for the duration of this report.

1.6.2 The Supply Gap

In addition to increasing consumption of electricity over the next 20 years, some of the generating plants that are currently operating will be retired (or need to be significantly rebuilt) as they reach the end of their working life. Figure 11 illustrates how the electricity consumption has been met since 1990 (to the left of the vertical orange line), and which of these resources are expected to be available for the next 20 years (to the right).

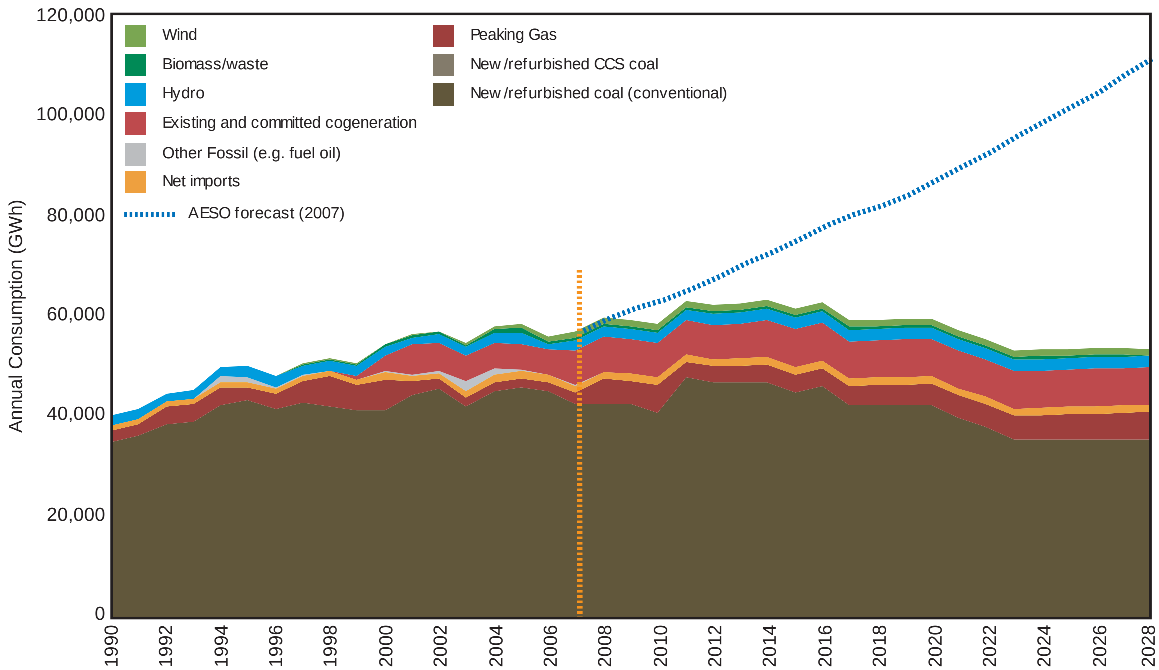


Figure 11. Projected supply gap in the Alberta electricity sector

The steps up and down in the graph reflect new coal generating plants that have received approval and estimated coal plant retirements as they reach 50 years of age; all other technologies are extrapolated linearly. It can be seen that there is a gap of approximately 56,000 GWh between the

2028 demand for electricity and the known supply. New capacity will therefore need to be added in order to fill this gap.

Interpreting Figure 11

The diagonal dotted blue line represents the estimated future electricity consumption based on AESO's projections. Because AESO's projections are only until 2027, data for 2028 was extrapolated linearly. Generation data previous to 2007 (as indicated to the left of the vertical orange line) was compiled from historic data.[33] Actual production data for 2007 was taken from AESO's online database[34] and was used to verify historic data. Data for future generation (as indicated to the right of the orange line) shows decreases that represent the expected retirement of existing coal plants[35] and increases that represent start-up dates of confirmed plants[36] (such as the Keephills *3* coal plant west of Edmonton in 2011, for which construction has already begun). The white space under the AESO forecast line represents supply shortages based on projected demand and known supply capacity.

As of September 2008, more than 30 GW of capacity has been formally or informally announced in the province,[37] and almost 20 GW of which represents projects that have already submitted applications to AESO for interconnection to the grid.[38] Reserving a spot in the interconnection queue is not a guarantee that a given project will necessarily be built. As a result it remains uncertain which proposed projects will actually proceed, and it is very likely that only a fraction of the projects with a spot in the queue will actually proceed.[39] This report evaluates the potential and technical feasibility of various portfolios of generating technologies that could meet the electricity demands between now and 2028.

1.6.3 Projecting Generating Capacity

The amount of electricity consumed on any electricity grid increases and decreases second by second throughout every day in any year. The amount generated must match, within very small tolerances, the amount consumed otherwise the electric grid becomes unstable very quickly.

For many generating plants, the amount generated can be increased and decreased at will within specified operating parameters, in order to follow the amount of electricity consumed. For example, in the case of a gas-fired plant, fuel combustion can be increased or decreased as power consumption increases or decreases. Such a plant is said to be "dispatchable" meaning that the plant can produce at some determined level upon orders from the system operator. These plants are used to supply the varying portion of the electricity consumption above the base load and are known as "peaking" plants.

The output of variable generation technologies, such as wind, can be predicted for long-range forecasts and anticipated based on weather data for short-range planning.

For some plant designs (mostly ones that use coal, uranium and heat to generate steam), it is very costly and/or very time-consuming if they need to be stopped and restarted, and have relatively slow response times in order to follow the changes in the amounts of electricity consumed. These relatively inflexible plants are collectively used to generate electrical energy for what is termed "base load" — the portion of electricity consumption that varies little over a given time period. In 2008, the required base load generating ability is approximately 6,400 MW.

In contrast to these two categories, the amount of electricity generated by some renewable energy technologies such as wind, solar, and run-of-river hydro, are neither dispatchable, nor are they capable of providing base load without some sort of energy storage; rather, they can only generate according to availability of wind, sun, etc. It is important to note, however, that while the output of these "variable" technologies is not guaranteed at any time of the year, the gradual changes in electricity production can be statistically predicted for long-range forecasts and anticipated based on current local weather pattern and weather data for short-range planning.

Base load and peaking plants can be controlled to varying degrees as electricity is required whereas generation from some renewable energy technologies is determined by factors outside the control of the plant owners. For example, a combined-cycle natural gas-fired plant is available to generate electricity at any time AESO requires because the plant's operator can plan when the plant can operate. However, the ability of a wind turbine or a solar electric system to generate electricity depends on the wind speed or the intensity of solar radiation at that time. As a result, system planners cannot rely upon intermittent technologies to meet the projected amount of consumption. Instead, planners estimate the portion of a technology's capacity that will be available at any given time as averaged over all installations with similar technologies around the province and based on much experience and study about the technology's performance. This portion is called "capacity credit," and it indicates the technology's ability (or capacity) to be available at any point in time to meet system demands. AESO estimates the capacity credit of hydro plants in Alberta to be 50% of their rated capacity at any given time of the year and the capacity credit of wind plants is estimated to be 20%.[40] The other technologies currently in Alberta's supply mix (including imports) are given a 100% capacity credit (with the exception of solar which is estimated to be available 0% of the time because it is not ever available at night).

To meet the consumption demands, system capacity must be sufficient at any given time of the year, and most notably during the system "peak" — the one hour every year that demands the most electricity. In Alberta, this peak happens in the winter. In order to accommodate the fact that power plants may be offline for maintenance or other unplanned outages, the grid also requires what is called a "reserve margin," which is a cushion above the total capacity credits for the entire system and the peak demand. Over the last 28 years reserve margins ranged from 14% in 1997 to 42% in 2004, averaging about 28%.[41] In 2007 the reserve margin was about 33%.[42] Predicting and planning for peak is difficult and given the long lead times to get new plants and transmission on line, it is necessary to err on the side of adequate capacity rather than shortfalls.

The previous section presented the expected annual consumption and generation projections and the effect that the retirement of plants would have on generation shortages. The provincial electric system, however, must also have sufficient abilities to generate, transmit and deliver electricity to meet peak levels of consumption. Figure 12 illustrates AESO's 2007 peak forecast together with an extrapolation of the present generating abilities for each technology to meet the peak. Known coal plant additions and retirements are also included, as they were in the previous section. Additional and refurbished natural gas plants are likely to come online to help meet peaking and variable demands. As a conservative estimate, the natural gas capacity was assumed to be constant for the next 20 years for the reserve margin calculations. While there is currently a sufficient reserve margin to meet peak loads, growing demands, combined with coal power plant retirements will result in insufficient reserve margins and ultimately the absolute inability to generate electricity to meet peak levels sometime after 2016.

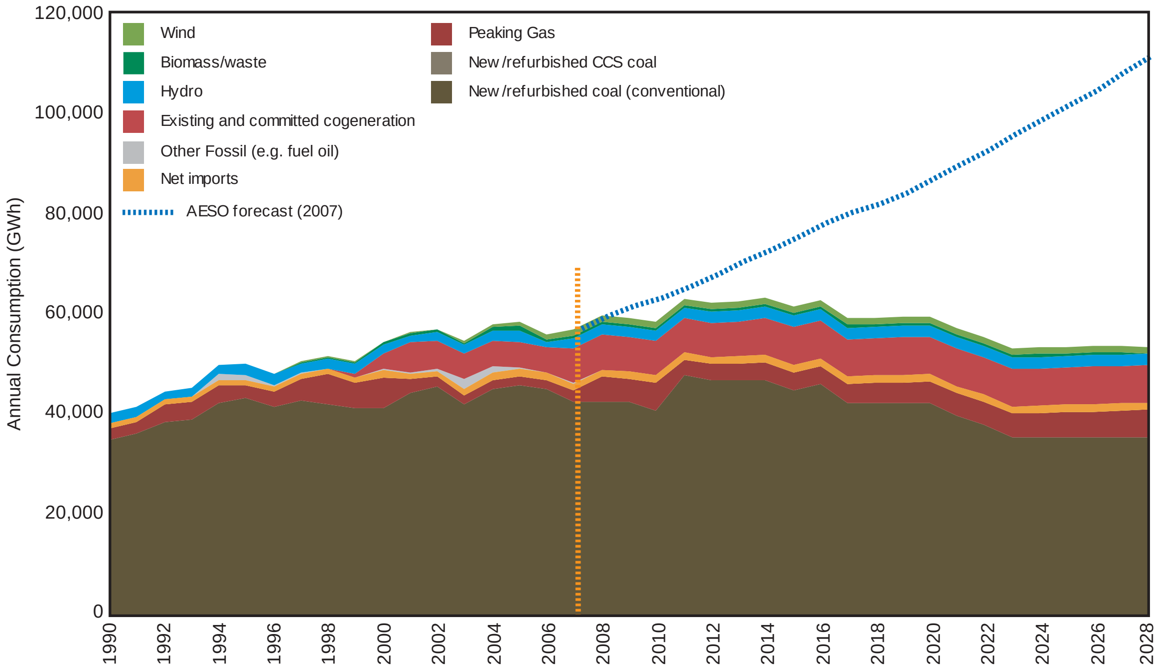


Figure 12. Projected peak capacity gap in Alberta

Source: Based on AESO projections

2. Business As Usual

2.1 AESO's Generation Scenarios

What technologies are currently expected to meet projected requirements for electrical energy and peak consumption? In addition to forecasting electricity consumption AESO also predicts the portfolio of technologies that will likely be built to meet these demands, where they are likely to be built and where loads are likely to grow, all in order to be able to plan the transmission system to accommodate these technologies. AESO's goal is to ensure grid stability and adequate ability to transmit electricity and not to pre-suppose or favour one technology over another. In their 2007, November Draft Generation Scenarios,[43] AESO illustrated five distinct generation portfolios it considers to be the most likely between 2007 and 2017 and another two scenarios between 2017 and 2027. For the analysis in this report, these potential electricity supply mix portfolios were averaged and are illustrated in Figure 13. For example, the amount of new coal projected in each of the first 10 years was averaged and added to the average amount of new coal in the next 10 years and the process was repeated for each of the technologies. The generation portfolio used here does not therefore reflect any one specific scenario put forth by AESO, however it does reflect the best thinking about what types of technologies and in what relative proportions they are considered to be likely and we, therefore, consider this to be the "Business-As-Usual" scenario in this report.

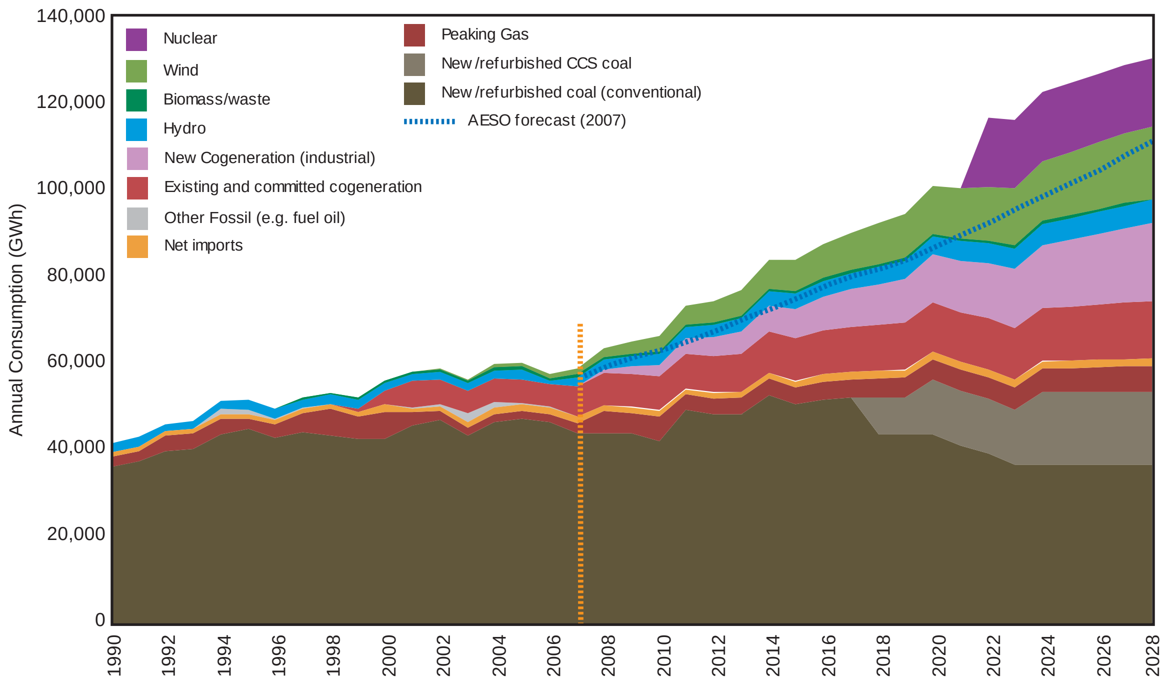


Figure 13. Business-As-Usual portfolio to meet projected consumption

Source: Based on a compilation of AESO's most recent generation scenarios[44]

It is worth noting that while AESO expects coal will continue to be relied upon to meet the base load for future electrical energy consumption, increased deployment of cleaner technologies (such as cogeneration) and of renewables (such as wind and hydro) are common to all their scenarios to meet consumption by 2028. AESO does not distinguish between coal with or without carbon capture and storage (CCS). One further assumption of note was that the new coal capacity projected to come on line between 2007 and 2017 is assumed to be conventional supercritical technology without CCS and that it is subsequently retrofitted with CCS in 2018 in order to comply with expected federal regulations. Any new coal projected post 2017 is assumed to come on line with CCS. AESO also expects a nuclear generating plant to be built sometime between 2017 and 2027. Given lack of certainty around the possible nuclear proposal it was assumed that a startup date earlier than 2022 was unrealistic.

Figure 14 illustrates the projected peak generating capacity for the Business-As-Usual scenario based on an averaging of AESO projections. The figure shows that AESO anticipates there will be little trouble meeting peak demand and a safe reserve margin of 25% is anticipated in 2028.

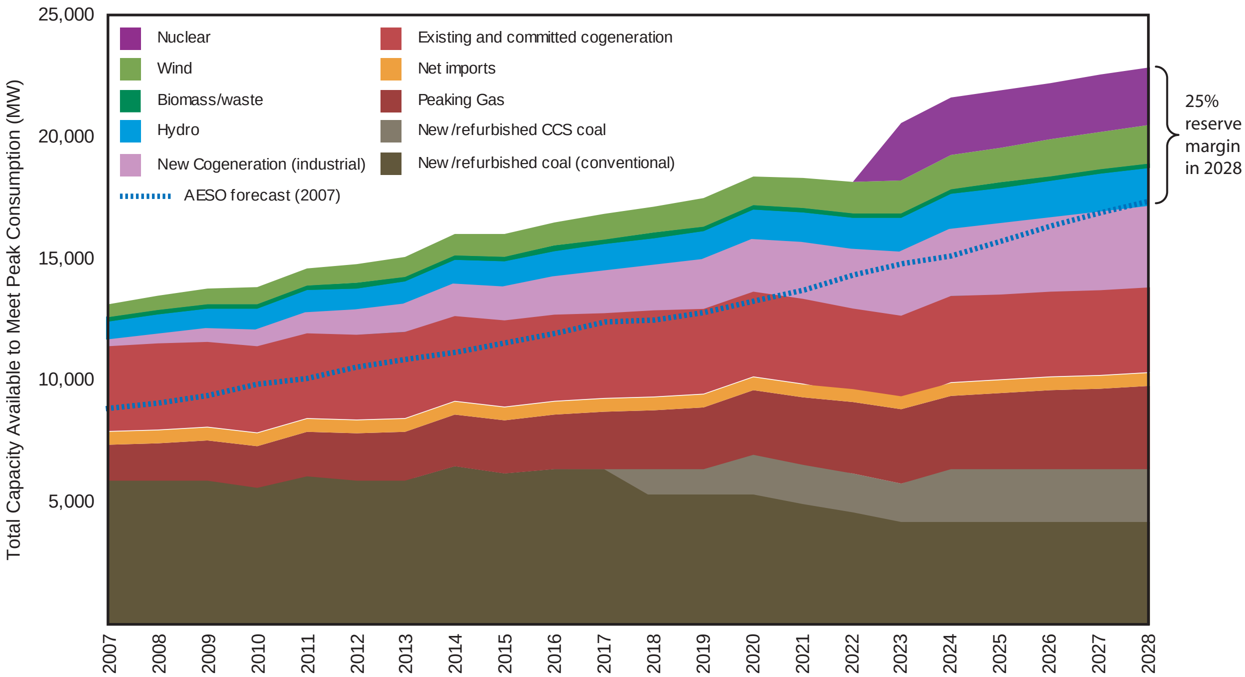


Figure 14. Business-As-Usual portfolio to meet projected peak consumption levels

Source: Based on AESO's most recent generation scenarios[45]

It is clear that Alberta's current portfolio is inadequate in terms of GHG emissions, air pollution and long-term sustainability. Any generation portfolio going forward ought to treat 2007 portfolio as a mix that needs to be improved upon. This will not be the case if Alberta proceeds in the Business-As-Usual approach.

2.2 Impacts of Electricity Generation

Electricity generation has numerous impacts, both local and far-reaching, some of which are positive such as job creation, and others like pollution are negative. Some of the key — and sometimes competing — implications of choices of electricity generation sources are discussed in this section. The degree to which renewable or non-renewable resources are relied upon into the future will shift the balance of these impacts.

2.2.1 Greenhouse Gases

Coal is Alberta's most GHG intensive means of generating electricity, and the Business-As-Usual scenario projects about 175,000 GWh[46] of electrical generation from new or refurbished coal plants over the next 20 years. Our electricity sector already accounts for about 25% of the province's GHG emissions.[47] Unless future electricity consumption is met by utilizing the province's tremendous wealth in renewable energy coupled with energy efficiency, the projected additional consumption would contribute significantly to Canada's GHG emissions and undermine efforts to significantly reduce GHG emissions provincially and nationally. Growing electricity sector emissions in Alberta could put emission-reduction targets out of reach.

To date there are no examples anywhere in the world of full-scale coal plants with functioning carbon capture and storage (CCS)[48] and at current price projections, the commercial prospects of the technology is unknown. Nonetheless, there is an expectation by both the Alberta and federal governments that CCS systems will begin to sequester CO_2 emissions beginning sometime after 2012. Assuming that all new coal power plants anticipated in the Business-As-Usual scenario built after 2012 are able to capture and store the majority[49] of their GHG emissions, Alberta's electricity emissions would still rise from today's 50 Mt to approximately 55 Mt of CO_2e by 2020. Of the new coal plants currently being proposed, there are a few proposing a CCS component.[50] Whether the proposed plants go forward and the extent to which they will incorporate the technology remains uncertain.

The federal government predicts that its "Turning the Corner" regulatory proposal will result in reductions from the electricity sector of about 30 Mt by 2020 (with provincial actions contributing a further 30 Mt of reductions).[51] Instead of contributing to these goals, a Business-As-Usual scenario will result in an 11% increase in GHG emissions. Clearly more needs to be done to enable the province to make a meaningful contribution to Canada's GHG emissions reduction targets.

2.2.2 Other Pollution

In addition to GHG emissions, the Business-As-Usual projections will also result in major increases in several other pollutants. Table 2 summarizes the scope of problems that are linked to the current electricity generation technologies. Should the proportion of coal generation increase in our generation portfolio, these existing problems could be exacerbated. CCS, the technology being proposed to clean up coal, mainly carbon dioxide emissions, does not capture other toxins such as airborne mercury. Additional pollution-reducing technologies will also need to be installed to reduce other forms of air and water pollution for both existing and proposed coal plants.

Table 2. Portion of annual Alberta pollution caused by electricity generating sector (2002*, 2006)

Pollutant	%	Tonne/yr	Problems
Sulphur oxides (SO_x)	30.3	130,792	Contributes to fine particles, and acid rain, respiratory and cardiac problems.
Nitrogen oxides (NO_x)	10.9	88,054	Contributes to fine particles, acid rain, ground level ozone formation, respiratory and cardiac problems, and visible smog.
Mercury and other metals	80	0.870*	Toxic to humans and wildlife. Bioaccumulates.
Particulate matter >10 microns (PM_{10})	9.1	5,256	Contributes to smog, asthma, other respiratory problems, heart attacks and other cardiovascular problems.
Particulate matter >2.5 microns ($PM_{2.5}$)	6.0	2,500	Contributes to smog, asthma, other respiratory problems, heart attacks and other cardiovascular problems.
Volatile organic compounds (VOC)	0.2	679	Carcinogenic. Can lead to ground level ozone
Carbon monoxide (CO)	0.8	13,038	Highly toxic, prevents the absorption of oxygen into bloodstream.
Ammonia (NH_3)	1.2	185	Toxic, especially to aquatic animals

Source: Clean Air Strategic Alliance*[52], Environment Canada[53]

2.2.3 Water Use

Thermal electricity generating plants require enormous quantities of water for cooling. Alberta's generating plants account for one quarter of total water "allocations" (i.e., water set aside for use by permit) and 3% of total volume "consumed"[54] (i.e., not returned to the watershed, in this case lost in evaporation in the cooling process) (see Figure 15). In at least one watershed total water consumed for cooling generating plants approaches the amount of water that is consumed for irrigation. Although it is not typical, of the overall water allocation of the Battle River watershed southeast of Edmonton is used for cooling thermal generating plants whereas 22% is used for irrigation.[55] Construction of additional thermal plants would require additional water allocations and result in additional water consumption, adding stress to Alberta's water resources. The diverse portfolio of renewable and transitional electricity generating options, which are currently underutilized in the province, would require little or no cooling water.

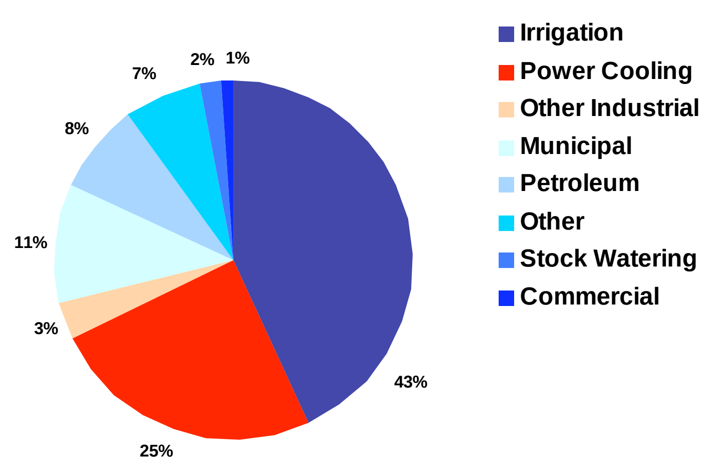
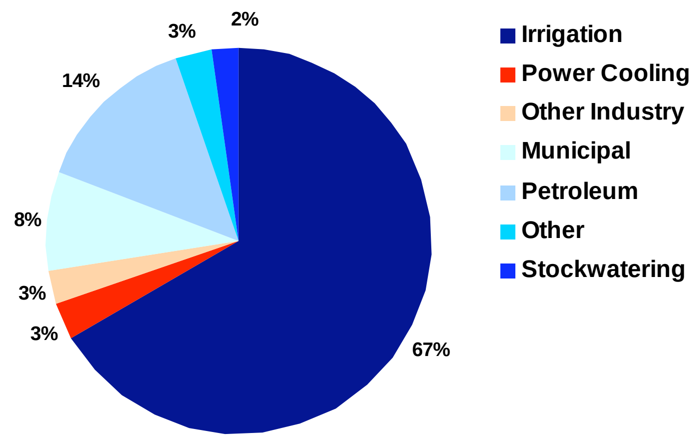


Figure 15. Proportion of Alberta water allocated to the electricity sector (2005)

Source: Compiled by the Pembina Institute based on data from Alberta Environment[56]

Figure 16. Proportion of Alberta water used by the electricity sector (2005)

Source: Compiled by the Pembina Institute based on data from Alberta Environment[57]



2.2.4 Land Use

The Business-As-Usual scenario is also expected to negatively affect land in several ways.

Coal Mines

Electricity infrastructure by nature requires land. Large coal plants need a concentrated source of fuel, which needs to be mined and which results in large environmental footprints. Much of Alberta's easy to mine coal deposits are often located under farmland, and extracting those deposits displaces communities consisting of farming families and landowners. Mining operations can draw down the water table in the surrounding area, negatively affecting adjacent landowners. Mines themselves are also a significant source of noise, air, and water pollution (which are not included in Table 2).

Land Area

Many of the renewable and transitional energy options use less land than conventional generating plants because the generating equipment is incorporated into existing sites (see Table 3). For example, a gas cogeneration plant can be incorporated into existing industrial sites and solar photovoltaic (PV) arrays can be installed on rooftops or industrial sites without the need for additional land use. Therefore a shift from conventional electricity generation to cleaner options could also help alleviate land use pressure. Grid infrastructure associated with generation plants, both renewable and non-renewable, require significant amounts of land.

Table 3. Incremental land area required for selected generating technologies

Technology	Land required (ft^2/kW capacity)
Solar PV (roof top)	0.0
Commercial cogeneration	0.4
Industrial cogeneration	0.6
Wind	10.6*
Natural gas	11.0
Nuclear	42.0
Coal	69.0

Source: U.S. DOE[58], and NREL*[59]

Siting

The siting of new generating plants is often controversial (as, for example, with proposed coal gasification plant in the Dodds Roundhill area southeast of Edmonton as being proposed by Sherritt International and EPCOR[60]). Controversy can result in projects being delayed, which adds significant cost, or cancelled. Renewable electricity technologies can also face siting difficulties. For example, some wind developments in southern Alberta have faced opposition by some local residents.[61,62]

2.2.5 Flora and Fauna

Both non-renewable and renewable technologies can have adverse impacts on local animals and plants. Wind turbines, for example, have been shown to be harmful to birds and bats.[63] Both bats and birds can be killed by spinning wind turbines if precautions are not taken during siting. Hydro-electric plants affect fish populations and reservoir-based systems particularly can have severe affects on wildlife both up and downstream. Whole ecosystems can be flooded upstream of dams and reduced volume and changes in seasonal flow patterns downstream from dams can negatively affect fish, birds and other organisms. Large thermal plants, in addition to the pollution impacts outlined above, can affect wildlife in other ways. For example, thermal pollution in the form of cooling water prevents winter ice from forming which affects migratory patterns of birds, encouraging migratory birds to stay throughout the winter where they may suffer from lack of food.[64] A federal law in the United States that is in the process of being adopted to force thermal power plants to adopt closed loop cooling systems, is designed to help address this type of problem.[65]

Figure 17. Coal generating plants, such as this one west of Edmonton, have major land use implications when the mine, lease area, plant and transmission lines are considered

Photo: David Dodge, Pembina Institute

2.2.6 Employment

Statistics show that 17,000 people worked for Alberta “utilities” in 2007, with an average growth of 0.8% per year since 1998.[66] More of the same types of generating technologies may mean more of the same employment increases. Trends elsewhere, however, show that the coal industry is downsizing its workforce while at the same time opportunities for renewable energy are surging[67] and creating employment. In the United States, for example, employment in the coal sector halved over the last 20 years despite output increasing by 30%.[68] A shift to cleaner technology would result in a major new economic sector, in turn resulting in a more diverse and larger employment pool. Green jobs have grown by 75% in the last four years in Germany, from 160,000 in 2004 to nearly

214,000 today. "Green technology" is expected to be the single largest employment sector in Germany by 2010, ahead of car manufacturing and electrical engineering. In Spain an estimated 190,000 are employed in the renewable energy sector.[69] A recent UN study concluded that "2.3 million people have in recent years found new jobs in the renewable energy sector alone, and the potential for job growth in the sector is huge."[70] As always, clear government policies help maximize the employment benefits of renewable and transitional technology development. In Quebec, for example, the provincial government passed a law requiring power plant developers to spend 60% of project costs in the province, which has spurred a local wind manufacturing industry and created a sustainable industry.[71]

In a 1997 study for Environment Canada comparing job creation numbers from numerous electricity projects across North America, the Pembina Institute found that investments in energy efficiency and renewable energy produce substantially higher levels of employment than equivalent levels of investment in conventional energy supply. The report found that every $1 million invested created an average of 36.3 jobs in the energy efficiency sector and 12.2 jobs in the renewable energy sector. For every $1 million invested in conventional energy, an average of only 7.3 jobs are created.[72]

2.2.7 Cost

Recent price increases of materials such as steel, cement, boilers, rotating equipment, piping, electrical components, and electric wiring has greatly increased the cost of building large generating plants; some regions have witnessed a 50% increase in costs since 2006.[73] SaskPower recently shelved work on a coal generating plant because its projected cost had more than doubled to $3.8 billion compared to the original estimates.[74] Conventional large central generating plants are becoming increasingly expensive even when using conventional economic analyses, let alone by employing a more comprehensive full-cost accounting approach, while increasingly stringent carbon dioxide emission allowances will force fossil fuel plants to add additional capital costs to clean up their GHG pollution.

Although rising commodity prices have also put upward price pressure on renewables in recent years, the long term trend shows prices for most renewable electricity technologies going down.[75] The sustained global enthusiasm for wind energy has resulted in a short-term turbine supply shortage, causing their prices and lead times to increase in recent years.[76] Increasing manufacturing capacity in North America, in addition to continually improving technology is expect to reverse this trend.[77] The largest advantage that renewable energy sources offer is long-term price certainty. Requiring no fuel, renewables are not subject to changes in fuel prices as with natural gas, uranium or even, to a lesser extent, coal. In addition, renewables are likely to be positively affected by an increasing provincial, national, continental or global price of carbon.

Siting of generating plants is often more challenging for larger, dirtier plants than smaller cleaner ones; lengthy negotiations and project modifications can cause development uncertainty. Renewable technologies require a smaller footprint and can be developed modularly over time. Liability is another major concern for larger plants that does not affect renewable plants to the same extent. Examples include cost overrun liability (such as Ontario tax payers having to pay $15 billion for nuclear plant cost overruns[78]), or pollution liability (such as the narrowly avoided ash lagoon breach at Keephills west of Edmonton[79]). As stated in the Alberta energy strategy "until recently (renewables) were more expensive, but the rising prices of fossil fuels have leveled the playing field considerably.[80] According to the Alberta Electric System Operator, wind and cogeneration are among the cheapest generation options, behind only upgrading existing coal plants (see Figure 18).

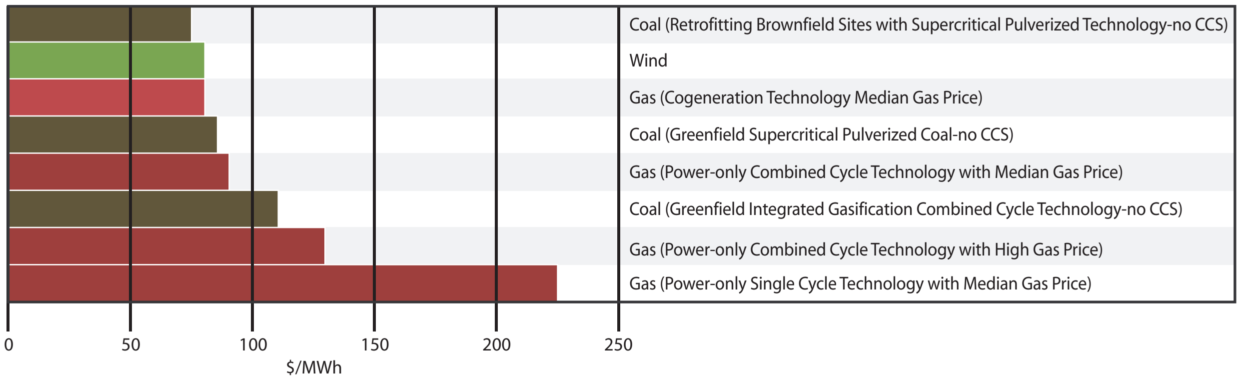


Figure 18. Cost of generating electricity by selected technology

Source: AESO[81] Note: not all technologies considered in this report were examined

Alberta is endowed with an abundance of energy resources, some of which have traditionally been easier to exploit than others. Alberta has been extracting conventional oil since the 1950s, but it was not without decades of government support, a national and provincial tax holiday and a change in market prices that the oil sands became profitable. If the full environmental costs of conventional generating plants are considered, such as the cost resulting from increased GHGs or other air pollutants including increased health care costs, then renewable energy technologies look more and more favourable. Currently some jurisdictions put a modest price on carbon emissions but in most cases electricity generators remain free to emit other pollutants, as set out in Table 2. Xcel Energy, a major energy company in Colorado, perhaps providing a hint of what the future has in store, recently sought and received regulatory approval to shut down two of its existing coal plants, which Xcel viewed as an environmental liability, and replace them with large-scale solar and wind energy plants with storage.[82]

Future work of the Pembina Institute will examine cost implications of various electricity options in more detail.

2.3 Other Options

Alberta is fortunate to have abundant energy sources of almost every type: from huge coal reserves to conventional and unconventional gas, wind, biomass, solar and (preliminary data suggests) geothermal.

Up until now Alberta has relied very heavily on coal to meet its electricity needs but there is no reason why Albertan's cannot shift to a cleaner portfolio such as being done in many European countries, American states and Canadian provinces. The Government of Alberta has a clear role in charting the path and determining the supply portfolio in Alberta in the coming decades.

The following chapter lays out two scenarios of how the province could meet its electricity requirements in a much more sustainable and less costly manner.

3. Cleaning Alberta's Grid

3.1 Introduction

This section analyzes the potential, constraints and realistic deployment rates in Alberta of renewable and transitional electricity technologies that are already operational in many countries throughout the world. The purpose of this section is to illustrate the extent to which alternatives exist to the present, emission-intensive, non-renewable generating technologies. It is a growing certainty that large CO_2 emitters, like coal-fired generating plants, will be required to implement "carbon capture and storage" (CCS) technologies to reduce their CO_2 emissions, the economics of which are still highly uncertain. Already in Alberta companies operating coal plants are required to pay $15/tonne of CO_2e (carbon dioxide equivalent) into a fund if they are unable to meet reduced emission intensity targets, as set out in the Specified Gas Emitters Regulation introduced in 2002.[83] The current federal climate change plan lays out a regulatory framework requiring all coal-fired electricity plants that come into operation after 2012 to employ CCS.[84]

Meeting future demand using generators with significantly lower emissions is certainly not without its challenges, but neither is the conventional approach (as illustrated by recent delays in trying to gain approval for a new transmission line between Edmonton and Calgary[85] or public opposition to major new coal generating plant proposals[86]). Building a clean electricity grid and the accompanying industries in the province will require political leadership and both public and private investment. However, a cleaner grid is not only a laudable goal, it is a realistic one.

This chapter introduces and frames the potential for renewable and transitional technologies in the Alberta context. The goal of this section is not to describe in detail each of the technologies examined in this report because that information already readily exists. Readers who need additional technical background information on renewable energy can find it at re.pembina.org/sources. A good source of information on transitional technologies can be found at the website of the World Alliance for Decentralized Energy[87]

This section puts technologies in their Alberta context both in terms of their potential and current barriers and lays out the basis for the assumptions, such as the capacity and the deployment rates, for each technology that were made when compiling the various scenarios. Clearly barriers exist to clean energy alternatives or they would be the norm and not the exception in Alberta. However, none of the barriers listed below are insurmountable, and countries, provinces and utilities that have chosen to overcome them have been overwhelmingly successful and are too numerous to list. The barriers are listed below to recognize the fact that targeted efforts are needed to level the playing field for these technologies.

The two subsequent chapters lay out scenarios that can meet future electricity consumption much more responsibly and sustainably than the current Business-As-Usual case. The Pale Green scenario, discussed in chapter 4 is built upon a conservative analysis using the state of current technology with a few modest assumptions and strategic investments. The Green scenario, on the other hand (chapter 5), is much more ambitious and would require significant political leadership. Its assumptions are still realistic, but in some cases it assumes modest improvements to current technology over the next 20 years. Both scenarios would put Alberta on a path toward a sustainable electricity future. The Green scenario would transform Alberta's electricity supply portfolio from one of the dirtiest in Canada[88] to among the cleanest.

3.2 Improved Efficiency

Figure 19. Adopting advanced metering technology, more efficient lighting and more efficient industrial processes are among the easiest means of cleaning up the grid

Photos: (left) David Dodge, (middle) NREL, (right) Dave Mussel

3.2.1 Technology Description

While businesses and homeowners pay for electricity, they are in fact not interested in the energy itself, but in the services that the electricity provides us. Efficiency improvements reduce electricity consumption while continuing to provide those services. Everyone has an economic incentive to be continually looking for ways to reduce their electricity consumption but the potential for efficiency improvements is rarely maximized in spite of the benefits of long-term savings. Reasons for this include the higher capital costs of buying more efficient equipment, competing investment priorities, the lack of understanding of economic returns, the lack of environmental incentives, the lack of product performance standards and labels, as well as simply being unaware of financing options and current technological advances. Despite being under-exploited, improving the deployment of efficient technologies is a very real way of meeting future demands, and many jurisdictions from Texas to Vermont to British Columbia have been able to meet projected future needs partially through investments in energy efficiency.[89] A kWh that is saved through efficiency is available for use to the rest of the grid, in this sense energy efficiency can be thought of as a source for meeting future consumption demands, and is treated as such for the remainder of this report.

The term "efficiency" covers a very broad spectrum of technologies from compact fluorescent light bulbs in houses to variable frequency motors or improved natural gas compressors. Opportunities to improve electricity efficiency exist across all sectors. This section briefly describes some of the potential technology improvements that exist and estimates the impact their deployment could have in helping to meet the projected future electricity demand gap.

Industrial Sector

A wide range of industrial energy efficient technologies and management practices are available. In refining, upgrading, manufacturing and other industries, efficiency opportunities are realizable by replacing individual components, such as efficient motors, drives, compressors, pumps, conveyor belts and boilers.

Superior gains are often possible by increasing the efficiency of the larger system as a whole and adopting plant wide energy management standards and optimization techniques. For example, replacing a pump with an efficient one is good, but larger gains may be possible by substituting with an optimized (likely smaller) size. One author's evaluation is "there is little benefit in producing compressed air, steam, or pumped fluids efficiently only to oversupply plant requirements by a significant margin or to waste the energized medium through leaks or restrictions in the distribution system. System energy efficiency requires attention to the entire system including energy flows and piping."[90]

In the electric industry sector itself, efficiency opportunities include replacing simple cycle turbines with combined cycle and cogeneration applications, installing highly-efficient motors at generating plants, installing distributed generation, reducing distribution line losses, and installing efficient distribution transformers.[91]

Buildings and Homes

There are also significant opportunities to increase electrical efficiency in homes and buildings. The largest gains can be achieved in commercial and institutional facilities where even new buildings are seldom operated as efficiently as they could be. Using high efficiency lighting, heating and air conditioning, and office equipment can improve the efficiency of a building by over 30%. Some energy efficiency options in homes include switching light bulbs, installing energy efficient fridges, freezers and furnace fan motors, and eliminating stand-by losses in home entertainment and computer systems. An important conservation measure recently passed in Ontario is to ensure that homeowners are not constrained by neighbourhood regulations to hang dry their laundry as opposed to using clothes dryers, while launching an advertising campaign to encourage this.

Farms

Many options exist for farms to improve their energy efficiency including accurately sizing irrigation pumps and improvements to hog, chicken and dairy operations. Climate Change Central in partnership with the Alberta Agriculture has a program specifically aimed at helping identify opportunities for savings in the farming sector.[92]

3.2.2 Scale of Resource

Without intervention to overcome market barriers, changes in the market mix and gradual improvement in technology tend to result only in modest annual energy efficiency improvements. A study done by the International Energy Agency found that from 1990 to 1998, Canada's energy demand increased by an average of only 1.2% per year despite increases in both population and production of goods and services at rates greater than this. Without any change in types of goods and services produced or energy used for production, an increase in energy demand of 2.2% per year would have occurred. This analysis indicates that energy efficiency (of production equipment or processes) in the entire Canadian economy decreased the energy demand in that period by 1% per year. That is to say, increased energy productivity was able to meet almost half of the increased energy demand needed for increased production.[93] AESO does not forecast what electrical demand would be without improvement in energy efficiency and these natural improvements in energy intensity are already factored into their forecasts. Therefore, to reduce projected energy consumption by energy efficiency, the improvements would need to be better than this Business-As-Usual case.

In 2006, a report was commissioned by the Council of Energy Ministers to determine the potential for energy efficiency in Canada by the year 2025. This report suggested that a demand reduction between 5–25% beyond Business-As-Usual was "achievable" over a 20-year horizon, which amounts to an annual reduction of 1.4% beyond Business-As-Usual as the more aggressive "achievable" scenario. If all cost effective efficiency opportunities (additional cost paid for from the savings) were realized then energy demand could be kept constant over the 20-year period.

At the recent Council of the Federation meeting in 2008 in Quebec City, the Alberta Premier, along with all other Premiers, committed Alberta to achieving a 20% increase in energy efficiency by 2020. No details were provided by any of the premiers about what reference point the goal referred to, nor if it was specific to one energy sector over another (heat, transportation or electricity). However, assuming the target of a 20% reduction is applied evenly across all energy using sectors and is in addition to the Business-As-Usual improvements; it is a goal that is certainly achievable if appropriate investments are made.

In California sufficient efficiency measures have been implemented to displace the equivalent of about 12,000 MW of generation.[94] Research by the Ontario Power Authority shows it is possible to reduce electricity demand by 5,100 MW through energy efficiency by 2020 while saving consumers over $7 billion over and above the cost of implementing the efficiency programs.[95] A recent study completed by Marbek and Jaccard and Associates for the Canadian Gas Association identified electricity savings potential by 2025 in the order of 23% for the residential sector, 44% in the commercial building sector and up to 86% in the industrial sector.[96]

As part of the Texas Restructuring Act 1999, Texas was one of the first North American jurisdictions to introduce mandatory energy savings goals for electricity providers. The state required electricity providers to meet 10% of their annual growth in consumption through energy efficiency. The Public Utilities Commission of Texas was given the task of adopting rules and procedures and ensuring the goals were met within five years. These goals were indeed met by the electricity providers, and discussions are underway to determine whether to increase the goal to 50% of annual growth.[97] In the first 10 years of its Power Smart program (1989–99) BC Hydro was able to reduce 2,312 GWh annually, or the equivalent of a 264 MW power plant at full output.[98] This was a result of a modest program aimed exclusively at the residential sector.

Alberta's industries currently consume more than 60% (see Figure 8) of the electrical energy generated in the province. Therefore, based on the Alberta Premier's commitment and the amount of energy generated in 2007, industry should be able to reduce consumption by at least 6,200 GWh between now and 2028 below projected consumption, which is more than 10% of total consumption in 2007.[99]

3.2.3 Constraining Factors

Because energy efficiency is such a broad category that covers industrial, commercial and residential sectors in numerous different applications and configurations, it is not possible to concisely discuss all of the factors that would act as barriers to implementing large-scale energy efficiency programs. Table 4 describes some significant factors that have previously limited efficiency uptake.

Table 4. Barriers to improved efficiency

Barrier Description	Barrier Removal Measures
Lack of awareness. Decision makers are often unfamiliar with energy efficiency opportunities and the technologies available to realize them. There is a lack of clear information available to consumers on which products are most appropriate and effective for their particular application, as well as a lack of government targets and incentives to build this awareness.	Mandatory labeling of energy performance, benchmarking and feedback to owners and managers on energy performance, clear information on best practices from governments and utilities, and market leading procurement of efficient technologies by government are just some of the options to overcome this barrier.
Lack of skills/training. A general lack of emphasis on energy and efficiency at trade schools. There are very few specific programs offering energy efficiency training results, as such there is in lack of awareness about efficiency within the design as well as within installation jobs.	Specialized energy training programs for designers, builders, renovators, and operators; incorporation of energy efficiency into trades and professional curricula; and well trained technical service providers to step energy users through a complete efficiency upgrade can greatly reduce this barrier.
Lack of Access to Financing. Most energy efficiency investments are unique in that they can pay for themselves out the savings achieved yet appropriate financing vehicles are not available. Many companies and institutions do not allow operating savings to be used for capital expenditures, tying the hands of would be energy savers.	Training programs for financial managers and innovative financing options such as green mortgages and use of municipal local improvement charges would remove these barriers.
Outdated building codes. Codes that require dated technologies or inhibit innovative decision making.	Solutions include adding energy efficiency requirements to building codes and reviewing other provincial and municipal bylaws and regulations for perverse energy efficiency barriers. In the longer term to ensure that all buildings and homes are as efficient as possible, consideration should be given to requiring existing buildings and homes to meet efficiency standards when they are sold or upgraded.
Slow turnover of infrastructure. Major infrastructure investments that are expected to have a long lifetime resulting in a short window of opportunity for replacing inefficient equipment with more efficient versions. For example, many of the inefficient furnaces in the province still have many years of life before they need to be replaced even though it is now cost-effective to replace them before their lifetime is up. Other technologies, such as commercial heating systems and industrial machines are similarly "locked in" for many years once initial investment is made.	This barrier can be reduced by providing "just in time" energy efficiency support measures. For example targeting appliance retail stores with appliance efficiency information, or real estate companies with efficient building financing options.

3.2.4 Advantages of Improved Efficiency

Of all the options available in Alberta to meet future requirements for electricity, improvements in the efficiency of electricity generation and use (using less electrical energy to obtain the same energy service) are the most environmentally sustainable and quickest to deploy. Improving the efficiency of energy use not only reduces short- and long-term operating costs, it also helps to provide price certainty by reducing any impacts that fluctuating energy prices might have. Several recent studies have outlined the importance of energy efficiency in meeting GHG reduction[100] targets because of its relative cost effectiveness, its ability to be rapidly deployed in addition to the vast underexploited potential in Canada.

3.3 Wind Power

3.3.1 Technology Description

Wind turbines are what likely come to mind for most people when "clean electricity" is mentioned. Wind energy has been the fastest growing source of electricity worldwide for the past 10 years, led by Germany, Spain, Denmark and, recently, the United States. Turbines can range from very small individual turbines ideal for farms and acreages to huge 125-m multi-million-dollar machines for wind farms that each produce enough electrical energy for over 1,200 homes. For the purposes of this report we will use the term "wind" to refer to large-scale, wind-farm machines only, like those shown in the picture. Smaller, residential scale wind turbines are included as micropower (section 3.9).

Figure 20. More than 11,000 MW of wind capacity are currently being considered in Alberta

Photo: Tim Weis

3.3.2 Scale of Resource

Alberta's economically viable wind energy potential is vast. In 2007, Alberta had about 496 MW of installed wind generating capacity, and was the leading Canada province in installed wind capacity. As of mid-2008, there was more than 11,000 MW of wind generating capacity under development, seeking approval from AESO to connect to the grid.[101] This is approximately double the total installed coal generating capacity in the province. While it is not likely that all of these projects will be developed, this queue provides a good estimate of the size of the resource in the province because project proponents are confident enough in the business case for the project to have invested significantly in getting the projects to this stage. Even if all of these proposed projects were to proceed, Alberta would still have significant untapped wind power capacity, because a rough estimate of Alberta's total wind energy potential is about 64,000 MW.[102]

Alberta's wind energy resource is one of the best and most accessible land-based wind resources in Canada as can be seen in Figure 21. The winds are strongest in the south of the province, although there are pockets of windy regions in the west and northwest. Regions with a minimum annual wind speed of 7 m/s are generally considered to be potentially economically viable for wind energy production. Germany, with a land mass approximately half that of Alberta, and a considerably weaker wind resource had already installed 22,250 MW of wind generation at the end of 2007.[103]

In 2007, more than a third (35%) of all new capacity additions in the United States and 40% of capacity additions in Europe were from wind.[104] Wind capacity in China more than doubled between 2005 and 2006 and again between 2006 and 2007.[105]

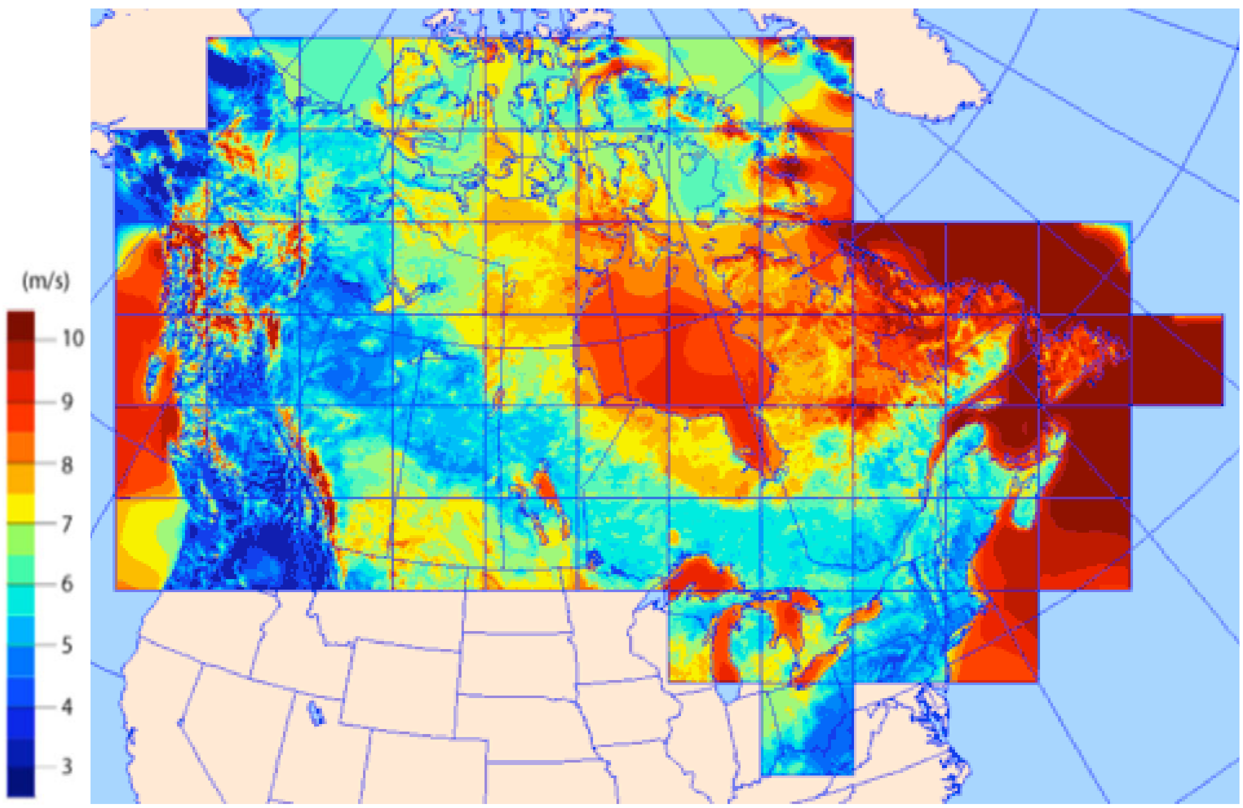


Figure 21. Average annual wind speed at 80 m above ground level

Source: Environment Canada[106]

3.3.3 Constraining Factors

The main factors that continue to pose problems for developers interested in developing wind power in the province are shown in Table 5.

Table 5. Barriers to wind power

Barrier Description	Barrier Removal Measures
Insufficient grid infrastructure. Insufficient power line infrastructure to accommodate wind capacity (most existing lines are already at capacity and even where upgrades are planned they will only accommodate a fraction of the available resource).	A comprehensive grid development plan designed to give priority to distributed wind system would alleviate this constraint.
Lack of complementary technologies. There is a current shortage of clean complementary technologies that can help buffer fluctuations in wind power, such as dispatchable hydro systems, storage technologies, fast response peaking plants, or curtailable load[107]	Advances in grid management will facilitate the incorporation of large proportions of variable energy source. Geographic dispersion of wind projects and better interconnections can also help manage variability. Several promising storage technologies are close to commercialization, and when coupled with wind systems could provide constant or dispatchable power.[108]
Landowner concerns. Some members of the public do not wish to have wind turbines located near their residences or change their "viewscape" by having wind turbines in the distance, a problem that can be exacerbated with increasing development.	Alberta has huge agricultural and range land suitable for wind farms so that no wind farm need be placed near residences. Revenue sharing practices can also help generate support from neighbours for wind developments.
Supply constraints. Global demand for wind turbines has already exceeded supply and continues to grow rapidly. Supply of turbines, parts and skilled workers to build and maintain a large number of turbines is stretched.	The entry of China and other countries into the wind turbine manufacturing industry and the opportunities for Canadian-built wind systems should ultimately remove this constraint.

3.3.4 Advantages of Wind Power

Wind turbines are generally considered to have the lowest life-cycle environmental footprint of any electricity technology. Wind turbines can be very quick to deploy when necessary (initial study to implementation can happen as quickly as three years assuming minimal regulatory constraints). Wind energy has the advantage of being the most commercially attractive low impact renewable energy source and has therefore garnered significant sustained annual growth. This has resulted in continual improvements in the technology and in reliability of turbines which are considered to be a very mature technology. In spite of the current supply constraint, it is forecast that the price of wind energy will continue to decline in the coming years.[109]

One of the most conducive landscapes for wind turbines is Alberta is on farm land. As developers compensate farmers for the use of their land, the addition of wind turbines adds a "second cash crop" to farmers' revenue streams.[110] Not only are high skill jobs created in rural areas, but taxes from wind farms provide huge new sources of tax revenue to rural municipalities (e.g., currently close to 27% of all revenue for the MD of Pincher Creek in Southern Alberta) benefiting all residents there.

3.4 Hydro

3.4.1 Technology Description

In Canada nearly 60% of electricity is supplied from hydro plants, whereas less than 5% of Alberta's electricity is generated from hydro. A number of different technologies are available to generate hydroelectricity. Technologies that employ a dam/reservoir increase flexibility of hydro generating plants but have larger environmental impacts. Run-of-the-river configurations reduce environmental effects but are more dependent on the seasonal flow of rivers and therefore lose some of their reliability.

Figure 22. Run of river hydro projects, such as the 6.2 MW China Creek project developed by Hupacasath First Nation in British Columbia, can have minimal fish habitat impact

Photos: Daniel VanVliet

3.4.2 Scale of Resource

Some of the oldest operating generating plants in the province are hydro plants. In 2007 there was 869 MW of hydro generating capacity in the province.[111] The Canadian Hydro Association estimates that Alberta has more than 11,500 MW of remaining economic hydro potential including both reservoir and run-of-the-river projects.[112] Some of this potential would be low impact hydro but much of it would also require higher impact development. Further study of the resource is required to determine what proportion of the estimated potential could be developed in a low impact manner.

3.4.3 Constraining Factors

There are a few main factors that continue to pose problems for developers interested in trying to maximize the use of hydro electricity in the province, shown in Table 6.

Table 6. Barriers to hydro

Barrier Description	Barrier Removal Measures
Public acceptance. For hydro projects to proceed they must be developed in a way that is acceptable to the public. Large hydro developments and the resultant flooding and habitat destruction are likely to face steep public opposition, although some reservoirs have become popular public lakes, albeit artificially created. Even small and other low impact hydro projects, like other renewable projects, may face local landowner concerns.[113]	Adherence to strict and transparent environmental criteria and protocols, for example those set out by EcoLogo, would help considerably in fostering public support for hydro projects. Involving local community stakeholders from the beginning of proposed projects is also vital. Utilization of run-of-the-river technologies as opposed to building dams should also reduce public opposition.
Environmental impact. Very large hydro projects in particular tend to be highly controversial and if they result in upstream flooding, they can have enormous impacts on upstream and downstream ecosystems.	Limiting size and ensuring full impacts are considered is vital. Things to consider include: - change in ecosystem type (e.g., reservoirs can change existing river habitat into more lake-like habitat) - upstream fish migration delays or barriers - downstream fish migration delay - downstream fish mortality - predator-prey dynamics Employing run-of-the-river technologies is one approach that limits environmental impact of hydro because no reservoirs are required. Measures to reduce impacts on fish (e.g., fish passages or ladders) are also key.
Regulatory and permitting procedures. Developing hydro projects can be particularly challenging from a permitting perspective because they involve "navigable waters" and therefore require permitting from both provincial and federal authorities.	Burdensome permitting and approval procedures can be overcome via pilot permitting and training programs.
Proximity of existing infrastructure. The economics of hydro developments are greatly dependent on the distance of the resource to roads and transmission infrastructure.	A thorough resource inventory should be conducted for the province and sites closer to existing infrastructure should take priority over more distant ones.

3.4.4 Advantages of Hydro

Water is a very dense material and as a result relatively small projects can produce very large amounts of electricity. Hydroelectricity also lends itself well to storage because water can be kept in reservoirs from wet season to dry. Run-of-river hydro systems can be designed to minimize ecological impacts on the rivers where they are deployed. While water levels will vary the capacity of a hydro plant throughout the year, the electrical output from hydro systems is very predictable on an hour to hour and month to month basis.

Figure 23. The Integrated Manure Utilization System in Vegreville, Alberta, generates electricity and uses waste heat for internal processes

Photo: David Dodge, The Pembina Institute

3.5 Biomass and Biomass Cogeneration (Including Biogas)

3.5.1 Technology Description

Biomass, a category that includes all organic matter that can be used as a fuel, is often associated with transportation fuels, but it can also be used as a sustainable fuel for generating electricity. The term generally includes resources such as sawdust, woodchips and other forest waste, straw and other agricultural residues, as well as sources of methane such as from landfills, waste water and agricultural sources. Though burning biomass produces emissions as with any other fuel, it is considered clean because it is merely releasing carbon that was previously absorbed from the atmosphere, and so is a net-zero emission process (at least in terms of GHG). Although the combustion of biogas releases carbon dioxide, the alternative to this combustion leaves the biomass material to decompose, which results in the release of methane, a gas with significantly higher effects on climate change.

In some countries energy crops are also grown specifically for generating electricity. Though this is certainly possible in Alberta, this report will only consider bioenergy from waste because of the controversial nature of energy crops that in some cases compete with food crops. While some fuel crops, such as "switch grass" or "saw grass," can be grown on very marginal soils, and there is increasing global interest in using algae as a fuel, these options are notcurrently used in Alberta. To keep estimates very conservative, they are not considered for the purposes of this report.

As with burning any fuel, biomass electricity is generated most efficiently in cogeneration applications (see section 3.7). Without the recovery of heat from the burning process, the efficiency of that process is as low as 25%.[114] In cogeneration applications, such as the Iron Creek plant south of Viking,[115] efficiency can be as high as 80–90%.

3.5.2 Scale of Resource

Although further research is needed to estimate the potential for generating electricity from biomass, even with imperfect data it is obvious that this is a significantly under-utilized opportunity. Alberta Agriculture estimates that about 7,000 GWh of electricity could be generated annually if the full potential for agricultural biomass was realized, which is some 12% of current electrical energy consumption.[116] Solid biomass such as wood residues could meet an additional 6% of current generation according to the Alberta Energy Research Institute.[117] A 2006 study estimated that there was an additional 108,000 GWh (390 PJ) of annual energy generation potential from biomass waste of all kinds.[118]

Although the population of Germany is almost 30 times that of Alberta there is about one head of livestock for every two people whereas in Alberta there are more than two head of livestock per person.[119] Using this rough estimate one would expect Alberta to have roughly a fifth the agricultural biomass resource as Germany. Germany had installed more than 3,700 biogas plants with a capacity of almost 1,300 MW as of 2007 and more than 3,000 MW of capacity is expected by 2020.[120] It is worth noting however, that there is significantly more free range ranching in Alberta than Germany, making the resource more difficult to harvest, but nonetheless, it is clear when a country wants to take advantage of this resource it can.

3.5.3 Constraining Factors

Biomass energy development in the province is and may continue to be hampered by a number of factors.

Table 7. Barriers to biomass energy development

Barrier Description	Barrier Removal Measures
Distance between fuel supply and demand. Biomass is used optimally where feedstocks are located immediately beside where the power generated will be utilized.	Biomass electricity in Alberta is thus ideally used in towns or industrial facilities near to where the biomass fuel is concentrated.
Low density of fuel production. Biomass tends to be generated/grown in a decentralized nature which makes using it in urban areas a challenge.	Feedlots, capped landfills, sewage/waste water treatment plants, large food processing facilities and forestry operations are already existing concentrators of biomass wastes. Initial efforts to tap into biomass potential should focus on such facilities.
Land use. Even if biomass is only sourced from waste products it can have land use implications. For example, a biomass plant based on a garbage dump is premised on the continued existence of large amounts of waste continually being generated.	Focus on "win-win" situations that use waste products that will be generated no matter what such as methane in waste water treatment plants.

3.5.4 Advantages of Biomass Systems

Biomass systems offer various advantages not only compared to conventional technologies (they are renewable) but also compared to other renewable options. Because the economics of biomass cogeneration improves as annual run-times increase biomass can be considered a base load technology. Because fuel can be stored intra-seasonally and boilers can be stoked on demand they can be considered "dispatchable" (unlike wind). Another distinctive benefit of biomass technologies is the promise they offer for diversifying and strengthening the economies of rural areas.

3.6 Geothermal Electricity

3.6.1 Technology Description

Geothermal means "ground heat." Geothermal energy is most often associated with heating applications such as ground source heat pumps but the term also refers to the generation of electricity using natural energy from deep within the earth.

There are two distinct types of processes to generate electricity using heat from the ground: hydrothermal and enhanced geothermal systems (EGS). Hydrothermal electricity is widely used around the world and is considered a proven technology. Hydrothermal electricity uses naturally-occurring steam or hot water to turn a turbine that generates electricity.

Enhanced geothermal systems include several sub-categories (volcanic rock, sedimentary rock, etc.). EGS involves conventional drilling of geothermal wells deep enough into the earth surface to reach temperatures hot enough to boil water. Water is then pumped from the surface into fissures in the hot rocks and the resultant steam rises to the surface to turn a turbine. In Alberta, rocks with temperatures sufficiently high to be suitable for the electricity generation are found between 3 and 10 km deep.[121]

Google's philanthropic arm recently announced more than $10 million in research to develop EGS.[122] Although there are still very few proven EGS projects the technology has huge potential. In June 2008, France unveiled the world's first operational EGS project. The 1.5 MW generating plant, based on injecting water into wells drilled to a depth of 4 km, is now feeding electrical energy to the grid.[123]

The considerable experience Albertans have with drilling for oil and gas should be easily transferable to geothermal electric technologies, which is a considerable advantage when evaluating job re-training and business shifting opportunities and deserves emphasis because this may help create enthusiasm for geothermal technologies going forward.

3.6.2 Scale of Resource

Although, compared to other jurisdictions, very little information has been gathered on the size of the Alberta's geothermal potential, research data that is available shows that the potential is enormous.

The United States, as of 2004, already had more than 2,500 MW of installed hydrothermal generating capacity.[124] Over 10,000 MW of generating capacity has been installed globally.[125] Estimates by the American Geological Survey suggest that between 95,000 and 150,000 MW of hydrothermal generating potential exists in America.[126] So far, no research has been conducted to estimate the scale of the resource in Alberta and where it may be located. The hot springs at Jasper, Radium and Banff suggest that there may at least be a resource along the eastern slope of the Rockies. No research has yet been conducted to determine if a resource exists at greater depths farther from the mountain parks (projects in other jurisdictions have rarely required drilling deeper than 3 km[127]). As a result, Alberta's hydrothermal resources could be very small or could be huge.

There is a similar lack of conclusive research on the potential of EGS in Alberta. In the United States, it has been estimated that more than 3750 billion GWh (13,500,000 EJ) of thermal energy may be available down to 10 km below the earth's surface. The most detailed study to date in Alberta suggests that the potential in the province may be enormous. An estimated 21 billion GWh of energy are released every year underneath the surface of Alberta at depths of less than 5 km.[128] Even with the conservative assumption that only 0.5% of this potential is recoverable, it represents the equivalent of roughly 14,000,000 MW of generating capacity, more than 1,100 times the current total installed generating capacity in Alberta.[129] This amount does not include potential resources deeper than 5 km. Given the relatively immature nature of geothermal technology and today's drilling technology, it is unclear what proportion of this potential would be economically viable without subsidies. A consortium of players, including Shell and Suncor, has formed to look at the potential for EGS in the oil sands.[130]

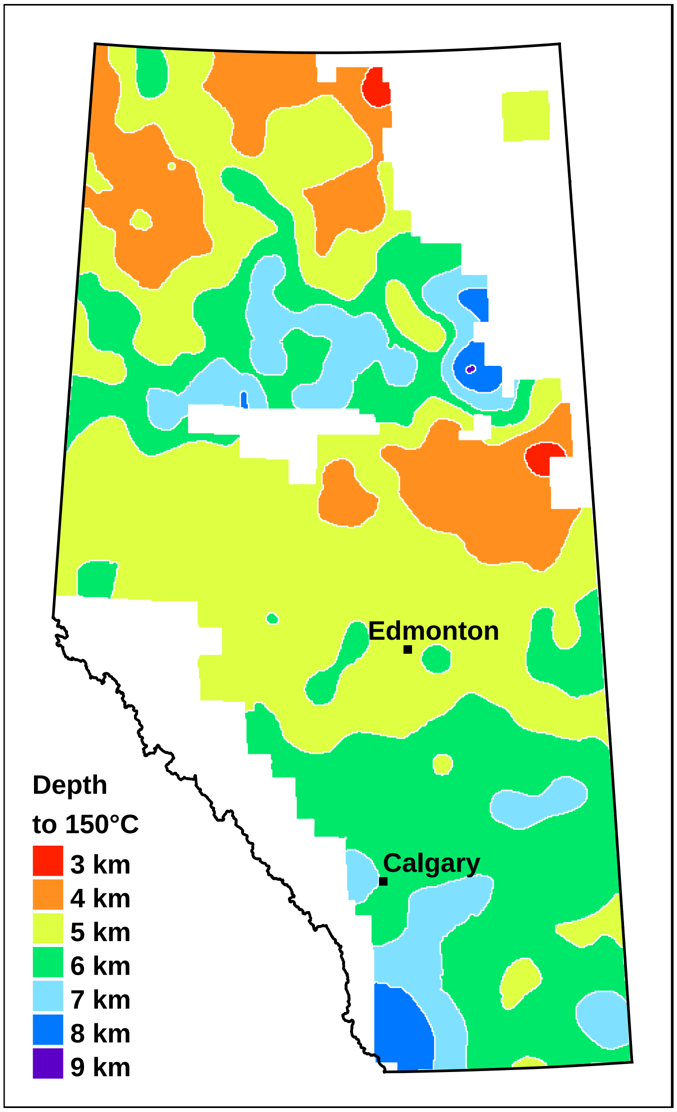


Figure 24. Map of Alberta's enhanced geothermal system potential

Map: Roland Lines, The Pembina Institute.
Source: Adapted from Moore and Majorowitcz

3.6.3 Constraining Factors

There are various factors that limit both hydrothermal and EGS technology in the province (see Table 8). Some factors apply to the less mature EGS technology and not the more proven hydrothermal technology.

Table 8. Barriers to geothermal electricity

Barrier Description	Barrier Removal Measures
Lack of awareness. Very little time has been given to considering geothermal electric technologies in the province, and in most of Canada.	Education is required to raise awareness of the potential for geothermal energy in general and geothermal electricity in particular. Public campaigns to educate Albertans about renewable energy should be carried out that include geothermal electricity. There are several firms actually developing sites in Canada, particularly in British Columbia. The completion of such projects will help to improve awareness.
Uncertain resource. In the case of both hydrothermal and EGS more research is needed to confirm the existence of a sufficient resource before any investors are likely to commit to projects.	A detailed study mapping the quality and quantity of Alberta's resource is required in order to estimate scale of resource. This information needs to be made public.
Drilling challenges. Conventional oil and gas wells drilled in Alberta tend to average a depth between 1 and 2 km with some of the deepest reaching more than 7 km.[131] If research confirms that there are sufficient geothermal resources within this depth then technical drilling issues may not prove a problem. If no resources are identified at shallower depths exploiting geothermal resources may still be feasible despite the greater depths required (up to 10 km below the surface) and would create technical difficulties which would have to be overcome although there are precedents of deeper wells elsewhere. In the 1970s Russian scientists successfully drilled to a depth of 12 km, a record that has still not been broken.[132]	While wells of 1 or 2 kilometers deep are the norm in Alberta, many wells in Alberta are drilled to depths of 4 km and some as deep as 7 km. Alberta has significant experience in drilling and experimenting with new drilling techniques. Existing research programs should shift from conventional petroleum drilling to geothermal. Research dollars currently allocated to developing drilling capability in the oil patch should reallocated to applying existing knowledge to geothermal applications.
Uncertain costs. With few existing examples of operational EGS units in the world the capital cost of EGS units is difficult to estimate. If pilot projects prove too costly then there may be little interest in developing the province's resource.	Costs are no less certain than CCS which has already received significant public investments both provincially and federally. The potentially vast scale of geothermal resources in Alberta warrants significant consideration in this same vein.

3.6.4 Advantages of Geothermal Electricity

Geothermal is the renewable energy best able to provide base load. Because residual heat is still left over after the naturally occurring heat has been used to generate electricity, geothermal can simultaneously provide zero-emission heating and cooling for buildings (assuming buildings are adjacent to the plant).

Figure 25. The Southampton District Energy geothermal CHP plant in Southampton, U.K., provides the entire neighbourhood with clean power, heat and cooling from a geothermal electric plant

Photo: Used with the permission of SCC and Utilicom

3.7 Cogeneration for Industry and Buildings

3.7.1 Technology Description

Cogeneration refers to the simultaneous production of electricity and heat by burning a single fuel. Although cogeneration is not renewable (unless the fuel is biomass) it can be considered a form of energy efficiency, and, because it offers considerable potential for reducing emissions it is included within the portfolio of options recommended for Alberta's electricity generation.

With cogeneration, more useful energy is produced from the burning fuel because heat that would otherwise be wasted is recovered. For example, a typical natural gas-fired generating plant is only about 45% efficient. A gas-fired cogeneration plant in contrast can be up to 90% efficient by recovering the waste heat for use in space or water heating or an industrial process. Any heat used in this manner also displaces fuel that would have otherwise been burned thereby conserving fuel and reducing emissions. The heat from cogeneration plants can also be used by absorption chillers to provide industrial or space cooling. Cogeneration therefore relates more to how technologies are designed and used rather than incorporating a different technology. Cogeneration can be on any scale from very large applications in refineries to tiny machines in individual homes (such as the WhisperGen Stirling engine currently being piloted by Enmax, as covered in Section 3.9). Cogeneration plants are based on proven standard engine generators, gas turbines and steam turbines as well as emerging technologies such as microturbines, Stirling engines and fuel cells. Cogeneration plants can use any fuel but for this report we only consider natural gas. (Biomass-fired cogeneration plants are included under the biomass sub-section.)

Figure 26. The Southern Alberta Institute of Technology supplies electricity and heat to the campus using the cogeneration units in its Energy Centre

Photo: David Dodge, The Pembina Institute

3.7.2 Scale of Resource

The capacity of grid-connected cogeneration plants in Alberta has expanded rapidly since deregulation from about 500 MW in 1998 to about 3,500 MW in 2006.[133] This is largely a result of the oil sands companies in Fort McMurray moving away from grid power to much more efficient onsite cogeneration.[134] Much potential remains for the large industrial facilities that still purchase electricity from the grid despite burning considerable volumes of natural gas for onsite heat/steam requirements. There are also many large commercial and institutional buildings that could be employing cogeneration plants.

Although much cogeneration has already been developed in Alberta, the potential is not fully exploited. The technical potential is strongly linked to the requirements for on-site or nearby thermal energy for heating or cooling and has been estimated to be more than 8,000 MW of electrical generating capacity.[135] Alberta has considerable need for space heating in the winter and industrial heat year round. There is also growing need for space cooling in the summer and many industries also require year round cooling. Considering the likelihood that thermal energy loads for new buildings and industrial developments could be met through the use of waste heat from electricity generation the scope for cogeneration is vast. Enmax is currently constructing a cogeneration plant to provide heat and electricity to buildings in downtown Calgary.[136] Industrial proponents such as developers of the proposed Athabasca Oil Sands Project upgrader near Edmonton are also including cogeneration plants in their plans.[137]

Figure 27. ENMAX is currently constructing a district energy plant in downtown Calgary to provide heat to the surrounding buildings. There are plans to eventually turn it into a cogeneration plant using waste heat from an electricity generator.

Images: Courtesy of Enmax

3.7.3 Constraining Factors

Several important factors remain that are preventing the full potential of cogeneration from being realized in the province.

Table 9. Barriers to cogeneration

Barrier Description	Barrier Removal Measures
Seasonal variation in heat demand. Because cogeneration economics are driven by demand for heat, reduced demand for space heating in summer makes some cogeneration projects less attractive unless another use for the heat can be found (for example, cooling processes, laundry or an industry that needs heat in summer).	Technologies that could alleviate this challenge include integration of thermal storage and improved cooling integration. Using existing thermal storage technologies allows heat from the summer to be stored for use in the winter and low winter temperatures to provide cooling in the summer. Various technologies exist but most common is using water or earth as the storage medium. These technologies complement cogeneration perfectly. Better integration of existing technologies such as absorption chillers (a technology which allows excess heat in the summer to provide cooling) is another way of dealing with the same challenge.
Difficulty securing host buy-in. Cogeneration is not a core business of industrial project developers. In order for cogeneration projects to proceed the project needs support of factory managers or property managers yet these decision makers are more concerned with maintaining productivity or tenants.	The most important strategies for encouraging host buy-in include market design that provides transparent information about financial benefits of cogeneration including tariffs that can be earned from electricity sale, reduced exposure to electricity price volatility, and financial benefits from improved reliability. Elimination or reduction to exposure to risk from gas price volatility and maintenance issues can be guaranteed from outsourcing cogeneration construction operation and maintenance to third parties. Industrial zone planning could be built on an eco-industrial networking model or regulations could be drawn to require cogeneration in buildings or industry under specific conditions based on precedents in other jurisdictions.
Cost premium. There is a premium required in up front capital cost between a cogeneration unit and a conventional furnace or boiler. Securing additional financing needed to upgrade to cogeneration can be problematic.	Improved financing schemes will prove important and the fostering of third party investors in the form of Energy Service Companies (ESCOs) would also prove important, including development of training programs for ESCOs by industry.

3.7.4 Advantages of Cogeneration

The main benefit of cogeneration as a source of energy is that is provides stable generation which can act like base load generation. When natural gas fired it has much lower emissions than other forms of fossil-fired generation because of its increased efficiency. Cogeneration can also employ either a renewable fuel such as biomass or geothermal heat, in which case its emissions are zero. In the case of cogeneration in buildings the technology can also have the benefit of raising the awareness of energy issues to building tenants.

3.8 Recovered Industrial Energy

3.8.1 Technology Description

Every day more than the equivalent of tens of thousands of barrels of oil are wasted in Alberta industrial facilities in the form of waste heat from combustion processes, steam exhausted through cooling stacks, and unutilized pressure releases from compressed gases and flares. If the energy is of sufficient quality (i.e., high enough temperature or pressure) it is often possible to drive a turbine and generate electricity.

Figure 28. Maxim's Gold Creek plant turns valuable waste heat from a compressor station into electricity that is sold to the grid

Photo: Courtesy of Maxim Power

3.8.2 Scale of Resource

Some estimates show that such resources in the United States could meet 19% of total energy consumption.[138]

The best publicly-available data on the potential of waste heat recovery in Alberta suggests that there is a minimum potential equal to 375 MW of generating capacity,[139] about the size of a typical large coal plant. The resource is geographically tied to the province's main industrial areas, such as Fort McMurray and Fort Saskatchewan.

3.8.3 Constraining Factors

Table 10 lists the main factors limiting investment in recovered industrial energy.

Table 10. Barriers to recovered industrial energy

Barrier Description	Barrier Removal Measures
Lack of high quality data. Insufficient data exists in the province on the scope of the potential to determine what projects may be feasible. Preliminary data suggests there is potential but this needs to be tested.	Alberta needs to conduct a detailed survey of potential resources by sector.
Prerequisite of cooperation of host facility. Energy recovery projects cannot proceed without the support of the host facility where the waste energy stream to be recovered is being produced.	Market design that provides transparent information of financial benefits of energy recycling including tariffs that can be earned from electricity sale, reduced exposure to electricity price volatility, and financial benefits from improved reliability. Eliminate or reduce exposure to risk from gas price volatility and maintenance issues by outsourcing construction operation and maintenance to third parties. Industrial zone planning can be built on an eco-industrial networking model or regulations can be drawn to require energy recovery in industry under specific conditions based on precedents in other jurisdictions.
Lack of third party developers. Because electricity is not the core business of potential industries where industrial waste energy recovery exists, host companies tend to be risk adverse when opportunities present themselves. Third party "energy service companies" have therefore tended to be the key to realizing potential elsewhere but there is a lack of such companies in the province.	Improved financing schemes will prove important and the fostering of third party investors in the form of Energy Service Companies (ESCOs) would also prove important, including development of training programs for ESCOs by industry.

3.8.4 Advantages of Recovered Industrial Energy

The main advantage of recovering energy from existing industrial operations is that the fuel is free. Heat that would otherwise be exhausted or pressure differentials that would be released are instead captured and used to generate electricity. As well as being free, the fuel also has zero net GHG emissions — the process just captures more value from fuel that has already been used. In some cases industrial energy recycling can also improve general plant efficiency, which helps optimize productivity.

3.9 Micropower

Micropower is a term that incorporates all technologies that generate electricity at a very small scale compared to centralized generating plants — technologies that can be purchased by farmers, homeowners or small businesses to generate all or part of their electricity requirements. Definitions of what is included with this term vary, but for this report micropower includes rooftop solar photovoltaics (PV), residential scale wind turbines and residential scale cogeneration.

3.9.1 Technology Description

Solar Photovoltaics

Solar electric modules, which use the photovoltaic (PV) process, convert the energy in solar radiation directly into direct current electricity. The price of solar PV systems has been decreasing steadily over the last several decades.[140] PV systems are ideally suited for onsite power production and, in countries leading the way with PV development, they are commonly integrated directly into building cladding such as roof shingles or walls (as in the case of the Yellowknife NWT federal building, see Figure 29). The solar PV market is the fastest growing energy sector in the world. It has been growing at 42% per year for the last 15 years.[141] The majority of PV being installed work wide now feed directly into the grid.


Figure 29. Left: Residential solar system in Red Deer. Right: Building-integrated solar PV in the Yellowknife federal building, NWT.

Photos: Gordon Howell (left); Tim Weis (right)

Microwind

Microwind turbines are much smaller capacity versions of the large industrial-scale wind turbines described previously. The generating capacity of a typical microwind turbine would range from 0.4 kW to 100 kW. The turbines are typically mounted on poles fastened by guy-wires, while some manufacturers including units sold from Canadian Tire can be installed on manufacturers' monopole.

Figure 30. Small-scale wind turbines are ideal for many farms and acreages

Photo: Tim Weis, Pembina Institute

Micro-Cogeneration

Micro-cogeneration units are smaller applications of the cogeneration concept explained previously. Small units based on a variety of technologies, such as internal combustion engines, external combustion engines, microturbines or fuel cells, provide heat and electricity simultaneously from a single fuel, typically natural gas. Units can range from the size of a kitchen appliance, supplying energy for a single family dwelling, to larger units for multi-family units or larger businesses.

Figure 31. Technologies such as this one being piloted by Calgary's Enmax simultaneously provide electricity and heat for a house from a single fuel

Photo: courtesy of Whispertech

3.9.2 Scale of Resource

Solar

The solar resource in Alberta is sufficient to meet total demand for electricity. Japan installed more than 400 MW of PV power in 2007 alone, more than the size of Alberta's average coal plant.[142] The United States installed about 260 MW of solar in the same year whereas Germany installed almost 1,300 MW, more than Alberta's 3 biggest coal units combined.[143] Figure 32 shows that Alberta has some of the best solar resource in the country. The best available data shows that the average resource in Alberta is 1,100–1,400 kWh of electricity generated per kilowatt of installed PV capacity per year.[144] This can be compared to Germany, where the average is less than 1,000 kWh/kW/year.[145]

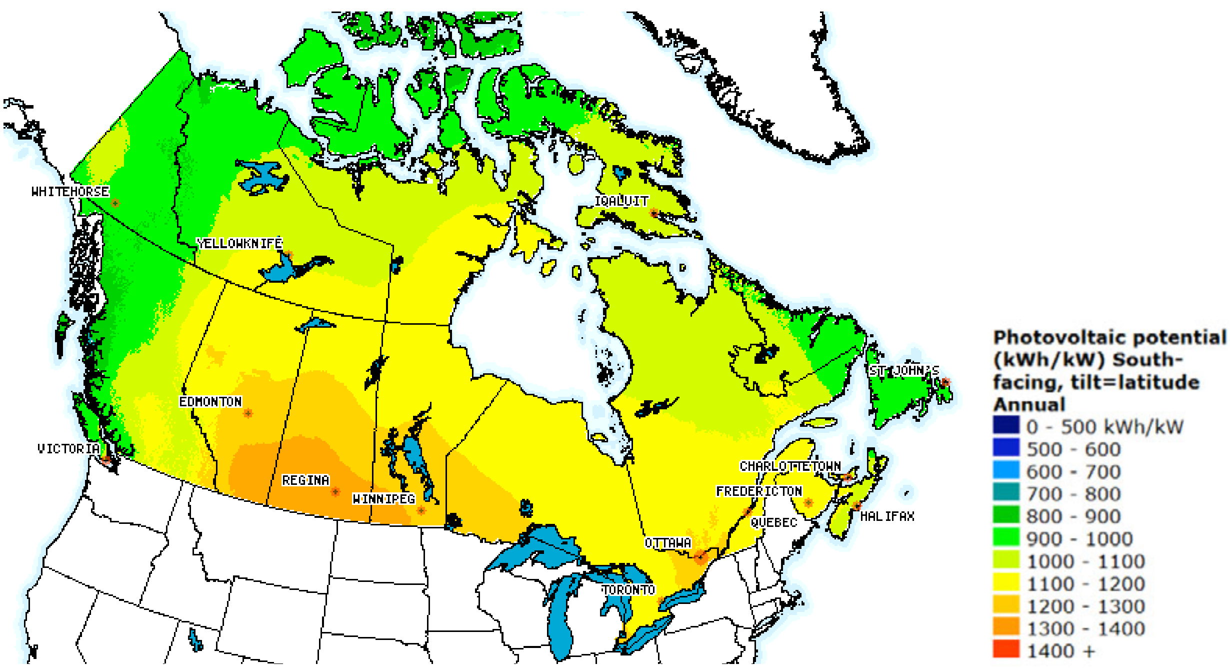


Figure 32. Solar photovoltaic potential in Canada

Source: Natural Resources Canada[146]

Microwind

> Germany, which has a land mass approximately half that of Alberta, installed almost 1,300 MW of solar power in 2007, more than Alberta's three biggest coal plants combined.

Microwind potential is largely rural and such applications are ideal for farms or acreages, albeit highly conditional on the presence of a sufficient wind resource. There may also be limited potential in urban areas, including open areas, such as light industrial areas and school yards, again assuming the presence of a suitable resource. The Canadian Wind Energy Association has estimated that there is 600 MW of microwind potential in Canada.[147]

Micro-Cogeneration

Alberta in many respects is an ideal market for micro-cogeneration: heating seasons are long, retail natural gas markets and corresponding gas infrastructure are well established and the deregulation of the electricity market allows those who invest in the technology to increase rate of return by allowing any excess power to be sold to the grid. Based on studies of the potential for micro-cogeneration uptake in European countries[148] an estimated 75–110 MW is thought to be a realistic estimation of the potential over the next 20 years in Alberta.

3.9.3 Constraining Factors

The main factors holding back investment in microgeneration are shown in Table 11.

Table 11. Barriers to microgeneration

Barrier Description	Barrier Removal Measures
High cost. Despite continuing cost reductions micropower technologies are still among the most expensive options for generating power and they are expected to remain so for the foreseeable future. In the case of solar, for example, installation costs plus operation and maintenance as well batteries, inverters, etc., if required, further add to the cost of PV bringing cost to $0.30-0.60/kWh and up.[149,150]	Like any technology, expanded production/sales are expected to drive down costs via economies of scale and competition. In the case of solar and micro-cogeneration especially, technology breakthroughs could also be an important factor in cost reduction. For example thin-film solar technologies, although less efficient than more common crystalline technologies can be produced much more cheaply. Innovation in the various micro-cogeneration technologies can similarly be expected to result in cheaper manufacturing. Government financial support could also play an important part in overcoming cost barriers for individual investors. Examples include grant programs, feed-in tariffs and tax breaks.
Labour shortages. Shortage of skilled labour to install the micropower technologies will limit uptake.	Training programs for microgeneration installers, maintenance staff as well as electrical and gas inspectors and utility staff are required. Such programs could be based on programs elsewhere.
Persisting interconnection issues. Because micropower is used optimally in grid-connected contexts, remaining obstacles to interconnection in the province (e.g., application procedures, technical requirements) will impede uptake.	The Microgeneration Regulation and Alberta Utilities Commission Rule 24 should largely address the concern from a legal perspective, but there will likely be remaining barriers of a more administrative nature (i.e., excessive paperwork). Fees may also be a continuing issue. Establishing streamlined and standardized application procedures will help overcome this issue.

3.9.4 Advantages of Micropower

Micropower's greatest advantage is that it involves more people directly in the production of energy which raises general energy literacy. Families and businesses investing in micropower learn also about the importance of energy efficiency and visible projects such as solar panels or wind turbines also generate awareness among neighbours. From a grid perspective some micropower technologies are more advantageous than others. Solar PV helps alleviate peak constraints during the summer; thermal technologies sized to meet local demand can be seen as negative loads.

3.10 Virtual Power Plants

3.10.1 Technology Description

Virtual power plants can imply one of two concepts: "demand response" and "networked distributed generation." In either case, a network of many small, geographically dispersed electricity resources are controlled remotely via a single operator. In the case of networked distributed generation, dozens or even hundreds of small generators are started by remote control via intelligent hardware over the Internet. In the case of demand response, dozens or hundreds of appliances consuming electricity are turned off (or to a lower power setting) via remote control, thus freeing up electricity for other users. Both approaches are typically (though need not necessarily) associated with controlling "peak" demand (see section 1.2). An example of "networked distributed generation" could be a company controlling a network of generators installed in office buildings for emergency or backup power. An example of "demand response" could include a network of pumps that can be remotely changed to a slower speed to conserve energy. The saved energy or "negawatts" can then be sold to the grid.

Figure 33. Remotely removing demand at peak times has the same effect on the overall system as supplying new power

Photo: Courtesy of EnerNOC

Although we do not include virtual power plants in the figures of our scenarios illustrating generation, we have considered the potential in estimating what is realistic for some of the more variable technologies such as wind or hydro. Virtual power plants therefore show up indirectly in the generation graphics (Figure 37 and Figure 38) and are shown directly in the peak graphics (Figure 39 and Figure 40). The more virtual power plants you have on the grid the more easily the grid can accommodate larger amounts of variable technologies such as wind. In peak times when there is insufficient wind the virtual plants can be called upon to reduce demand.

3.10.2 Scale of Resource

There are various examples in the United States where "demand response" equals between 5 and 10% of overall capacity. For example, in the state of Connecticut "virtual power plant" operators can remotely curtail electricity demand for up to 750 MW, 10% of total peak demand, upon request.[151] In other jurisdictions it has proven easier to install virtual power plants in industrial applications than the building sector. Because about two thirds of electricity demand is industrial (more than the jurisdictions where the technology has so far been pioneered) the potential in Alberta for virtual power plants is likely even bigger.

3.10.3 Constraining Factors

The main factors holding back investment in virtual power plants are outlined below.

Table 12. Barriers to virtual power plants

Barrier Description	Barrier Removal Measures
Lack of experience. There is currently a lack of companies with experience in developing virtual power plants in Alberta.	Modification of protocols will be required to reward dispatchable renewable power or incent provision of ancillary services. AESO has begun this process and already has one of best in North America, but it will need updating as new technologies emerge.
Prerequisite of cooperation of host facility. Like cogeneration projects, virtual power plant projects cannot proceed without the support of the host facility.	Protocols which sufficiently recognize the benefits of ancillary services will garner private interest.
Outdated Grid. Virtual power plants are only possible in grids with sophisticated metering and control system infrastructure that currently is not the norm in Alberta.	As identified in the provincial energy strategy, financial support for metering updates and/or strengthened protocols can overcome this barrier.

3.10.4 Advantages of Virtual Power Plants

A virtual power plant's greatest asset is that it can provide power instantaneously in a flexible manner when it is needed. Such flexibility is exactly what is needed to allow greater penetration of variable technologies, such as wind. Virtual power plants have the added benefit of not adding to the problem of pollution. Because virtual power plants often involve third party equipment, they can also raise awareness of energy efficiency at host sites, which can help drive interest in optimizing energy efficiency. A leading example of the application of this technology is EnerNOC, a company that has pioneered a profitable business model based on paying businesses to reduce energy usage during times of peak demand. EnerNOC manages hundreds of demand response events throughout North America from its Network Operations Centre in Boston, MA (see Figure 33).

3.11 Power Storage

3.11.1 Technology Description

As of 2007, Denmark generated almost 20% of its annual electricity from wind, while Spain and Germany relied on wind for close to 10% of their electricity consumption. On a particularly windy day in March 2008, 40% of Spain's power was coming from wind.[152] These countries are leading the world in wind energy development. To date they have done so without incorporating energy storage systems, in large part because they are well interconnected with neighbouring countries and can buy and sell power during fluctuations. However, as variable renewable energy sources play larger roles in supplying power, managing these variations will become increasingly important. Through short- and long-term shortage systems, renewable energy can provide reliable base load as well as be dispatchable to meet peak demands.

Storage technologies will have to play an increasing part in Alberta's future because they are needed to complement variable technologies, particularly wind power, to ensure that electricity is available for use when required. Adding power storage to the grid will allow our future base load and peak power needs to be met primarily with renewable power sources. Various storage options exist, including well-established technologies such as pumped water storage, and innovative ideas such as reversible flow batteries, compressed air storage, flywheels, supercapacitors, fuel cells, lithium ion batteries or even plug-in electric vehicles, all of which are described in detail in the Pembina Institute's power storage primer released in June 2008.[153]

As of 2007, there was 110 GW of pumped hydro storage in use globally, and about 850 MW of other types of storage — mostly compressed air and sodium-sulphur batteries. Sodium-sulphur and vanadium redox flow batteries are showing the highest market growth rates.[154] In 2008, Minnesota-based utility, Xcel Energy announced it would develop the first application of battery storage for wind generators in the United States.[155]

Storage capacity is measured by the following:

1. power capacity (MW) — the maximum rate at which power can be stored and released
2. energy capacity (MWh) — the amount of energy that can be stored equal to capacity times number of hours of storage
3. power density — the energy capacity per unit volume of storage

The particular specifications are unique to each technology and configuration.

3.11.2 Constraining Factors

Each specific storage technology has its own specific benefits and challenges, but several common elements exist.

Table 13. Barriers to electricity storage technologies

Barrier Description	Barrier Removal Measures
Lack of experience. There are few utility-scale examples storage systems globally.	Pilot projects in Alberta are required similar to investments being made in CCS research and development.
Cost structures. Because storage technologies do not generate any electricity, their revenue depends solely on being able to shift electricity availability from times of low demand and revenue potential to times of high demand and revenue potential.	Like virtual power plants, modification of protocols will be required to reward dispatchable renewable power or benefits to ancillary services.

3.11.3 Advantages of Power Storage

Besides firming up variable power sources, power storage technologies have many other benefits for power grid operators and distribution utilities. These include bringing stability to the entire grid, allowing better management of peak demands, reducing transmission needs and improving power quality and frequency regulation. Storage technologies can also help mitigate errors in both load and renewable resource prediction.

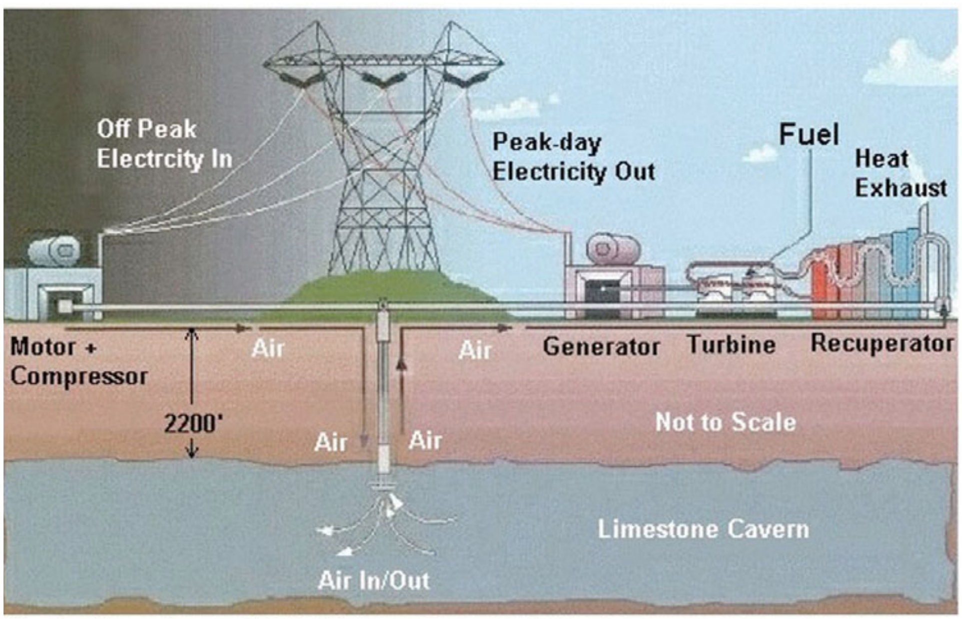


Figure 34. Electricity storage system

Source: Electricity Storage Association[156]

3.12 Summary of Supply Options

Table 14 summarizes the potential of the various technologies outlined above.

Table 14. Summary of potential technologies

Technology	Approximate Cost	Approximate Resource realizable in AB
Efficiency	$27/MWh [157]	3,200 MW [158]
Wind	$75/MWh [159]	64,000 MW [160]
Hydro	$60/MWh [161]	11,600 MW [162]
Biomass	$60/MWh [163]	15,500 MW [164]
Geothermal	$70/MWh [165]	10,000 MW [166]
Cogeneration	$75/MWh [167]	10,000 MW [168]
Recovered Industrial Energy	$25/MWh [169]	2,000 MW [170]
Micropower	$250/MWh [171]	11,500 MW [172]

4. Pale Green Scenario

4.1 Summary

By employing conservative estimates of the clean energy deployment potential over the next 20 years in Alberta, Figure 35, shows that Albertans are able to meet the consumption that is projected by AESO with a diverse range of clean energy options.

The three technologies featuring most prominently in the scenario (end-use efficiency, wind and natural gas fired industrial cogeneration) all grow steadily between 2008 and 2028. *Keephills 3* (a conventional coal plant) along with all other plants that have been confirmed by AESO as going ahead are included in the scenario. The scenario includes no new unconfirmed coal or nuclear but existing coal plants are assumed to start being retrofitted with CCS in 2018, the same year federal regulations require that new coal plants must be utilizing CCS. In the early years gas peaking plants are relied upon to meet consumption but feature less prominently in later years, being used primarily to complement wind power.

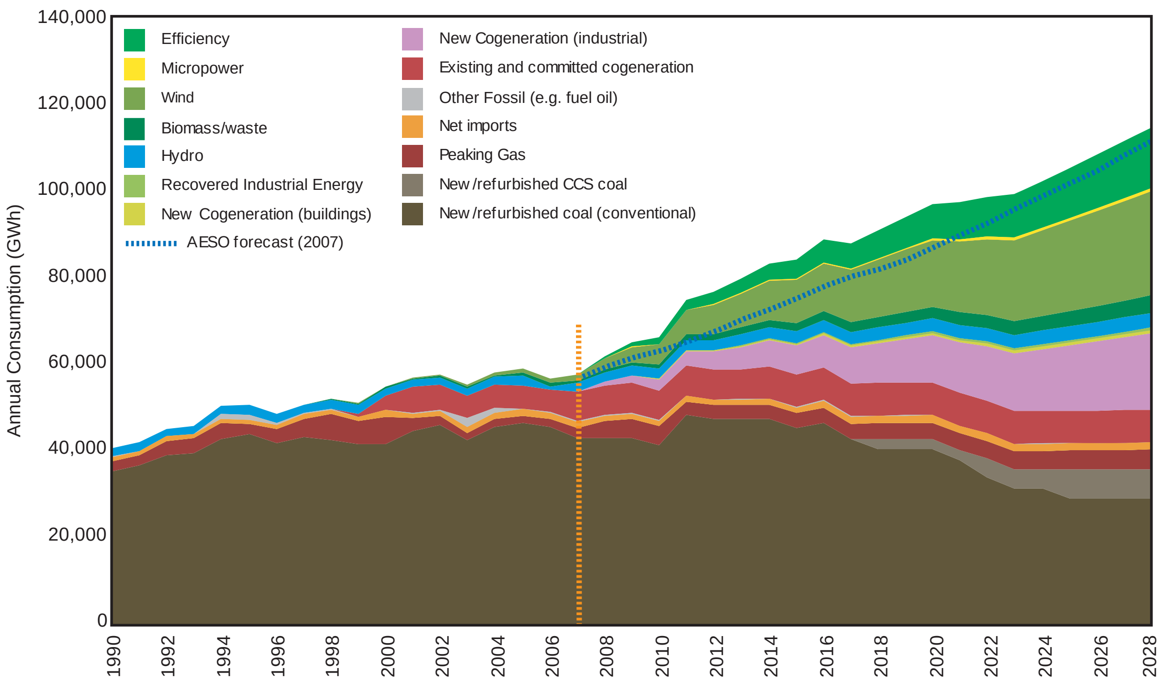


Figure 35. Pale Green scenario for meeting future electricity demand

Figure 36 shows that although there is a high proportion of wind the portfolio is able to reliably meet consumption even at peak times. The scenario exhibits a 14% reserve margin in the final year, which exceeds the target set by the North American Electric Reliability Corporation, the bilateral agency in charge of enforcing grid reliability.[173] This margin is achieved after having de-rated by wind by 80%.

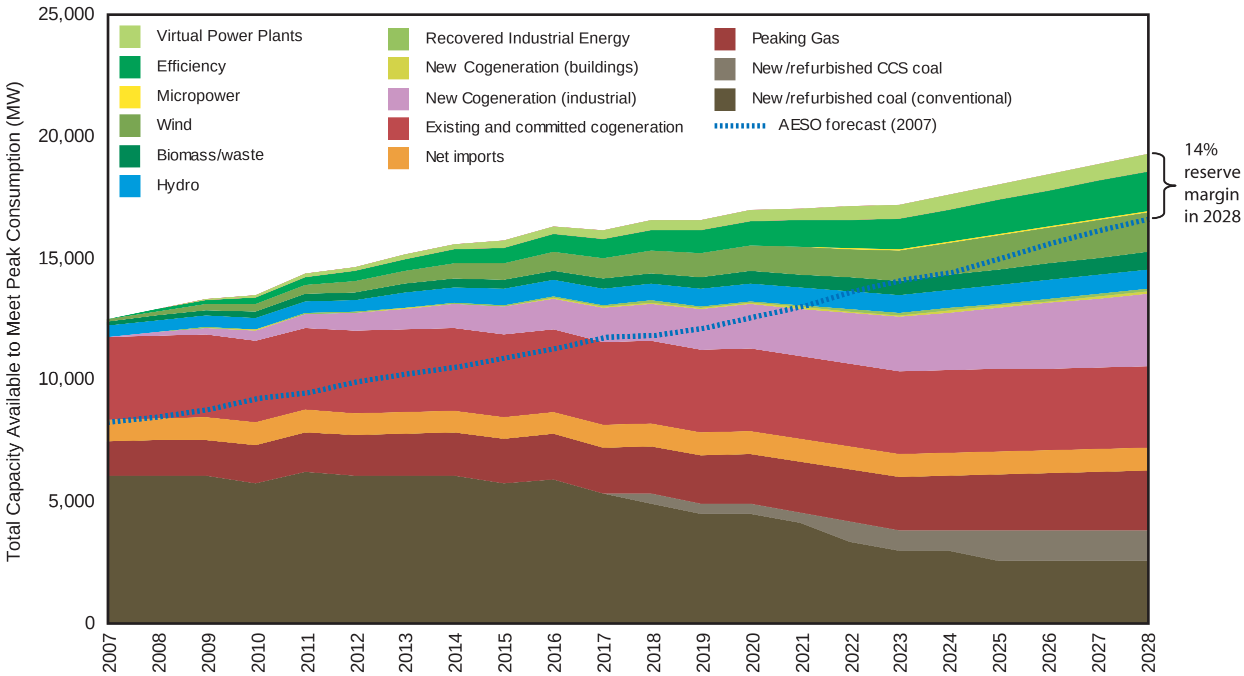


Figure 36. Pale Green scenario for meeting future electricity peak demand

The key aspects of the scenario are summarized in Table 15. Each clean energy option is discussed in turn in more detail in the sections that follow, where assumptions and logic are explained.

Table 15. Summary of technology assumptions for Pale Green scenario

Technology	Capacity assumed (MW)	Core Assumptions
Efficiency	1,590	• A detailed study of the potential for energy efficiency for industrial, commercial, residential and farm sectors is commissioned by the Government of Alberta • Financial incentives are tied to efficiency investments • A series of “energy efficiency workshops” are organized for all major industries, including conventional upstream oil and gas, conventional downstream oil and gas and petrochemicals, oil sands, forestry, manufacturing etc.
Wind	7,400	• Additional transmission lines are built between the southern wind resource and the Calgary region. • Some energy storage and peak shaving capacity (see virtual power plant section) will come online which will help wind smooth its generation and ensure power from wind is available when the customers demand it whether or not the wind is blowing. • About 2/3 of the proposed 11,000 MW of wind projects would have to go ahead (financing would have to be achieved, labour and equipment obtained etc.)
Hydro	500	• Government of Alberta takes the lead in developing a publicly accessible hydro potential database • A tiny fraction (1/22) of the hydro potential identified by the Canadian Hydro Association would have to be developed
Biomass and biomass cogeneration	500	• One or two new major waste water treatment plants adding onsite power capability • Several new wood waste cogeneration projects in the forestry sector go ahead • Some smaller biogas agricultural projects.

Geothermal	0	n/a
Cogeneration for Industry	2,860	• Minimum number common to all of the AESO generation scenarios plus 500 MW • New projects in Fort McMurray and Fort Saskatchewan's "Upgrader Alley" being built with onsite power plants of sufficient size that excess power can be fed to the grid • Between 1998 and 2006 about 3,000 MW of capacity came online in Fort McMurray alone which proves that there is precedent for this type of capacity growth for cogeneration
Cogeneration for Buildings	100	• The 50 MW district energy plant currently being proposed by Enmax for downtown Calgary goes ahead, along with one major addition to that project or a similarly sized project in another Alberta community
Waste heat recovery	105	• Approximately a quarter of the estimated potential in the province is realized over the next 20 years, although the estimated potential likely underestimates the total potential (data only includes stacks over a 50 m tall and is not a complete inventory)
Micropower	185	• Mix of small solar, wind and cogeneration developed • Political commitment to micropower in the form of incentives such as feed-in tariffs, capital grants, etc. • Municipal leadership in the form of policies favourable to micropower (for example building permit standards that require a certain percentage of a building's energy come from renewables, as is common in the U.K.) • Incentives to attract PV entrepreneurs to Alberta
Virtual Power Plants	710	• AESO expects a peak demand for power in 2024 of 14,250 MW, 5% of which is roughly 712 MW • The amount is thought to be realistic based on precedents already achieved in other jurisdictions
Storage	770	• Combined with virtual power plants, this represents 20% of wind power capacity

4.2 Core Assumptions and Justifications

4.2.1 Efficiency

In July 2008 the Canadian Premiers, including Premier Ed Stelmach, committed "to achieving a 20% increase in energy efficiency (including electricity) by 2020." While no specifics around the definition of the goal were released, nor any details of policies or programs announced, it was nonetheless assumed that the government will keep its stated commitment over the next 12 years for the Pale Green scenario. A 20% reduction of end-use electrical efficiency from 2008 generation over a 12-year period translates into an annual improvement of approximately 1.85%. If we extrapolate this number over a 20-year period, this represents approximately 13,910 GWh of annual savings by the year 2028 (equivalent to 1,590 MW of capacity). This, therefore, is the number we have assumed is achievable between now and 2028 for our Pale Green scenario.

Examples of activities that could make a big impact include optimizing size and number of pumps and compressors in the oil and gas sector and investing in intelligent control software to ensure pumping and compression occur off-peak and only when required. In the building sector efficiency would involve bringing the operation of all buildings up to best practices, upgrading lighting and cooling systems and using on site micro-generation. In the residential sector efficiency would involve replacing light bulbs and upgrading refrigerators, computers, home entertainment and other electrical appliances to more efficient models. In any sector these changes will involve investments in hardware, awareness-raising campaigns, education initiatives, incentives and favourable policies. An effective energy efficiency strategy for the province could identify the most effective policies and actions.

4.2.2 Wind

We used the most optimistic of the latest AESO projections of 7,400 MW[174] of new wind installations estimated between now and 2027 as our number for what is achievable in the Pale Green scenario. There are international precedents showing that this amount is achievable in far less than 20 years. Spain, with an area smaller than Alberta, installed 3,522 MW of new capacity in 2007 alone and over 8,750 MW in the last four years.[175] In order for this amount to be achievable Alberta would require the following:

- Additional transmission lines would have to be built between the southern wind resource and the Calgary region. AESO would have to identify need in a "Need Identification Document." Texan regulators recently approved $4.9 billion to upgrade transmission lines specifically to accommodate wind.[176]
- Some energy storage and peak shaving capacity (see virtual power plant section) will come online, which will help wind smooth its generation and ensure energy is available when the customers demand it, whether or not the wind is blowing. Gas-fired peaking capacity would also help firm up variable output generation, such as wind.
- About two thirds of the proposed 11,000 MW of wind projects would have to go ahead (financing would have to be achieved, labour and equipment obtained, etc.)

4.2.3 Hydro

For our Pale Green scenario we assume that 500 MW of low-impact hydro potential are realistic, which is less than 5% of what the Canadian Hydro Association has estimated as possible in the province. This is equivalent to two thirds of the default number used in all AESO generation scenarios.[177] In order for this to happen, the Government of Alberta needs to take the lead in developing a publicly accessible hydro potential database.

4.2.4 Biomass and Biomass Cogeneration (Including Biogas)

In our Pale Green scenario we assume that an additional 500 MW of solid and gaseous bio-electricity is realistic for Alberta. Meeting this capacity would only require using biomass feedstocks that are currently wasted (for example, capturing methane from wastewater treatment plants that is currently vented into the atmosphere or wood waste that is left to decompose on sawmill properties or burned). Agricultural waste such as feedlot waste and waste from food processing plants would also be utilized. This additional biomass capacity would comprise

- one or two new major waste water treatment plants adding onsite power capability
- several new wood waste cogeneration projects in the forestry sector
- some smaller biogas agricultural projects.

4.2.5 Geothermal

We assume for the purposes of the Pale Green scenario that no geothermal capacity is built either in the form of hydrothermal or EGS.

4.2.6 Cogeneration for Industry

For our Pale Green scenario we have assumed that an additional 2,860 MW of industrial gas-fired cogeneration is likely to come online over the next 20 years. This number is modestly bigger than the minimum number common to all of the AESO generation scenarios (2,360 MW) and likely implies any new projects in Fort McMurray and Fort Saskatchewan's "Upgrader Alley" being built with onsite power plants of sufficient size that excess power can be fed to the grid. Between 1998 and 2006 about 3,000 MW of capacity came online in Fort McMurray alone[178] which illustrates that there is precedent for this type of capacity growth for cogeneration.

4.2.7 Cogeneration for Buildings

For our Pale Green scenario we have assumed that 100 MW of building integrated cogeneration over the next 20 years. Apart from campuses and hospitals there is little precedent for building integrated cogeneration in the province. We are assuming that the 50 MW district energy plant currently being proposed by Enmax for downtown Calgary goes ahead along with one major addition to the that project or a similarly sized project in another Alberta community.

4.2.8 Recovered Industrial Energy

For the purpose of our Pale Green scenario we have assumed about 105 MW of industrial waste energy recovery is developed. About a quarter of the estimated potential in the province, can realistically be realized in the province over the next 20 years. Given the fact that the data likely underestimates the total potential (data only includes stacks over a 50 m tall and is not a complete inventory), we feel this estimate is conservative.

4.2.9 Micropower

For our Pale Green scenario we assume that 185 MW of micropower capacity will be installed between now and 2028. This amount includes an estimated 60 MW of solar, 20 MW of microwind and 105 MW of micro-cogeneration. Again, precedent in other jurisdictions shows this is achievable. Germany has installed more than 4,000 MW of solar PV in the last 10 years with 1,300 MW of new capacity installed in one year alone (2007).[179] Already in 2003 Germany had installed about 30 MW of micro-cogeneration[180] and the American Wind Energy Association estimated that 50,000 MW of small wind turbines could be installed by 2020.[181] In order for 185 MW to be achievable Alberta would require:

- Political commitment to micropower in the form of incentives, such as feed-in tariffs and capital grants. The existing microgeneration regulation provides retail rate for any electricity from qualifying systems fed to the grid provided the system is sized to meet internal load only.[182] Additional policies that provide a premium (i.e., above retail rate) to systems and/or reward systems that are sized larger than to meet local needs would provide additional incentive for micropower systems.
- Municipal leadership in the form of policies favourable to micropower (for example building permit standards that require a certain percentage of a building's energy come from renewables, as is common in the U.K.[183])
- Incentives to attract entrepreneurs to Alberta (for example the Canadian solar PV company Arise was lured to Germany to build their new factory thanks to generous incentives from the German government). In Germany "grants of up to 50% of the capital cost of plant and equipment are available from German federal and state governments to a maximum investment of €50 million. These grants are available in the form of refundable tax credits for expenditures incurred."[184]

4.2.10 Virtual Power Plants

Five percent of peak capacity is a reasonable penetration to expect for virtual power plants based on precedents elsewhere. For example, Connecticut has 750 MW of "demand response" out of 7,500 MW peak. Similarly, New England has 1,500 MW compared to its 30,000 MW peak, and the Pennsylvania New Jersey Maryland Interconnection region (PJM mid Atlantic) has 4,500 MW out of 140,000 MW.[185] AESO expects a peak demand for power in 2024 in Alberta of 14,250 MW, 5% of which is roughly 710 MW. 710 MW of peak clipping capacity in Alberta by 2028 is therefore thought to be a conservative estimate of what is achievable in the province. Assuming this amount of virtual power plant capacity comes on line between now and 2028 helps justify the large amount of wind in the Pale Green scenario.

4.2.11 Power Storage

Between the various storage technologies there are already some 150 MW of advanced battery storage capacity installed in North America and another 20 MW in the pipeline, as well as 110 MW of compressed air storage in North America with 3,500 MW in the pipeline.[186] Given that storage potential also includes pumped storage (an estimated 25,900 MW already existing in North America), our estimate of 770 MW is thought to be reasonably conservative. The assumption is also premised on Alberta research institutes and government departments making energy storage a research and demonstration priority.

5. Green Scenario

5.1 Summary

If Albertans made the development of clean energy a priority, Figure 37 shows that projected demand would be easily met and exceeded by the available clean options and would simultaneously allow phasing out of existing coal.

The same three technologies prominent in the Pale Green scenario (end-use efficiency, wind and industrial cogeneration) feature even more significantly in the Green scenario and make up the lion's share of the generation. In addition, however, the Green scenario includes a variety of other technologies in greater abundance, such as biomass, hydro, micropower, cogeneration in buildings, waste heat recovery, and also modest amounts of geothermal. As with the other scenarios any plants confirmed as going ahead by AESO have been included, notably the Keephills 3 coal plant being built west of Edmonton. The plant is assumed to be retrofitted with CCS (90% capture) in 2018.

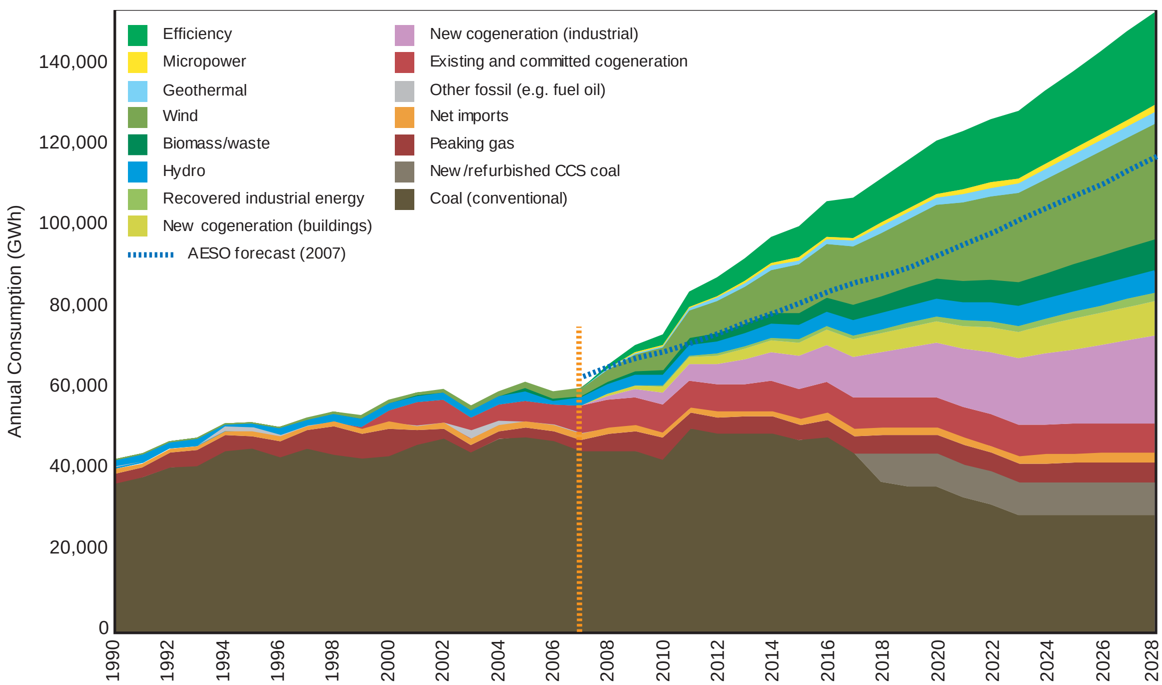


Figure 37. Green scenario for meeting future electricity demand

The scenario demonstrates that sufficient excess generation from clean sources is possible to allow the phase out of coal in Alberta, as is currently being done by the government in Ontario. This is illustrated in Figure 38, which is another version of the same scenario. Alternatively new export markets for excess clean generation could be explored (shown in Figure 37).

Figure 39 and Figure 40 show the same scenario from the perspective of ability to meet peak consumption without and with coal phase out respectively. Figure 39 shows that if coal is not phased out supply reliability can easily be met even with a heavy utilization of variable wind power. The scenario results in a reserve margin of 31%, more than double the North American Electric Reliability Corporation target.[187] Figure 40 shows that even with the phase out of all existing coal, reliability could still be maintained; a reserve margin of 19% exceeds NERC targets by a healthy margin. A more detailed hour by hour analysis for meeting the forecast base and peak demands using the portfolio of technologies outlined in this scenario is included in the appendix.

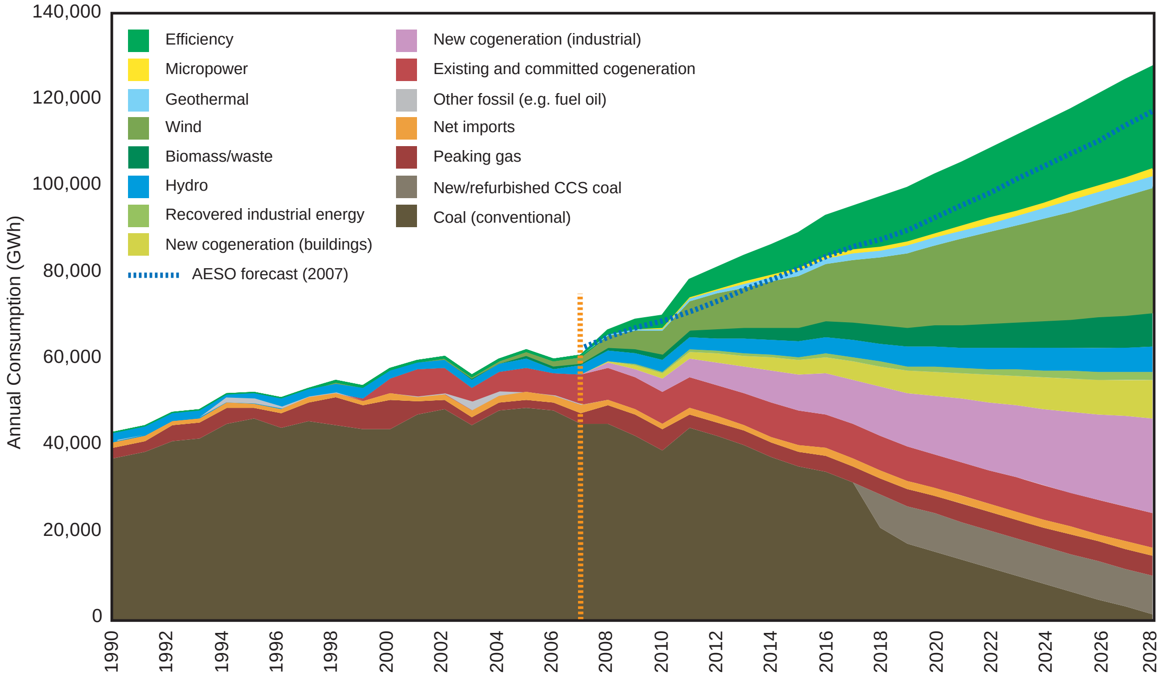


Figure 38. Green scenario showing coal phase-out

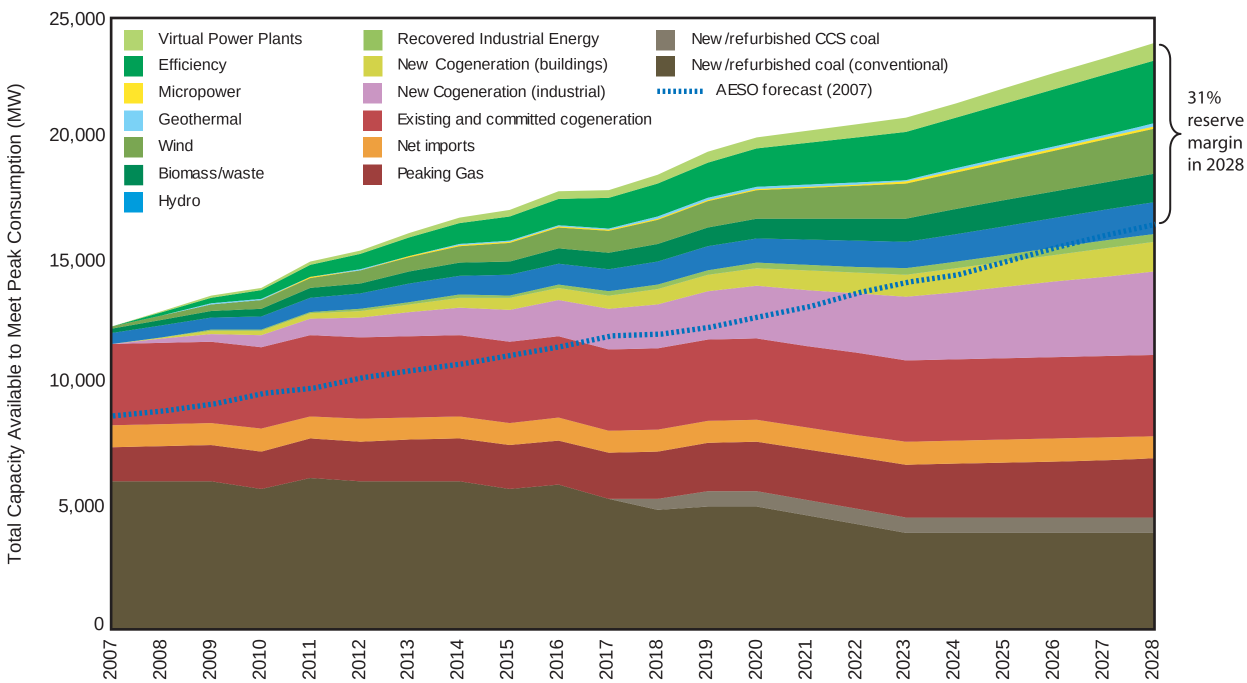


Figure 39. Green scenario for meeting future peak demand

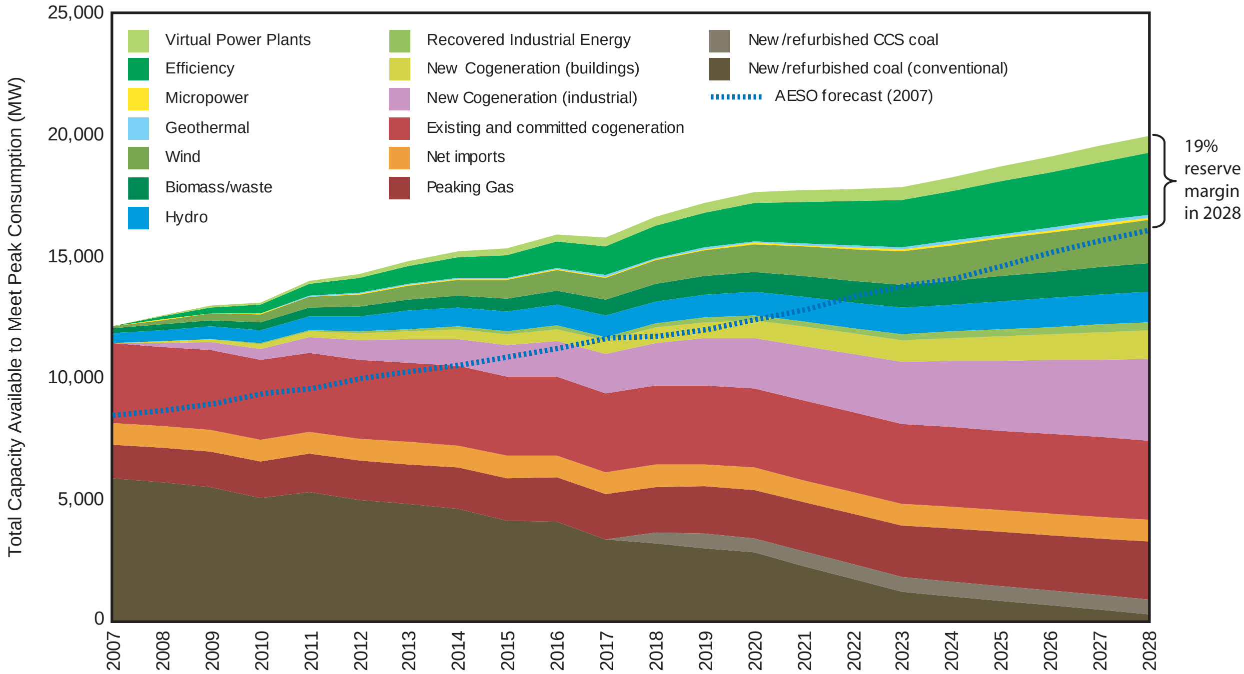


Figure 40. Green scenario for meeting future peak demand (with coal phase-out)

Given that phase out of coal is possible in the Green scenario, existing plants are not assumed to be retrofitted with CCS as in the Pale Green scenario; rather, as illustrated in Figure 38 and Figure 40, existing plants are phased out linearly.

The scenario is summarized in Table 16. Each clean energy option is discussed in turn in more detail in the sections that follow, where assumptions and logic are explained.

Table 16. Summary of technology assumptions for Green scenario

Technology	Capacity assumed (MW)	Core Assumptions*
Efficiency	2,530	• Renewed interest in energy intensity targets by government • Aggressive province-wide promotional and educational campaign to tie economic goals to efficiency improvements • Investing large portion of oil and gas revenues/government surpluses in rolling funds to provide low-interest financing for energy efficiency in homes and businesses • Series of major government RFPs for third party energy services provider (ESCO) contracts in the province specific to all the major industries
Wind	8,350	• Much of the potential for virtual power plants in the province is captured which can be relied upon in times when the wind is not blowing • Additional storage capability is built in the province • Communities in which the wind resource is rich will benefit from the developments
Hydro	1,500	• One eighth of the potential identified in the province will go ahead
Biomass	1,000	• Considerable additional new research dollars will be put into biomass technology including a government-funded research mission to Europe where Alberta farmers and investors can learn about the technology first hand • A detailed study will be conducted to determine the scale of the resource in the main sectors (forestry, waste and waste water, agriculture, food processing) • RFP for biomass technology pilot projects will be issued

Geothermal	400	• The most uncertain of all the assumptions in the Green scenario because very little information is available to give clues to the scale of the resource that will be economic to develop over the time frame of 20 years • 400 MW could be developed in a combination of ways • The hydrothermal resource is determined to exist in the province and then 4 major projects are developed over the next 20 years using technology that has been proven many times over in countries as diverse as the USA, Iceland and Indonesia • Modest technological improvements in EGS allow dozens of smaller EGS projects to proceed in the areas of the province where the resource is of sufficient quality to make projects economically attractive to investors • A combination of the above two cases is possible (for example two major hydrothermal projects and a half dozen EGS projects)
Cogeneration for Industry	3,360	• Mandate that all new upgraders or other major industrial projects generate their own electricity using high-efficiency cogeneration • Issue renewable portfolio standard for new cogeneration projects
Cogeneration for Buildings	1,190	• Based on 15% of what has been estimated as possible based on the heat requirements of buildings in the province • Although there is currently little CHP in buildings in Alberta, precedents in Denmark and elsewhere have shown that a society can greatly increase the percentage of cogeneration over a short period if the correct policies are put in place • Mandate that all new buildings join district energy where density is sufficiently high or have onsite power where sufficient thermal load exists • Issue RFP for new cogeneration projects, as has recently been done in Ontario or an renewable portfolio standard
Waste heat recovery	310	• Develop 75% of the potential of industrial energy recovery projects that have been identified based on preliminary estimates • Conduct a detailed inventory of where waste recovery potential exists for all major industries
Micropower	570	• This amount is less than one quarter over the next 20 years of what Germany installed in 2007 alone • Government of Alberta mandate that all existing and new buildings meet a proportion of their onsite energy needs with micropower systems • RFP to build micropower manufacturing capability in Alberta or RFP for micropower capacity with stipulation that the product must be built in Alberta
Virtual Power Plants	710	• Realistic based on precedents elsewhere that show that 5% of peak is a reasonable amount of demand response to expect to achieve
Power Storage	960	• Combined with virtual power plants, this represents 20% of wind power capacity
* Assumptions in addition to those in the Pale Green scenario		

5.2 Core Assumptions and Justifications

5.2.1 Efficiency

In our Green scenario we assume that about 22,200 GWh/yr of savings — the equivalent to the generation from 2,530 MW of generating capacity — can be captured between now and 2028 in energy efficiency measures. This is roughly equivalent to a 1.43% efficiency improvement per year from a baseline of 2008 over and above energy efficiency improvements typical of the Alberta economy (the efficiency of energy use in Canada has tended to improve at about 1% per year historically).[188] The number is based on the most optimistic scenario of what is possible in Alberta, as detailed in an industry commissioned report.[189] In order for this potential to be realized, a concerted effort by the government would be required through either an energy efficiency strategy, as described in section 7.2, or an Energy Efficiency Act.

5.2.2 Wind

In the more ambitious Green scenario we assume that the equivalent of 75% of all the wind projects currently in the queue to connect to the Alberta grid go ahead between now and 2028. This is the equivalent of about 8,350 MW of capacity, more than double what is common to all the AESO scenarios (3,600 MW), or about 20% more than most ambitious AESO scenario (7,400 MW). This is achievable if

- Much of the potential for automated reduction of electricity demand (either at peak times or when wind is not blowing) is captured in the province and can be relied upon when the wind is not blowing (see sections 3.10 and 4.2.10).
- Additional storage capability is built in the province. For example compressed air storage technologies under turbines are being piloted which would allow wind-turbine-storage hybrids to supply at average output throughout the year, greatly increasing the reliability of wind.[190]
- Communities in which the wind resource is rich will have to benefit from the developments. Communities will either have to invest in turbines directly (as the wind industry was pioneered in Denmark) or those who do invest will have to explore methods of sharing benefits more directly with those landowners in the communities where there is potential for building wind capacity.

5.2.3 Hydro

In the Green scenario we assume 1,500 MW of low-impact hydro is built in the province. This is equivalent to developing about one eighth of the potential in the province as identified by the Canadian Hydro Association.

5.2.4 Biomass and Biomass Cogeneration (Including Biogas)

Installing 1,000 MW of new biomass/biogas fired capacity between now and 2028 is thought reasonable in the Green scenario. Germany saw more than 5,000 small biogas power plants installed between 1995 and 2005 representing more than 500 MW capacity.[191] In 2006 5.4 billion kWh of electricity was generated from biogas in Germany, about 10% of what Alberta generated from all sources in the same year.[192] Our number includes development of both biogas and solid biomass. For Alberta to realize this potential the following would be required (in addition to that described in section 4.2.4):

- Considerable new research dollars need to be put into biomass technology, including the government-funded research mission to Europe, where Alberta farmers and investors can learn about the technology first hand.

- A detailed study needs to be conducted to determine the scale of the resource in the main sectors (forestry, waste and waste water treatment, agriculture, food processing)
- RFP for biomass technology pilot projects is issued.

5.2.5 Geothermal

We assume in the Green scenario that 400 MW of geothermal electricity can be built in the province between now and 2028. This is the most uncertain of all the assumptions in the Green scenario because very little information is available to give clues to the scale of the resource that will be economic to develop over the time frame of 20 years. We could see the 400 MW being developed in a combination of two ways.

The hydrothermal resource is determined to exist in the province and then four major projects are developed over the next 20 years using technology that has been proven many times over in countries as diverse as the USA, Iceland and Indonesia. The Philippines developed more than 1,000 MW of hydrothermal capacity in 15 years.[193]

Modest technological improvements in Enhanced Geothermal Systems (EGS) allow dozens of smaller EGS projects to proceed in the areas of the province where the resource is of sufficient quality to make projects economically attractive to investors.

In reality we assume that a combination of the above two cases is possible (for example two major hydrothermal projects and a half dozen EGS projects).

5.2.6 Cogeneration for Industry

For our Green scenario we assume over 3,360 MW of new industrial cogeneration capacity is built in the province. The number is an average of what is currently being projected by various industry projections and is about 1,000 MW more than what is common to all AESO scenarios. The number is also thought to be conservative because neither the industry studies nor AESO fully account for large cogeneration projects which are likely in Fort Saskatchewan's "Upgrader Alley." In order for this potential to be realized Alberta would have to (in addition to those steps outlined in section 4.2.6):

- Mandate that all new upgraders or other major industrial projects generate their own electricity using high efficiency cogeneration.
- Issue a Renewable Portfolio Standard (RPS) to require minimum amounts of electric cogeneration projects compared to pollution rates.

Although it is not considered as part of this report, if CCS becomes more cost effective, cogeneration plants should also be considered for mandatory CCS, either directly onsite or through a carbon pipeline.

5.2.7 Cogeneration for Buildings

For the Green scenario we assume that about 1,190 MW of new cogeneration in buildings is constructed over the next 20 years. The estimate for building integrated cogeneration is based on 15% of what has been estimated as possible based on the heat requirements of buildings in the province. Although there is currently little combined heat and power in buildings in Alberta, precedents in Denmark and elsewhere have shown that a society can greatly increase the percentage of cogeneration over a short period if the correct policies are put in place.[194] Ontario[195] has recently taken steps to encourage cogeneration. In order for this potential to be realized in Alberta, the following would have to be done (in addition to those steps outlined in section 4.2.7):

- Mandate that all new buildings join district energy where density is sufficiently high or have onsite power where sufficient thermal load exists.
- Offer incentives for new cogeneration projects in existing buildings.

5.2.8 Recovered Industrial Energy

For the more ambitious Green scenario we assume that Alberta could develop 75% of the potential of industrial energy recovery projects available (310 MW), which would require the following:

- Conduct a detailed inventory of where waste recovery potential exists for all major industries.
- Offer a capital cost incentive for host or third-party developers of energy recovery projects.

5.2.9 Micropower

The Green scenario foresees 570 MW of new micropower between now and 2028, including almost 300 MW of rooftop PV, 60 MW of microwind and 210 MW of microcogeneration. The PV amount over 20 years is less than a quarter of what Germany installed in 2007 alone.

The other estimates are thought to be similarly conservative. Nevertheless, for them to occur in Alberta, the developments outlined in 4.2.9 would have to go ahead, as well as the following:

- Government of Alberta mandates that all existing and new buildings meet a proportion of their onsite energy needs with micropower systems.
- RFP to build micropower manufacturing capability in Alberta or RFP for micropower capacity with stipulation that the product must be built in Alberta. The Quebec government did this in 2005, which has successfully driven investment in various manufacturing facilities in the province.[196]

5.2.10 Virtual Power Plants

For the Green scenario we assume that a minimum of 710 MW of virtual power plant capacity comes on over the next 20 years. This number is thought to be realistic based on precedents elsewhere that show that 5% of peak is a reasonable amount of demand response to expect to achieve.

5.2.11 Power Storage

North America already has an estimated 26,160 MW of storage capacity, including utility scale advanced batteries (150 MW), compressed air storage (110 MW) and pumped storage (25,900 MW).[197] Given the increasing interest in storage, the 960 MW estimate in the Green scenario is thought to be reasonably conservative, especially because it is also premised on Alberta research institutes and government departments making energy storage a research and demonstration priority.

6. Conclusions

The preceding three chapters outlined three possible scenarios (Business-As-Usual, Pale Green and Green) for Alberta's electricity future. Each of the scenarios is plausible. What the future holds will depend largely on the priorities and actions of Alberta's utilities, consumer demands and the leadership shown by elected officials.

6.1 Electricity Generation and Capacity

Table 17 summarizes the various technologies in each of the three scenarios, illustrating the total energy generated in 2028, as well as the estimated amount of capacity available to meet peak demand that year.

Table 17. Comparison of scenarios showing 2028 generation and capacity available to meet peak demands

	Scenario					
	Business-As-Usual		Pale Green		Green*	
Technology	Annual GWh	Peak MW**	Annual GWh	Peak MW**	Annual GWh	Peak MW**
Nuclear	15,418	2,200	0	0	0	0
Coal (conventional)	35,723	4,149	29,022	2,549	1,289	300
Coal (CCS)	16,456	2,210	6,701	1,200	8,213	600
Gas (peaking)	5,866	3,148	4,499	2,368	4,499	2,368
Gas (industrial cogeneration)	30,476	6,128	25,019	6,128	28,093	6,629
Gas (buildings cogeneration)	0	0	701	100	8,344	1,191
Recovered industrial energy	0	0	632	103	1,897	309
Hydro	5,343	1,669	3,372	785	5,450	1,259
Biomass	555	178	4,059	678	7,563	1,178
Wind	16,486	1,488	23,967	1,579	26,867	1,768
Micropower	0	0	687	37	1,668	114
Geothermal	0	0	0	0	2,803	113
Efficiency	0	0	13,909	1,588	22,190	2,533
Imports	1,664	494	1,664	900	1,664	900
TOTAL	127,986	21,664	114,231	18,015	120,540	19,263
Reserve Margin		25%		14%		19%
Non-Generation Technologies						
Virtual Power Plants		0		710		710
Storage		0		770		960
* assumes coal-phase out variation						
** denotes MW capacity available at peak times (wind derated by 80%, micropower by 80%, hydro by 50%, etc.)						

6.2 Environmental Impacts

By multiplying the annual generation numbers in the three scenarios by an "emission factor" for each of the technologies we can estimate what kind of impacts the various scenarios would have. Table 18 and Table 19 below illustrate that Alberta could almost stabilize GHG emissions from the electricity sector by 2028 (compared to 1990) by choosing the Pale Green scenario; or, more than halve emissions by 2028 via the Green scenario (compared to 1990). The Business-As-Usual scenario results in absolute increases in emissions no matter what base year is chosen despite the increased use of wind and cogeneration as well as CCS.

Table 18. Comparison of Alberta's cumulative emissions from its electricity sector

Scenario	Business-As-Usual	Pale Green	Green*
Cumulative Emissions 2008-2028 (MtCO_2e)	1,165	1,095	772
Reduction compared to Business-As-Usual scenario (MtCO_2e)	n/a	70	394

* Assumes scenario with coal phase out

Table 19. Comparison of Alberta's annual electricity emissions for select years by scenario

Year	1990	2007	2020			2028		
Scenario	n/a	n/a	Business-As-Usual	Pale Green	Green*	Business-As-Usual	Pale Green	Green*
Annual Emissions (MtCO_2e)	39	50	55	52	27	51	42	17
% difference from 2007	n/a	n/a	+11%	+4%	-45%	+3%	-15%	-67%
% difference from 1990	n/a	+25%	+40%	+30%	-31%	+29%	+7%	-58%

* Assumes sub-scenario with coal phase out

6.3 Reliability Impacts

Significantly ramping up renewable resources for electricity generation offers many benefits, including reduced air and greenhouse gas emissions, and a diversification of supply mix, both geographically and in fuel type. However, as with any new technology, challenges to integrating variable output generators, such as wind power, into the system exist, particularly at increasing high levels of penetration. Many European countries have been dealing with these challenges for several years, and increasingly American states are looking into the issue.

There have been several recent studies into wind integration in the United States, notably the report by the Department of Energy, which suggests wind energy could provide 20% of total electricity needs in the United States by 2030.[198] This number is similar to estimates proposed in the current research. Some states would have a level of penetration much higher than 20%, and some with weaker wind regimes would have lower levels. Factors studied include the level of penetration, reliability considerations, the size of balancing areas, improved system flexibility, ancillary service requirements, wind forecasting and transmission requirements. There are several groups that are working on these issues including the Utilities Wind Integration Group (UWIG) and the North American Electric Reliability Corporation (NERC). Key findings of NERC's "Integration of

Variable Generation Task Force"[199] recognize that higher penetrations of wind power will require the following:

- Forecasting of resources must be improved to manage wind uncertainty.
- Flexibility of the bulk power system must be expanded to manage wind variability.
- Transmission must be constructed to enable management of both the uncertainty and the variability of wind resources.
- Regulators and policy makers must support the development of cost effective transmission resources, including equitable cost allocation guidelines for the delivery of both remotely located wind resources and ancillary services (such as spinning reserve and frequency response) to demand centres where such resources and/or services are deemed necessary and beneficial.
- A coordinated effort is needed to better determine appropriate calculations for measuring the availability of wind on peak.

6.4 Going Forward

By highlighting the technical and economic potential for clean energy options in the province, the Pembina Institute hopes to inspire investors in clean energy to demand transmission infrastructure that meets their needs while simultaneously inspiring the Government of Alberta, AESO and other stakeholders to work together to create a framework which levels the playing field for cleaner options in Alberta and allows local investors to capitalize on the emerging new industry that is "clean-tech."

No matter what route Albertans take to meet future electricity demand there will be challenges. Conventional coal-fired power plants will likely be disproportionately affected by surging commodity markets and will face increasing challenges securing skilled labourers as new green energy technology companies compete for scare human resources. Fossil fuels will also continue to encounter siting difficulties and new carbon pricing will shift the markets in favour of cleaner competitors. Cleaner options also face significant hurdles including high capital costs and grid infrastructure shortages. The Pembina Institute believes that the benefits of investing scarce resources in clean electricity capacity will offer higher long term returns than making future investments in coal and nuclear. A cleaner grid is not only a commendable goal, it is an achievable one.

Based on the above two scenarios it is clear that it is possible to develop a lower impact electricity portfolio in Alberta thanks to the wealth of renewable resources available. Clear leadership from the provincial government and the power industry will be required in order to take advantage of the potential and realize the many benefits that the cleaner option offers. It may not be realistic to expect the Alberta grid to become clean overnight, but over the next 20 years it is possible to move considerably toward a clean energy future that relies mostly on renewables and uses only a small proportion of fossil fuels. Investments in new renewable capacity or highly efficient transitional technologies are signs of progress. Further spending on coal or inefficient gas should be seen as a setback.

7. Getting to Green

Below we outline five recommendations that must be undertaken by the Government of Alberta in order to make progress in realizing the province's renewable energy potential.

7.1 Recommendation 1: Renewable Electricity Task Force

It has been demonstrated in the preceding section that no new coal or other unsustainable technologies (nuclear) are needed to reliably supply Alberta electricity. There at least three specific policy options that could be implemented in Alberta to make a renewable electricity system a reality, but an in depth analysis of the best approach is outside the scope of this report. This analysis must nevertheless be done, and it must be done as objectively as possible. In order to determine what actions and policies are best the Pembina Institute recommends that the Government of Alberta assemble a task force or expert panel, analogous to those that have already been assembled to look at nuclear energy and carbon capture and storage (CCS), to examine the best ways of promoting renewable electricity.

7.1.1 Precedent

Given that renewable energy and transitional technologies are, from a technical perspective, a feasible option for Albertans, these clean options deserve at least as much government attention as coal and nuclear. This is especially the case given that renewable options pose less environmental and financial risk than either coal or nuclear. As such, an Alberta task force on renewable energy is both a logical next step and a step that should meet little resistance politically. Table 20 and Table 21 document the previous panels that have been assembled for nuclear energy and CCS respectively.

Table 20. Alberta Energy Nuclear Energy Expert Panel

Findings			
Expected December 2008			
Position on Panel	**Name**	**Job Title**	**Organization**
Chair	Harvie Andre	president and CEO	Wenzel Downhole Tools
Member	Joseph Doucet	Professor, Energy Policy	University of Alberta
Member	Harrie Vredenburg	Chair, Competitive Strategy and Sustainable Development	University of Calgary's Haskayne School of Business
Member	John Luxat	Specialist in nuclear safety analysis	McMaster University

Source: Alberta Energy[200]

Table 21. Alberta Energy Carbon Capture and Storage Task Force

Findings			
Canada's Fossil Energy Future, The Way Forward on Carbon Capture and Storage, released January 9, 2008			
Position on Panel	**Name**	**Job Title**	**Organization**
Chair	Steve Snyder	President and Chief Executive Officer	TransAlta Corporation
Member	Ian Anderson	President	Kinder Morgan Canada Inc
Member	David Keith	Director, Energy and Environmental Systems Group, ISEEE	University of Calgary
Member	Kathleen Sendall	Senior Vice-President, North American Natural Gas	Petro-Canada
Member	Patricia Youzwa	President and Chief Executive Officer	SaskPower

Source: ecoENERGY Carbon Capture and, Storage Task Force[201]

7.1.2 Task Force Composition

Table 22 illustrates the suggested make up of an analogous task force that the government should assemble to consider the role of renewables in the province. Renewable Electricity Task Force members should also be selected to represent the renewable energy sector as a whole and therefore should include representatives for the full diversity of renewable energy technologies.

Table 22. Recommended structure for Alberta Energy Renewable Electricity Task Force

Findings	
Recommended to Release May 2009	
Position on Panel	**Organization**
Chair	Alberta Private Sector (non-energy related)
Member	Alberta Private Sector (wind energy leader)
Member	Alberta Academic (with renewable energy focus)
Member	Alberta Private Sector (other renewable energy leader)
Member	European Private Sector (renewable energy leader)

7.1.3 Timeline

The Pembina Institute recommends that the Renewable Electricity Task Force is convened in 2009, and the recommendations of the panel are released publicly during 2010.

7.1.4 Scope

The Renewable Electricity Task Force should be charged with deciding which of three key approaches, or combination of approaches, is best for promoting renewable energy in the Alberta context. The three distinct approaches have two things in common: each involves the introduction of a single, relatively simple policy, and each would effectively ensure a shift to clean energy as envisioned in this report.

Each of these approaches could prove an effective technique for moving the province toward a goal of increased renewable and transitional energy. The challenge that will face the Renewable Electricity Task Force is not only determining which of three approaches will be the most effective, but also which is the most politically feasible. Polls show that the majority of Albertans support actions to clean the environment along the lines of the options proposed;[202] this fact should make the job of the task force easier.

It is also worth noting that the strategies described below need not be mutually exclusive. Combined, the approaches could be even more effective. The general scope of work for the Renewable Electricity Task Force should be to look at each of the strategies more carefully, evaluating the performance of such strategies in other jurisdictions and considering how they may need to be fine-tuned to best work in the Alberta context. The final report of the Renewable Electricity Task Force should include an annotated analysis of the pros and cons of each approach along with a clear choice of which approach or combination of approaches should be chosen, along with explicit recommendations on how the Government of Alberta should proceed to best promote renewable and transitional electricity in the province.

Option One: Significantly increase the price of carbon pollution

The quickest way to increase the proportion of renewable and cleaner transition technologies in Alberta's electricity mix is by shifting the cost burden for pollution arising from electricity production from society as a whole to those who supply and use electricity — in short, incorporate the true cost of pollution into the market. Alberta has already made the commendable step of in effect introducing a price on GHG in the province. With the introduction of the Climate Change and Emissions Management Amendment Act (and its accompanying Specified Gas Emitters Regulation) Alberta companies had three options for complying with the rules aimed at reducing GHG intensities by 12%. Companies could either: 1) reduce GHG emission intensity of their operations, 2) buy carbon credits in the Alberta-based offset system or 3) pay $15 into the Climate Change and Emissions Management Fund for every tonne over their reduction target.[203] Because paying into the fund tends to be the cheapest option the price of carbon has effectively been capped at $15 a tonne. There is evidence however that this price is insufficient to ensure the real reductions needed. Indeed, the 2008 Alberta energy strategy recognized the need to "increase this price over time."[204] In 2007 $40 million was collected by the Government of Alberta from large final emitters in order that they comply with the act.[205] At the same time overall GHG emissions in the province rose to an estimated 242,000,000 tonnes in 2007;[206] albeit without the act emissions would have likely risen by closer to 245,000,000 tonnes according to estimates from Alberta Environment.[207] Effective emission regulations must aim to reduce net emissions, not simply slow the increase of emissions. Making polluting generators pay for the pollution they emit would raise the cost of more polluting technologies and make renewable and transitional technologies the more economic options. Therefore one potentially very effective option for spurring innovation in the electricity sector would be to raise the price of carbon in order to effectively reduce emissions. In order for a carbon price to be effective, the cost of the carbon tariff would have to be higher than the marginal cost of abatement for the power plants. In other words it must be cheaper for plants to reduce their emissions than the price of simply paying into a fund for each unit of GHG they emit. According to the United Nations Intergovernmental Panel on Climate Change, a price of at least \$20–80/tCO_2e[208] would be required to see significantly deep reductions. Based on Canadian industry estimates of CCS cost, a price on the order of \$95 a tonne would be required to make CCS an economic prospect for retrofitting existing coal plants;[209] in order to spur that technology carbon would have to be similarly priced. Past work by the Pembina Institute indicates that immediately doubling the price cap to \$30 a tonne and raising it to \$75 a tonne by 2020 would be the minimum amount required to put the province on track to levelling the playing field for low and zero carbon electricity options.[210]

Option Two: Guarantee return on investment for renewable and transitional electricity

Evidence suggests the single most effective approach for spurring investment in renewable or transitional electricity is via the use of a policy called a “feed-in tariff” or a “renewable energy payment.” A feed-in tariff is an incentive policy which has been successfully employed in more than 40 jurisdictions around the world including many of the world’s leaders in clean energy (notably Germany and Spain).[211] The typical approach charges all electricity customers in the area a very small surcharge on every unit they buy from the grid[212] and then uses that money to offer a small premium for each unit of electricity fed into the grid from renewable energy projects (for example if retail price was \$0.07 a feed-in tariff program may charge electricity users in the service area an additional \$0.025 to finance the feed-in tariff premium). Largely attributable to its pioneering work employing feed-in tariffs, Germany enjoys the status of the world leader in renewable energy investment; in 2007 Germany generated 12.5% of its electricity from renewable power. Germany offers up to \$0.17/kWh premium for biogas, up to \$0.76/kWh for solar and \$0.22/kWh for geothermal.[213] Ontario, in 2007, successfully introduced an analogous approach in the form of its “Renewable Energy Standard Offer Program.” The project generated over 1,300 MW of proposed projects after its launch.[214] This response far exceeded all expectations, surpassing the 10-year target for renewable energy in the first year of the program.[215] Ontario authorities are currently trying to deal with the challenge of accommodating so many projects.

The Government of Alberta should consider adopting a similar approach adapted to the realities of the Alberta market. Although Alberta’s electricity market pool does create some problems for this type of approach, none are insurmountable, and this option remains viable for Alberta as long as some detailed design work is carried out to ensure the policy is made to be compatible with the Alberta context.

A strict feed-in tariff option would favour certain renewable technologies over market incumbents by offering a premium over and above the price the generator managed to secure in the power pool. There is Alberta precedent of the use of bilateral power purchase agreements (PPAs), a concept which could offer a more politically viable variation of the feed-in tariff for the provincial context. This approach would auction off renewable based PPAs via the existing market and then the price would be topped up using the feed-in tariff funds.

Option Three: Revise market rules to ensure electricity gets cleaner

Deregulation in Alberta has introduced innovation into the market and competition is now offering customers more choice in terms of supplier. The rules have been adjusted many times and continue to evolve. Another option for quickly realizing the potential for renewable and transitional energy in the province would be to revise electricity market regulations, this time to help foster clean energy. The aim should be to continue to allow the market to decide optimum investment decisions but tie decisions to minimum criteria in terms environmental performance. Existing regulations put upper limits on many pollutants including toxic heavy metals and sulphur dioxides, among others. Similar regulations could be introduced to limit carbon pollution by putting an absolute cap on GHG emissions per unit of output in the electricity sector. A revised regulation would still allow customers to choose freely from which supplier to purchase electricity. Investors could also invest in whichever technologies they chose as long as the supplier meets the specified emission limits. For example, whereas current emission intensities range from zero (for renewables) to close to 1 tCO_2e/MWh (for least efficient coal), new market entrants could be required to meet a maximum 0.5 tCO_2e/MWh emissions intensity. Such an emission regulation would preclude coal without cogeneration or carbon capture but is high enough to still allow power-only gas. Therefore an even lower intensity may be desirable. There is already precedent of this kind of action in British Columbia. The 2008 Greenhouse Gas Reduction (Emissions Standards) Statutes Amendment Act, actually requires that new “electricity generation must have net zero emissions.”[216]

Several existing pieces of Alberta legislation may also provide some legal precedent in Alberta and a legal foundation on which to base such measures. The Alberta Energy Resources and Conservation Act was drafted to “effect the conservation of, and prevent the waste of Alberta’s energy resources.”[217] The Electric Utilities Act’s Micro-Generation Regulation already incorporates the principle in the context of smaller generators. In order to qualify as “renewable or alternative energy” the installation must have a GHG intensity of less than 0.418 tCO_2e/MWh.[218]

7.1.5 Additional Items for Review by Renewable Electricity Task Force

The three options presented above will require decisive leadership in order to be realized. Which option or combination of options the Renewable Electricity Task Force ends up choosing will require rigorous debate. In addition to the above options there are a diversity of other measures that complement the above options which also need to be adopted and or considered, many of which were laid out in the recently released provincial energy strategy.[219] The mandate of the Renewable Electricity Task Force must therefore also include the requirement to study and make recommendations on the options outlined in Table 23. The menu of initiatives listed below would allow Alberta to quickly move forward to develop its renewable and transitional energy potential while complementing the core option that is chosen from the three options above. Many of the following items are prerequisites to any significant renewables being developed, but the specific appropriateness of each approache must be determined by the Renewable Electricity Task Force.

Table 23. Additional items that require attention of Renewable Electricity Task Force

Opportunity	Need Description
Catalogue Efficiency Opportunities	Immediate efforts need to be undertaken to pinpoint the energy saving opportunities in Alberta's industrial, agricultural, commercial and residential sectors and set down explicit realizable targets. The provincial energy strategy assumes that "by 2027, we will need twice the power we currently consume." An aggressive energy efficiency program would allow Albertans to have the same services with much reduced electricity use.
Invest in clean energy research and development	The energy strategy states that "The bulk [of research and development funding] will be dedicated to … [coal] gasification-CCS and directly related questions." Alberta needs to broaden the scope of its research strategy and invest in similar levels to CCS in research and development for renewable energy, and related technologies (storage, smart grid technology, etc.).
Invest in the Green Grid and provide full energy consumption and pollution disclosure	Strategic investments in the grid include smart control systems which better allow multidirectional flow of power at a distribution level. As per the energy strategy Alberta should also: "enable online measurement of electricity consumption by all consumers including integration of energy and carbon measurement systems at industrial, commercial and residential levels."
Introduce incentives for renewables and efficiency	Various options exist for providing incentives for renewable and transitional technologies. Options include tax incentives, generous capital cost allowances, direct grants and direct subsidy per kWh.
Ensure landowners benefit from renewables	Taking into account the values of Albertans the province should explore the various approaches that could be used to better garner continued support for realizing Alberta's renewable energy potential, especially wind electricity. As per the energy strategy Alberta needs to "ensure that all impacted landowner issues are heard, impacts are mitigated to the extent possible, and that landowners receive fair compensation."
Encourage Siting of Plants as Close as Possible to Demand	The energy strategy states "since electricity is most commonly generated at large single-point sources, the environmental impacts of its generation are easier to address." However, by siting generation in a decentralized manner close to demand generating this pollution in the first place can be avoided. Rules should be updated so that any locational benefits of siting are explicitly valued in the electricity market.
Establish strategic transmission corridors to facilitate renewable energy development	As per the energy strategy, efforts must be undertaken to "adopt and implement a policy to build transmission." Priority should be given to transmission that facilitates renewable electricity, perhaps using the approach of Competitive Renewable Energy Zones as pioneered in Texas.[220] As per the energy strategy, any such corridors should be built in accordance with the provincial *Land-use Framework* and to reduce the need for land disturbance corridors should be planned for multi-use.
Training and skills	Alberta should build a comprehensive training and job transitioning strategy to ensure Alberta's workers have the necessary skills on which to found the emerging renewable energy economy. Training and skills development were identified as priorities in the 2008 provincial energy strategy but training is specifically required for renewable and transitional technologies.
Virtual power plants and storage	Investing heavily in intelligent control and storage technologies will not only allow optimum use of those variable resources that are developed but also has the potential to make Alberta an international leader in these emerging energy sectors. The energy strategy recommended "implemention of policy and provide financial support for the development and deployment of 'smart grid' technology."

7.2 Recommendation 2: Energy Efficiency Strategy

The Government of Alberta will need to develop a comprehensive energy efficiency and conservation strategy leading to a suite of regulations, education and outreach, collaborations with industry, and economic instruments:

- A detailed study into the potential for electrical energy efficiency for industrial, commercial, residential and farm sectors.
- Development and implementation of electricity efficiency transformation strategies and policies for each sector and end-use, involving a mix of financing, training, procurement, strategic incentives and regulations.
- Organization of a series of “energy efficiency workshops” for all major industries, including conventional upstream oil and gas, conventional downstream oil and gas and petrochemicals, oil sands, forestry, manufacturing, etc.
- Participation in on-going collaboration on electrical efficiency among governments and energy users, including those under the Council of the Confederation, Council of Energy Ministers, Canadian Industrial Program on Energy Efficiency, Canada Green Buildings Council, and Canadian Energy Efficiency Alliance.
- Direct engagement with major industries through energy audits (focused on equipment, processes and management related to energy), capacity building and financial support (possibly in the form of low interest loans).
- Continuous improvement of regulations to ensure Albertans are receiving the most cost effective technologies.
- Targeted and coordinated education, outreach, marketing and incentives to markets not easily reached through regulations or partnerships (such as existing residential buildings and small to medium sized enterprises).
- Changes to energy price signals (e.g., integrating more of the environmental and social costs of energy into its price).
- Incorporation of a system benefit charge into energy prices as a permanent mechanism to enable efficiency initiatives.
- Renewed interest in energy intensity targets by government.
- Aggressive province-wide promotional and educational campaign to tie economic goals to efficiency improvements.
- Investing a large portion of oil and gas revenues or government budgetary surpluses in rolling funds for providing low-interest financing energy efficiency in homes and businesses.
- Series of major government RFPs for third party energy services company contracts in the province specific to all the major industries.
- Creation of an Energy Efficiency Act which encompasses the above items and sets clear targets. Such an Act could be inspired by jurisdictions such as Texas that have mandated that a portion of new generation be met by efficiency.[221]

7.3 Recommendation 3: Renewable Energy Assessment

Much more public research is needed to determine scope for economic development of the various renewable options. Research is particularly lacking in certain specific technologies such as geothermal, hydro and biomass, as well as benefits of broad geographic dispersion of renewable technologies. Without a detailed inventory of the potential resources it is difficult to develop a sustainable energy plan. While many natural resources, notably fossil fuels, are well mapped out there is comparatively little detailed technical information Alberta's renewable energy potential in the public sphere. A Renewable Energy Assessment for Alberta (REAA) will provide detailed information for public and private decision-makers about the quantity and quality of the province's renewable resources. Such a resource map will facilitate decisions on cost-effective and environmentally sensitive development of renewable energy and inform long-term transmission planning decisions and sustainability strategic planning.

7.4 Recommendation 4: Public Investment in Renewable Energy

Alaska is using its fossil fuel revenues to create a quarter billion dollar "Renewable Energy Fund." With over five times the population, a comparable investment in renewables in Alberta would still be less than the money allocated to carbon capture and storage.

7.5 Recommendation 5: Earmark Research Funds for Renewable Energy

To date more than $40 million has been collected by the Government of Alberta from large final emitters for the Climate Change and Emissions Management Fund. These funds should be earmarked for spending on the promotion of renewable energy and appropriate spending of the these financial resources include funding of work required, as outlined in section 7.1 (see Table 23) section 7.2 and 7.3. A large proportion of the Climate Change and Emissions Management Funds should be set aside to fund these initiatives.

7.6 Final Remarks

This report has examined the current electricity system in Alberta and considered various scenarios for the future. At this point all three of the scenarios are plausible. What will determine Alberta's future energy path is not technology or technological limitations, but political and social limitations. Developing a clean electricity future for the province based primarily on renewable technologies is technically doable. The environmental and social benefits of such an approach are clear and the economics even look favourable for the cleaner options. What we need more than anything in the province to realize what is possible is leadership.

Although touched on, a detailed examination of the economic costs of the various options as well as the policies that will be required to promote them are outside the scope of this report. Future reports in this series by the Pembina Institute will examine these questions in more detail.

The first step for the government is to convene a Renewable Electricity Task Force which will consider various policies for moving forward with renewable energy in Alberta to start to take advantage of the huge potential that clean energy offers the province.

Appendix: Peak Analysis

Overview

In order to determine if the suggested mix of electricity supply sources could meet the forecast demand in 2028, an hourly analysis of the demand and forecast supply mix was completed. While this analysis does not take into account important issues of minute to minute variability and pool balancing, it does suggest that the technologies making up the supply mix in the Green scenario are able to meet both simulated future base and peak demands.

Forecasting Hourly Demand

Hourly supply and demand data were collected from the AESO's public data archive for the year 2007. December, illustrated below, not only represented the peak demand (8,300 MW on December 3rd at 17:30), but also one of the lowest wind periods of the year.

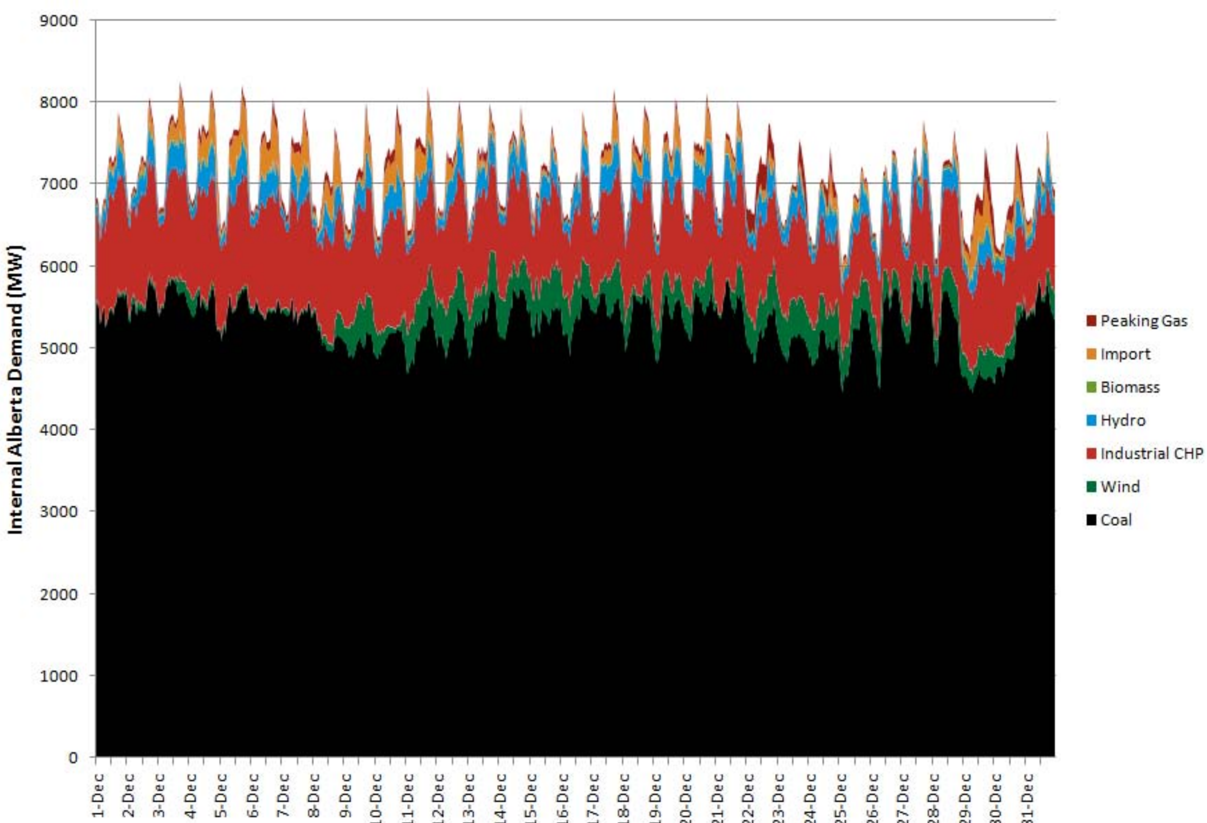


Figure 41. Alberta electrical supply and demand, December 2007

Source: AESO

In order to model the supply and demand in the Green scenario, demand was projected for the year 2028 by scaling up 2007 demand data assembled from a total demand of 58,815 GWh in 2007 to a projected demand of 110,578 GWh in 2028. The demand was adjusted by gains in energy efficiency that are possible and assumed to be realized under this scenario. Both sets of hourly data, along with the daily average (shown in black) are illustrated below.

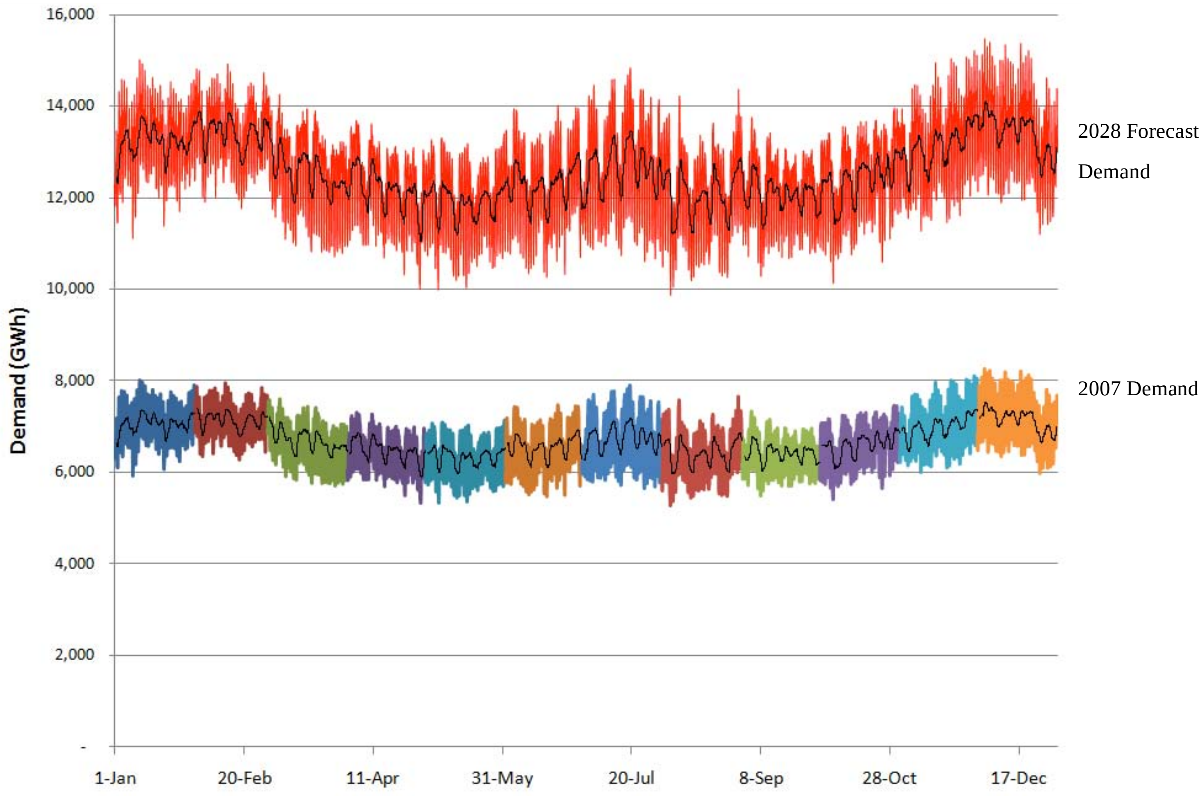


Figure 42. Current (2007) and forecast (2028) hourly electricity demand in Alberta

Meeting Future Demand

To model the ability of the potential supply mix to meet the future demands, future supply technologies were, with the exception of wind energy, scaled appropriately from their current installed capacity to their installed capacity in the Green scenario in the year 2028 and were assumed to be able to respond with similar peak and capacity factors as they did in the year 2007. As a worst-case scenario, neither power storage nor load curtailment through virtual power plants were considered.

Wind energy was treated separately and uniquely as it not only represents a significantly larger proportion of future supplies, but, as a variable resource was given priority over other technologies which would then respond to both the demand and the load supplied by the wind. The 8,800 MW of wind power were modelled based on actual 2007 wind data available through Environment Canada. It is important to note that this data is collected at a height of 10 m and is not collected with the intention of being used for wind energy development. Nonetheless, it does illustrate the order of magnitude of the relative variability of winds in the regions of interest in Alberta.

Data was collected from five Environment Canada wind masts located in Pincher Creek, the Blood Tribe, Coronation, Peace River and Grande Prairie. The wind data was scaled from 10 m to a hub height of 80 m and a distribution of the projected wind farms was associated with each of the aforementioned masts. The majority of wind farms were assumed to be located in the south of the province near Pincher Creek, the Blood Tribe and Coronation, with approximately 10% assumed to be located in the Peace Region. In the case of Coronation and Peace Region, Environment Canada data indicating unfeasible wind speeds (less than 5 m/s at 10 m) was adjusted upwards to commercially feasible wind speeds (above 6.5 m/s) because it is known that there are local regions of good wind regimes in these areas, despite the data collected at the specific location of the weather monitoring stations in these regions. As the geographic variability of wind data was of interest for the modeling exercise, the variability and the relative wind speeds in the regions represented by these towers compared to the other towers used in the study were of relevance.

Because of the large area over which the wind turbines would be constructed it is unreasonable to assume that they will all experience the same wind speeds at the same time as weather systems move through the region. Averaging the wind speeds over several hours is often done to model how quickly weather systems move through the regions where wind farms would be developed. In order to account for the varying wind speeds that turbines would experience simultaneously across this distance, the wind data was smoothed using an 11-hour average. The average was centred on the hour in question to account for the fact that the weather systems could be approaching from any given direction. While the simulation used a rolling average to represent some of the inherent reductions in output variability it is clear, that the actual power output will be smoother than the data presented.

A more accurate simulation would use actual wind data from various towers in the locations of the future developments, as well as considering power smoothing within a wind farm caused by local variations in wind speeds, turbulence and turbine wakes and specific wind turbine models in each prospective farm. Such an approach would further smooth the data fluctuations. The current method was used as it can be considered a worst-case scenario in terms of the variability of the output power.

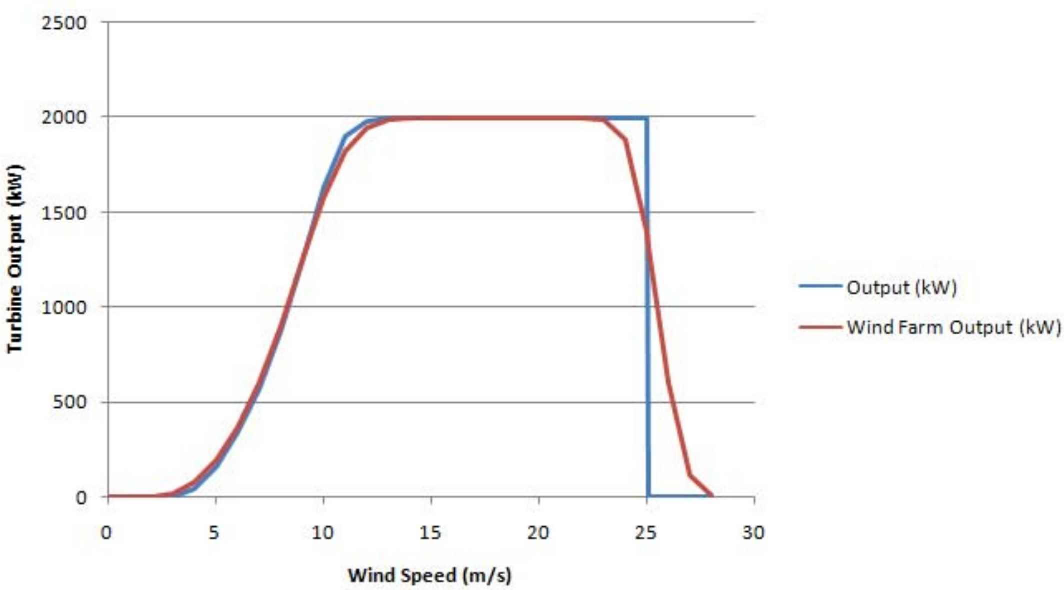


Figure 43. Modelled wind farm power curve

The wind farms were modelled using a the power curve of a 2.0 MW Vestas wind turbine with 10% local turbulence normally distributed to account for changes across a wind farm. The single turbine, and modified wind farm power curves are illustrated below. 15% overall power losses were also assumed to represent wake losses, individual turbine downtime and other losses. Using this approach resulted in an average capacity factor of 35%.

Model Results

To model the worst-case scenario in terms of meeting power demand, the coal phase-out scenario was considered. The remaining coal on the system is that with carbon capture and storage and was treated as a base load to the system. The output of the wind turbines was then added to this base load. The additional technologies were then added to the system model based on the peak and capacity factors of current technology on the grid in 2007. In all cases, available generation capacity exceeded demand (with minimum reserve margins over 13% even in the worst-case scenario). In reality, the market would dictate which technologies are used to meet load at which times and which power plants would curtail their output or look to export in times of excess capacity. Peaking gas and imports were used only when the load could not be met by the remaining suite of technologies. The model results for December are illustrated below for the modeled 2028 demand.

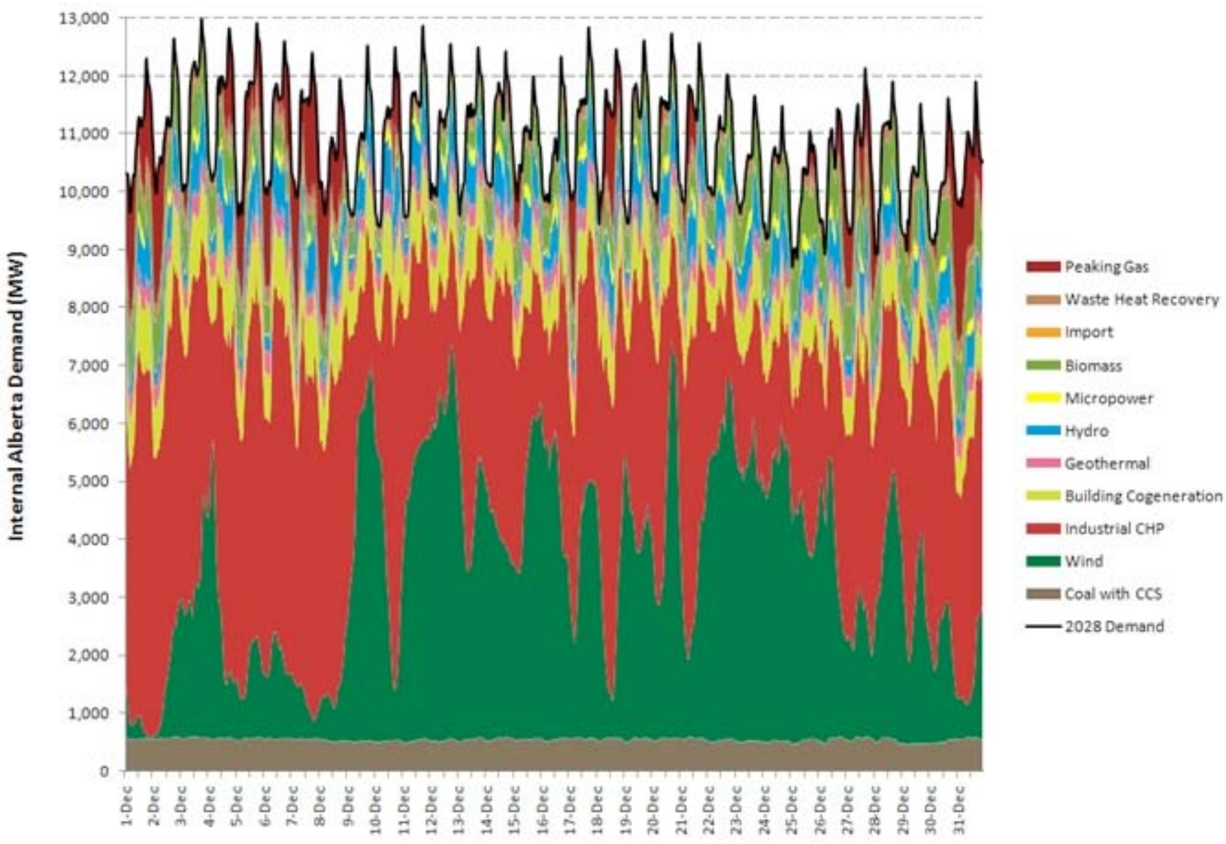


Figure 44. 2028 Green scenario supply and demand

The model illustrates that even during periods of low wind speeds and high demands that the technology portfolio illustrated in the Green scenario is capable of meeting both peak and base load demands. It should also be noted that for the most part, peak winds coincide with daily peak demands. When this is not the case, there is sufficient system reserve and resilience to meet demand. The model for the year 2028 found an average supply reserve margin of 25%, with 13% as a worst-case scenario during very low wind speeds. It should be noted that this did not include any smart grid technology such as deferrable loads through virtual power plants or electricity storage, both of which are suggested to be part of a Green scenario portfolio to assist in shorter time scale integration issues.

8. Endnotes

[1] Notes for an Address by The Right Honourable Stephen Harper, Prime Minister of Canada To the APEC Business Summit, 2007 September 7, Sydney, Australia, pm.gc.ca/eng/media.asp?id=1814.

[2] *Launching Alberta's Energy Future: Provincial Energy Strategy*, Government of Alberta, December 11, 2008, www.energy.gov.ab.ca/Org/pdfs/AB_ProvincialEnergyStrategy.pdf, p. 10

[3] Ibid p. 20

[4] Ibid, p. 45

[5] EcoLogo Program Category: Electricity Products www.ecologo.org/en/certifiedgreenproducts/category.asp?category_id=24.

[6] National Inventory Report 1990–2005 Canada: Final Submission, Environment Canada, ANNEX 9 www.ec.gc.ca/pdb/ghg/inventory_report/2005_report/2005_report_e.pdf.

[7] Coal combustion releases more GHGs than any other fuel, along with other air contaminants notably mercury and acid rain precursors. Jurisdictions that rely on it for the majority of their electrical energy can be said to have the dirtiest electricity grids.

[8] National Inventory Report 1990–2005 Canada: Final Submission, Environment Canada, ANNEX 9 www.ec.gc.ca/pdb/ghg/inventory_report/2005_report/2005_report_e.pdf.

[9] Alberta has 18 major coal plants, 17 of which use "subcritical" technology (23% to 38% efficient) and one of which uses the more modern "supercritical" technology (38-43% efficient). Source: A Study on the Efficiency of Alberta's Electrical Supply System, Clean Air Strategic Alliance (CASA), October 2004.

[10] 2008 Loss Factor Re-Calculation, AESO, March 2008, www.aeso.ca/transmission/12920.html According to AESO's 2006 annual report, p. 43, line losses cost Albertans $231.9 million in 2006, up from $200.8 million in 2005.

[11] Electricity: The Magic Medium, Book, Part 1-7, Alberta, p.1, Institute of Electrical and Electronics Engineers, 1985. p1 (of Alberta section). www.ieee.ca/diglib/library/electricity/pdf/P_one_7.pdf

[12] An Ordinance to Incorporate the Calgary Water and Power Co., Assented to November 22, 1889, No. 23 of 1889, section 15, File M1546 Glenbow Archives. Also, page xi of Electrifying Calgary, A Century of Pubic and Private Power, W.E. Hawkins, The University of Calgary Press, 1987.

[13] Candles to Kilowatts, The Story of Edmonton's Power Company, Heather Marshall, Debbie Culbertson, 2002, Duval House Publishing, p. 1.

[14] Electricity: The Magic Medium, Book, Part 1-7, Alberta, p.3, Institute of Electrical and Electronics Engineers, 1985. p1 (of Alberta section). www.ieee.ca/diglib/library/electricity/pdf/P_one_7.pdf

[15] Based on data from Alberta Electric System Operator, Alberta Energy, Athabasca Regional Issues Working Group, Clean Air Strategic Alliance, and various private sector web pages.

[16] Some prefer the term liberalized because no electricity market is 100% deregulated.

[17] Electric Utilities Act, Section 5 Purpose, Government of Alberta, 2003.

[18] Independent Power Producers Society of Alberta, Why Did the Government Deregulate Electricity?, June 2006 Factsheet, www.ippsa.com/pdfs/quickfacts2_0606.pdf.

[19] Canadian Wind Energy Association webpage, www.canwea.ca/farms/wind-farms_e.php, accessed September 1, 2008.

[20] Nuclear Power Expert Panel Order, www.energy.gov.ab.ca/Org/pdfs/MO_31_Nuclear_Expert_Panel.pdf.

[21] See sections 3.6 and 3.7 for definitions.

[22] The figure does not include electricity generated by large industry (such as oil sands companies) and used onsite but it does include any surplus electricity generated by those industries and sold into the grid. In 2007 about 10,000 GWh of electricity was generated by industry and, because it was used onsite, is not included in the usage pictured. Source: Quarterly Forecast Update, Third Quarter 2008, EDC Associates ltd., August 19, 2008.

[23] Quarterly Forecast Update, Third Quarter 2008, EDC Associates ltd., August 19, 2008.

[24] Distributed Generation- A Perfect Fit for Oil and Gas Production?, Bruce Peachy, 2008 Canadian Decentralized Energy Conference. Exploring Alternatives to Traditional Generation. 2008 September 15-16. Calgary.

[25] 2000 Charting New Frontiers: An Introduction to the Operations and Restructuring of the Electric Power Sector, September 2002 (binder), section 6, p. 5.

[26] Market Participant List, AESO's Energy Trading System, Alberta Electric System Operator, ets.aeso.ca/ip_web/Market/Reports/ParticipantListReportServlet?contentType=html (accessed September 17, 2008).

[27] British Columbia Greenhouse Gas Reduction (Emissions Standards) Statutes Amendment Act, 2008, www.leg.bc.ca/38th4th/3rd_read/gov31-3.htm.

[28] *Launching Alberta's Energy Future: Provincial Energy Strategy*, Government of Alberta, December 11, 2008, www.energy.gov.ab.ca/Org/pdfs/AB_ProvincialEnergyStrategy.pdf, p. 45

[29] AltaLink website, About AltaLink, www.altalink.ca/Default.aspx?DN=aa6c7882-56e0-4104-ab21-0e427c4dcaa9.

[30] Private sector is also free to invest in "merchant transmission" projects not identified as required by the AESO; however, if they do so the risk is borne by the investor — guaranteed return is not borne by ratepayers.

[31] See for example: 1) TransAlta and EPCOR to proceed with Keephills 3 power project, TransAlta Press release, (2007 February 26) www.transalta.com/transalta/webcms.nsf/AllDoc/39BA29A3499FB67F8725728E004AC362?OpenDocument; 2) New turbine powers up Alberta, EPCOR Press Release, Canada Newswire, March 10, 2008. www.newswire.ca/en/releases/archive/March2008/10/c2200.html.

[32] Alberta Electric System Operator, Powering the growth of Alberta's oilsands, March 2007, www.aeso.ca/downloads/HeartlandBroSinglePgs(4HR).pdf.

[33] National Inventory Report 1990–2005 Canada: Final Submission (p.574) ANNEX 11, Environment Canada, www.ec.gc.ca/pdb/ghg/inventory_report/2005_report/2005_report_e.pdf.

[34] Alberta Electric System Operator, Online Current and Historical Market Reports database ets.aeso.ca/, accessed June 5, 2008.

[35] Decommissioning dates based on estimates from the Clean Air Strategic Alliance.

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