2012 Integrated Resource Plan

BC hydro

Appendix

4F

Updated Market Scenario Weightings Factors

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1 Introduction

Black & Veatch was engaged to apply relative weightings to the market scenarios developed in May 2011 (the results are described in section 4.7.2 of the Integrated Resource Plan (**IRP**) and Appendix 4E). However, in the intervening year, the policy and market context evolved rapidly, specifically:

- Long-term gas prices continued to drop, due to shale gas reserves and advancements in gas extraction technology;
- U.S. greenhouse gas (**GHG**) policies were subsumed by economic priorities;
- All western states, except California, withdrew from the Western Climate Initiative (**WCI**);
- Demand for electricity and natural gas dropped throughout North America, due to the global economic slowdown;
- An oversupply of renewables occurred in the Western Electricity Coordinating Council (**WECC**), due to tax incentives.

As a result of the above changes, BC Hydro updated the quantified relative likelihood of the 2011 Market Scenarios. This appendix describes BC Hydro's internal process for, and results from, its March 2012 update of the market scenario weightings.

2 Background: Market Scenarios for the IRP

Through the GHG price forecasting work, Black & Veatch isolated 11 key variables driving future GHG prices. These are listed in the first column of Table 1. The first nine variables are discussed in detail in section 4 of Appendix 4A-1 and section 1 of Appendix 4A-2. The last two variables are discussed in Appendix 4C. Allowing these 11 variables to take on three future trend levels (e.g., high, mid and low) generated

too many combinations (3 x 3 x 3 x … x 3 = 3^{11} combinations) and an alternative approach to assessing these combinations was needed to address the uncertainties.

The approach used in the IRP to address uncertainty around future market prices is referred to as "scenario analysis". A scenario is defined as a specified collection of key uncertain variables. By letting these variables take on particular values (for instance, scenario X might have GHG prices that are "high", natural gas prices that are "low", and economic growth that is "mid", etc.), each scenario describes a specific way in which market prices might unfold.

The use of scenarios to capture uncertainty around market prices satisfies several objectives, such as:

- Using a wide, but plausible, range of key input prices (e.g., GHG prices);
- Generating a wide, but plausible, range of key output prices (e.g., electricity prices, REC prices);
- Assembling these prices in a way that is functionally consistent (i.e., the inputs were used to generate the outputs);
- Assembling these variables in a way that is reasonably consistent (e.g., avoided illogical combinations);
- Generating as many scenarios as is feasible to span the spectrum of what might happen to market prices.

Market scenarios were constructed to create a diverse, but small number of coherent views as to how future markets might unfold.

The five Market Scenarios are described below.

Scenario A – High Electricity Prices, Mid GHG Price and High Gas Prices

High global economic growth leads to high commodity demand and broad environmental regulation.

This scenario is characterized by high global economic growth driven by successful fiscal and monetary policies. It assumes a strong economy renews public and government interest in environmental impacts and issues and the costs of regulatory compliance are attenuated to some extent by increased government spending on research and development (**R&D**). A national renewable portfolio standard is assumed. This combined with strong spending on R&D and high natural gas prices, drives significant development of renewable energy, lowering renewable energy costs. Natural gas prices are high and linked to world natural gas prices, because of environmental issues limiting shale gas production.

Scenario B – Mid Electricity Prices, Mid GHG and Mid Gas Prices

Slow but steady global economic growth sees regional leaders paving the way for national GHG markets.

With slower but promising economic growth, regional initiatives such as the WCI take the lead in establishing GHG regulatory markets, with national U.S. and Canadian governments following suit by 2020. Medium levels of growth soften governments' ability to take on environmental initiatives. Although there are delays in national renewable energy standards, development is strong in later years (post 2020).

Scenario C – Low Electricity Prices, Low GHG Prices and Low Gas Prices

Low economic growth delays national GHG market development.

With slow economic growth and activity, this scenario envisions that GHG emissions start to fall worldwide, taking the urgency out of the climate change debate and lowering public and government interest in GHG regulation. Lower natural gas prices

and low electricity load growth delay spending on renewable energy development and Renewable Porfolio Standard (**RPS**) implementation. Investments in R&D in conservation are also down.

Scenario D: Mid Electricity Prices, High GHG Prices and Mid Gas Prices

Delayed high economic growth and lower international cooperation stifles national environmental initiatives, leaving regions to regulate.

Although this scenario sees high global economic growth, it is delayed until at least 2016. International agreements on GHG regulation are not reached, and the slower economic growth and lower GHG emissions in the first couple of years lead to low levels of public support for GHG regulation in the U.S. and lower public spending on renewable energy R&D. As with Scenario C, some state and provincial governments continue to move forward with emission trading, albeit under higher cost pressures for market participants.

Scenario E: Low Electricity Prices, No GHG and Low Gas Prices

Low economic growth and activity lead to lower GHG emissions and the absence of market prices.

This scenario is similar to Scenario C; however with persistent low economic growth and associated lower fuel prices and electricity load, there is no price for GHG as regional leaders begin to turn away from their GHG policies to focus on more pressing economic demands from their constituents.

Table 1 gives a more complete summary of the external factors and market prices that make up the five chosen scenarios. These factors are explained briefly below the table and a more detailed explanation of these factors and their interpretation can be found in Appendices 4A-1, 4A-2 and 4C.

Table 1 Scenario Assumptions

Scenario	A	B	C	D	E
National/Regional GHG	National	Reg/Nat	Reg/Nat	Regional	Regional
Gas Prices	High	EMP	Low	EMP	Low
Load Growth	High	EMP	Level	High	Level
Nuclear Adds	0.5	1.5	0.5	EMP	EMP
PEV	Yes	Yes	No	Yes	No
Renewables	High	High	Low	EMP	Low
CCS Cost	-0.25	0.25	0.25	0.5	0.5
2020/2030 Caps	Less Stringent	EMP	EMP	Base WCI	Base WCI
LRS Offsets	Full	Full	Full	Full	Full
ITC/PTC Continue	ITC expired after 2016, no incentives after	ITC expired after 2016, no incentives after	ITC (2016), PTC after	ITC (2016), PTC after	ITC expired after 2016, no incentives after
Renewables Cost	Faster decline	Faster decline	Slower decline	Baseline	Slower decline

Notes:

- Carbon Capture and Sequestration (**CCS**), Load Ratio Share (**LRS**), Plug-in Electric Vehicle (**PEV**), Investment Tax Credit (**ITC**), Production Tax Credit (**PTC**).
- EMP refers to the "best estimate" for value taken from Black & Veatch's Fall 2009 "25-year Energy Market Perspective" forecast, as described in Appendix 4A-1.

- **National GHG** means a linked, national-level cap-and-trade program that covers the U.S. and Canada.
- **Regional GHG** means a cap-and-trade program that covers only the WCI states and provinces located in the WECC;
- **Reg/Nat GHG** means a regional, WCI cap-and-trade system until 2020, which is then superseded by a move to national-level cap-and-trade.
- **Gas price:** EMP means the best estimate natural gas price forecast in 2010. "High" is BC Hydro's high gas forecast and "low" is Black & Veatch's updated low gas forecast, as described in Appendix 4B. For more detail, see Figure 9, page 27, of Appendix 4A-1.

- **Load Growth:** EMP means expected, or best estimate, U.S. and Canada and regional electric load growth from 2010. “Level” means fairly flat (e.g., no growth). “High” means higher than expected. For more detail, see Figure 3, page 23 of Appendix 4A-1.
- **Nuclear Adds:** EMP means the best estimate U.S. and Canada and regional nuclear additions in 2010. “0.5” and “1.5”, refer to 50 per cent and 150 per cent of the EMP, respectively.
- **PEV** means the penetration level of plug-in hybrid vehicles. “Yes” means a material impact on light load hour loads (all PEV load was assumed to occur during light load hours). “No” means no material impact on any hourly loads. For more detail, see section 5.4.7 of Appendix 4A-1.
- **Renewables:** EMP means “best estimate” assumption on renewable penetrations from 2010.
- **Carbon Capture and Storage (CCS) cost:** “-0.25” means a significant reduction (i.e., 25 per cent) in capital costs was assumed for CCS technology in the baseline case. “0.25” and “0.50” refer to 25 per cent and 50 per cent increases over the baseline case, respectively.
- **2020/2030 Caps:** EMP means the baseline assumption on the flexibility in banking and borrowing of GHG compliance instruments (allowances) was used. “Less stringent” gives more flexibility by limiting the amount of banking and borrowing. “WCI” means matching the WCI regional goal of reducing emissions to 15 per cent below 2005 levels by 2020 and only comes into play in the Regional GHG scenario.
- **LRS of Offsets**: The Load Ratio Share of allowable “offsets” for meeting GHG targets means the amount of offsets that would be available to the electricity sector. It is assumed to be the same in all five scenarios.

- **Tax credits for Renewables:** This refers to whether U.S. tax credits for renewables will be extended (PTC and ITC, as indicated in Table 1).
- **Renewables Cost:** A faster or slower decline refers to whether renewables costs will see a faster or slower rate of change than the baseline assumption reflected in the Black & Veatch 2009 Energy Market Perspective forecast of renewables cost reductions.

3 Approach to Assigning Relative Likelihoods to the Five Scenarios

In 2011 BC Hydro worked with Black & Veatch market experts to assign relative probabilities, or likelihoods, to each of the five scenarios. This process is described in detail in section 4.7.1 of the IRP and Appendix 4E. Using the same approach as in 2011, BC Hydro updated the five market scenario weightings. For the re-weighting exercise, two important points should be considered.

Firstly, the numbers assigned to any scenario are not intended to reflect the absolute forecast likelihood that a given scenario will occur. Rather, if Scenario X is assigned a likelihood of 10 per cent and Scenario Y is assigned a likelihood of 20 per cent, then Y is relatively twice as likely as X to occur. In reality, it is almost impossible that a specific combination of long-term price forecasts and external events will occur (making the forecast probability of Scenario X close to zero), particularly given that only five scenarios were considered. As a result, these weightings only make sense in relative terms.

Secondly, these results apply to the scenarios as a whole and not to the individual underlying variables or drivers. For instance, if Scenarios X and Y, at respective probabilities of 10 per cent and 20 per cent, are the only two scenarios with high gas prices, it is not correct to infer that the likelihood of high gas prices is 30 per cent.

The estimates were developed using the Modified Delphi Method[1], a methodology that systematically assists experts in reaching consensus. This appendix describes the activities undertaken to estimate the likelihood of scenarios, indicates some of the key factors used in the deliberations, and provides the resulting probabilities assigned to each of the five scenarios. For this study, the BC Hydro internal expert panel consisted of Tim Blair, Rob Campbell, Brenda Goehring, David Ince, Kevin Maxwell, Randy Reimann, and Patrice Rother, whose qualifications are summarized at the end of this report. The panel members have diverse backgrounds in the energy field, with emphasis on energy fuels.

The panelists gathered on March 9, 2012 to weight the probabilities of the five scenarios. The following materials were reviewed in advance of this session:

- IRP Technical Advisory Committee (**TAC**) presentations found at http://www.bchydro.com/planning_regulatory/irp/document_centre/tac.html:
  - Risk Framework;
  - GHG forecast and assumptions;
  - Gas forecast and assumptions;
  - Electricity forecast and assumptions; and
  - REC forecast and assumptions.
- Black & Veatch materials:
  - Appendix 4A-1: Black & Veatch Greenhouse Gas Price Forecast Report, dated April 2010;
  - Appendix 4A-2: Black & Veatch Addendum to Greenhouse Gas Price Forecast Report, Additional Scenarios Report, dated May 2011;

[1] For a description and discussion of the Modified Delphi Method, please refer to "Experts, Stakeholders, and Elicitation," in Mark A. Burgman, Risks and Decisions for Conservation & Environmental Management, 2005, Cambridge University Press, Box 4.1, page 104.

- Appendix 4B: Black & Veatch Low Natural Gas Price Forecast Report, dated November 2010;
- Appendix 4C: Black & Veatch U.S. Renewable Energy Credit Markets Report, dated May 2011;
- Appendix 4E: Black & Veatch Market Scenario Probability Assessment Report, dated June 2011; and
- The CEC Scenario report, CEC Case 5b+ and Case 2 found at http://www.energy.ca.gov/2007_energypolicy/index.html.

In addition, each panelist was asked to provide the facilitator with their thoughts on the following, prior to the March 9, 2012 session:

- What is the most likely scenario (and why);
- What is the least likely scenario (and why);
- A preliminary rank ordering of all five scenarios; and
- Special issues requiring discussion at the session.

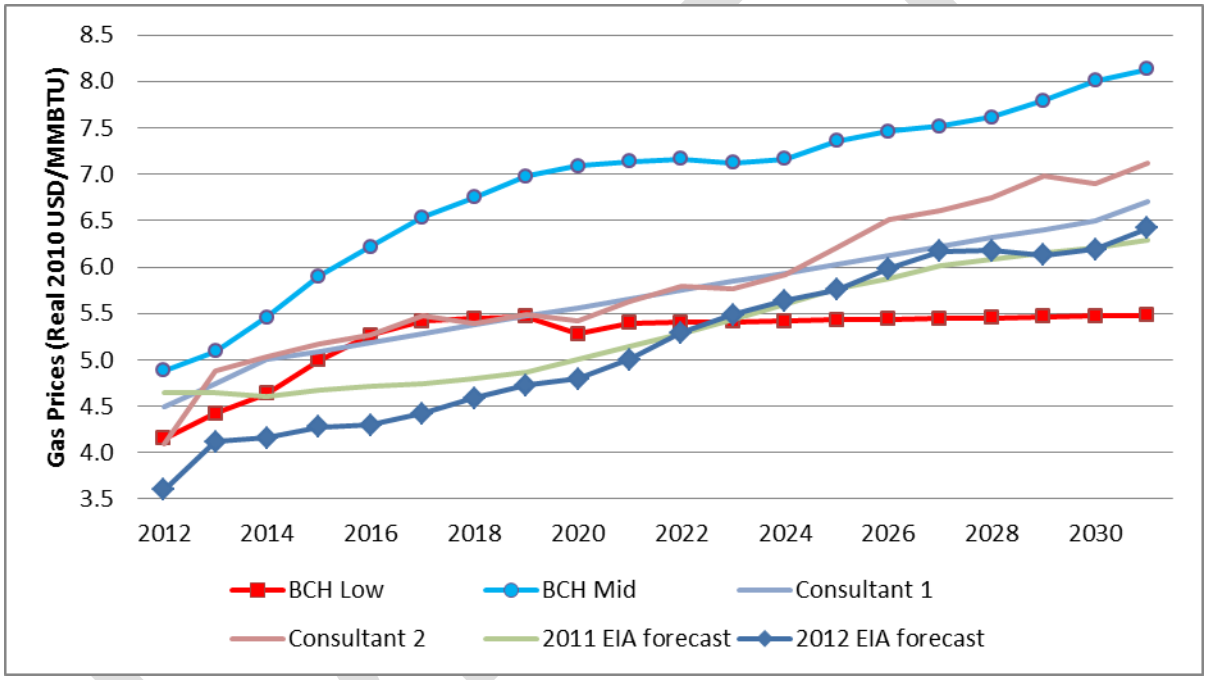
On March 9, 2012 the group reviewed the 11 variables listed in Table 1. Key points during the initial discussion were:

- The five scenarios cover a wide range of prices and input assumptions.
- The scenarios represent a long-term market world view.
- Two major drivers are world economic growth and GHG government action.
- Scenario A reflects how the world looked in 2007 with high oil/gas prices.
- Scenario D reflects a GHG policy that is locally aggressive. Localized/isolated high prices are unlikely to be sustained over the long-term, if they are due to regional government policy.
- CCS costs are a function of government policy.

- Key variables that influence market electricity prices are gas price, GHG price and the build-out of renewables.

As a benchmarking exercise, BC Hydro tracks and compares its Natural Gas Price Forecasts against other external forecasts, such as those produced by the U.S. Energy Information Administration (**EIA**) and other consultants. Figure 1 compares BC Hydro's mid and low gas price forecast to other long-term gas forecasts at Henry Hub.

Figure 1 Long-term Gas Comparison



After discussing the key variables, the panel ranked the scenarios from most likely to least likely (summarized in Table 2) and described why they chose a particular scenario as being most and least likely.

Table 2 Panel Ranking after General Discussion

Ranking	Panelist 1	Panelist 2	Panelist 3	Panelist 4	Panelist 5	Panelist 6	Panelist 7
1st	C	C	C	C	C	C	C
2nd	E	B	B	E	E	E	E
3rd	B	E	E	B	B	B	B
4th	A	A	D	A	D	D	A
5th	D	D	A	D	A	A	D

Panelist 1 selected:

- Scenario C is the most likely scenario, because it has delayed action on national government policy, and growth will be lower and sluggish. Panelist 1 also noted that Scenarios C and E were very similar and suggested that they could be considered together.
- Scenario D is the least likely scenario, because a regional GHG action with high prices is unlikely to persist in isolation in the long-term.

Panelist 2 selected:

- Scenario C as most likely, because it had low gas prices persisting in the long-term. Panelist 2 felt that national action on GHG policy would occur, although perhaps not in 2020. Consequently, Panelist 2 felt that national cap-and-trade (as in Scenario C) was more likely than no cap-and-trade (as in Scenario E).
- Scenario D was seen as least likely scenario, as it was unlikely that long-term high GHG prices would exist in isolated pockets in the U.S.

Panelist 3 selected:

- Scenario C as the most likely scenario, because a cap-and-trade system is most likely to occur at a regional, then national level, but in small steps. Panelist 3 felt that market prices will oscillate between Scenario C and Scenario B levels over the long-term.

- Scenario A as the least likely scenario, since it is unlikely that high gas prices and very high load growth will be experienced in the long-term.

Panelist 4 selected:

- Scenario C as most likely scenario, because low gas prices are expected to reduce Mid-C prices.
- Scenarios A and D as the least likely scenarios, because long-term high growth is unlikely and regional isolated high GHG prices are unlikely to persist over the long-term.

Panelist 5 selected:

- Scenario C as the most likely, due to low gas prices and low (but not zero) GHG prices.
- Scenarios D and A as the least likely, due to RPS not being driven by GHG reductions, but rather by regional job creation.

Panelist 6 selected:

- Scenario C as the most likely, because interest in GHG reductions will continue, whereas in Scenario E there is no U.S. GHG policy in the long-term.
- Scenarios D and A as equally unlikely, because of high gas prices and isolated regional policy in the face of high GHG prices.

Panelist 7 selected:

- Scenario C as the most likely, because of the low gas price, low growth rate and the existence of some GHG policies (vs Scenario E, which has no active GHG policy).
- Scenario D as the least likely, due to its high growth rates and high GHG prices.

After each panelist described the rationale for their rankings, general conclusions were drawn as follows:

- Scenario C is most likely;
- Scenarios C and E could be grouped together, because of some of their similarities;
- Scenarios A and D are least likely and are fairly equally weighted;
- Scenario C reflects current world conditions, which may move towards Scenario B in the long-term.

The final step was to assign relative likelihoods to the market scenarios. This was done by:

(a) Using rankings and discussion to surface some tentative quantitative conclusions:

- Scenarios A and D were ranked either fourth or fifth by all panelists who felt that these two scenarios should have roughly the same very low probability.
- Scenarios E and C seemed similar, given similar variations of a low growth future, but Scenario C seemed much more likely than Scenario E, due to its government policy context.
- Taken together, there was much more likelihood of a low growth future (e.g., Scenarios C or E) than there was of the growth levels in Scenario B.

(b) Assigning relative probabilities consistent with the groupings and discussion above:

- 10 per cent weight for Group 1 (Scenarios A and D together)
- 60 per cent weight for Group 2 (Scenarios C and E together)
- 30 per cent weight for Scenario B.

(c) Assigning relative probabilities to the scenarios in each group:

- Both scenarios in Group 1 had a low, equal weighting of roughly 5 per cent.
- Scenario C was much more likely to happen than Scenario E. Therefore the panelists gave Scenario C a 40 per cent weighting and Scenario E a 20 per cent weighting.
- Scenario B still had a weighting of 30 per cent.

The final relative likelihoods from the panelists are summarized in Table 3.

Table 3 Final Relative Likelihoods

Scenario	2011 Probability (%)	2012 Updated Probability (%)	Change from 2011
Scenario A (High Electricity Prices (Mid GHG Prices, High Gas Prices))	10	5	-5 percentage points
Scenario B (Mid Electricity Prices (Mid GHG Prices, Mid Gas Prices))	45	30	-15 percentage points
Scenario C (Low Electricity Prices (Low GHG Prices, Low Gas Prices))	25	40	+15 percentage points
Scenario D (Mid Electricity Prices (High GHG Prices, Mid Gas Prices))	5	5	0 percentage points
Scenario E (Low Electricity Prices (No GHG, Low Gas Prices))	15	20	+5 percentage points

4 Recommendation

Based on the results in Table 3, 60 per cent of the relative weightings were given to the market scenarios with low gas prices, 35 per cent to the market scenarios with mid gas prices and 5 per cent to the market scenario with high gas prices. Based on the panel's relative probability assessments, and comparisons with other

consultants' long-term gas forecasts (Figure 1), it is recommended that Scenario C be considered as the most likely of the five market scenarios.

Appendix – BC Hydro Panelist Biographies

Tim Blair

Tim Blair is a Senior Engineer in System Optimization with BC Hydro. Tim is part of the team that runs the marginal cost model, which provides the economic signals for system operations. To support the optimization, Tim is responsible for the medium-term market modeling, forecasting prices for the next five years, and the simulation and optimization of the Columbia system.

Rob Campbell

Rob Campbell is the Managing Director for Exports, Renewables and Structured Products at Powerex Corp., the non-regulated trading arm of BC Hydro. Since 2009, Rob has been responsible for Powerex's activity in renewable and carbon markets.

Rob holds an engineering degree from Queens University in Ontario, and an MBA (Finance) from the University of British Columbia. Prior to joining Powerex, Rob was Head Trader at TransAlta Energy Marketing in Calgary, Alberta.

Brenda Goehring

Brenda Goehring is the manager of Corporate Safety, Health & Environment (**SH&E)** with BC Hydro. After more than 24 years working across BC Hydro, Brenda currently manages the Regulatory and Relationship Management team within the Corporate Safety, Health & Environment group). This function provides policy and management system oversight and reporting on SH&E performance externally and to the Board of Directors, develops strategies to address emerging issues like climate change, and provides leadership on the integration of evolving environment and social requirements into business initiatives.

Currently her focus is on supporting the integration of BC Hydro's management systems to incorporate safety, health, and environment, particularly with an emphasis on identifying and controlling risks, assessing the implications of emerging regulations, such as environmental mitigation and offsetting, developing mitigation and adaptation strategies for climate change, and advancing leading metrics to support the corporation's safety, health & environment objectives

Brenda is a member of the Electric Power Research Institute Sustainability Interest Group, the Network for Business Sustainability, the Canadian Hydropower Association Clean Energy Policy Working Group, and the BC Business Council Environment Committee.

David Ince

David Ince is an engineer by training. He spent the first 13 years of his career in the Alberta natural gas industry, where he was involved in production & pipelining, and gas supply strategies and contracting. He was in the gas industry during the transition to supply deregulation. In the late 1990's, during Alberta's electricity market reforms, he worked on electricity supply strategies and procurement and green energy contracting and development, and he was integrally involved in the transition to market deregulation. David joined BC Hydro in 1999, and has since been involved in electricity supply planning and contracting, electricity trade oversight, and most recently, managing BC Hydro's long-term load and market price forecasts.

Kevin Maxwell

Kevin Maxwell is a Senior Engineer in Market Forecast group within BC Hydro. With BC Hydro he has lead the development of Market Scenarios with Black & Veatch and is engaged with CERA and PIRA to follow long-term market trends. For the past eight years he has been responsible for running BC Hydro's long-term market simulation models. In addition, he has worked on a number of other projects, including forecasting Independent Power Producers energy forecast.

Randy Reimann

Randy has been leading the development of BC Hydro's long-term energy plans since 2005. His role includes providing expert advice to management on energy planning issues, as well as developing the current Integrated Resource Plan, the 2008 Long Term Acquisition Plan and the 2006 Integrated Electricity Plan and Long Term Acquisition Plan.

Prior to 2005, Randy had a number of roles within BC Hydro, including playing a key role in the development of the BC Transmission Corporation, leading BC Hydro's interests in the development of the first Open Access Transmission Tariff, and acting as a sector manager in the Key Accounts group. Prior to joining BC Hydro, Randy worked as a consulting engineer and with ATCO Power in Alberta.

Randy is a Professional Engineer with an MBA from the University of Alberta and a degree in Electrical Engineering from the University of British Columbia. Randy is a member of the Association of Professional Engineers and Geoscientists of B.C.

Patrice Rother

Patrice Rother is the Manager of Regulatory Oversight in BC Hydro's Environmental Risk Management Division. Her responsibilities include: the coordinated management of key environmental regulatory risks; operational environmental reporting; and maintaining an efficient and effective Environmental Management System (**EMS**) for BC Hydro's operational business groups. Prior to joining BC Hydro in 2005, Patrice worked on a number of environmental planning and regulatory programs at the Greater Vancouver Regional District (now Metro Vancouver) and the Fraser Valley Regional District.

Patrice holds an M.Sc. degree from the University of Saskatchewan, and an MBA from Simon Fraser University.

Basil Stumborg

Basil Stumborg is BC Hydro's Decision Analysis Expert, Energy Planning and Economic Development, Finance.

Basil joined BC Hydro in 2000 and has worked on a number of projects across the company, assisting BC Hydro in structuring its decision processes, where decisions are complex and outcomes are uncertain. In particular, Basil helped structure and implement: the Water Use Planning program that rebalanced competing interests at Hydro's dams, long-term energy planning processes (including the IEPs, LTAP, and currently the IRP), BC Hydro's Business Case Requirements, and some litigation strategies. Basil also created and hosts BC Hydro's internal training on Structure Decision Making, to assist staff in implementing the Business Case Requirements for complex projects and process changes.

Before joining BC Hydro, Basil did graduate work in Economics (at University of Wisconsin – Madison, McGill University) and Psychology (Cornell University), taught university level math, economics and psychology courses (Cornell University, University of Victoria, Pearson College) and consulted in the private and public sector. The core focus of these activities has been decision-making under uncertainty and multiple objective decision analysis – a discipline now known as behavioural economics.