Report on Risk Analysis in the NFAT

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An important component of the Manitoba Hydro report on Needs for and Alternatives to Business Case (NFAT, August, 2013) is the analysis of the risks associated with prospective development plans. As the NFAT (ch.10, p.1) notes, "it is important to recognize uncertainty and identify the way forward that has the best balance of value and risk given that uncertainty." This report looks critically at the methodology underlying the risk analysis in the NFAT and then examines how the risk analysis has been used to assess the plans.

Risk Analysis Methodology

Modern statistical risk assessment begins with a specification of the risk factors, an attribution of a probability distribution for each factor to describe the range of possible outcomes and their likelihood, and a model which links the factors to determine the outcomes of interest (e.g. the net present value of returns). Once these steps are taken, it is fairly straightforward with modern computing technology to make random draws from the probability distribution for each factor, calculate the outcome of interest, and replicate this process thousands of times to produce a probability distribution of outcomes for a specified development plan. This probability distribution of outcomes can be calculated for each development plan and characterized by measures of its central tendency (e.g. the mean or median outcome) and spread or risk (e.g. the range or variance of outcomes). This constitutes a full Monte Carlo analysis of risk and is, in fact, the methodology advocated by Drs. Kubursi and Magee (2010) in their independent review for the Public Utilities Board of Manitoba Hydro risk assessment practices.

Manitoba Hydro takes only tentative steps in this direction. First, it restricts its risk analysis to what it determines to be the three most important risk factors—energy prices, the discount rate, and capital costs—out of a group of ten risk factors. Their approach thereby ignores some potentially important risk factors, such as load and its determinants,[1] some of which are then considered separately in a "sensitivity analysis" in chapter 10. Moreover, the basis for the determination of the three most important risk factors is the calculated difference in NPV between a "plausible high value" of the factor and a "plausible low value" of each factor for the two development plans with the "most significant difference in characteristics – the All Gas development plan and the Preferred Development Plan (K19/C25/750MW (WPS Sale & Inv))" (ch 10, pp 2-3). Since there are five "pathways" or types of plans (ch 14, p 5), it seems important (or at least less arbitrary) to assess the risk factors on more than pathways 1 and 5.

Second, the "probability distributions" describing the range of possible outcomes for each of the remaining three risk factors are limited to three points, representing low, reference (expected) and high outcomes or scenarios. The NFAT refers the reader to Appendix 9.3 for details of the formation of these scenarios and their associated probabilities, but the details are sketchy. For energy prices, for example, the NFAT states that Manitoba Hydro commissions energy price forecasts and requests a consultant's

[1] This is discussed in the Load Forecasting Report by Gotham and Simpson to these hearings.

"best estimate" (reference scenario) and plausible scenarios for the lower and upper limits of "prolonged pricing" (the low and high scenarios). It is not clear how consultants interpreted these directions, especially the low and high scenarios, and how the consultants' forecasts were combined by Manitoba Hydro. For example, the NFAT states that some of the forecasts were dropped, but it is not clear why. There is mention of a P10 and P90 standard for the low and high scenarios for capital costs, but no mention of this standard for the energy price forecasts. Once the high, low and reference scenarios are determined for natural gas and carbon, they are combined to form a "nine-branch distribution" of electricity prices (Fig.2.3, App.9.3, p.42) and this distribution is then collapsed into low, reference and high scenarios with probabilities that match "well" with the mean and variance of the nine-branch distribution, although no criterion or statistical test of the match is mentioned. Similar methods are used to find low, reference and high scenarios for the discount rate and capital costs. The process is designed to generate what Hydro considers to be a manageable number of scenarios (3) for each of 3 factors, although much more could be accomplished with modern computational methods and capabilities to analyze more factors with more conventional distributions.

Once the three scenarios for each of the three factors have been developed and assigned probabilities, the joint probabilities for the 27 scenarios are determined under the assumption that the factors are independent (Table 2.11, App 9.3, p.61). The net present value (NPV) for each of the 27 scenarios is calculated and the expected value of the plan (expected NPV) is calculated in the conventional way (sum of NPV for each plan times its probability of occurrence). At this point measures of risk (the variance or other measures of spread of the NPV outcomes) could also be calculated to assess the riskiness of the plan in a more conventional way, but Hydro now uses what I would consider to be a less conventional S-curve methodology of risk assessment instead.

The S-curve methodology first calculates the incremental NPVs for each plan as the difference between the NPV for a given scenario and the expected NPV for the plan. The incremental NPVs for the 27 scenarios are placed in ascending order and assigned the cumulative probability of that plan and all plans with lower NPVs to form the data points for the S-curve (Table 2.14, App 9.3, p.64), where

> "each point represents the probability that the value [NPV] will be less than or equal to that value (for example, there is a 40.6% chance the NPV will be less than $0M in the All Gas case). However, given that 27 discrete scenarios have been used as the centre points of ranges to represent what is in reality a continuous distribution, there is some imprecision. The points were connected linearly to preserve the actual scenario values recognizing that the resulting lines are not smooth, but removing any subjectivity in how the points should be smoothed" (App. 9.3, p.65).

The range of outcomes is now represented as the difference between points on each side of the estimated (linearly interpolated) median (50^{th} percentile or P50), e.g. the NPV at P75 minus the NPV at P25 ("the box") or the NPV at P90 minus the NPV at P10 ("the whiskers") in Fig.10.7 (ch.10, p.18). As far as I can determine, these ranges (and the median) should correspond to those that would be calculated directly from the (27-point) distribution of NPV outcomes for each plan if those NPV outcomes were adjusted as differences from the mean of the distribution and simple linear interpolation methods were used rather than more state-of-the-art curve fitting methods.

Using the Risk Analysis to Evaluate Development Plans

Much of Hydro's subsequent discussion compares the plans on the basis of their expected values, using the expected value of the All Gas Plan 1 as the reference case, and the amount of "downside risk" and "upside potential" (or reward) involved in the plan. For example:

> "Plan 5 has a smaller box and shorter whiskers than the Preferred Development Plan (Plan 14); this indicates that the Preferred Development Plan has greater variability but has more upside potential. The long whiskers between the 10th and 25th percentiles on the All Gas and Wind/Gas plans indicate a significant downside risk for these plans" (ch.10, p.19).

In particular, there is direct acknowledgement of the importance of assessing the risk (spread of NPV outcomes) against the return (expected plan NPV) in that

> "there is uncertainty in the reference scenario assumptions and therefore in the consequences of the different plans for Manitoba Hydro revenues and expenditures and customer rates. It is not just the consequences of the Preferred Development Plan, but rather of all the plans that are subject to considerable uncertainty. The question thus arises, does the uncertainty favour some plans over others – is there a risk trade-off that could change the relative advantage of the different plans based on the reference scenario analysis" (ch.13, p.68).

The risk-return trade-off is particularly clear in the concluding chapter 14, where Table 14.2 (p.9) provides a "Development Plan Economic Evaluation Summary" that includes the expected value (difference from All Gas) and the P90 ("reward" or upside potential) and P10 ("risk" or downside risk) for each plan. The extended comparison of plans that follows might be usefully compressed into a graph comparing risk (spread) and return (expected value) as follows:

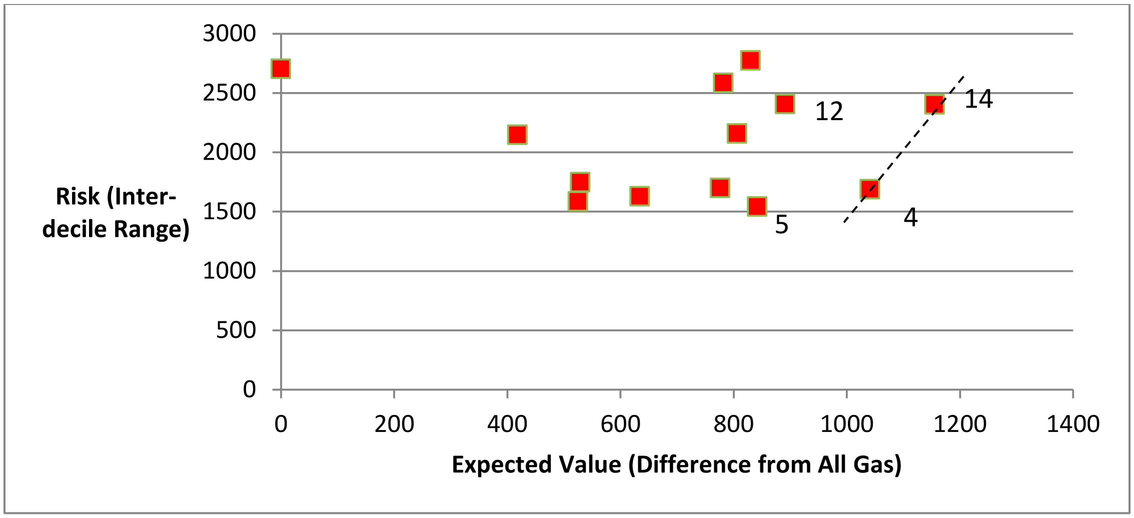

Figure 1: Risk vs. return from Table 14.2 of the NFAT

Risk is measured here as the gap (divided by 2) between the P90 and P10 outcomes, or the interdecile range, which constitutes one conventional measure of risk that incorporates both upside potential (reward) and downside risk (risk) in the terminology of the NFAT. The pertinent plans are labelled. Figure 1 shows that two plans clearly dominate, based on Hydro's calculations: Plan 14, the Preferred Development Plan (K19/C25/750MW (WPS sale)), dominates the plans to its left, including plan 12, which have similar risks to Plan 14 but lower returns, while Plan 4 (K19/Gas24/250MW) dominates the plans to its left, including plan 5, which have similar risks to Plan 4 but lower returns. Between Plans 14 and 4 there is a trade-off between the higher projected returns in Plan 14 and the lower risk in Plan 4, illustrated by the dotted line. (The slope of the line indicates the size of the trade-off for the measures of risk and return used.) The choice then depends on tolerance for risk by the investors, the citizens of Manitoba. This is a significant choice, since the plans are quite different as are the outcomes for the economy and ratepayers.

An alternative two-way comparison can be made between downside risk (difference between P10 and expected value in Table 14.2) and return (expected value) as follows:

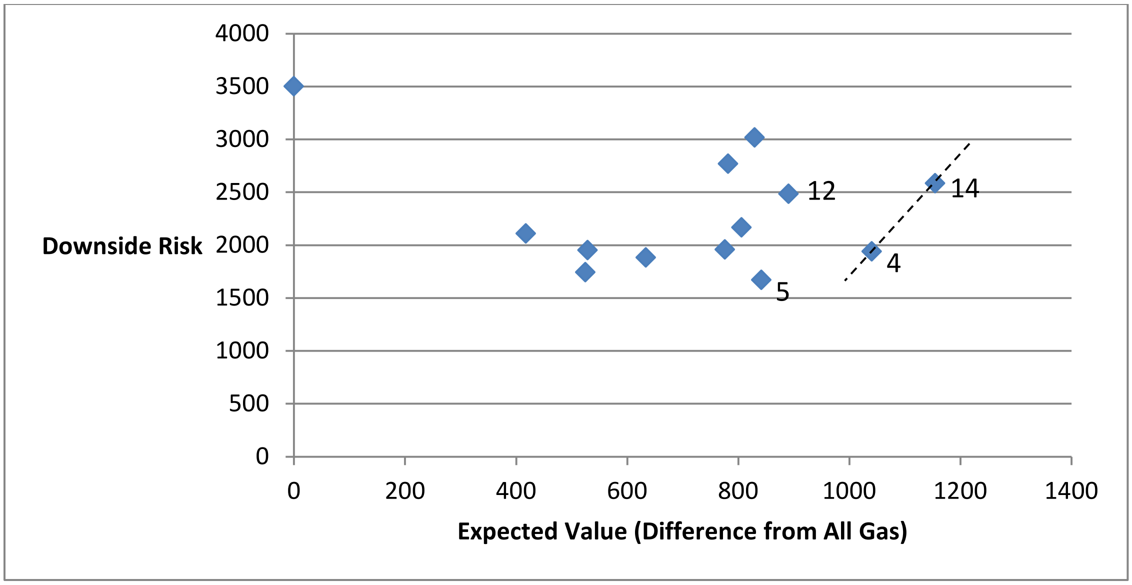

Figure 2: Downside risk vs. return from Table 14.2 of the NFAT

Figure 2 illustrates that the use of total risk (Figure 1) or downside risk (Figure 2) does not change the conclusions, since Plan 14 still dominates the plans to its left, including plan 12, which have similar risks to Plan 14 but lower returns, while Plan 4 dominates the plans to its left, including plan 5, which have similar risks to Plan 4 but lower returns. Between Plans 14 and 4 there is again a trade-off illustrated by the dotted line.

Caveats

The analysis above is illustrative, based on the figures in Table 14.2 of the NFAT. Readers are reminded of the limitations of Hydro's calculations of risk, which include limitation of the risk analysis to three factors. Readers are also reminded of the methodology for developing the probability distributions for the risk factors, which assigns only three points (low, reference and high scenarios) to each distribution. It is difficult to assess how these limitations of the NFAT methodology matter to the comparison of alternative plans without a more extensive risk analysis.

The NFAT introduces three other risk factors—drought, climate change, and load growth—in a separate sensitivity analysis in chapter 10 (section 10.2). The sensitivity analyses assess the separate impact of each of these new risk factors on the reference scenario for selected plans, which falls well short of the risk analysis methodology used for energy prices, discount rates and capital costs. This is puzzling, since these are risk factors that can be quantified, may well be very important, and were ignored in the consideration of factors for their risk analysis. For example, the impact of the low and high load growth forecasts (from Appendix C of the NFAT) on NPV for development plans 1, 2 and 14 are calculated, but it is not clear what this tells us about, say, the comparison between plans 4 and 14 that seems most relevant in Figures 1 and 2.

Chapter 10 (section 10.3) also lists five other risk factors that are discussed in a general and cursory fashion, but these are risks where quantification would appear to be much more difficult.

References

Kubursi, Dr. Atif, and Dr. Lonnie Magee (2010) “Manitoba Hydro Risks: An Independent Review,”submitted to the Public Utility Board of Manitoba, November 15.