2013 Integrated Resource Plan

Appendix 4B

Assessing DSM Uncertainty

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1 Introduction

BC Hydro continues to be among the North American leaders in pursuing energy savings in response to increasing electricity demand. As per the subsection 2(b) *Clean Energy Act* (***CEA***) British Columbia's energy objective, BC Hydro is expected to meet over two thirds of its load growth by the year F2021 through Demand Side Management (**DSM**) initiatives; pursuing the DSM target of 7,800 gigawatt hours per year (**GWh/year**) of energy savings by F2021 would result in BC Hydro meeting 78 per cent of its incremental load through DSM by F2021 (without Liquefied Natural Gas (**LNG**) load).[1] Thus, by that year, BC Hydro will be relying on DSM to a greater degree than on supply-side resources to meet its forecasted increase in load. While supply-side resources entail delivery risk due to permitting and other issues, attributing savings to DSM initiatives raises challenges. As such, better understanding of the uncertainty inherent in DSM and incorporating that into the decision-making framework is warranted so that BC Hydro is better informed when making comparisons among supply and demand side options, and also so that BC Hydro can assemble realistic and adequate Contingency Resource Plans (**CRPs**) in case the future unfolds significantly differently from the plan's forecasts.

The 2008 Long-Term Acquisition Plan (**LTAP**) highlighted some key sources of uncertainty in relying on DSM savings in a long-term planning process:

- BC Hydro's co-ordinated use of three DSM tools (rate structures, programs, and codes and standards) is complex and in terms of reporting is unique in the DSM industry;
- The DSM options considered aim above past experience, and so require making estimates of future impacts that are above and beyond existing data. Since data is limited, estimating levels of savings and ranges of uncertainty

[1] The corresponding figure for the Expected LNG load of 3,000 GWh/year is about 69 per cent.

around this rely on the elicitation of subjective probabilities, a complex endeavour;

- DSM savings are interrelated with load growth. Understanding and untangling the relationships between DSM savings and load growth is difficult and an ongoing effort;
- There will always be 'unknown unknowns' which require additional professional judgment to be layered upon quantified aspects of uncertainty.

The process used to identify sources of uncertainty and, where possible, quantify them has continued to build on work started in the 2008 LTAP. While the activities to understand DSM uncertainty savings were based on BC Hydro's internal expertise in the area, a jurisdictional assessment was carried out to help situate the magnitude of BC Hydro's past experience and future energy and capacity savings plans within other utilities' experiences. This is reported in section 2 below.

A significant effort was made with BC Hydro staff to understand the range across which DSM savings forecasts might vary and to describe this uncertainty in a quantitative manner. The method for doing this and the results are described in section 3.

Finally, there are still some significant information gaps and unknown unknowns surround the quantification of DSM uncertainty. These are summarized in the conclusion of section 3. Given the importance of DSM savings in meeting future load growth, professional judgment will continue to play an important role in interpreting the magnitude of DSM savings uncertainty and how this uncertainty is incorporated into the Integrated Resource Plan's (**IRP**'s) resource analysis planning framework.

2 Jurisdictional Assessment

It is difficult to compare DSM energy savings targets across jurisdictions due to large variations in electricity prices, climate and customer mix; different time frames, political environments and legislative requirements; and the number of DSM tools employed and reported on (e.g., BC Hydro uses three DSM tools – DSM programs, inclining block rate structures and codes and standards support while other public utilities typically focus on tracking program-related savings).

Nevertheless, BC Hydro looked externally to determine whether other leading jurisdictions as measured by DSM spending as a per cent of retail sales have claimed to deliver on similar levels of DSM savings, or are planning to deliver on similar savings levels in the future. The resultant DSM jurisdictional assessment, compiled by the Cadmus Group can be found in Appendix 4D (DSM Jurisdiction Review Comparison of DSM Achievements, referred to as the **Cadmus Report**). BC Hydro supplemented the Cadmus Report with a review of the April 17, 2012 evidence of Mr. John Plunkett of Green Energy Economics Group, Inc. submitted by British Columbia Sustainable Energy Association and Sierra Club of British Columbia (**BCSEA Evidence**) as part of the F2012 to F2014 Revenue Requirements Application (**RRA**).[2] Common to both the Cadmus Report and the BCSEA Evidence was a lack of data for the mid to long-term; consequently both sources focus on the period to 2015. In addition, both sources use saving ratios (GWh savings/GWh sold, the per cent of sales) as opposed to per cent of load growth as the metric with which to compare jurisdictions. This is because per cent of sales is the industry standard and the most commonly available metric.

The remainder of this section summarizes the experiences in other leading jurisdictions in two ways:

- First, by looking at levels of savings claimed in other jurisdictions

[2] Exhibit C10-13 in the F2012/F2014 RRA; www.bcuc.com/archived-2012.aspx.

- Second, by looking at future savings targets from other jurisdictions

2.1 Comparing Past Savings

The Cadmus Report was finalized in June 2011 and looked at 26 utilities and DSM implementers based in North America. This sample comprises a snapshot of applications of DSM in the North American electricity sector from industry leaders, large utilities and jurisdictions of interest to BC Hydro and is useful for understanding achieved program savings. However, as few jurisdictions report on energy savings from codes and standards and rate structures, the comparison is much less useful for changes to codes and standards and is of no use with respect to rate design experience.

Table 1 lists these organizations and compares their recent (2005 – 2009) stated energy savings achievements. This shows that, from years 2005 to 2009, only a small number of the top of DSM leaders in North America claim savings above 1 per cent level per cent of sales. To put Table 1 in context, the BCSEA Evidence provides that in 2006 and 2007, for public utilities that did report savings the U.S. average (weighted by sales) was 0.35 per cent of sales, with values ranging from 0.01 per cent for four jurisdictions (Arkansas, Alabama, Mississippi and Missouri) to up to 2 per cent (Hawaii and Vermont).[3]

Drawing additional inferences from this table must be done with some caveats:

- Verification methods and reporting vary amongst jurisdictions. Savings levels claimed in other jurisdictions may not necessarily translate into potential to reduce BC Hydro load given differences in verification methods, load composition, and opportunities for saving.

Finding jurisdictions that reported using a combination of programs, codes and standards, and rates to meet DSM targets was not possible. From the list in Table 1,

[3] *Ibid*, Exhibit JJP-2 to the BCSEA Evidence, page 4.

only the three California utilities include changes to codes and standards in their reported DSM savings. As a result, Table 1 provides insight into the comparison of DSM program levels, but does not provide insight into benchmarking BC Hydro's combination of its three DSM tools to achieve DSM savings.

Table 1 Average Annual Energy Savings from DSM Programs as Per Cent of Retail Sales (2005 to 2009)

Organization	Average (%)
San Diego Gas & Electric^	2.00
Pacific Gas & Electric Co^	2.00
Southern California Edison Co^	1.70
Massachusetts Electric Co	1.60
Vermont	1.60
Connecticut Light & Power Co	1.40
Puget Sound Energy Inc.	1.10
Nevada Power Co	1.00
BC Hydro	**1.00**
Interstate Power and Light Co	0.90
Energy Trust of Oregon	0.90
Wisconsin Electric Power Co	0.80
MidAmerican Energy Co	0.80
Idaho Power Co	0.70
Arizona Public Service Co	0.70
Manitoba Hydro	0.70
Wisconsin Power & Light Co	0.60
PacifiCorp	0.50
Hydro Quebec	0.50
New Jersey Clean Energy	0.40
Public Service Co of Colorado	0.40
New York State Research and Development Authority	0.30

Organization	Average (%)
Kansas City Power & Light Co	0.20
Consolidated Edison Co-NY Inc	0.20
Florida Power & Light Co	0.20
Ontario Power Authority	0.20
Average Excluding BC Hydro	0.85

1. ^ Includes Codes and Standards.

2.2 Comparing Forecast Savings Targets

The Cadmus report found few other utilities with long-term planning horizons of the duration used in BC Hydro's IRP. The Cadmus Report looked at planned levels of energy savings for 2010 – 2015 for states that have Energy Efficiency Resource Standards and compared these to BC Hydro's DSM plans. Similarly, the BCSEA Evidence only provided planned energy efficiency portfolio savings beyond 2015 for Vermont and what is called the 'Pacific Northwest': Vermont plans on achieving about 2 per cent of sales from 2016 to 2021.[4] As such, there is little jurisdictional evidence against which to benchmark BC Hydro's DSM long-term savings targets.

The Cadmus Report is dated June 2011. Since that time, additional political and economic developments may influence future investment in DSM, such as the timing and extent of economic recovery as described in section 3.3.1, Chapter 3 of the IRP. The following issues and uncertainties may also influence DSM program spending in North America going forward:

- Increased policy drivers. Since 2011, more U.S. states have adopted Energy Efficiency Resource Standards such that more than two-thirds of U.S. states currently have requirements. At the federal level, President Obama recently announced a goal for the U.S. to double its energy efficiency by 2030 and commitments to providing more funding and developing standards. In Canada,

[4] *Ibid,* page 19.

Ontario is currently consulting on its ‘Conserve First’ strategy, which provides a commitment to expanding current conservation efforts;

- Increased codes and standards activity/lowered program potential. Planned new U.S. state building codes and U.S. federal and state equipment standards could raise the baseline against which program savings are measured, thereby shrinking the remaining potential for efficiency;
- Lowered economic potential. Although natural gas prices are projected to rise over the next 20 years – refer to section 5.3, Chapter 5 of the IRP – they are nevertheless expected to remain lower in real terms than the prices of the last decade when most U.S. states set their energy savings targets. To the extent that natural gas is on the margin, lower natural gas prices translate into reduced program benefits as measured for example by Total Resource Cost (**TRC**) benefit-cost ratios, which in turn may lead to constraints in DSM program spending because the overall economic potential for conservation is lowered. The timing and extent of the U.S. economic recovery is also a factor.

2.3 Conclusion of Jurisdictional Assessment

From what has been claimed by other jurisdictions, the following observations can be made:

- No other jurisdiction in these tables is reporting savings based on a combination of programs, codes and standards, and rate design in a coordinated way to meet DSM targets
    - ▶ This makes an “apples to apples” comparison very difficult
- Almost no evidence was available from the jurisdictional assessments to help benchmark BC Hydro’s longer-term (F2021) conservation targets against other long-term conservation targets over the same timeframe

- While a number of leading jurisdictions have reported program annual energy savings between 0.65 and 1.25 per cent of retail sales, very few have claimed savings in excess of roughly 1.25 to 1.5 per cent of retail sales for a sustained period of time
- At least one other conservation leader in North America (PacifiCorp) plans on using less than the full amount of seemingly low cost DSM potential due to concerns regarding portfolio diversification and deliverability risk

While the Cadmus Report gives some reasons for cautious optimism about moving forward with DSM programs at the current level, it also highlights the uniqueness of BC Hydro's combination of all three DSM tools to achieve DSM targets. This further underscores the uncertainty surrounding long-term planning estimates of energy conservation.

3 Quantification of DSM Uncertainty

This section focuses on the quantification of DSM savings uncertainty. In particular, this section examines the estimation of uncertainty arising from three strategic elements of DSM:

- Programs;
- Codes and Standards;
- Rate structures

and also addresses uncertainty of associated capacity savings resulting from these three DSM tools. Details regarding the composition of these tools can be found in section 3.3, Chapter 3 of the IRP.

A number of the results below rely on the application of statistics and subjective probability elicitations. Appendix 4A gives a generic description of some of the tools used in the resource planning analysis framework to quantify uncertainty and further background as to how these tools were used to derive the results shown below.

3.1 Energy Savings from Programs

Program savings are made up of many individual programs spread across residential, commercial and industrial customer groups. While BC Hydro has extensive experience working with its customer groups to encourage energy conservation and efficiency, the fact that DSM depends on voluntary customer participation makes forecasting DSM savings inherently uncertain. As a result, the performance risk of these energy savings was made a key part of the IRP planning framework's quantitative uncertainty analysis.

While each individual DSM program was planned to achieve a certain level of energy savings by F2021, the level of energy savings per program is subject to two key drivers of uncertainty:

- The participation rate of customers for that program
- The energy savings per participant

Total savings from DSM programs was estimated as the sum of the individual DSM programs. However, calculating the spread of uncertainty is more involved as significant interdependencies amongst some of the key drivers of uncertainty are expected. Failing to capture these interrelationships would significantly understate the spread of uncertainty around DSM program savings:

- The first key interrelationship estimated was participation rates. It was felt that BC Hydro's DSM promotion and marketing strategy and the creation of a 'conservation culture' through raised awareness, advertising or accessible energy saving information could be seen as a common influence across all sectors. As a result, BC Hydro staff estimated a moderate correlation amongst participation rates across all programs and across all customer classes.

- A second set of important relationships was that between the participation rate and the savings per participant for each program. It was felt that a DSM program that delivered more savings per participant than planned would draw in more participants, but that those that did not deliver high savings per participant would see fewer participants involved. BC Hydro staff estimated that there would be a low correlation for this relationship. This means that these variables would tend to move together, but that it would not be uncommon to find higher than planned participation rates even when savings for that program were lower than planned, and lower than planned participation rates for some programs even when savings per participant were higher than planned.

Total DSM program savings were taken as a sum of the savings from the individual programs. The savings from each program was a random variable, depending on the product of the participation and the savings per participant. Taking into account interrelationships amongst these random variables, a Monte Carlo simulation analysis was carried out using 5,000 random draws to calculate the total savings across all customer classes. The results are shown in Figure 1 DSM Program Savings Uncertainty (GWh/year, F2021)

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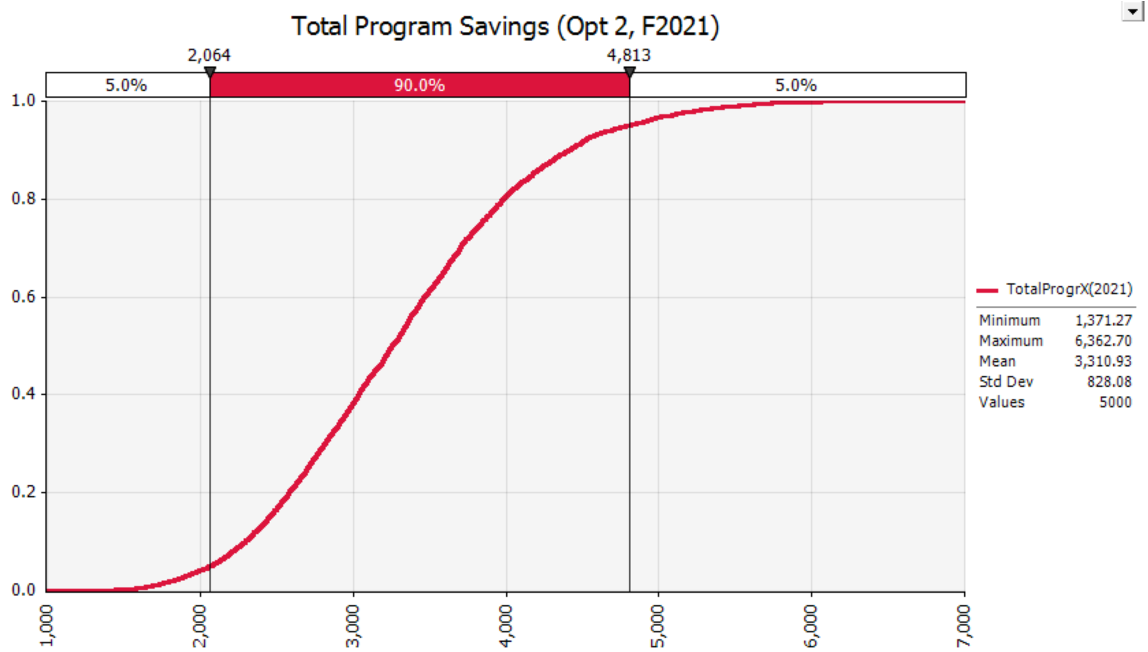
Figure 1 DSM Program Savings Uncertainty (GWh/year, F2021)



This cumulative distribution function is read in the following way. The horizontal axis denotes savings in F2021. The vertical axis gives the probability of seeing that level of savings or less. As an example, the curve transects the point (0.4, 3,000). That means there is a 40 per cent chance that this collection of DSM programs will deliver 4,000 GWh/year savings in F2021 or less.

Recent experience through prolonged recession has shown that both participation and the savings potential for DSM participants are linked to the economic cycle. Notably, in a downturn, DSM program savings potential may be reduced. While BC Hydro has noted this effect in section 3.3.1, Chapter 3 of the IRP, the strength of this relationship, and also the nature of this relationship when growth starts to rebound, is an unknown. This effect is not captured in the uncertainty assessment done for DSM programs.

Another area of program uncertainty concerns ‘ramp rates’, and in particular the rate of program take-up after BC Hydro moderates spending on DSM programs during the F2014 to F2016 period as described in section 8.2.1, Chapter 8 of the IRP. There is no perfect way to know the achievable rates. BC Hydro reviewed its historic experience and achievements, as well as year-to-year changes, to assess ramp rates. The first significant BC Hydro suite of DSM programs was launched in 1989 but it was ramped down during the 1995-1998 period. DSM programs were not ramped back up again until 2001.

BC Hydro’s experience with trying to rebuild Power Smart programs during this period was that it can take at least five years of sustained effort to rebuild relationships with customers, retailers, manufacturers and industry organizations that are required to successfully develop and implement DSM programs. The challenges were particularly acute because of how far DSM program activities had been cut back in the late 1990s – a number of initiatives were abandoned, leaving little to build from when programs were restarted.

BC Hydro’s jurisdictional assessments discussed above in section 2 support its ramp rate assumptions. Danielle Gidding (Bonneville Power Administration), Tom Eckman (Northwest Power and Conservation Council) and Kenneth M. Keating in an article entitled “The Geezers and Geeks: Passing the Thumb Drive for Energy Efficiency Knowledge” catalogue the problems U.S. utilities had in re-introducing DSM programs after having largely vacated the market for a number of years. Among the problems discussed is the attempt to quickly ramp up programs, which in some cases resulted in higher acquisition costs than necessary, and a failure to properly understand the market and the need for infrastructure, trained personnel, supply chains and proper quality control.[5] While acknowledging that DSM is more flexible

[5] 2012 American Council for an Energy-Efficient Economy (ACEEE) Summer Study on Energy Efficiency in Buildings, page 10-136 to 10-137; copy available at www.aceee.org/files/proceedings/2012/data/papers/0193-000314.pdf.

than supply-side resources because for example programs can be acquired in smaller increments, the authors warn against overplaying the flexibility of DSM, and in particular how quickly programs can be scaled up or down, particularly after drastic swings in expenditure and program activity.[6]

The BCSEA Evidence referenced in section 2 noted only two cases where jurisdictions ramped up DSM programs over a relatively short period of time and claimed success: (1) Connecticut increased annual DSM program savings from 0.37 per cent to 1.52 per cent of sales between 2003 and 2010; and (2) Nova Scotia is reported to have gone from 0.17 per cent of sales in 2008 to 0.68 per cent of sales in 2010.[7] In addition, BC Hydro notes the BCSEA Evidence which provides that as of the date of the BCSEA Evidence (April 2012) jurisdictions claiming to achieve at or near 2 per cent of sales consist of only nine program years of experience – California for four years; Vermont for four years; and Connecticut for one year.

Another example is found in PacifiCorp’s 2013 IRP. PacifiCorp developed an accelerated DSM resource option, which allowed its model to select DSM resources at a rate of up to 2 per cent of retail sales per year. PacifiCorp’s resource modelling program selected these options to the exclusion of other resources. However, PacifiCorp used professional judgment to cap the amount of DSM in its preferred portfolio.

BC Hydro’s conclusions concerning program ramp rates are:

[6] *Ibid*, page 10-138.
[7] *Supra*, note 2 at page 15.

- The ability to ramp up to higher levels of DSM program savings depends on a number of factors, including the technical and economic potential,[8] the relationship with customers and industry partners, and the maturity of the market
- There is limited evidence to support sustained average annual incremental energy savings as a per cent of sales in the range of 1.5 to 2.0 per cent
- While BC Hydro has the ability to ramp DSM programs up and down, history and practical experience suggest that there are limits to the flexibility of DSM
- Achieving future high ramp rates may be more challenging starting from sustained periods of extreme levels of DSM investment (either high or low). BC Hydro's experience in the 1990s suggests that it takes a number of years to return to market after cutting back on program efforts. Conversely, sustained levels of high investment in DSM may start to exhaust the technical and economic potential, which would lead to additional challenges with finding new energy savings
- There is a risk of developing programs that are unsustainable associated with high ramp up rates. If programs are developed and ramp up too quickly without proper planning or clear implementation strategy, they can become unsustainable over the long period
- Professional judgement and resource planning objectives play a role in determining what ramp rates are achievable and practicable

[8] Technical potential is the theoretic upper limit of DSM, where all efficiency measures are phased in regardless of cost. Economic potential includes only those measures that are cost-effective. The most commonly applied economic screen is the TRC, and in particular programs are cost-effective if they have a TRC cost-benefit ratio of equal to or greater than 1. Achievable potential refines economic potential by taking into account expected program participation, customer preferences and budget constraints.

3.2 Energy Savings from Codes and Standards

BC Hydro included a number of potential changes to codes and standards that could be encouraged or accelerated to achieve energy savings, including changes to both federal and provincial regulations. The estimates of these savings were subject to several sources of uncertainty, including:

- The timing and efficacy of these changes due to support from the business community, the general public and policy makers
- The level and rate of adoption and compliance with these changes by end users. BC Hydro staff participated in several workshops to elicit ranges and probabilities around these energy savings estimates

These conversations followed similar guidelines to those used when discussing the potential success of DSM programs.

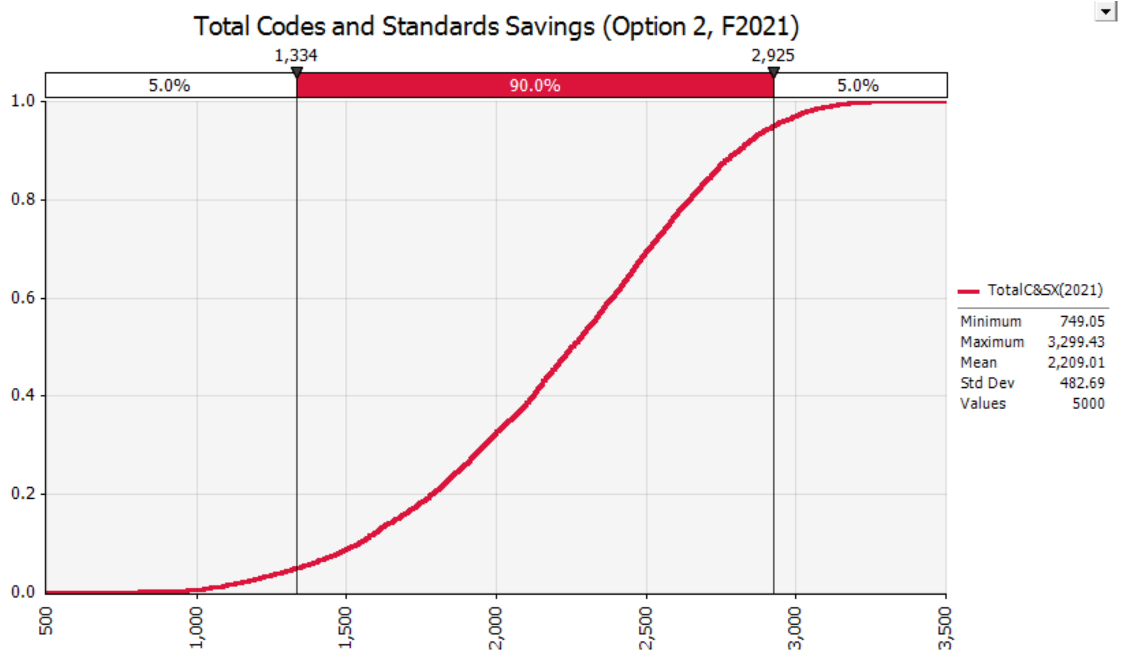
In designing portfolios with the integrated use of the three DSM tools, care was taken to separate out the influence of codes and standards from the general progress of energy efficiency in the economy. Section 2.2.5 in Chapter 2 of the IRP provides some details on this topic. As well, the DSM portfolios were designed recognizing that programs might target a given technology up to a certain level of market saturation and then would drop off as codes and standards were instituted as a replacement. However, for simplicity, the uncertainty assessment treated the variation of these influences as independent; the over or under-delivery of codes and standards was not correlated with variation in load growth or in DSM programs.

The total amount of energy savings attributable to changes codes and standards was treated as the sum of all of the individual codes and standards changes. However, the spread of uncertainty around this estimate required additional analysis as BC Hydro staff identified several ways in which the success (or lack of success) amongst the codes and standards would probably be correlated.

Staff identified several common drivers of uncertainty for changes to codes and standards including continued support from the business community, general public and policy makers. It is expected that the success or lack of success with codes and standards savings might tend to move together. However, this correlation is not perfect as there are different levels of decision makers, and each code and standard is also subject to resistance or support from diverse stakeholders. The estimate was that this effect could be strong, but there was not enough information to differentiate amongst different levels of government/ decision makers. As a result, the IRP uncertainty assessment used a moderate positive correlation amongst all changes.

Savings from changes to codes and standards was calculated as the sum of the savings arising from each of the individual changes to regulations. Using the estimated energy savings, the probability distributions and the assumed relationships among these efforts, a Monte Carlo simulation analysis was run using 5,000 random draws to estimate the expected level of energy savings and the spread of outcomes around this mean. These results are summed up in Figure 2.

Figure 2 DSM Codes and Standards Savings Uncertainty (GWh/year, F2021)



3.3 Energy Savings from Rate Structures

Estimates of energy savings arising from rate design are uncertain, particularly in B.C. where, until recent years, customers had been facing low and stable rates. Data specific to this jurisdiction is only now becoming available to guide forecasts. As a result, it was important to consider the range of uncertainty around rate savings estimates.

To begin, BC Hydro distinguishes between rate savings achieved through general increases in the overall rate levels needed to recover rising costs (also referred to as “natural conservation”), and rate savings achieved through specific changes to the structure of a particular rate. Each of these effects is assigned a rate elasticity of demand. Elasticity of demand is a parameter that describes the percentage change in quantity consumed divided by the percentage change in the price charged.

In the 2008 LTAP, BC Hydro adopted a short-run price elasticity estimate of -0.1 to estimate the aggregate impact of average rate increases and rate design change from a flat rate to inclining block tariffs for residential and commercial customers. The use of the -0.1 as a price elasticity was supported by the results found in other comparable low-cost winter-peaking jurisdictions such as those in the U.S. Pacific Northwest. A long-run elasticity could lead to double counting of energy savings that may occur due to the combined use of a long-run elasticity estimate and conservation induced by government codes and standards, and BC Hydro's DSM programs.

To capture the range of uncertainty for residential and most commercial customers, rate savings attributed to the design of rate structures (e.g., the inclining block structure) were forecast using a wide range of elasticity of demand estimates. The ranges of elasticity estimates used for residential and commercial customers are shown in Table 2. These elasticity estimates include the impact caused by the rate level (e.g., revenue requirement-related rate increases) and by conservation inclining block rate structures. Rate savings attributed to general rate increases were not varied from an elasticity of -0.05; it is assumed that the uncertainty ranges in Table 2 capture the overall uncertainty in rate savings estimation.

Table 2 Elasticity of Demand Estimates

	Low Estimate	Mid Estimate	High Estimate
Residential Rates			
Elasticity Parameter	-0.05	-0.1	-0.15
Probability (%)	30	40	30
Commercial Rates			
Elasticity Parameter	-0.05	-0.1	-0.15
Probability (%)	33	34	33

BC Hydro continues to use -0.05 price elasticity for decomposing the total rate-induced conservation impact into general rate level-induced natural conservation and rate-design induced DSM. Rates saving attributed to rate design (as defined by section 1 of the *CEA*) is the difference between the aggregate impact (calculated at an elasticity of -0.1) and the general rate impact (calculated at an elasticity of -0.05). As part of evaluating its Residential Inclining Block rate, BC Hydro reviewed the jurisdictional assessment conducted for the 2008 LTAP. There is a wide variation of elasticity estimates in the literature due to differences in data samples, estimation methods and model specifications, but for those jurisdictions comparable to BC Hydro, the jurisdictional assessment continues to be a basis of support for an overall elasticity of -0.1. BC Hydro also notes that Avista Corp., a public utility with a service area in Washington State and Idaho, uses a -0.15 price elasticity for its residential and -0.1 for its commercial customers in its most recent, 2011 IRP.[9]

The interplay between rates savings and program savings is another uncertainty; while the design of the portfolios of DSM savings attempted to avoid double counting among the DSM tools, the uncertainty assessment did not. The variation in rate savings was modelled as independent from variations in DSM program savings.

For larger industrial (Transmission Service Rate) customers, a different approach was taken where a triangular probability distribution was created to capture the range of potential savings for sub-portions of this class.

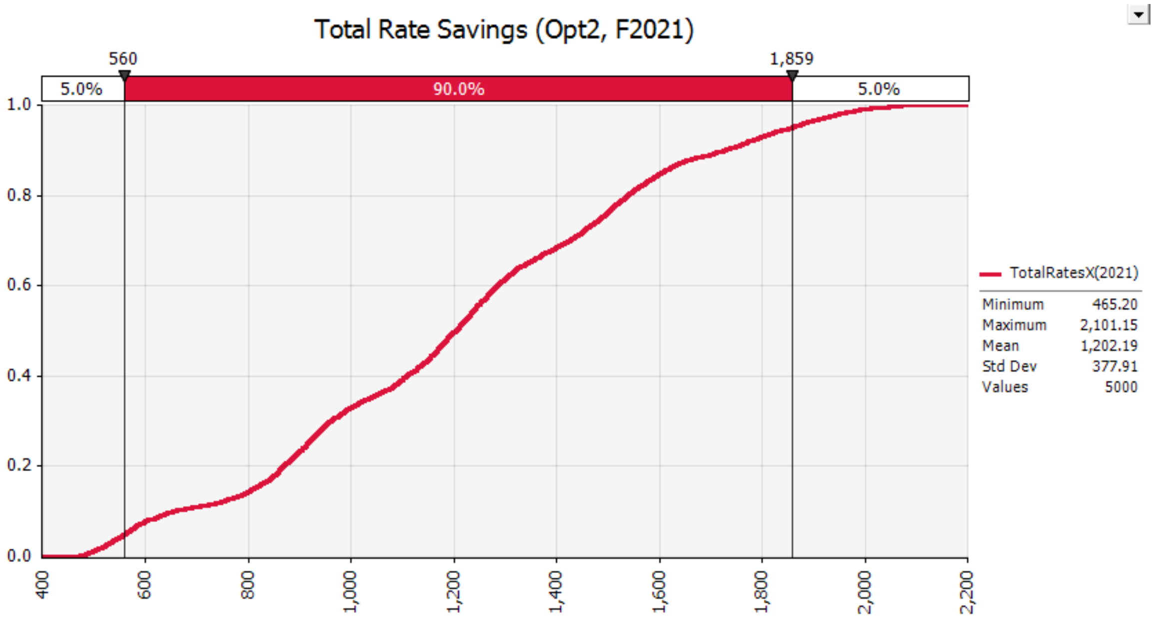
A simple additive model was assumed for the total rates savings across all customer classes; the total rates savings was calculated as the sum of rate savings from each rate class. However, calculating the appropriate range of rate savings required more than just adding up the individual results. It was identified that the performance of the rate structures across rate classes was probably interrelated; capturing some aspects of these correlations was needed to get a better sense of the spread of uncertainty around the average.

[9] Avista 2011 IRP, page 2-8; copy available at www.avisatutilities.com/inside/resources/irp/electric/Documents/2011%20Electric%20IRP.pdf.

Concerning the elasticity measures, it was felt that the ability to respond to changing energy prices is probably similar amongst the commercial and industrial customers. However, these customers' ability to respond is probably not correlated to the ability of residential customers to respond in the face of new rate structures. Savings arising from rate changes seen at the business level (commercial and industrial) were estimated to be strongly correlated, but only loosely correlated to savings seen from residential customers.

Total rate savings was taken as the sum of rate savings from each customer class. Taking interrelationships into account, a Monte Carlo simulation analysis was carried out using 5,000 random draws to calculate the total savings across all customer classes. The results are shown in Figure 3.

Figure 3 DSM Rate Structure Savings Uncertainty (GWh/year, F2021



3.4 Total DSM Energy Savings

The total energy savings from DSM was modelled as a sum of the energy savings across customer classes arising from programs, changes to codes and standards, and conservation rate structures. While care was taken during the construction of the DSM options to take into account how these tools overlap and interact, for the uncertainty assessment it was assumed that the three DSM tools (rates, codes and standards, and programs) varied independently from each other.

A Monte Carlo simulation analysis was carried out and 5,000 random draws were used to calculate the mean and spread of outcomes for all DSM savings. Before turning to the aggregated results, Table 3 below splits out the results by customer class and DSM tool in a way that allows a comparison of the relative uncertainty of each slice of the aggregate forecast savings for F2021. The last column in this table shows the Standard Error, which allows a comparison of the range of uncertainty by normalizing the absolute range of outcomes by the mean of that range.

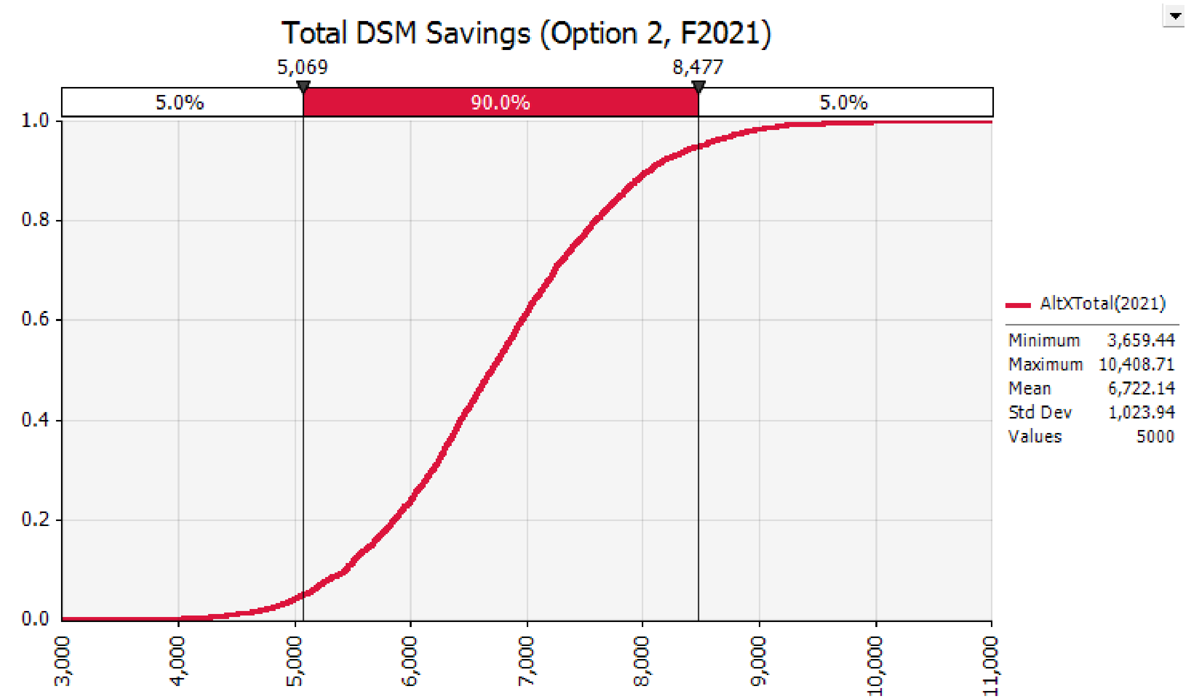
Table 3 Comparing Levels of Uncertainty Among DSM Tools and Among Customer Classes (GWh/year, F2021)

	Mean (1)	Standard Deviation (2)	Standard Error (2)/(1)
Rates	1202	378	0.31
Codes and Standards	2209	483	0.22
Programs	3311	828	0.25
Residential	2670	501	0.19
Commercial	1525	192	0.13
Industrial	2496	708	0.28

As the table above shows, savings arising from rates make up the smallest of the sources of DSM savings, but when normalized for size, rate design is the most uncertain of the three DSM tools. The bottom half of Table 3 shows that across customer classes, the Industrial class generates close to the largest amount of savings and is also, when normalized for this size, the most uncertain source of DSM savings.

The results for aggregation of all DSM savings across all tools are shown in Figure 4. Since the total savings was calculated as a line-by-line aggregation across the three DSM tools, this is referred to here as a “bottom-up” analysis.

Figure 4 Total DSM Savings Uncertainty – Bottom Up Analysis (GWh/year, F2021)



Since the bottom-up analysis was based on a line-by-line assessment of uncertainty by internal BC Hydro staff, this narrow focus lacked a more holistic view of what uncertainties might exist for the overall portfolio of DSM activities. In particular, the bottom-up view did not assess uncertainties that would be common across many line items, across multiple DSM tools, or that might be emergent in the larger aggregation of uncertainty. As such, the result shown in Figure 4 should be considered only as an input into the overall DSM uncertainty assessment.

A "top-down" assessment of DSM uncertainty was then carried out so that BC Hydro could better reflect upon and capture broader sources of uncertainty that could impact DSM savings. The goal of this was to incorporate, and quantify where possible, professional judgment regarding DSM uncertainty not captured in the "bottom-up" approach.

The top-down consideration of DSM uncertainty identified a number of additional sources of uncertainty not already captured in the previous analysis:

- The interaction of all three DSM tools (programs, rate structures, codes and standards) appears to be a unique aspect to BC Hydro's DSM approach. While the design of the DSM portfolio accounted for the overlap of these tools, the uncertainty assessment treats them as independent. Therefore, there could be additional areas of overlap or double counting, or synergies or dysergies, pushing DSM savings above or below their expected levels;
- Optimism bias is common among dedicated professionals whose task it is to deliver projects. This is a general decision-making heuristic and not unique to this field, but a step back to review how plans might unfold differently (for better but also for worse) is a well-known correction for this tendency;
- The timing of savings and their ramp rates was also examined. The uncertainty assessment did include the impact of some BC Hydro programs partially withdrawing and then re-entering certain program areas, but there was additional concern and uncertainty about how this might impact the market as a whole and whether, in aggregate, market partners providing these DSM programs could rebound quickly when BC Hydro's plans required ramped up DSM activities;

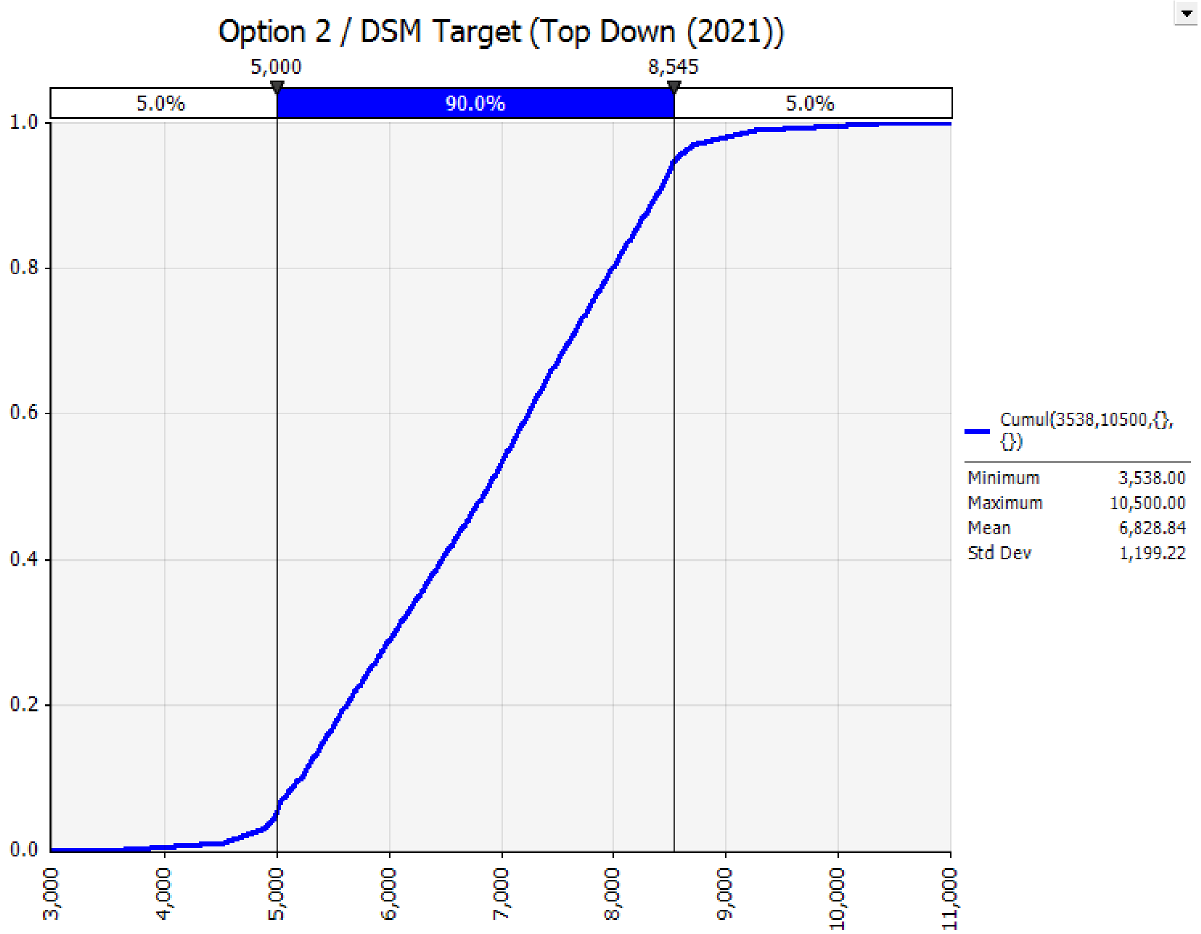
- The assumption that the savings estimates from the three DSM tools would always add to achievable levels of savings, even when all tools were over performing, was also scrutinized; testing the upper levels of savings amounts against the total savings potential (the economic potential in the 2007 Conservation Potential Review) was used as a gauge for the reasonableness of the overall DSM savings levels planned; and finally,
- The relationship between DSM savings potential and the lingering economic recession was discussed. The importance of the industrial sector to DSM savings was noted, as was the fact that this was also the largest driver of DSM uncertainty. The modelling of DSM savings uncertainty and the size of the net gap treats these as independent, but there is a growing awareness of the positive correlation between economic growth and DSM potential as slow growth reduces capital turnover and investor attention in this field.

Figure 5 below shows the result of this top-down assessment of DSM savings uncertainty for Option 2. Several aspects of these results are of interest.

The first is that the quantified levels of DSM savings, after adjustment for uncertainty, are rough estimates only. The uncertainty assessment's main goal is to ensure that the broad range of possible outcomes is captured. Therefore, the interpretation of some of the statistics, in particular the mean (expected value), should not be overly precise.

Figure 5 roughly maintains the lower end and the upper end of the range of potential DSM uncertainty generally intact since it was felt that the bottom up analysis captured how DSM savings might perform on the extreme upside (when everything goes far better than anticipated) and on the extreme downside (when all DSM tools across all customers classes vastly underperform). However, the range of uncertainty was broadened for the middle of the distribution; the remaining information gaps and "unknown unknowns" discussed cautioned against being overly certain about what energy savings might turn out to be in F2021.

Figure 5 Total DSM Savings Uncertainty – Top Down Analysis (GWh/year, F2021)

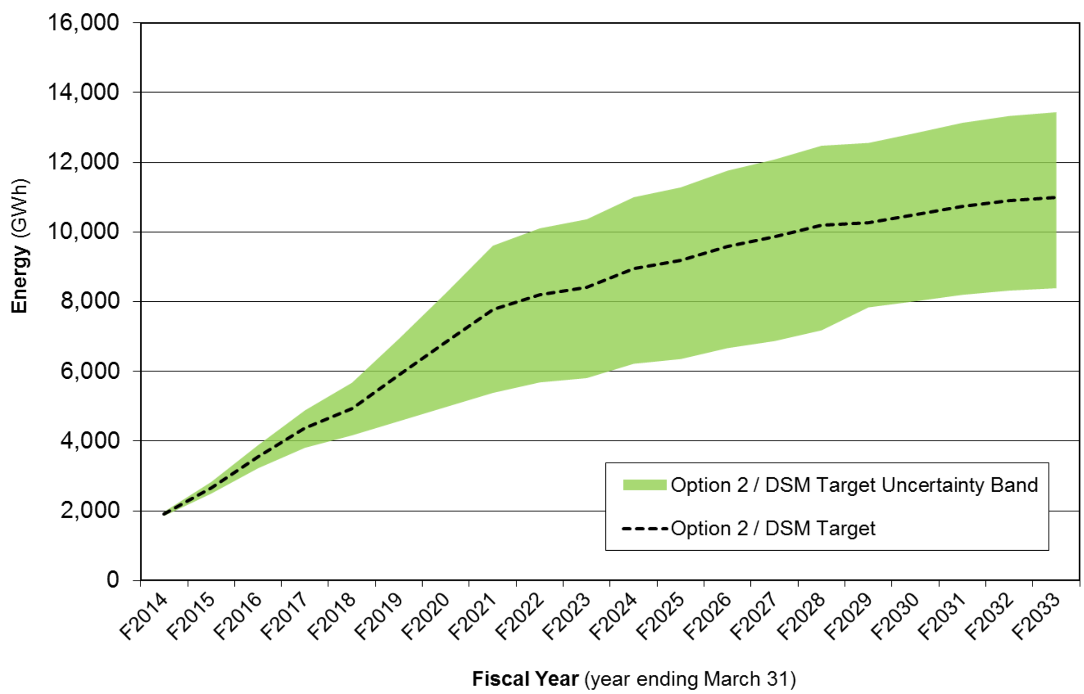


This process was also carried out for savings estimates for F2029. Results were interpolated and extrapolated across the planning horizon for the remaining years.[10] The results for this are plotted in Figure 6 below. The dotted line shows the expected level of savings in each year. The outer edge of the shaded area corresponds to the

10 This introduces an additional area of concern as uncertainty usually grows in a non-linear way into the future, a factor not captured in this uncertainty analysis.

mean of the upper twenty percent of the distribution and the mean of the lower twenty percent of the distribution, respectively. The shaded area is also approximately equal to the 80 per cent confidence interval[11]. It is important to note that higher and lower outcomes are possible, but at lower probabilities.[12]

Figure 6 Range of Potential Energy Savings for DSM Option 2



As Options 1 and 3 were updated and substantially changed during the latter stages of the IRP analysis, a full and rigorous uncertainty assessment was not carried out for those options. Professional judgment suggests that their range of uncertainty

[11] The method relating the quantile "cutoffs" and the means of the tails can be found in Appendix 4A.

12 Subsequent to the DSM uncertainty assessment, Option 2 was updated for a number of reasons including changing the starting year, minor adjustments to the program mix, and changing view so that savings were expressed at the system level, not at the customer meter. As a result, total savings in Figure 6 will appear higher than the probability distributions.

could be roughly approximated by scaling up and down the range of uncertainty estimated here to match their estimate levels of savings.

Section 4.3.4.3 in the IRP uses the results shown in Figure 6, in combination with those of the load forecast, to generate the Net Gap, which forms the starting point for selecting additional supply side options to meet long term energy and capacity needs.

The process followed by BC Hydro for this IRP put considerable effort to consider, identify and quantify the impact of uncertainty on DSM savings estimates. Where possible and available, BC Hydro has looked at what other jurisdictions have done on this subject and finds that its attempts to understand the uncertainty meet or exceed what most others are doing. However, given the number of challenges in estimating and quantifying uncertainty in this field, professional judgment will continue to play an important role in both the interpretation of data and in balancing DSM deliverability risk with other key energy planning objectives.

4 Associated Capacity Savings

BC Hydro is counting on the DSM target to deliver 1,400 MW of associated capacity savings by F2021 – about 86 per cent of incremental peak load growth from F2013 not including LNG load. This is a substantial undertaking – the DSM peak demand savings are roughly the equivalent to the dependable capacity savings of the next three Mica and Revelstoke Generating Station units (Mica Units 5 and 6 and Revelstoke Unit 6). Yet, while BC Hydro's DSM plans rely on a substantial amount of capacity savings, there is good reason to believe that these planned savings are even less certain than their associated energy savings. This topic is addressed briefly in sections 4.3.4.2 and 6.9.4.2 of the IRP. Additional details underlying these analyses are provided here.

Energy savings will translate into capacity savings to the extent that the individual sources of energy savings (e.g., reduction in energy used for lighting, heating, cooling) occur in the short time frame that defines peak load. A capacity factor is the mathematical parameter that translates GWh (energy) savings into MW (capacity) savings for each device or initiative, where applicable. If the bulk of energy savings occurs during weekday, evening, dark and winter hours (e.g., savings on residential lighting), then the capacity factor will be high since this is when the system peak occurs. But if energy savings is spread out evenly across all hours of the year, then peak savings will be low and the capacity factor will be low.

BC Hydro staff identified three key drivers of uncertainty when estimating capacity factors:

- Measurements of peak load by end use
- The shape of energy savings applied to load
- Extrapolating results into the future (forecasting)

Since these influences may vary depending on customer class, the relative importance of each of these was considered for the residential, commercial and industrial customers. A range of capacity factors and a best estimate was derived for each customer class that took into account these factors. An additional distinction was made between savings arising from customers' behavioural change versus other DSM measures, for example the installation of energy-efficient equipment. These ranges are reproduced in Table 4.

Table 4 Capacity Factor Estimates, by Customer Class

	Capacity Factor Estimates		
	Lower Bound	Most Likely Estimate	Upper Bound
Behaviour / Operational **Industrial**	0.1	0.13	0.14
Commercial	0.12	0.14	0.15
Residential	0.14	0.215	0.32
All other DSM **Industrial**	0.1	0.12	0.14
Commercial	0.12	0.135	0.16
Residential	0.15	0.2	0.27

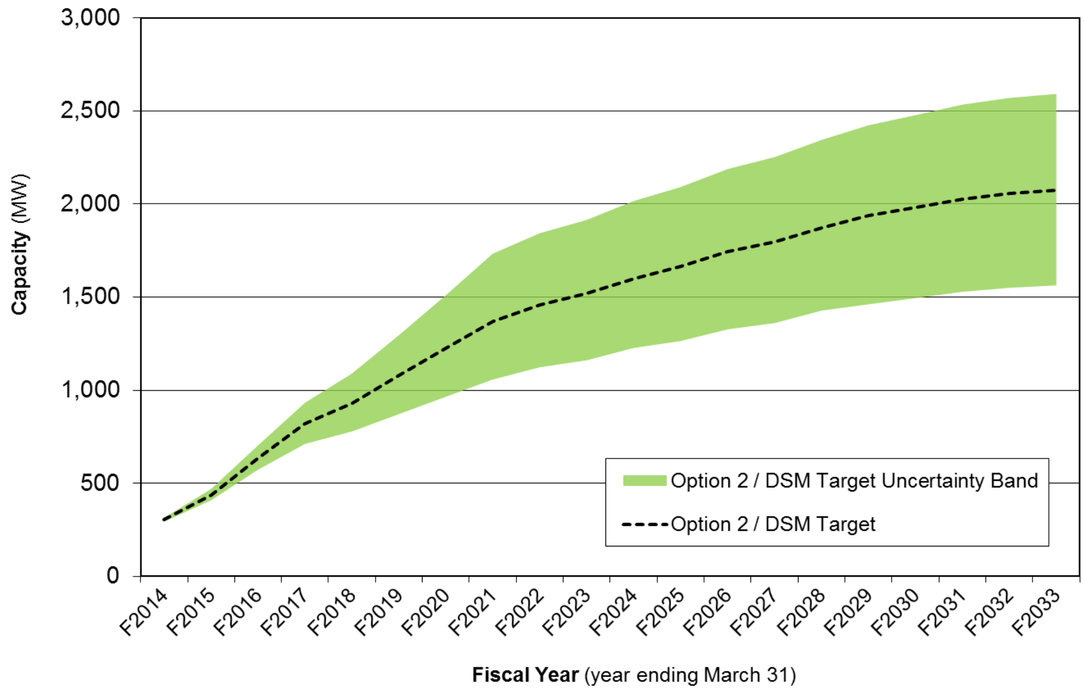
Using these estimates, triangular distributions were used to capture the range of possible values and their associated probabilities for capacity factors.

No other sources of uncertainty were identified at this time for the estimation of the possible spread of energy-related capacity savings. As well, no common factor estimates were identified that might have a common influence across all capacity factors. Finally, it was assumed that any errors in estimating capacity factors were treated as independent. All of these assumptions have the potential to significantly underplay the estimation of uncertainty regarding energy-related capacity savings.

A Monte Carlo simulation was undertaken using 5,000 draws to derive the uncertainty levels of energy savings and then to combine these with the uncertain capacity factors across all customer classes. This gave an estimate of total capacity savings for each DSM option. This is reproduced below in Figure 7.

As with the estimates of uncertainty for energy savings, the capacity savings' uncertainty estimates were created for two time periods. Data for the remainder of the planning horizon was generated through interpolation and extrapolation. This simplistic approach misses the fact that uncertainty is usually assumed to grow in non-linear ways into the future.

Figure 7 Associated Capacity Savings (MW, F2021)



The fan of uncertainty shown in the figure can be looked at in two ways.

First, the lower edge of the shaded area roughly gives the P10 statistics for energy related capacity. This then says that BC Hydro is 90 per cent confident that it can deliver energy related DSM capacity savings of roughly 1000 MW or more by F2021. Given the difficulties and limitations identified in the quantification of DSM uncertainty, there is good reason to assume the spread of uncertainty is likely larger, and this should be considered as a lower bound of uncertainty when assembling contingency resource plans.

A second piece of information is with regards to the spread of the uncertainty around the expected level of savings. By construction, the lower edge of the fan of uncertainty is an estimate of a “low outcome”. More precisely, it is the low DSM scenario that has a roughly one in five chance of happening. As an example, in F2022, BC Hydro expects to have achieved 1,500 MW of savings from DSM. However, there is a one in five chance that this could be lower, about 1,200 MW. Again, keeping in mind that this is likely a lower bound on the estimation of uncertainty, it still gives an indication of what resources BC Hydro will need to have on hand as a contingency if it relies on DSM for this level of capacity and is a critical part to understanding part of the cost of DSM deliverability risk.

As with the energy savings, the quantification of uncertainty surrounding capacity savings is a work in progress. In particular:

- While it was recognized that the use of capacity factors to translate energy savings into capacity savings is an additional source of significant uncertainty, the resultant modelled numbers only reflect a small increase in the spread of uncertainty. This is an area of modeling that will require priority attention in future modeling processes.
- Verifying that DSM actually reduces system load is a struggle for all DSM implementers. Since BC Hydro has traditionally focused its verification processes on energy, there is additional uncertainty related capacity savings.
- The consequences of DSM under-delivery are significantly more critical than the under-delivery of energy. Generally markets can be counted on for supply of energy across the year (albeit with costs) but during winter peaks there are issues with:
    - ▶ The illiquid (thinly traded) nature of the market for capacity
    - ▶ Insufficient transmission capacity

- The U.S. market not having surplus to sell

This is one of the major reasons why BC Hydro develops CRPs that can provide dependable capacity to meet its customers' requirements.

Given these caveats, the application of professional judgment will play an important role in interpreting and using the modelled outputs of this DSM uncertainty analysis.

5 Overall Conclusions Regarding DSM Savings Uncertainty

Energy conservation continues to be BC Hydro's first and best response to load growth. By F2021, BC Hydro expects that 78 per cent of its energy growth and 86 per cent of its capacity growth will have been met through DSM. However, the inherent uncertainty in DSM savings, the degree of reliance BC Hydro is placing on this resource and the uniqueness of the tools used to characterize this uncertainty for decision making continue to warrant the extra effort and attention displayed in this IRP.

Where possible and available, BC Hydro has looked at what other jurisdictions have done on this subject and finds that it is among the leaders in the field in its efforts at assessing DSM uncertainty in the long term planning context.

Despite the advancement in understanding around some of these issues since the 2008 LTAP, uncertainty around the large DSM savings being targeted continues to be a central issue in long-term energy planning. These are difficult issues and none of them can be considered "solved". Moreover, data sets and learning continue to evolve over time, even over the course of an energy planning cycle. So while the focus of this Appendix has been on the quantification of DSM uncertainty, it is important to keep in mind that these quantified estimates likely form a lower bound to the actual levels of uncertainty surround DSM savings. Because of this, professional judgment will continue to play an important role in both the interpretation of data and in balancing DSM deliverability risk with other key energy planning objectives when comparing options to fill the long term energy and capacity needs of BC Hydro's customers and in informing BC Hydro's Contingency Resource Plans.