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Environmental Predictions and the Energy Sector: A Canadian Perspective

Study commissioned by:

Environment Canada Environnement Canada

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Presentation Outline

- Background
  - Defining EP
  - Study Objectives
  - Current Energy Outlook in Canada
- Methodology
  - Tasks & Deliverables
  - Classification Framework
- Case Studies
- Main Findings and Outcomes
- Recommendations

Background

- Project awarded through competitive tender (Request for Proposals)
- Timeline
  - March 1st, 2007: Project kick-off
  - March 31st, 2007: Literature Review Report completed
  - October 15th, 2007: Case Study Report (draft) completed
  - December 24th, 2007: Final Report completed
- Project coordination
  - Steering Committee: members from various government departments (Environment Canada, Industry Canada, Natural Resources Canada…)
  - Research team

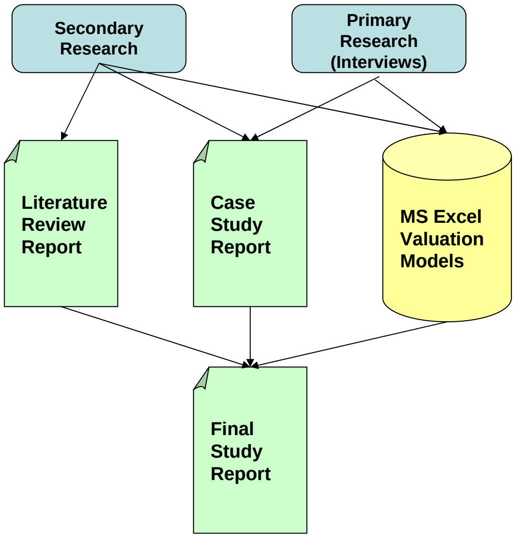
Defining Environmental Prediction

- “Developing and using knowledge of environmental and socio-economic sciences to project likely or conditional states of the natural world in order to assess future risks and opportunities that support decision-making regarding human health and safety, the environment, and socio-economic well being.” (Cantwell, Heffernan and McCulloch 2007).

Study Objectives

- To understand the nature of Environmental Predictions, and its significance for the energy value chain in Canada
- To create a solid, multidisciplinary framework for quantifying economic benefits of EP, based on energy finance, economics, earth observation, and other disciplines
- To identify various case studies which demonstrate the interaction between EP and energy, by focusing on four priority areas: electricity generation, electricity transmission, renewable energy, and upstream oil and gas.
- To create a framework for classifying these case studies based on different criteria, including their relative position on the value chain and the nature of the decisions involved.

Study Methodology



Secondary Research

Primary Research (Interviews)

Literature Review Report

Case Study Report

MS Excel Valuation Models

Final Study Report

Classification Framework

	Strategic Level	Tactical Level	Operational Level
Supply Side	√ Site selection for natural gas storage facilities √ Site selection for a new wind turbine √ Site selection for solar power plants √ Space weather early warning system for electricity grids	√ Incorporating wind forecasts into power line maintenance √ Optimal scheduling of power plant maintenance √ Inflow monitoring for hydroelectricity plants, including the incorporation of snow pack thickness √ Hurricane forecasts for offshore oil production √ Sea ice and iceberg now- and forecasts for offshore oil exploration and production √ Corn variant selection for biofuel production	√ Plant scheduling based on load forecasts √ Plant scheduling based on smog forecasts √ Performance monitoring for solar power plants √ Space weather impact assessment on pipelines and oil & gas exploration efforts
Demand Side	√ Design of demand-management programs which allow the incorporation of weather forecasts	√ Predicting El Nino – Southern Oscillation events for improved seasonal weather prediction: Impacts on hydroelectric system, Impacts on natural gas markets	√ Electricity load forecasting based on weather parameters
Financial Markets	√ Design of novel financial markets for emissions trading, weather derivatives, and catastrophe bonds	√ Designing financial market trades based on climate-based demand trends	√ Energy trades depending on short term information such as hurricane impacts on oil & gas production

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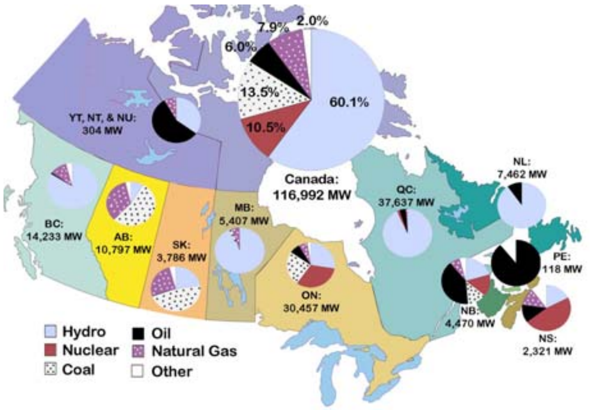
Some remarks about valuing forecasts

- A forecast has value if it is both: a) Actionable and b) Allows for actions that give value beyond those taken with some naïve information set
- Ideally a forecast valuation mechanism incorporates the fact that no forecast is perfect, however the value of a perfect forecast over some time horizon provides an upper bound for the value of an imperfect forecast
- Risk averse users find imperfect forecast worth much less than perfect ones
- A simple but insightful “rain/fair” forecast example is analysed in the accompanying spreadsheet

The Current Energy Outlook in Canada



Electricity Generation by Province and Fuel Type (2003 figures)
Data Source: National Energy Board (2005)

Case Studies

Title	Valuation Focus
Sea Ice	**Making better decisions to manage sea ice threats and managing the overall risk of an off-shore platform**
Supply Side of Hydro	**Various benefits ranging from optimal storage to minimizing spinning reserves.**
Wind/Water Integration	**Better operational decisions if a wind energy generator uses EP and has access to a pump storage in order to manage wind variability and maximize revenues**
Earth Observation for Renewables	**More accurate long-term revenue forecasts for off-shore wind farms**

Sea Ice Prediction

- Case study objectives
  - To document the application of EP predicting drift of pack ice and icebergs which threaten East coast oil platforms
  - To develop a valuation framework which can capture the economic benefit of using such EP to reduce the need to move platforms
- Sea Ice
  - Complicated multidisciplinary factors in its formation and destruction: depends on wind, insolation, temperature, currents
  - Motion of ice which breaks free from pack depends on wind, currents, and coriolis force in that order.
  - Satellite imagery very important for prediction, as is aerial recon.

Offshore Oil and Gas: East Coast of Canada

- Jeanne D'Arc Basin, 315 km SE of St John's in water 80m deep.
- Oil and gas produced out of a Cretaceous formation
- Three producing zones from a resource of more than 1 billion barrels of oil.
- Three drilling sites: Hibernia (150,000 barrels per day), White Rose (ca. 100,000 barrels per day), and Terra Nova (150,000 barrels per day)
- Different oil platforms at Hibernia vs. other two sites

Gravity Based Oil Platforms

- Hibernia: Very expensive (> C$1B) , invulnerable to ice and wind

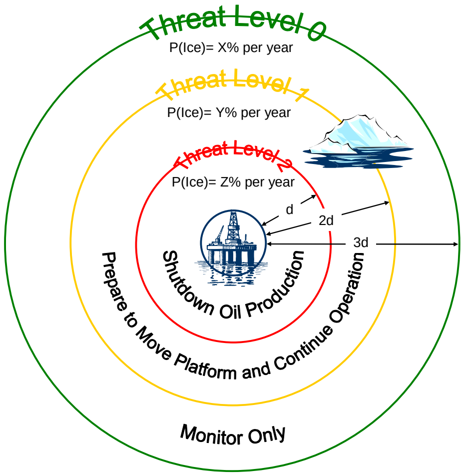
Mobile Platform (FPSO)

- Floating Production Storage and Offloading Vessel.
- Cheaper, more fragile than Gravity Based Structur
- Must move to respond to weather and ice threats.

Sea Ice valuation Framework

- Area protected by vessels which can divert ice
- For FPSO (mobile) units, protocol for disengagement
- Three phases to disengagement: -- Make ready – disengage pumping apparatus – Leave.
- Increasing costs
- Benefit is to avoid damage of unit and possible loss of life.
- As consequence very little value in < perfect forecasts

Sea Ice Valuation Framework



Sea Ice Case Study: Results

- Terra Nova and White Rose are in relatively ice-safe regions (in some years experiencing no ice events)
- Under reasonable assumptions accurate sea ice forecasts utilized in the above “get the hull out of there” decision framework are worth about half a million dollars per year. This is fairly small relative to the size of the industry.
- High risk aversion is expected in the offshore, reducing the value of EP for imperfect forecasts.
- Currently a great deal of attention is being paid to wind forecasts in the offshore, but little attempt is being made to forecast ice motion by integrating current forecasts.
- Oceans Ltd is currently working on such a package.

Sea Ice Case Study: Future Directions

- There is also interest in oil production from Canada’s Artic Coast (the Beaufort Sea)
- Of interest is the impact of sea ice formation on the end of the summer drilling season.
- EP integrating all aspects of the Sea Ice problem will be important for this.
- With global warming the potential for the Northwest passage to be more open exists – this might have impact in allowing Beaufort and Mackenzie Delta oil and gas to be serviced from Canada’s East Coast.

Hydrology Case Study

- Future water inflows and stage levels are uncertain
- Ability to forecast these hydrological variables is valuable for hydroelectric power producers
- This value depends on the time horizon
- We present four small case studies here valuing hydrological forecasts on time scales ranging from very short operational scales to long range climatological scales.

Hydrology Case Study: Spinning Reserve

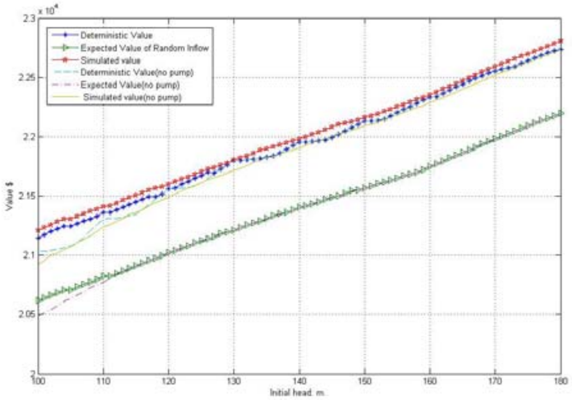
- Applicable to very short term (24 -48 hour) water inflow forecasts
- Model hydro production as “negative power demand (load)”
- Framework for value of accurate load forecasts exist (Hobbs et al. 1999)
- This framework allows the value of accurate short term water forecasts to be characterized as worth about $55,000 per year in Alberta – a rather modest amount

Hydrology Case Study: Optimal Flow Control

- Some hydro power facilities allow water to be stored behind the dam.
- What is the best way to use this stored water?
- It is best to save water when power prices (or power demand) are low and to use it to generate power when prices (or demand) is high.
- However maximum and minimum flow rate and water level constraints, often set by other river stakeholders, must be obeyed
- Optimizing the use of water whilst obeying the constraints creates value for accurate inflow/water level EP.

Value of a model hydro facility with and without accurate 48 hour hydrological EP I

Low water inflow case; From Zhao and Davison, 2007



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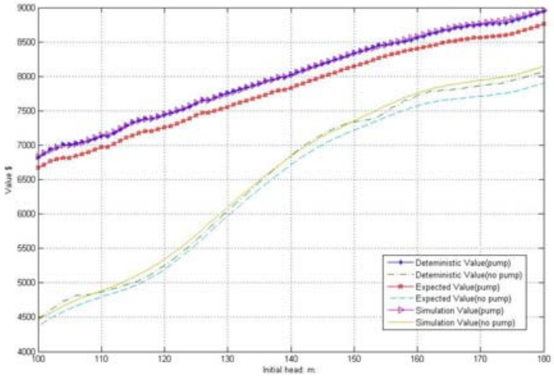
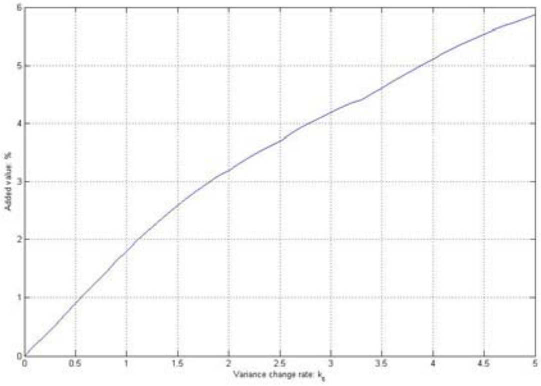


Additional Sales expected from optimal use of hydrological EP – as function of inflow process variance

- **From Zhao and Davison (2007)**



Hydrology Case Study: Optimal Flow Control – Results

- An EP-driven increase in sales of 2-5% could be, for the huge Canadian hydroelectric sector, worth hundreds of millions of dollars per year
- Of course not all Canadian hydro facilities are suitable for this – more study is required to accurately quantify this opportunity

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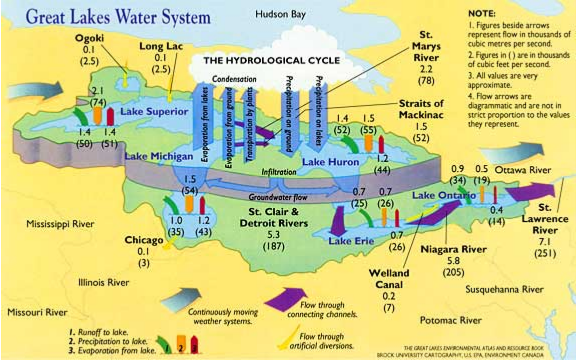
Hydrology Case Study: Medium-Long range forecasts

- In Alberta hydroelectricity comprises about 8% of the provincial generating capacity of 10000 MW.
- However the contribution of hydroelectricity varies a great deal over the course of the year --- it is high during "freshet" or spring runoff, and dwindles to a trickle in the winter
- The market for electrical power is deregulated in Alberta with huge variations between high and low prices, partly depending on the season: Power is cheapest in the spring and dearest in the summer and winter
- Significant water storage prospects exist in Alberta and good 3 month water inflow forecasts could generate significant additional revenue by allowing deferred power generation
- Our estimate of the value of EP allowing better deferred generation decisions is an annual $3.6 million.

Hydrology Case Study: Strategic Case

- Great Lakes drain through the Niagara River and over Niagara Falls.



Strategic Hydrology: Tunnel 3 at Adam Beck

- Niagara Falls, while generating a large fraction of Ontario and Western New York’s power, does not use all the water it could.
- To rectify this a third tunnel is being built at Ontario Power Generation’s Adam Beck power plant
- With current flow rates and power prices this project will result in additional sales of about $80MM per year for OPG.
- The facility is project to cost nearly $1B and to last for more than 50 years
- Go/No go decision on facility construction required long range EP on Niagara River flow rates

Wind-Water Case Study: Introduction

- Wind Power is a promising new technology but “it needs a dance partner”
- This is because wind is intermittent – its lack of reliability means that it requires expensive backup generation facilities.
- This intermittency gives wind forecasts a value under certain power market designs
- Stored water generation is an ideal partner for wind.
- Water could be stored behind a dam while the wind is blowing and released when it is not.
- The US Bonneville Power Authority has a mechanism allowing wind generators to access, for a fee, their water storage capacity

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Wind-Water Case Study: Pump Storage Facility Design

- Not every jurisdiction has the right geography to allow for such water storage however
- Sometimes the construction of pump storage facilities is required to procure such storage capacity
- This case study creates a feasibility analysis mapping out a design for such a pump-storage facility situated in Alberta

Market-based values of Wind forecasts

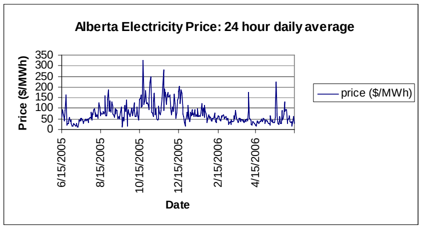
- Some deregulated markets have a dual structure with a Day Ahead Market (DAM) and an Actual Real Time Market (ART) (terms vary across markets)
- Power must be offered into the DAM and, if the offer is accepted and it is all delivered, this price is used
- If there is a shortfall or surplus of power, it must be settled in the ART market.
- Typically shortfalls in power are expensive to make up in the ART or balancing market
- This makes accurate short term wind forecasts very important.

Water Storage: The BPA experience

- The Bonneville Power Authority (BPA) has a scheme whereby wind producers can, at very short notice, deliver power in lieu of their hydro generated power.
- The water thus saved is used to generate power later, allowing the wind generator to offer power for firm delivery into the network.
- The BPA charges US$4.50 per MWh for this service
- For a geographical area with abundant water storage opportunities, this $4.50 likely represents an upper bound for the value of any wind forecast.

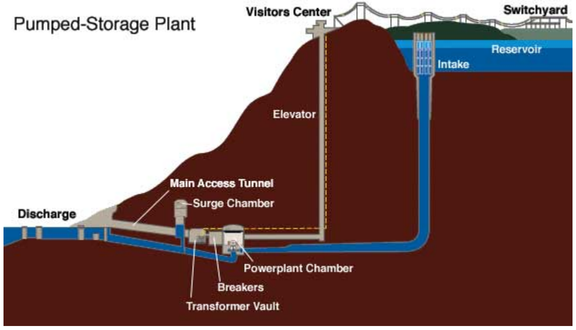
Alberta: The Wind/Water Outlook

- Alberta has an abundant wind resource
- It has some hydro power but not abundant storage facilities like in BPA or British Columbia
- It has a deregulated electrical power market
- It has a terrain with varying elevations.
- This makes it a prime candidate for pump storage facilities



Pumped Storage Facilities

- Pump storage works by pumping water from a low reservoir to a high reservoir when demand or prices are low; reversing the process when demand or prices are high
- Graphic from www.tva.com/power



Design and valuation of simple PSR facility

- We designed a hypothetical pump storage facility to buffer the output of a 1MW wind turbine located in Brocket Alberta.
- We have real wind speed data for this turbine and know the operating characteristics of the turbine, allowing the corresponding (extremely variable) power output to be computed
- Our challenge was to design a facility that allowed this variable power output to be converted to an output which was constant during “on peak” hours (Monday-Friday, 7AM-11PM) during which power demand, and power prices, are highest.

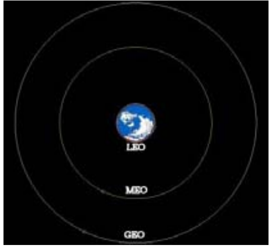
Design of PSR II

- We found that a 100 hectare upper reservoir with a depth of 10m, located at an elevation of 50m above a lower reservoir, worked to buffer the output in this way.
- This facility is highly valuable as it converts completely intermittent “undispatchable” wind power to the most desirable kind of power: reliable peak load servicing power.
- We estimated that the annual income from such a facility would be about $300,000 per year.
- The capital cost for constructing the facility would be large, but amortized over many years.

Earth Observation for Renewable Energy

- Case study objectives
  - To document applications of EP for various types of renewable energy systems, including off-shore wind and solar energy
  - To develop a valuation framework which can capture the economic benefit of using satellite data for offshore wind energy resource assessment
- Earth Observation
  - Techniques based on remotely sensing data using airborne or space-based platforms. Case study focuses on satellite data.
  - Depending on their orbital characteristics and on-board instruments, satellites can provide a wide range of data for renewable energy projects (passive microwave, radar, etc.).
  - Access to historical satellite databases is a big advantage: enables understanding long-term trends in resource variation.

Orbits & Capabilities

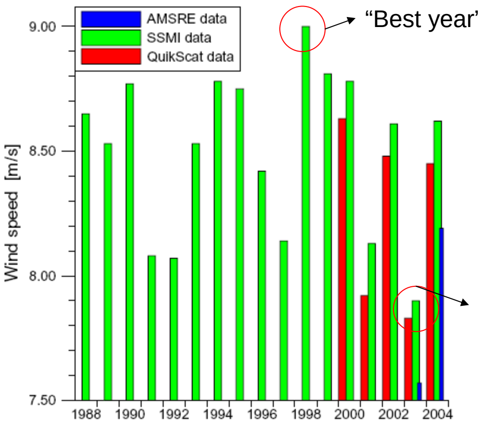


	Advantages	Disadvantages
Geo-synchronous Earth Orbit **(~36,000km altitude)**	•Satellite is "stationary" and therefore visible from a third of Earth's surface •Instruments can be used to monitor a given spot on the Earth's surface continuously	• Polar regions cannot be observed • Lower spatial resolution due to the distance from the Earth's surface
Low Earth Orbit (~1,000km altitude)	•Global coverage •Increased spatial resolution •All weather and night time observation capabilities in the case of satellites with active instruments, such as radar	•Continuous observation of a given spot is not possible •The satellite can observe some spots on Earth only twice per day for a limited amount of time during each pass

Valuation Framework

- Focus on offshore wind energy
  - No existing offshore wind farms in North America. Significant installed capacity in Denmark and Germany.
- Base case scenario
  - Offshore wind farm with a total nameplate capacity of 160 MW (80 x 2MW turbines)
  - Determining the long-term average wind speed at “hub height” of 70m is critical (“fuel” of wind energy)
  - Conventional measurement technique
    - offshore meteorological mast (very costly: 1M euro/year)
    - Provides very accurate measurement once installed, but long-term wind variability characteristics cannot be captured with 1-2 years of data.

Wind Variability



“Best year”

“Worst year”

Approx. 14% difference between these two years

Annual average wind speeds - North Sea
Source: Hasager et al., 2007

Valuation

- Strategic level impact of overestimating the wind resource
  - Impact of the wind speed variability on annual power output was calculated using the RETScreen tool (developed by NRCan).
  - Annual power output estimate was then used to compute annual revenues from the wind farm.
  - Only relying on meteorological mast measurements for a year can result in significantly lower revenue estimates from an off-shore wind farm (approximately $5.75 million/year less revenue for the base case).
  - Just 1% error in long-term mean wind speed estimate results in a revenue reduction of $350,000/year.
  - Satellite data driven EP can create value by avoiding wrong decisions based on poor estimates.

Findings/Outcomes

- We have presented a suite of case studies, taken from 4 different areas, to estimate the value of EP to the Canadian Energy Sector
- These case studies are not meant to give an exhaustive inventory of the value of EP to this sector but rather evidence for value.
- We have found that EP is greatly valuable to participants across the Canadian Energy Sector

Conclusion

- In this light we were surprised by the fact that many participants were only now starting to incorporate EP into their decision making.
- There are both technical and business reasons for this.
- A risk averse decision maker will find less than certain EP much less valuable than an expected value decision maker.
- A challenge is to find ways to convert risk averse situations into expected value situations: market solutions may be of value here.

Potential Future Work

- Enabling Financial Applications
- Capturing Societal Benefits
- Valuing EP across Provinces
- Quantifying the Value of Diversification
- Enabling Conservation through better EP
- Insights for Public Policy
- Carrying the Message