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THE CHALLENGE OF INTEGRATING RENEWABLE GENERATION IN THE ALBERTA ELECTRICITY MARKET

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INTRODUCTION AND OVERVIEW

Renewable electric generation is forecast to enjoy an increasing share of total capacity and supply regimes in the future. Alberta is no exception to this trend, having initiated policy incentives in response to calls for increasing the fraction of wind and solar energy available to the province over the next decade.[1] This call is coming from various sectors including advocacy groups, the provincial government and some utilities.

The University of Calgary's School of Public Policy convened a roundtable discussion on Sept. 15, 2015. Given the wide-ranging aspects of increased renewables integration (for example the policy options, economic forces and engineering/technical issues) the topic demands attention from a wide range of experts and stakeholders. To that end, we endeavoured to group expert panellists and representatives of utilities, public agencies, academe and consumer groups to consider the planning necessary to integrate new renewable capacity into the existing and future grid system in the province and its potential impact. The purpose of the roundtable was to facilitate and foster a knowledge exchange between interested and knowledgeable parties while also aggregating this knowledge into a more complete picture of the challenges and potential strategies associated with increased renewables integration in the Alberta electricity grid.

The topic for discussion was broadly framed as "*meeting the challenge of integrating renewable-energy generation into the Alberta Grid*."[2] The symposium took the

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1 See for example, the Government of Alberta's Climate Leadership report: Canada. Government of Alberta, "Climate Leadership: Report to Minister," November 20, 2015, http://www.alberta.ca/documents/climate/climate-leadership-report-to-minister.pdf.

2 The discussion background paper titled "Renewable Energy: Policy Goals and the Reality of Grid Integration-Issues for Consideration:" is included in Appendix B.

form of a keynote address, followed by two structured panel discussions and an open session during which questions were posed both directly to panellists and to the attendees at large. All sessions were conducted under the Chatham House Rule,[1] and were attended by 40 stakeholders including panellists.

The first panel, titled "Collision or Co-operation, the outlook for meeting policy goals," examined whether public policy objectives designed to develop new renewable capacity in electric markets have, or are likely to be, proven successful. The second panel, titled "Reality versus Aspiration and Expectation," discussed the technical aspects of performance involved in integrating renewables over the past 10 years in North America.[2] The panel presentations were followed by an open discussion session focused on many of the core elements presented by the panellists.

The discussion on issues and strategies was quite nuanced, and in many of the specific elements differences of opinion persisted across the various participants. However, through the course of the roundtable, a near consensus emerged on several elements. The general premise of the roundtable, that increased integration of cost-effective renewable generation is desirable, was shared by all participants. But all participants recognized that integration of this type of generator poses clear engineering and economic challenges. In defining strategies to deal with these challenges, the panellists indicated that a better respect for the costs and benefits of potential technologies is needed to promote effective policy.

A common sentiment among participants was that any serious achievement in further integrating renewables into the Alberta electricity grid would likely best be driven by some degree of market restructuring. However, careful attention must be paid to this restructuring.

In particular it was generally agreed that "technology-neutral" modifications to the existing electricity market should be favoured. That is not to say that any market restructuring should ignore the difference between renewables and non-renewables; quite the opposite. Policy should be constructed to encourage those aspects of renewable generation that we find beneficial (sustainable, low- or zero-carbon emissions, etc.) without presupposing a need for any specific generation technology or ignoring the historically critical role of traditional thermal generation in maintaining grid stability. This means that designing a market that will price in important aspects like stability, environmental damage and ramping, is critical to balancing the goals of renewable integration and an adequately functioning electricity grid.

Geographic and technological diversity were raised and supported as likely components of a successful path to increased renewables integration. Since generation in different regions and across different technologies can act as complements (rather than substitutes), they reduce the risk of grid failure and can increase the stability of an integrated Alberta electricity grid. Beyond the use of different generation technologies, the panellists also raised the concept of non-generating assets (energy storage, demand-side management and expanded interties) as ways to bolster and overcome the shortcomings of renewable-generation assets. However, these assets, if they are to be a useful part of the electricity grid, must be able to produce an effective return where appropriate.

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1 Under this convention, participants are free to use the information received, but neither the identity nor the affiliation of the speaker(s), nor that of any other participant, may be revealed.

2 See agenda in Appendix A.

THE KEYNOTE ADDRESS

The symposium opened with a keynote address by Prof. Marvin Shaffer from Simon Fraser University. He emphasized that the integration of renewable-generation technologies into a grid that has been historically dominated by thermal generation must go beyond traditional technical and economic considerations. Shaffer highlighted the need for effective social cost-benefit calculations as a component of any effective policy designed to incentivize renewable integration.

The general theme to the keynote address is that it is important to maintain focus on the questions, not just the answers, when searching for effective energy policies. Shaffer pointed out that, while there is widespread public support for renewables (which are becoming increasingly cost-competitive with non-renewable electricity generation), we must nevertheless prioritize efficient and fair strategies for emissions reductions. There should, and will be, more wind and solar development, but not for its own sake. Any new capacity must contribute to the policy goals in a cost-effective and equitable manner.

Shaffer identified the U.S. Clean Power Plan[3] as a policy package conforming to this standard. The Clean Power Plan does not impose specific targets for resources, instead setting targets for emissions reductions. How these targets are met is entirely up to each individual state. The outcome can be achieved in a variety of ways: increasing the efficiency of generators, shifting to lower emission resources and conserving demand. Ultimately, state-level policy choices will determine which emission reduction methods are deployed.

Elaborating on this point, Shaffer noted a critical element of the Clean Power Plan is that policy instruments must be demonstrably capable of achieving emissions reductions. This makes emission reduction the core objective of the policy, allowing for efficiency and equity considerations to play a role in defining the specific means by which this objective is maintained. Shaffer's conclusion from this is that the most potentially favourable policies are therefore explicit prices, rather than individual targets, as the former allow for consistent, efficient results. He further cautioned that, in the absence of well-considered policy, measures can be very costly and create public backlash. Many bold energy plans have lost sight of cost-effective delivery of their objectives. Perhaps the most critical insight of the keynote presentation was the assertion that *if we are willing to pay anything it takes to reduce carbon emissions, then we are willing to pay too much.*

With that assertion on the table, Shaffer identified some obvious pitfalls to avoid, for instance: Offering "feed-in tariffs"[4] for new wind and solar at *whatever cost it takes*; Comparing the levellized cost of electricity[5] across technologies without regard to the value of the energy (e.g., intermittency and firmness, which are presented in more detail during the Panel 1 discussion below) and justifying wind/solar/other renewables based on job-creation metrics and associated economic stimulus without regard to the opportunity costs of the labour.

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3 United States. Environmental Protection Agency, "Clean Power Plan," https://www.epa.gov/cleanpowerplan.

4 Feed-in tariffs are long-term payment contracts structured to provide energy producers with sufficient revenues to cover upfront investments. These contracts are intended to reduce or eliminate the risk of investment and often imply a cost for renewable generation that is in excess of what would otherwise be the market price.

5 The "levellized cost of electricity" is a measure of the electricity costs intended to allow for comparison between different methods of electricity generation. It is based on an economic assessment of the average total cost per megawatt-hour over the economic life of a generation asset.

Shaffer's address was summarized by five recommendations:

1. The province should be aiming to create a base amount of capacity and rate of development based on an explicit, consistent GHG value that will drive the measures taken, not the other way around.
2. A full range of renewables should be considered, including geothermal and hydro.
3. There are energy-market reforms needed in Alberta to provide appropriate incentives for renewables to be built.
4. The province should consider strengthening east-west intertie (to capitalize on hydro potential in northern Manitoba, for example) where a larger integrated market will allow for more development of intermittent resources.
5. Policy-makers should recognize the critical importance of the demand side (conservation and efficiency), since smart management of demand (and additional capacity) will be needed to manage variable supply.

PANEL 1 – COLLUSION OR CO-OPERATION: THE OUTLOOK FOR MEETING POLICY GOALS

This goal of this session was to examine whether public policy objectives designed to develop new renewable capacity in electric markets has proven successful, both in terms of performance and installed capacity. Discussants were directed to review common policy objectives in North America and contrast them with those that have been developed and implemented in Alberta.

The panel began with a discussion around a challenge framed by the keynote speaker: "How should Alberta reduce greenhouse gas emissions in the utilities sector in a cost-effective and equitable way?" There was general agreement that achieving and sustaining this goal required a comprehensive regulatory structure as well as consistent policy initiatives.

Echoing the assertion made in the keynote address, the panellists made it clear that the most efficient emissions-reduction strategy is likely to be one based on specific price or value characteristics associated with control of emissions, rather than an arbitrary target.

For instance, a strategy that was based primarily on reducing carbon emissions might not provide sufficient incentives for transition to wind and solar. In fact, achieving this type of transition is only one of many possible outcomes of an emissions-reduction strategy, rather than a goal in and of itself.

The importance of good policy in promoting desirable outcomes in the utilities sector was further emphasized with reference to a case study of B.C.'s power-generation grid. In this case, the B.C. provincial government imposed restrictive self-sufficiency targets combined with green targets on the B.C. utilities sector. The result was a massive call for green energy, kick-starting a new private power industry.

Lauded by some, these policies led to power being bought on long-term contracts that were low in overall value relative to their costs. The resultant financial loss to BC Hydro was in the order of hundreds of millions of dollars per year, leading to higher rates, which in turn led to substantial ratepayer dissatisfaction with the program.

As the keynote speaker suggested, herein lies a caution to policy-makers: In the absence of well-considered policy, measures can be very costly and create public backlash. The more important the objective is, the more important it is to be cost-effective and efficient in getting there. The panellists reinforced this point by reiterating the statement that "if you are willing to pay 'all it takes,' you are willing to pay too much."

Further elaborating on some of the issues introduced in the keynote, the panellists considered an illustrative list of potential pitfalls and a set of recommendations necessary for formulating good policies with respect to renewable integration. In particular, the use of feed-in tariffs and the levellized cost of electricity (both discussed in the keynote) were once again presented for critique.

It was suggested and generally agreed that the use of feed-in tariffs and similar mechanisms generally leads to excessive and unnecessary costs. Specifically, since these mechanisms require increased electricity prices beyond the normal market-based prices, and often in excess of the price that would otherwise be required to motivate emissions reduction. Therefore feed-in tariffs were generally presented as a policy instrument that should be avoided.

The direct comparison of levellized cost of electricity between different energy sources was similarly offered as poor metric for achieving emissions-reduction goals. This is because other aspects of the value of energy from specific generation technologies have substantial value that is not captured by the levellized cost of electricity. Photovoltaic-solar and wind, for example, have very different attributes related to their firming needs — intermittency, inertia, etc. — as compared to each other and certainly as compared to thermal resources. To appropriately compare the costs and benefits of renewables, value and costs must be placed on the different attributes that different resources provide.

In terms of renewable-energy resources, the panellists indicated that investment demands in particular are associated directly with a need for a return on investment and the unique preferences of those investors interested in sustainable technologies. Consideration of the following characteristics is important to ensuring an economically viable return on investment for renewables:

- Acting as a hedge against fossil fuel prices, since there is more certainty in the marginal cost associated with renewable technologies.
- Increasing the diversity of a generation portfolio in order to reduce the risks associated with relying on a single technology for production.
- Satisfying a demand for renewable resources in an investor's portfolio, since many large-scale investors are concerned with their public image.
- Developing proven technologies that can be relied upon (wind) or contributing to the development of new technologies that are expected to prove cost-effective in the near term (solar).

The panel agreed that the increasing reliance on intermittent sources of electricity, implicit in increased renewable integration, suggests that an increased east-west intertie would benefit the combined market for Alberta and its regional neighbors. This led to the conclusion that the larger (geographically) the integrated system, the more diverse it tends to become, with greater potential to reduce the negative impact that renewable intermittency has on grid stability.

The panellists also considered data showing how renewables often present poor hedges against each other and/or are unlikely to support generation during periods of peak demand. As an example, in order to maintain balance in the grid, it is possible to replace a unit of coal-fired capacity with a unit of natural-gas-fired capacity one for one, but we cannot do the same with wind or solar due to a lack of predictability.

The result was a list of seven elements that should be at the core of evaluating the potential for renewable integration:

- *Emissions reductions*: As a main goal of increased renewables, clearly the amount of emissions reductions places high on the metrics framework.
- *Comparability*: Different renewables bring different value attributes in terms of firmness, intermittency, etc. A well-defined metric needs to properly take into account the value of these attributes so success does not mean a lot of the low-cost, low-value resources. The panel also discussed specific attributes necessary to include in a metric for comparability. These were: reliability, resiliency, flexibility and security.
- *Costs*: Accounting for both the direct costs of renewables, and the avoided external costs from what they replace. We also need to consider the cost to integrate new generation assets into the extant grid.
- Equity: Who pays what? Do solar feed-in tariffs disproportionately benefit the rich?
- *Speed of development*: Sometimes mistakes in the policy process are necessary to make improvements in the future. While these mistakes can be rectified, the costs associated with both incurring and rectifying errors become the literal cost of future efficiency.
- *Policy stability and public acceptance*: Public backlash can mean you lose the policy altogether. Going slower and creating sensible policies can mitigate this risk. Community involvement through co-operatives and other local revenue streams aids in public acceptance.
- *Installed capacity*: For a policy to be considered successful, we need to see adequate development of installed capacity to meet all the needs of the grid.

With these criteria, and the above pitfalls in mind, the panellists made several recommendations throughout the discussion. We have summarized the most critical of these in the list below

- *Values should drive actions:* The amount and rate of renewable-generation developments should be based on an explicit and consistent assessed cost of emissions, such that the value of emissions reductions drives the measures taken (and not the other way around).
- *Policies should be technology agnostic:* The full range of potential renewable technologies (geothermal, hydro, etc.) must be considered and assessed based on their relative merits.
- *Market designs should be conscious of incentives:* Energy-market reforms will be needed in Alberta to provide appropriate incentives for renewables to be built.
- *Inter-regional co-operation is important:* Policy-makers should consider strengthening east-west intertie (to help realize the hydro potential in northern Manitoba and British

Columbia), since a larger integrated market allows for more development of intermittent resources as they can be firmed using a more diverse composition of generation capacity.

- *Consider Both Supply* ***and*** *Demand:* Policy-makers should recognize the critical importance of the demand side (conservation and efficiency). Smart management of demand can be leveraged to better manage the variable supply associated with renewables.

PANEL 2 –REALITY VERSUS ASPIRATION AND EXPECTATIONS

The goal of this session was to discuss the performance and experience of integrating renewables over the past 10 years in North America. Panellists were directed to examine the ability of the current electric grid to accommodate various types of renewable resource technologies during normal operation and discuss issues such as sudden resource loss, reserve generation and firming, and appropriate, effective pricing and incentives for renewables. The challenge of replacing thermal generation while substituting alternative technologies in terms of cost and performance was communicated to panellists as a key theme of the panel.

Renewable technologies, due to their very nature, represent a challenge in anticipating changes in generation, both regionally and seasonally, and the impact on other dispatchable technologies. This panel discussed those challenges and offered experience from other jurisdictions and some anticipation of changes yet to come in renewable electric markets.

Using data from the Alberta Electric System Operator (AESO), one panellist showed that 10 years ago (in 2005) Alberta had 250 megawatts of wind, while the current total (as of September 2015) is 1,400 megawatts. The historic trend represents a 20 per cent annual growth rate over the last decade and there are still an additional 2,400 megawatts currently in the planning queue.

So far, the existing market structure has accommodated the current amount of integrated wind, but this is admittedly the low end of the band of development expectations. In 2015, wind provided 4.4 per cent (all renewables yielded nine per cent) of Alberta energy generation. For reference, the wind-production values included a capacity factor[6] for wind during peak hours of up to 50 per cent in last five years (this range included hours of zero per cent generation). In the five years previous to 2015, all wind values were below 15 per cent of total generation, even at peak times, highlighting the variability of this resource.

The panellist relayed that the AESO has studied up to four gigawatts of integrated wind capacity and it believes that additional wind capacity may reach break points within this range. The non-linear effects[7] of wind generation being added after a certain point makes dispatch more complicated as well as implying a need for higher firming capacity within the system,[8] typically from gas-fired generators. For instance, if 20 per cent of all Alberta load

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[6] The "capacity factor" of an electricity-generation asset is the ratio of actual power produced to the nameplate capacity of the asset, where the nameplate capacity identifies the peak power that can be generated by the asset if sufficient resources (e.g., wind speed) are available.

[7] In this context, non-linear effects refer to the lack of scalability in wind beyond a certain capacity factor due to variability in available generation resulting from natural variations in wind speed.

[8] "Firming capacity" refers to the need to have additional generation assets on standby, ready for dispatch should intermittent renewable assets cease.

were served by wind, it would represent approximately 8,000 megawatts of energy capacity; or, as a capacity equivalent, approximately 24,000 megawatts of generation capacity. Panellists indicated that there is unfortunately no clear evidence on what will happen if and when every region has a high degree of renewable generation. It is difficult to make a conclusion on whether or not there is enough inter-regional diversity in resources to hedge against the intra-regional intermittency, and so the question of how to firm intermittent generation remains paramount.

The panellists identified a range of lessons that have already been learned from integrating wind capacity in other jurisdictions. Many of the worst fears originally presented at the outset of plans to integrate wind have not come to pass over the last few decades and several of the initial assumptions regarding wind integration have changed. For example, the expected make-up of the merit order[9] and the assumed response times of other generators have all proven more flexible than originally assumed. Thus, the ability to firm up wind capacity, while still difficult, is not as difficult as originally assumed. The actual production profile of wind has also changed to become more geographically diverse, allowing wind to lower its overall variability as a component of the generation profile.[10] The takeaway from this discussion is that market participants do respond to market signals. Geographic diversity is a response to market prices; improved expected profiles illustrate a market response wherein wind-generation-asset investments are driven by price expectations.

However, returning to a point made in both the keynote address and Panel 1, the second panel reflected that the levellized cost of electricity is still a poor metric for achieving emissions-reduction goals. There is still a significant issue in how to fit variable resources into an existing market structure (based on merit-order dispatch) with the goal of locking down dispatch schedules well in advance to avoid market imbalances. For wind in particular, the interruptibility of supply combined with merit-order dispatch represents an inconsistency between market design and the social and commercial value of the assets.

Turning to developments in other jurisdictions for guidance, panellists discussed the Bonneville Power Administration's (BPA)[11] success in integrating over 5,000 megawatts of wind capacity in a system that delivers 8,000 megawatts of peak load supply. In particular there are issues with the concentration of wind capacity in the Columbia Gorge area that highlight the need for diversity in generation technologies.

The ramping time, for instance, is significant, representing as much as 20 minutes of ramping time up to four gigawatts of energy delivered. This has led to the question of how to compensate generators during this period with the balance of the generation fleet. The Pacific North-West Hydro system is being maxed out during these periods, through a combination of water-release limitations and the need to provide continuous baseload support.

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9 The "merit order" is the order in which different generation sources are dispatched. It is based on the marginal-cost/price of electricity from each source such that low-cost sources are dispatched first, followed by successively higher-cost sources, until demand is met.

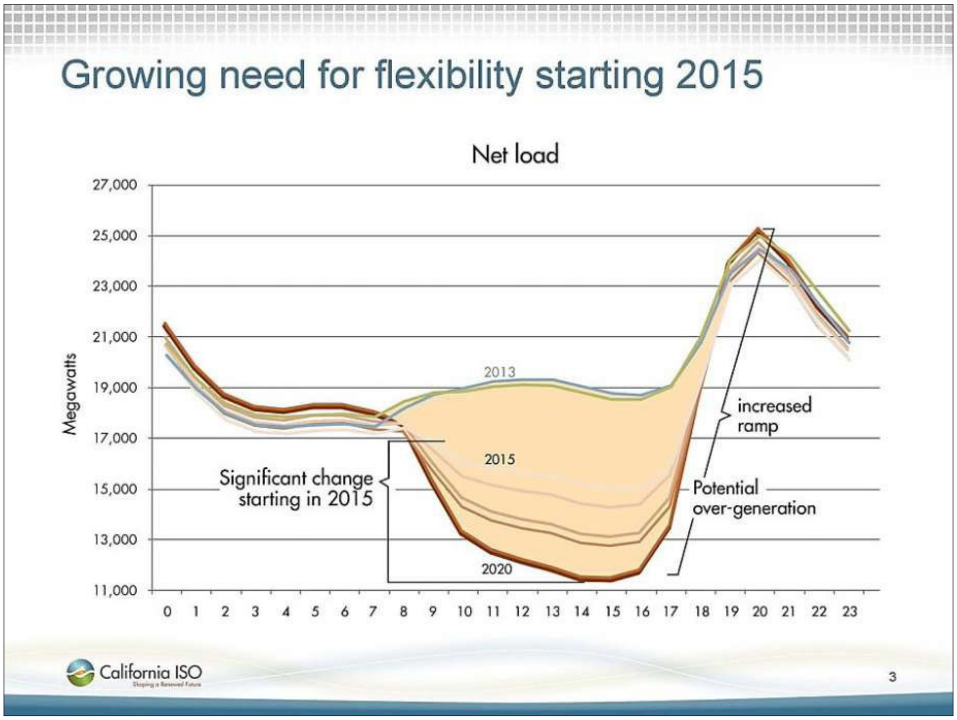
10 Regional diversity in wind generation allows for a more stable source of generation, since wind speed and presence is at least partially uncorrelated across different regions. That is, just because it is not windy in southern Alberta does not necessarily imply it isn't windy in northern Alberta.

11 The Bonneville Power Administration is a market operator that manages wholesale electrical power and the electricity-transmission grid in the Northwestern United States. The territory managed by the BPA includes Idaho, Oregon, Washington, and portions of Montana, California, Nevada, Utah and Wyoming.

Panellists suggested that some solutions might be found by taking advantage of both energy storage and demand-side management (DSM). From an electrical-systems perspective, most solutions will lie in a regional context; the key difficulty can be found in getting disparate jurisdictions to agree on objectives.

Turning to recent experiences in solar, the panellists acknowledged that most of the growth in overall solar photovoltaic (PV) installations has come so far from rooftop installations. However, this has introduced the phenomena represented by the "Duck Chart" (see example in Figure A below), which must be dealt with in terms of dispatch. The panellist relayed to the roundtable the reality that introduction of photovoltaic solar power has introduced a need for significant ramping throughout the day, especially in the late afternoon when demand is high (and often increasing) and the sun begins to set. This removes solar generation from the grid at a time when it is most needed, leaving other generation assets (notably thermal) to pick up the slack. This necessary ramping is expected to put significant pressure on systems operators, who must constantly balance demand and supply, as solar becomes a larger part of the electricity-generation mix.

FIGURE A THE "DUCK CHART"— CHALLENGES IN BALANCING THE NET LOAD



Source: California Independent Systems Operator, "Long Term Resource Adequacy Summit," February 26, 2013, http://www.caiso.com/Documents/Presentation-Mark_Rothleder_CaliforniaISO.pdf.

One method, suggested by panellists and discussed by participants, is to use energy storage or demand-side management to smooth the required ramp in supply. California, for instance, has a mandatory procurement of energy storage. Unfortunately the original targets in the legislation were set too low, both on size and characteristics, leaving this program short of total effectiveness. Here again, the panellist reiterated the problem with an energy-only market in that storage represents a cost without any net generation (rendering the concept of a levellized cost of electricity meaningless in this application). The biggest value of energy storage doesn't come from energy markets; it lies in creating capacity and ramping capabilities to complement other sources of generation. This assertion led the panel to the conclusion that the key elements in assets complementing generation are agility and flexibility, not necessarily total megawatts of energy capacity.

Through their prepared statements, the panellists generally agreed on the broad characterization of choices that maximize the utility of grid operations including renewables. As a group they outlined six dimensions by which the value of different generation technologies should be considered and classified: **reliability, resilience, flexibility, affordability, sustainability** and **security**. [12]

Careful consideration of these six dimensions is critical to assessing what the panellists identified as the most significant challenges of integrating wind power into the grid. These challenges include:

- ***Understanding the resource variability***: What is the accuracy of forecasting for intermittent resources and how can it best be applied to facilitate cost-effective integration of generation based on these resources? Given these forecasts (even if they are very precise), variability will still persist, so how can this variability be managed?
- ***Maintaining grid stability***: How can reserve requirements be met most effectively (type of reserves; required capabilities) and given these new assets, what are the associated infrastructure needs (what transmission upgrades are needed and what can be retired)?
- ***Dealing with project finance***: What should be done to restructure the current market design to fairly compensate firms for the fixed costs, and not just the marginal costs, of electricity production? And how should storage and flexible dispatch assets be paid for?

Another critical insight shared by the panellists and audience is the clear need for new and more detailed operational data to make better decisions on investing in renewable assets like wind power. There are lots of studies based on synthetic data — but panellists and participants recognized and asserted that these studies may not actually represent realistic performance characteristics, which could conceivably lead researchers to make poorly informed and damaging policy prescriptions.

Following their prepared statements, several systems-level questions were directed to the panel regarding the issues they discussed.

Multiple questions were put to the panel on the issue of how best to design a market with the goal of promoting effective grid integration. Specifically, the panel was asked *whether a "market setup" would be necessary, or even sufficient, to induce an efficient level of renewables investment and integration*.

The panellists all agreed that a formal market (as opposed to a centrally planned system) is certainly not essential for, nor an impediment to, effective continued operation of Alberta's power system with increased renewable integration. It was acknowledged that Alberta developed a power system for half a century without markets, but that an open market is potentially an optimal way to achieve the goal of a cost-effective power system with integrated renewables.

Responding to related questions on *technology neutrality in the energy market, the optimal design of the energy market, and how an optimal market would compare to the current market*,

[12] These six dimensions have also been identified by the U.S. Department of Energy as topical areas to be further explored to characterize grid modernization.

panellists emphasized again the importance of considering the non-energy components of competing technologies.

The panel once again highlighted that continued use of the levellized cost of electricity (as is used in Alberta's market) as a base metric for market pricing is an ineffective strategy for promoting efficient investment in and integration of renewables. In particular, the notion of comparing everything to levellized costs is meaningless for many important technologies (e.g., energy storage and demand-side management) that are complementary to the continued integration of intermittent technologies.

In further pointing out deficiencies with the current market design, one panellist pointed out that, since externalities exist for all generation technologies, their costs are not directly comparable using a simple metric such as the levellized cost. Per unit of generation, levellized cost assessments show wind as having the lowest carbon footprint, but these do not factor in the need to keep thermal on standby to make up for a lack of stable generation. As such, while the goal of technology neutrality is admirable, it may not be practical unless we can directly price in all factors of generation capacity.

However, the panel cautioned that even with effective markets in place, the valuation of individual non-energy components would be difficult. With that caveat in mind, over the longer term, a forward market and/or capacity market along with an explicit price on carbon will likely lead to a fairly efficient outcome. The big issue in designing and facilitating these markets is how to reconcile and integrate the interacting markets. One panellist suggested that a carbon tax combined with a forward-capacity market could be effective, but that the optimal forward time horizon is unclear.

A follow-up question asked of panellists was *how long it would take to add differential pricing elements to the market*. The panel responded by pointing to the last example of major restructuring of Alberta's electricity market: deregulation, for which the process took approximately five years. Too quickly a transition, it was argued, would lead to a protracted period in which lingering defects would have to be fixed over time. Rushing to impose a new system that would need to be patched was presented as a less desirable outcome than a slower steady transition.

Speed of transition was also considered in a different context, in particular with respect to the phase-out of coal-fired generation in Alberta. The panel was asked *if a slower transition away from coal would help in avoiding a "dash to gas," wherein coal-fired electricity would be replaced with natural-gas-fired generation, which, while producing lower emissions than coal, would be less desirable than renewables from an environmental perspective.*

Members of the panel suggested that since Alberta does not have access to a strong alternative to thermal generation (such as hydroelectric), it will be difficult or impossible to avoid incorporating some natural-gas generation. This is because the cost of completely eliminating all emissions from the electricity sector in Alberta is too high to be practical.

The panellists also clarified that coal generation is not designed as an offset technology. It is instead designed as a baseload. Thus, the transition away from coal and the decision of how much natural-gas generation should be integrated to replace coal remains a question of how high Alberta's allowable emissions should be, or conversely, how much the province is willing to pay to reduce the emissions footprint of the electricity-generation sector.

The panel and participants also acknowledged the role that physical inertia in coal plants plays in the existing market. Currently, spinning resources are required and used for frequency regulation. While this is a critical role of coal capacity, new technologies and techniques are being explored to satisfy the need for frequency regulation. These technologies/techniques include harnessing elements of the demand side, like hot-water heaters and electric cars.[13]

As a final question, the panel was asked to comment on *where the current integration of renewables had proven easier than previously thought*. The panel indicated that many of the operational impacts of wind integration have not been as bad as previously feared. The system has coped well with renewable integration so far, and the myths of blackouts resulting from poor management of intermittent renewable generation have not manifested. Further, the panel pointed to the "can-do" mentality of the industry and regulators, especially since wind integration has proven far more successful than was expected a decade ago.

OPEN ROUNDTABLE DISCUSSION

The third and final session was an open roundtable discussion, which generally took the form of audience comments and questions for specific panellists. Several of the questions put to the panel explored the theme of unique aspects of the Alberta power grid and market, with a focus on how these aspects affect the application of lessons learned through renewable integration in other jurisdictions.

In particular, participants acknowledged Alberta's large industrial base and the associated potential for co-generation,[14] as well as the limited nature and difficulties of interconnections between Alberta and other regions. Predicated on this there was a general query put to the panellists: *Is Alberta unique enough to require a unique solution for including renewable energy in this mix?*

In response, panellists pointed to individual countries within the European Union as examples of a market similar to Alberta, but wherein storage is not a limiting issue due to interconnectivity between regions such as Germany and Poland, as well as Denmark and Germany. Thus, providing local complements to address intermittency of renewables is of particular importance for Alberta.

The issue of *hydroelectric potential in Alberta* was also raised. Since large-scale hydro is able to complement more intermittent renewable generation, members of the audience proposed that Alberta could make use of potentially large hydro resources in the north of the province. In addressing this line of argument, panellists and other roundtable participants indicated several limitations in exploiting hydro power due to cultural and economic concerns. Hydro projects require substantial public engagement, and social support seems to be lacking in

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[13] The implied management system would function as follows: Given a sudden deficit in the amount of generation capacity required to balance the grid (as the result of either a reduction in generation from intermittent sources, or a sudden increase in electricity demand), a demand-side management system would be able to interrupt service to specific appliances like electric hot-water heaters or electric-car charging stations for brief periods in order to close the defect in the short term until additional generation capacity can be dispatched.

[14] Co-generation is the process by which industrial operations using a steam plant as a component of their operations will jointly produce heat and electricity. In the context of Alberta, this often occurs in oilsands operations in north-central Alberta. These facilities produce and use steam in order to loosen and extract bitumen from oilsands while simultaneously generating electricity, any excess of which is often sold onto the electricity grid.

Alberta. Given these considerations, along with the observation that potential hydro resources are not located near demand centres, the panellists concluded that a much lower cost of capital (potentially obtained through public-private partnerships) would be necessary to motivate any significant investment in hydro in Alberta.

The audience next raised the issue of and possibility for *increased regional integration, allowing for resources in other regions to act as firming capacity against Alberta's intermittent renewables.* Roundtable members explained how an efficient regional interchange for Alberta might function. Such a market would be required to provide substantial flexibility such that Alberta (and other regions) would be able to buy surplus electricity from other provinces/regions and then return it in off-peak times. Markets work effectively, but peak-load expenses make it difficult to bring down gas and coal to accommodate wind and solar.

On the topic of regional integration, the question of emissions leakages was raised, specifically: *How can policy-makers deal with considerations of emissions reductions in a system where emissions reductions in one region can be offset by gains in another due to substitution between generators in different regions?* The panellists acknowledged that leakage is always going to be a problem unless emissions policies are applied broadly enough to catch all relevant emissions. So far, no single authority has attempted to impose a pan-North American emissions tax or market.

The discussion on emissions regulations led to additional focus on the topic of emissions markets in the context of renewable-energy credits (RECs).[15] Specifically, the panel was asked to consider *if and how market participants could "game the system" by double- and triple-counting RECs?*

Panellists conceded that gaming of the market was a legitimate concern and that double- and triple-counting for emissions-credit purposes is possible and does happen. This behaviour obviously leads to inefficient outcomes. However, even though the market is susceptible to some gaming, panellists pointed out the reality that, globally, renewable-resource-generation technology would not exist without government intervention to correct an existing market failure (emission externalities). The key point here was that the market/government relationship is more symbiotic than is commonly understood or referenced.

The final area of inquiry was a discussion of the cost issue, first acknowledged in the keynote, this time from the point of view of consumers. The question was posed: *At what point would the consumer impact be so great as to be considered a failure?* Put another way: *What cost can consumers be made to bear for the renewables push?*

In response to this, participants pointed to the fundamental value/cost relationship. In particular, while Albertans already pay very low electricity costs, there is a substantial potential for rate shock and public dissent if those costs were to increase. The issue here is then not so much about how high we should let prices get (since, we are starting from a relatively low price to begin with), but rather, how can the electricity sector and policy-makers demonstrate the value of Alberta's power grid to consumers. Following its existing efforts to integrate renewables, the U.S. is now spending less money as a percentage of disposable income on energy. So rather than just looking at rates, consumers need to be directed to look

[15] The REC market is an energy-commodities market in the United States. RECs represent tradable credits constituting proof that one megawatt-hour of electricity has been generated from an eligible renewable-energy resource. The intention is to provide a mechanism to specifically value the environmental attributes of renewable energy.

at their total bill, or their total bill as a percentage of income. Policy-makers need to show consumers the full picture, including efficiency improvements and affordability, in order to maintain support for renewable integration.

SUMMARY AND CONCLUSIONS

Summary

Based on reflections of the above roundtable proceedings we, the organizers, have synthesized some of the common themes and comments into a set of summary observations specific to the situation in Alberta, followed by general conclusions regarding the form of effective renewables-integration policies. As with the above descriptions of the events of the roundtable, these represent our views on the proceedings and may not conform to the views of the individual roundtable participants.

While we have listed a large group of potential renewable-energy alternatives previously, as a practical matter only solar and wind power have been seriously mentioned in policy debates recently. There are opportunities for some thermal generation of electricity from geothermal resources in the far north of the province where there is access to bulk transmission facilities, as well as ground-source heat offsets for gas heating. In this discussion, however, the most prominently discussed policy alternatives were limited to solar photovoltaic (not thermal) and grid-scale wind applications.

This focus on solar and wind makes sense as Alberta has tremendous wind resources at various locations throughout the province. However, the level of wind in Alberta's generation mix will be limited if wind's intermittency cannot be overcome with other sources of generation. There was some inconsistency of views among the panellists as to how this intermittency would best be overcome in Alberta. Both (yet-to-be-built) hydro generation in the north of the province and electricity interties with other regions were presented as possibilities, along with continued but reduced reliance on thermal sources of generation. In the nearby Pacific Northwest areas (specifically the area covered by the Bonneville Power Administration), the growth of wind as a proportion of the generation mix is likely to become limited if fluctuations in wind generation cannot be overcome by the use of other resources. Conditions such as this, which emphasize the relative strengths of different regions, highlight the importance of regional relationships and ultimately, sharing or interconnections.

There is, however, a significant difficulty in achieving regional integration in that the market design needs to recognize the value that other regions bring to the combined market. This likely means structuring an integrated regional market where consumers in each region pay for capacity through a pricing scheme that goes beyond a simple assessment of the marginal cost of generation, including some distribution among consumers of the fixed capital costs of different generation assets.

Wind generation undergoes both seasonal variation and intra-day or even intra-minute variation. Dealing with such variation has led to the development of increasingly accurate forecasting as a result of increasing wind generation. However, even accurate forecasts of renewable generation are not a complete solution to the issue of variability.

Solar photovoltaic has some advantages over wind in terms of generation growth potential. First, the cost profile of solar has improved dramatically due to technology advances over the last decade, and second, solar generation is far more consistent and predictable within a narrow time band, generally consistent with midday peak demand. However the solar incidence is not directly correlated with high energy density and capacity, as was illustrated by Figure A above.

Energy storage can overcome this characteristic, but only at extra expense. The most useful contribution from energy storage doesn't come as an energy-generation component, but rather in its ability to effectively add additional capacity and ramping capabilities to complement renewable-generation technologies like solar. Put another way, agility is a key measure of the value of storage, not simply its overall dispatch capacity (kilowatts). Storage (while expensive) may prove more cost-effective than maintaining generation capacity (leaving thermal capacity in place and on standby). However, in order to achieve the potential cost savings associated with storage, there must be effective compensation for storage built into the energy-market structure.

However, solar has significant scale and dispatch issues, which can lower its ultimate contribution to grid operations. The exchange value of generating capacity between solar and coal is profound, reflecting the lower energy capacity factor of solar (~15 per cent) and the corresponding land area required to equal coal-capacity losses. The generation profile of solar may also fail to accommodate demand over significant relevant portions of the daily demand profile (especially in winter) due to its reliance on hours of daylight.

Alberta must take into account the structure and performance characteristics of its current resource mix for electricity generation. In this context, the recently announced coal phase-out actually represents a much larger proportional commitment than that of Ontario, since coal represents a relatively larger role in Alberta's less-diversified resource mix.

Alberta will require some element of non-renewable generation in the market for the foreseeable future. Any market design must therefore include a way to compensate both the firms producing via non-renewables and those producing via renewables. The role and participation of utilities in this future policy is critical. Currently, utilities pay for non-renewable generation on a go-forward basis (e.g., keeping alive an old steam turbine to meet demand in peak periods). This is not an efficient way to support or incent future investment since it does not provide an appropriate reward for developing new technologies. A preferred approach (as discussed by the panel) is to have an explicit market for capacity and a market for flexibility, such that a utility can be compensated for the non-energy component of the value of its generation capacity.

Retiring current coal-fired capacity raises other cost issues as well. For instance, in terms of potentially stranded assets (existing thermal-generation capacity), panellists agreed that the problem is more complex than is usually imagined by decision-makers. In particular, since existing thermal-capacity investments have contributed to significant externalities (costs not internalized by investors), it will be questionable as to whether or not investors should be allowed to recoup the outstanding (underappreciated) value embodied in those assets.

In this area, long-term contracts should (and usually are) set to match the life of a project. Thus, if investments (and associated contracts) are staggered and diversified, there should be little or no potential for stranded assets, and there should also be an effective maintenance of generation capacity. Shorter contracts are possible as long as contracts are sufficiently overlapped (such that individual contracts end and are replaced at different times) and rely on diverse sources.

A key challenge in integrating renewables in future markets has to do with the variability of renewable-based generation. Since the electricity market must be in a constant state of balance (where generation is equal to consumption of electricity), understanding the variability of different renewable resources is key to maintaining a well-functioning electricity transmission and distribution grid.

Conclusions and Recommendations for the Future

From the roundtable discussion it is evident that there is a clear preference in the policy arena and the consumer market for access to cost-effective renewable generation with the added benefit of carbon-emissions control. Actual, rather than theoretical integration of this type of generator poses clear engineering and economic challenges. Dispatchability, timing, pricing and matching load to energy density require special programs and staff to accomplish safely.

Other challenges pose equally daunting hurdles. These include the lack of long-term power-purchase agreements, which can dramatically reduce the risk (and by extension the cost) of long-term capital costs, short-term subsidies for new technologies, buffers from power-pool pricing rules, and other supports for overcoming risk profiles in long-term finance.

In the face of these difficulties, a number of conclusions can be made representing conditions for a positive future for renewables in the province.

1. **Technology-neutral choices**
   There is a need to develop a technology-neutral market design as opposed to simply adopting the technique of retrofitting the current market specifically to incentivize renewable integration. A formal market (as opposed to a centrally planned system) is certainly not necessary for the effective continued operation of Alberta's power system with increased renewable integration, but it may be an effective and efficient way to achieve the goal of a cost-effective power system that includes renewables.

2. **Look beyond the LCOE**
   Investment in the current market structure in Alberta is based on comparisons of the levellized cost of electricity. Continued exclusive use of this metric as a base for market pricing is an ineffective strategy for promoting efficient investment in, and integration of, renewables, since the notion of comparing everything to levellized costs is meaningless for many important technologies that are complementary to the continued integration of intermittent technologies.

3. **The need for market redesign**
   As more highly differentiated generation capacity becomes available, an effective market structure will need to figure in the costs and values of the non-energy components of different generation technologies (specifically stability, environmental damage and ramping). Given this, the answer to valuing non-energy components may lie in differentiable markets (markets for capacity, ramping and generation characteristics) as each of these would price a different relevant aspect.

4. **Be mindful of costs and benefits**
   To once again paraphrase the point made in the keynote address, if we are willing to pay all it takes to reduce emissions in the utilities sector, then we are willing to pay too much. An effective strategy for the integration of renewables into the Alberta utilities grid must be focused on a balance of costs and benefits. From an economics perspective this means focusing on costs and benefits such that actions are taken if and only if the benefit (whether it be in the form of reduced emissions or increased firming capacity) exceeds (or is equal to) the cost. [16]

5. **Consider the benefits of geographic and technological diversity**
   An effective and well-functioning electricity grid will make use of several diverse technologies and will include regionally diverse generation centres. These aspects allow for a more stable grid and one wherein different technologies act as complements, and not necessarily substitutes, for each other. Early efforts at wind integration in Alberta largely focused on the southern portion of the province, however regional diversity in wind-generation assets generally allow for lower risk and a more certain generation profile. While it may not be feasible to develop policies that are totally technology agnostic, policy-makers must keep an open mind when it comes to considering multiple new technologies for renewable grid integration. Perhaps most overlooked is that an effective policy needs to consider and accommodate both generating assets (like wind and solar photovoltaic) as well as non-generating assets (energy storage, demand-side management and expanded interties), and must be able to provide an efficient return on these investments where appropriate.

In closing, we wish to thank all roundtable participants (both panellists and the audience) for sharing their insights and views. While the sessions raised many questions, the general theme was that good policy is best derived by asking the right questions. We hope this document can serve as a foundation for policy development founded on that principle.

[16] It is important to stress the nuance of this conclusion. Correctly identifying the costs and benefits of different policy approaches is difficult and requires a comprehensive approach. Looking at marginal expansions of our infrastructure will lead to inferior or sub-optimal results compared to long-term planning methods. So, if we only expand and modernize the grid by incremental steps on the margin, we may miss out on larger infrastructure enablers that are superior in the long run. Therefore, the most optimal outcomes ***may*** require more transformative approaches.

APPENDIX A: ROUNDTABLE AGENDA

8:00 a.m.	Registration and light breakfast
8:30 a.m.	**Opening Remarks** Michal Moore, *The School of Public Policy*
8:45 a.m.	Keynote Address **Evaluating Renewable Policy from a Benefit-Cost Approach** Marvin Shaffer, *Professor, Simon Fraser University*
9:00-10:15 a.m.	**Collusion or Co-operation: The outlook for meeting policy goals** This session will examine whether public policy objectives designed to develop new renewable capacity in electric markets has proven successful, both in terms of performance and installed capacity. Discussants will review common policy objectives in North America and contrast them with those developed and being implemented in Alberta. All participants will be involved in a roundtable discussion of objectives, time frames and outcomes as both political and engineering systems evolve. Moderator: Michal Moore, *The School of Public Policy* Discussants: [*Academia, regulatory and industry representatives*]
10:15-10:30 a.m.	Break
10:30-11:45 a.m.	**Roundtable Discussion: Reality versus Aspiration and Expectations** This session will discuss the performance and experience of integrating renewables over the past ten years in North America. Discussants will examine the ability of the current electric grid to accommodate various types of renewable resource technologies during normal operation and discuss issues such as sudden resource loss, reserve generation and firming and appropriate and effective pricing and incentives for renewables. The challenge of replacing thermal generation while substituting alternative technologies in terms of cost and performance will be a key theme of the panel. Moderator: Matt Ayres, *Market Surveillance Administration* Panellists: [*Academia, Regulatory and Industry representatives*]
11:45 a.m.- 12:30 p.m.	**Open Discussion: Research Directions** with working lunch Moderator: Michal Moore, *The School of Public Policy* Two or three discussants from previous panels will lead a roundtable involving all participants.
12:30 p.m.	**Adjournment**

APPENDIX B: BACKGROUND ISSUES PAPER

This short issues paper, authored by Michal Moore (The School of Public Policy), was circulated to all roundtable participants (panellists and audience) prior to the roundtable discussion.

Renewable Energy: Policy Goals and the Reality of Grid Integration.
Issues for Consideration

This issue paper has been developed to identify the major issues surrounding the future integration of renewable-energy resources into the Alberta electricity grid. In the last decade, significant increases in capacity from wind power have been developed, although with limited geographic distribution, to take advantage of wind resources in the province (see Table 1 below from the AESO). The incentive for adding capacity is a reflection of independent power-producer interest and some policy incentive from both the federal and provincial government, yet the electric power grid continues to be dominated by thermal-electric generation. Future increases in renewable commitment from both public and private sources will depend on a combination of appropriate economic, political and regulatory incentives and market demand. All of these must be viewed in terms of a well-established grid with transmission and fuels delivery designed to generate and deliver power using a much different historical paradigm.

Changing this paradigm will depend on a combination of political will, political sentiment and a common view of which future is being considered, from environmentally "friendly" to business as usual, and over what time frame.

1.0 Background

The quest for renewable-energy sources[17] has been long and constant. Since every society has a continuous need for energy in various forms, they must seek out or reward those who can develop affordable and reliable sources; this is especially true where fuels are not diminished over time.[18] Acquiring and producing energy from renewable resources is a policy, scientific, engineering and economic topic and goal that has long-term implications for every country; in this effort, most of the implementation, standards and incentives are the responsibility of regulatory institutions, utilities and private power generators.

Most early development of renewable-energy resources relied on mechanical or direct use of available resources such as wind turbines for pumping water, waterwheels for grinding, or hydraulic assistance or direct heat from geothermal sources. Recent interest in developing and utilizing grid-scale renewable generation can largely be traced to the 1970s, where government mandates for renewable capacity and intense research and development of new technologies, especially in wind and solar resources, initiated a new era of expansion. Along with these advances came new government and policy mandates for higher deployment of renewables, increased regulatory interest and compliance, and more active and reliable management of intermittency and firming demands for grid operations.

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[17] For purposes of this short paper, renewable-energy resources are assumed to be electric generation — AC and DC — but not biofuels or demand-side management (DSM)

[18] Economists consider these "flow" rather than "stock" resources.

TABLE 1 RENEWABLE ELECTRIC CAPACITY AVAILABLE TO THE AESO

TNG - Total Net Generation	All values listed are in MW
DCR - Dispatched (and Accepted) Contingency Reserve	
MC - Maximum Capability	

HYDRO	**MC**	**TNG**	**DCR**
Bighorn Hydro (BIG)	120	92	27
Bow River Hydro (BOW1)	320	76	167
Brazeau Hydro (BRA)	350	18	80
CUPC Oldman River (OMRH)	32	17	0
Chin Chute (CHIN)	15	10	0
Dickson Dam (DKSN)	15	9	0
Irrican Hydro (ICP1)	7	6	0
Raymond Reservoir (RYMD)	21	14	0
Taylor Hydro (TAY1)	14	12	0

WIND			
Ardenville Wind (ARD1)*	68	0	0
Blackspring Ridge (BSR1)*	300	0	0
Blue Trail Wind (BTR1)*	66	0	0
Castle River #1 (CR1)*	39	0	0
Castle Rock Wind Farm (CRR1)*	77	0	0
Cowley Ridge (CRW1)*	38	0	0
Enmax Taber (TAB1)*	81	0	0
Ghost Pine (NEP1)*	82	0	0
Halkirk Wind Power Facility (HAL1)*	150	0	0
Kettles Hill (KHW1)*	63	0	0
McBride Lake Windfarm (AKE1)*	73	0	0
Oldman 2 Wind Farm 1 (OWF1)*	46	0	0
Soderglen Wind (GWW1)*	71	0	0
Summerview 1 (IEW1)*	66	0	0
Summerview 2 (IEW2)*	66	0	0
Suncor Chin Chute (SCR3)*	30	0	0
Suncor Magrath (SCR2)*	30	0	0
Suncor Wintering Hills (SCR4)*	88	0	0

BIOMASS AND OTHER			
APF Athabasca (AFG1)*	131	67	0
Cancarb Medicine Hat (CCMH)	42	0	0
DAI1 Daishowa (DAI1)	52	44	0
Drayton Valley (DV1)	11	0	0
Gold Creek Facility (GOC1)	5	0	0
Grande Prairie EcoPower (GPEC)	27	13	0
NRGreen (NRG3)	19	0	0
Weldwood #1 (WWD1)*	50	31	0
Westlock (WST1)	18	12	0
Weyerhaeuser (WEY1)	48	47	0
Whitecourt Power (EAGL)	25	21	0

Source: AESO, "Current Supply Demand Report," http://ets.aeso.ca/ets_web/ip/Market/Reports/CSDReportServlet.

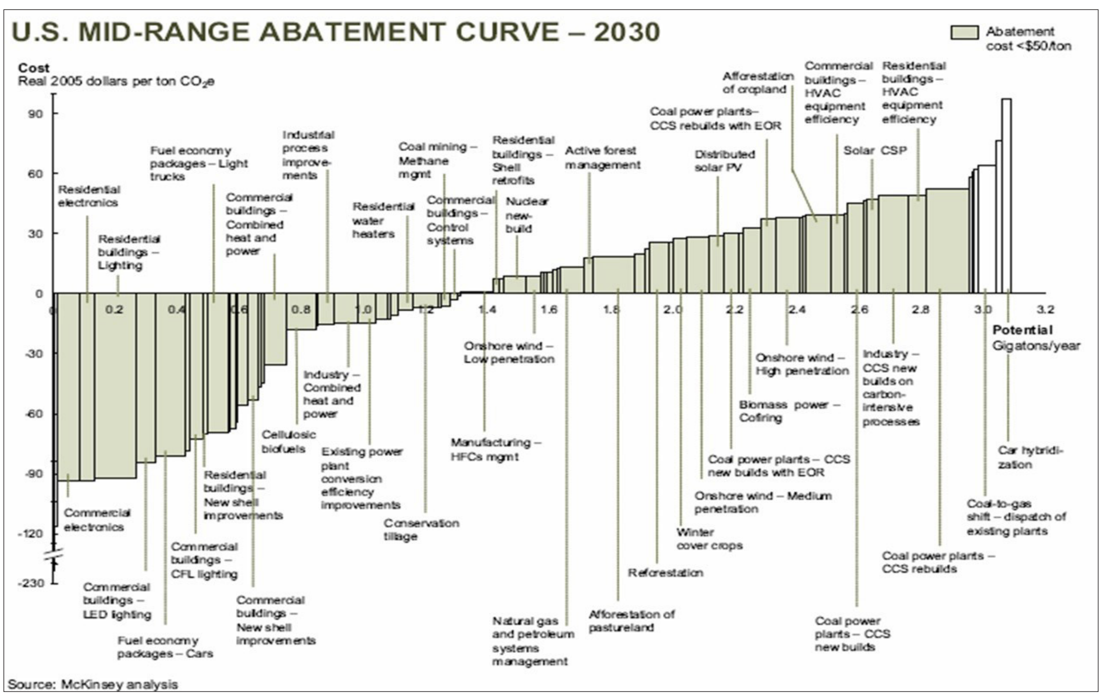
Public interest, acceptance and support has waxed and waned since that period, roughly correlated with energy costs, personal income and tax burdens. As well, the ability of grid operators has evolved, reflecting the balancing act necessary to match existing capacity, withdrawals of older, inefficient generators, such as pulverized coal, and demands for new, cleaner technologies that include natural gas as well as renewables to meet changing load both regionally and locally.

Alberta does not have a wide range of renewable energy developed, although the diversity available to the AESO for dispatch is not trivial. The recent report of available capacity is shown in Table 1 below.

2.0 Role of Policy

The policy-associated interest in renewable-energy resources has fluctuated over the last two decades, depending on location, economic conditions and the interest and participation of the public (for instance in subsidizing different renewable technologies). In recent years, the claimed benefits of "green" characteristics attributed to renewables and their potential to lower GHG (greenhouse gas emissions) or to control carbon byproducts has changed the political and even economic calculus and, consequently, their attraction in the public arena. Figure 1, following from McKenzie (in 2005 dollars), illustrates the attraction in terms of substitution of various technologies over time, and the impact they have on carbon reduction.

FIGURE 1 ASSUMED CARBON ABATEMENT CURVES BY TECHNOLOGY



Source: P. Enkvist, T. Naucler and J. Rosander, "A cost curve for greenhouse gas emissions," McKinsey and Company (2007), http://www.mckinsey.com/insights/sustainability/a_cost_curve_for_greenhouse_gas_reduction.

Why are policy-makers interested? Clearly, recent news about carbon emissions changing regional climate patterns has gotten the attention of policy-makers and regulators. They can observe changing public opinion, not to mention evidence suggesting there may be a connection between power generation and long-term climate impacts. This, combined with assertions of technology-price declines and the success of some institutions in shifting large segments of their generation derived from renewables, enhances the attraction of advocating, and adopting various schemes to increase the renewable share of total generation.

Other attractive considerations for policy-makers include the potential for new employment (manufacturing, construction and maintenance, and grid operations), the claim that more renewable generation will ensure a more diversified and more resilient grid, the promise of distributed generation with lower long-distance transmission costs and, in the end, more robust and resilient environmental quality.

However, there are divisive and divergent opinions on whether or not all these claimed benefits will occur in a timely or cost-effective manner. The fact that the discount rate for policy-makers is traditionally very high (with a return period coincident with election periods) makes consistent support difficult. Additionally, the political support, programs and incentives vary widely from jurisdiction to jurisdiction, impeding consistent investment as well as regional dispatch.

Policy Incentives

Policy-makers and their representatives in regulatory institutions rely on a wide variety of incentives and initiatives to try and increase the share of renewable capacity available to serve consumers.

These incentives and programs have in the past included direct subsidies to producers to reduce the per unit cost of production, or to reduce the capital cost for investors, changing tax incentives to influence long-term investment patterns, and even the cross-subsidization of consumers or ratepayers who opt in for preferential renewable generation.

In the short term, the attraction of adding renewable capacity has also included contracts for renewable capacity from large-scale public-load sources (government institutions, educational facilities or military installations), guaranteed feed-in tariffs at above-market rates, standard-offer contracts, or preferred utility arrangements. Governments have written down leases for renewable installations on publicly owned lands, waived environmental standards in the interest of longer-term impact reduction, guaranteed capacity on bulk transmission lines, built special renewable-transmission links, and offered to transfer public research and development information to private developers in an effort to minimize upfront costs.

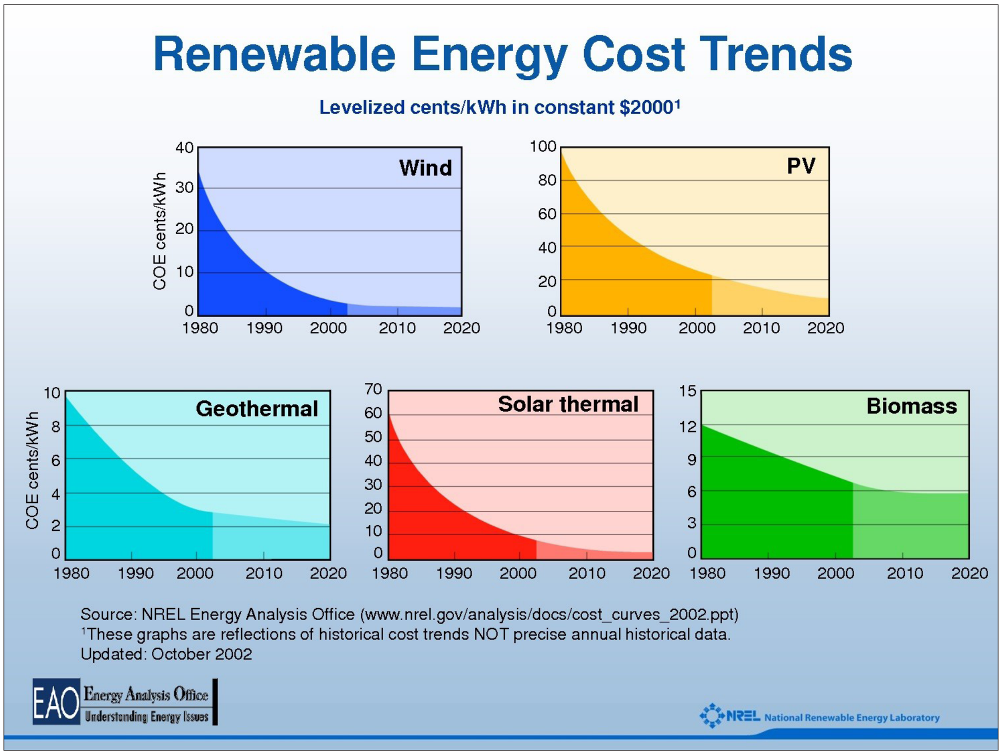
Long-term programs such as renewable portfolio standards, offsets combined with cap-and-trade programs and carbon markets or carbon-offset schemes have become a mainstay for many policy institutions, although there is a wide ranging set of criteria that govern operations (and success or failure) between co-operating or even adjacent jurisdictions. One outcome of this range of approaches and solutions for renewable integration is the inconsistent interest from financing agents and institutions, which in turn causes changes in the perception of policy-makers as to the success and effectiveness of their approaches to increasing the renewable share of energy generation.

3.0 Costs and Benefits

The question of direct costs and benefits from increasing the renewable share of grid operations is topically positive in the mind of the public, but uncertain in reality, depending on the metric chosen for comparison. Over time (since 1980), the marginal cost of deploying renewables into grid operations has declined steadily, and in the case of wind energy, dramatically (see Figure 2 below). When measured against a traditional benchmark of the marginal unit deployed by system operators (typically a combined-cycle gas turbine), renewables can approach or even fall below these costs, and when viewed long term, have the promise to be more affordable and available in regions where transmission and fuel costs are high. The availability of these resources, however, is not always consistent, and thus their capacity factor has lowered attraction for systems operators and investors, who are critical for adding capacity or replacing existing thermal capacity.

Costs have fallen for renewables (relatively: note that the y-axes of the graphs differ substantially), but so has the cost of thermal, where, even with increased costs for installed turbines, the dispatch cost of natural-gas facilities has declined in real as well as relative costs.

FIGURE 2 PROJECTED COST OF RENEWABLE TECHNOLOGIES



Source: NREL, "Cost Database," (2015), http://en.openei.org/wiki/Transparent_Cost_Database.

This calculus changes dramatically when the potential for controlling environmental externalities is included. Here, the attraction of diminished fuel demand from hydrocarbons, or lowered reliance on dangerous fuels such as radioactive compounds, influences public policy even when full costs are not known or consistently measured from past deployment.

Policy documents, models and standards adopted by regulatory institutions concerning full lifecycle costs (and benefits) of providing incentives for and adopting renewable technologies are inconsistent to date. Thus, although there appears to be widespread agreement on the idea that full lifecycle cost accounting is important, the nature of discount rates embedded in each agency's or actor's expectations has defeated common agreement in this area to date.

4.0 Policy, Regulatory and Engineering Issues

Renewable technologies suitable for grid-scale dispatch have existed and been utilized for well over two decades throughout the world, but primarily in North America and Europe. A wide range of literature, from academic to industry-sponsored, has been developed to examine the role and performance of these technologies in a variety of locational and market-based applications.

The short sections below are used to illustrate the issues involved, but not to evaluate their relative cost, effectiveness or attraction within a jurisdiction such as Alberta. For purposes of argument and discussion, they are divided into three (non-pejorative) categories of real, relative and social or moral issues.

Real — Issues with direct, measureable and comparable costs and benefits

a) Availability and access — Renewable resources are not evenly accessible or distributed throughout the countryside. For instance, some geothermal or even wind resources may be found with useful characteristics in or under public lands such as national parks.

b) Cost of technology — The cost of renewable technologies is falling, but it is not always competitive with thermal or hydroelectric resources. Replacing existing technologies can impose very high costs that must be absorbed by the rate base (or taxpayers) and thus the marginal cost of operation may have a range of attraction from one jurisdiction to another.

c) Reliability — All power-generation systems are subject to operational failure and, for purposes of grid operations, must be "firmed" or backed up with replacements or substitutes. This reliability characteristic will reflect the perception and operational experience with the technologies available by jurisdiction and will be found embedded in the levellized cost of energy as well as the levellized avoided cost of energy for the energy mix for the jurisdiction. Less reliable technologies, or those that are still deemed less than mature, will imply a discounted value and require more backup capacity for jurisdictions choosing to use them.

d) Capacity factor — Other than geothermal-baseload energy, renewable technologies are not always capable of generating (due to time of day, temperature, wind flows, etc.). Literally, the capacity factor is the ratio of its actual output, over a period of time, to potential output (if it were possible for it to operate at full nameplate capacity continuously over the same period of time).

e) Transmission capacity and interconnect — Many bulk transmission lines were built decades ago and lack available capacity for expansion; moreover, displacing existing firm capacity can bring with it grid-reliability issues that are difficult to resolve. Additionally, getting sub-regional transmission interconnects from renewable sites, whether terrestrial or offshore in the case of some wind facilities, entails extra costs and construction time.

f) Lifespan and technological replacement — No energy technology has an indefinite lifespan: turbines decline in quality, as do boilers and heat-recovery units for thermal generation. Likewise, wind-turbine blades and gearboxes must be replaced periodically, inverters for solar PV facilities lose reliability, and geothermal wells must be periodically re-drilled and stimulated in order to remain effective.

g) Dispatch — The grid operator is responsible for ensuring continuous energy supply and quality assurance. Scheduling energy availability implies confidence in the source, which in turn implies that firming behind intermittent resources is available at competitive costs. Grid operators (systems operators) manage this characteristic with a combination of long-term contracts and competitive bidding, but are always balancing the technology characteristics of new, intermittent or distant technologies with a goal of ensuring reliable grid operations.

h) Integration — Successful, continuous grid operations depend on seamless integration of all available and deployed technologies continuously. Preferential bidding or dispatch must be matched against other fundamental goals of the operator including, among other things, voltage support, volt-ampere reactive power, replacement of any outage or capacity that is down for maintenance, line congestion and a balance of import and export obligations.

Relative — Issues that differ from jurisdiction to jurisdiction, varying by policy base or local culture

a) Finance — The power industry is a business and must be able to run and recover costs while still attracting sufficient investment to replace and extend capital investments and add or replace capacity where necessary. Technologies that are not competitive, but that may represent social values or commitments that are extra-market, will depend on public support, intervention in the form of common standards, system-benefit charges borne by all, or sponsored subsidies in order to attract necessary financing over time.

b) Environmental controls or performance — Maintaining environmental quality is a relative characteristic defined by policy and regulatory standards. This can include standards for operations, initial capital costs, the ratio of benefit to cost over the life of the technology, as well as the cost of retirement and remediation. In the end, measuring these characteristics must depend on a common definition of costs, time of measurement, or operation, and the disposition of facilities beyond their useful or productive life (so-called lifecycle costs).

c) Measurement of capacity and performance role — The current electricity system, including fuel delivery, generation, transmission and distribution, reflects more than 100 years of investment and development. Wholesale replacement of the capital stock is impractical; thus, the role and contribution of renewable technologies is best viewed temporally. In the case of Alberta, the retirement of existing coal facilities implies an opportunity to develop generating capacity to provide baseload generation (for instance using geothermal power) as well as integrating capacity dedicated to load-following or peak-shaving, roles traditionally taken up by hydro or gas turbines. Adding capacity is fundamentally different both in terms of finance and performance and reflects a long-term commitment not only to substitute technology, but to maintain overall system cost, reliability and availability equal to or superior to existing facilities.

Cultural — Issues that are difficult to quantify and which may differ significantly from one jurisdiction to another

a) Willingness to pay (WTP) — Consumers in general are responsive to utility costs before they consider the quality, or environmental considerations inherent in power-generation choices. There are a variety of reasons advanced by scholars for this phenomenon, but the issue of power sources and what externalities are involved procuring and delivering them tend to be of limited interest to consumers. WTP surveys indicate there are, however, concerns that will elicit a strong willingness to pay to avoid damages or long-term negative impacts on environmental quality from power generation. The commitment to add and pay for surcharges made voluntarily is historically short-lived; social commitments to control externalities are thus best accomplished through across-the-board policy and regulatory controls.

b) Morality — There is a growing consensus among consumers, industry and business leaders that environmental quality is threatened by the continuation of the current power system. This may translate to a moral imperative for policy-makers to address, but apportioning costs and responsibility over periods long enough to ensure system performance, and lowering impacts, has not been identified or uniformly accepted by the public at this time.

5.0 The Future and Next Steps

Renewable-energy generation and its integration into the power grid are enjoying a growing consensus as to their value and potential performance. Policy prescriptions are beginning to tilt in favour of increasing commitment in the form of funding, and required capacity contributions, for grid operators as well as public utilities. It is clear, however, that policy initiatives will not be sufficient to incent large volumes of new capacity in the absence of interest from investors, landowners, independent power producers and utilities.

To fully implement long-term integration goals for renewable-energy resources, energy markets will demand consistent goals that allow cost recovery and profit incentives to be fulfilled. Additionally, access to remote or non-grid resources will demand new access corridors, tax treatment that provides long-term assurance of cost burdens, and perhaps insurance for technologies that still struggle to compete against installed historical thermal or hydro-based technology.

Public programs such as feed-in tariffs or renewable portfolio standards must not only compete with these same technologies and their first-mover advantage, but with changing and volatile fiscal conditions that make the funding guarantees for these public programs chimeric and transient. Ultimately, all technologies available for dispatch must operate using first principles of performance and competition. In other words, absent continuous taxpayer or ratepayer support, no power-generation technology will continue to be called upon for dispatch and service without being competitive both in current and lifecycle cost evaluation.

About the Authors

G. Kent Fellows is a research associate at The School of Public Policy, University of Calgary. Kent recently completed his PhD in Economics at the University of Calgary where his research focused on Regulatory Economics and Bilateral Negotiations, with a special focus on the Canadian Pipeline Industry. He has previously worked as a research assistant for the University of Alberta's School of Public Health and as an intern at the National Energy Board.

Kent has published articles on the effects of price regulation and bargaining power on the Canadian pipeline and pharmaceutical industries. His current research agenda focuses on the area of computational economics as applied to the construction and use of large scale quantitative models of inter-sector and inter-provincial trade within Canada.

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Blake Shaffer is a PhD candidate in economics at the University of Calgary. Blake holds a MPhil in economics from the University of Cambridge, and a BSc (Honours) in environmental sciences from Queen's University. Prior to entering the PhD program, Blake enjoyed a 15-year career in the energy industry, most recently as head trader at TransAlta Corp., and previously as senior energy trader and analyst at Barclays Capital (N.Y.) and Powerex (B.C. Hydro). Blake was a member of the royalty review's natural gas expert working group, and assisted the panel in the development of its report.

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