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July 31, 2018

Board of Commissions of Public Utilities
120 Torbay Road, P.O. Box 2140
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**Attention: G. Cheryl Blundon, Director of
Corporate Services/Board Secretary**

Dear Ms. Blundon:

RE: Newfoundland and Labrador Hydro - 2017 General Rate Application
Revised - September 15, 2017
Revised - October 16, 2017
Revised - October 27, 2017
Revised - November 27, 2017
Supplemental Evidence - July 20, 2018

Further to the above-captioned, please find attached a Report prepared by James P. Feehan, MSC (Econ), PhD, Economic Consultant.

Yours truly,



Dennis Browne, Q.C.

/jl
Enclosure

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**The Long-Run Price Elasticity of Demand for Electricity
and the Feasibility of Raising Electricity Rates to Finance Muskrat Falls**

**A Report Prepared
for
Dennis Browne, QC
The Consumer Advocate**

by

**James P. Feehan, MSc(Econ), PhD
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July 31, 2018

1 **I. Introduction**

2

3 The Muskrat Falls project is expected to be completed in the third quarter of 2020. At

4 that time, the immediate consequence will be an increase in the cost structure of

5 Newfoundland and Labrador Hydro (Hydro). That is because that utility has entered into long-

6 term arrangements to purchase power from the Muskrat Falls generating plant and to use the

7 new transmission assets associated with that project to supply the island of Newfoundland's

8 interconnected electrical system. Hydro is pre-committed to paying whatever price is needed

9 to cover the MF project's costs regardless of how high those costs turn out to be. In turn,

10 Hydro will pass along the cost burden to ratepayers, which means a huge increase in the

11 wholesale price that it will be charging to Newfoundland Power (NP) the main distributor of

12 electricity on the island. The retail price faced by NP's domestic and commercial customers will

13 rise accordingly. Hydro's own retail customers on the island interconnected system will face

14 the same increase since their rates are, as a matter of public policy, set equal to those of

15 corresponding NP customers. Hydro's industrial customers would presumably face a

16 proportionately similar rate shock.

17 As yet, it is not known by how much prices will increase. In the June 2017 update on the

18 Muskrat Falls project, Nalcor – the provincial government crown corporation behind the

19 Muskrat Falls project and the owner of Hydro - indicated that Hydro's costs would ratchet up

20 considerably.¹ For 2021, the first full calendar year of Muskrat Falls operations, Nalcor

21 estimated the domestic (i.e., residential) customer cost would be approximately 23 cents per

22 kWh. In contrast, as of July 1, 2018, the domestic residential price was 11.4 cent per kWh.

23 Practically all the potential more-than-100-percent increase in the domestic consumer price

24 would be due to the increase in Hydro's cost structure resulting from its Muskrat Falls

25 commitments. Whether the actual increase will be as large as estimated by Nalcor is uncertain.

26 Nalcor's June 2017 figures were based on the full cost of the Muskrat Falls project being borne

27 by island interconnected ratepayers. However, in its 2017 Budget, the provincial government

¹ See https://muskratfalls.nalcorenergy.com/wp-content/uploads/2017/06/Muskrat-Falls-Project-Update-Presentation-June-23_Final.pdf.

1 indicated that it intended to take steps to limit the price increase to keep the rates competitive
2 with other Atlantic provinces.² Still, even such rate mitigation would entail significant increases
3 in island rates.

4 The purpose of this report is to assess the impact of higher rates on electricity
5 consumption. If higher electricity rates cause a substantial reduction in electricity consumption
6 then paying for Muskrat Falls by imposing higher rates may not be practical or even feasible.
7 Assessing how much higher rates will reduce consumption requires an assessment of the price-
8 elasticity of demand for electricity.

9 The remainder of this report is organized as follows. The next section, Section II, defines
10 the price elasticity of demand and provides evidence from various sources in order to ascertain
11 a reasonable estimate of it for interconnected island electricity consumers. Section III then uses
12 estimates of the long-run price elasticity to illustrate the implications that arise from the sorts
13 of rate increases that might occur. Brief concluding remarks are given in Section IV.

14 II. Price Elasticity of Demand

15

16 a) The Concept

17 The price elasticity of demand is an index of consumers' responsiveness to a price
18 change. Normally, when the price of a commodity goes down consumers will decide to
19 purchase more of it, and if the price goes up then they would purchase less. Price elasticity is a
20 measure of the magnitude of such responses. For example, if the price of electricity went up 10
21 percent and customers reduce their consumption by just 1 percent then that response would
22 be considered small. In that case, demand for electricity is insensitive, or inelastic, with respect
23 to the price change. The index value of that elasticity is measured by the ratio of the change in
24 the amount purchased (1 percent in this example) to the price change (10 percent); the result is
25 1/10 or simply 0.1; technically the value takes a negative sign but a widely used convention is to
26 express it in absolute value. In contrast, had the reaction to the price change been a 15 percent
27 reduction in consumption then that would be considered a big response and demand would be

² See http://www.budget.gov.nl.ca/budget2018/speech/budget_speech2018.pdf, p.32.

1 classified as price-sensitive or price-elastic. The index value would then be 15/10 or
2 equivalently 1.5. More generally, the measure of price elasticity (e) is calculated as:

$$3 \quad e = (\text{percentage change in consumption})/(\text{percentage change in price}).$$

4 The calculation is done under the assumption that other influences on consumption decisions,
5 such as income and prices of other commodities, have not changed. In other words, it isolates
6 the impact of a price change on consumption. Whenever the index value is more than 1,
7 demand is classified as price-elastic, or price-sensitive, and the more that it exceeds one the
8 greater is the price elasticity. When the ratio is a fraction then demand is said to be price-
9 inelastic, and the smaller the fraction the more inelastic. Additionally, elasticity is not generally
10 a constant; its value over one price range is usually not the same as over a different price range.

11 Price elasticity also has a time dimension. When a price changes, consumers are
12 typically limited in how they can react over a short period of time. For example, a higher price
13 of electricity might induce consumers who use electric space heating to turn back their
14 thermostats but not much else over the course of a few months. However, if the price increase
15 persists then consumers might over time decide to install more insulation, switch to other
16 space heating sources or replace an electric hot water tank with one that uses propane. Such
17 responses take more time and the consumer must be convinced that the upfront cost is
18 worthwhile, i.e., that the future electricity cost savings would exceed those upfront costs. Thus,
19 the index value of the price elasticity measured over a short period could be quite close to zero
20 but much larger over time. Therefore, there is a distinction between the short-run and long-run
21 price elasticity of demand. In the case at hand, it is the long-run that is relevant. That is
22 because the Muskrat Falls project's high operating costs and debt repayments will continue for
23 decades so pricing based on full or substantial cost recovery would mean persistently higher
24 prices. The long-run is not a specific period of chronological time. Rather, it is the amount of
25 time that consumers take to fully respond to a change in price. As may occur with the Muskrat
26 Falls project, if consumers believe that a large price increase is coming and will persist then they
27 may react at early stages or even prior to a price increase in anticipation of it. For this reason, in
28 the case of Muskrat Falls, the long-run may be a fairly short period of time.

29

1 b) Estimates of the Price-elasticity of Demand for Electricity in the Long Run

2 There is an extensive literature on price elasticities for electricity but there does not seem
3 to be any published estimates available for the island of Newfoundland's interconnected
4 system. However, there is some evidence based on provincial data as well as findings from
5 elsewhere that can provide a reasonable assessment of what that elasticity might be. They are
6 discussed in this subsection.

7 (i) Some evidence from Newfoundland and Labrador

8 Domestic, i.e., residential, customers are the largest group of electricity consumers on the
9 island's interconnected grid. They consume between 50 and 60 percent of the electricity
10 delivered over that system. Table 1 provides two possible values for the long-run price elasticity
11 of demand for electricity by island domestic consumers, and both are based on provincial data.

12 Table 1
13 Estimates of the Long-Run Price Elasticity
14 of Average Residential Demand for Electricity

Source	Estimate
Partial Adjustment Model (see Appendix)	0.42
Case Study of South Labrador Coast	1.20

15
16 The first estimate presented in Table 1 is 0.42. It was obtained from econometric estimation of
17 a partial adjustment model of residential demand for electricity, the details of which are given
18 in the Appendix to this report. Such a model incorporates the idea that consumers need time
19 to fully adjust to a price change, which is the case with electricity. That model incorporates not
20 just price but other relevant influences on average electricity consumption, notably the price of
21 substitutes and household income, with appropriate adjustments for inflation.³ Estimation was
22 based on annual data for the average consumption by NP's domestic customers, and who make
23 up the overwhelming majority of interconnected residential electricity consumers on the island.
24 The data covered the years from 1992 to 2016 inclusive.

³ Total residential consumption is also affected by the number of residential customers, which is influenced by demographics.

1 The estimate of 0.42 is a long-run figure. It suggests that following a price shock of, for
2 example 20 percent, that, given enough time to fully adjust, a consumer’s average annual
3 consumption would fall by 8.4 percent (i.e., 0.42 multiplied by 20 percent); analogously, had
4 the price decreased by 20 percent then an 8.4 percent eventual increase in electricity
5 consumption would be the model’s prediction. While a long-run elasticity of 0.4 is plausible,
6 there are reasons to suggest that it may be low when considering a possible future Muskrat
7 Falls price shock. First, that elasticity was estimated based on data from 1992 to 2016. The
8 magnitude of price elasticity depends on the availability of substitutes for the commodity
9 whose price has increased. In the early years of that time period, it may be that substitutes
10 such as mini-splits were not as well-known nor as efficient as they have become in more recent
11 years. Secondly, the figure was estimated based on the range of electricity prices that prevailed
12 during the 1992 to 2016 period. None of those prices was as high as the prices suggested by the
13 provincial government or Nalcor for the post-Muskrat Falls era so the analysis does not capture
14 that high-price experience.

15 Some areas of the province do have high-price experience. The second estimate in Table
16 1 is relevant in that regard. That elasticity is 1.2, which indicates a high degree of price
17 sensitivity. That figure is not based on an econometric estimate. It is from a recently published
18 case study of residential consumption in communities located on the south Labrador coast.⁴
19 Prior to 1997, all the communities on that coast were serviced by electricity from diesel plants
20 and faced increasing block rates. However, from 1997 onwards, the communities in the L’Anse
21 au Loup area of that coast began to be serviced from a nearby hydro plant in Quebec. As a
22 result, their residential rates were reduced to those of island interconnected customers.
23 Communities on that South Labrador coast further to the north remained on diesel rates. As of
24 July 1, 2017 the rate for electricity per kWh for electricity in excess of 1,000 kWh in the isolated
25 communities was 16.3 cents while those in the L’Anse au Loup system paid 10.6 cents.⁵ That
26 higher rate of 16.3 cents is similar to what the provincial government was alluding to in Budget
27 2018 for post-Muskrat Falls rates. The study showed that from 1992 to 1997 the two sets of

⁴ James P. Feehan (2018) “The long-run price elasticity of residential demand for electricity: Results from a natural experiment,” *Utilities Policy*, April.

⁵ See <https://nlhydro.com/wp-content/uploads/2018/07/July-1-2018-Rates-Rules-Regulationsv2.pdf>

1 communities had very similar electricity consumption patterns but following the reduction in
2 rates for L'Anse au Loup domestic customers in 1997 those patterns diverged. By 2016,
3 average consumption was much higher among L'Anse au Loup customers – approximately
4 double - and at least 50 percent of them had installed electric heat as their primary source of
5 space heating. Before the price change, neither set of communities had significant use of
6 electric heating and that has remained the case in the isolated diesel communities. The
7 observed change in electricity consumption led to the 1.2 elasticity result.

8 While the south Labrador coast experience may not carry over exactly to communities
9 on the island, the differences in distance and climate are not especially great. If the price
10 elasticity on the island is similar then the implications are profound. For example, with an
11 elasticity of 1.2, a 50 percent increase in price would imply a 60 percent reduction in
12 consumption. Since, in proportions, the reduction in consumption exceeds the price increase,
13 that would mean that the utilities would actually see a decline in their residential sales
14 revenues; selling 60 percent less at a 50 percent higher price implies a revenue drop of
15 approximately 10 percent.

16 (ii) Estimates from other Jurisdictions

17 Moving beyond Newfoundland and Labrador, there are many estimates of price elasticities.
18 For example, in one study, by Espey and Espey, found from their survey of various sources that
19 estimates of long-run price elasticities for residential electricity range from approximately 0 to
20 2.25 with an average of 0.85 and a median of 0.81.⁶ This wide range is in part the result of the
21 differences across various study areas and time periods. Climate, availability of substitutes,
22 income levels, and pricing regimes all tend to influence price elasticity. Nevertheless, the Espey
23 and Espey survey illustrates that the provincial values identified in the preceding subsection are
24 generally consistent with results found elsewhere.

25 Another report, from the Electric Power Research Institute (EPRI), has a somewhat
26 narrower range of values for long-run residential elasticities than in Espey and Espey. That may

⁶ See James Espey and Molly Espey (2004) "Turning on the Lights: A Meta-Analysis of Residential Electricity Demand Elasticities," *Journal of Agricultural and Applied Economics*, Volume 36 (1), p.66.

1 be the result of EPRI surveying a smaller number of selected studies. Their findings are
2 summarized in Table 2.⁷

3 Table 2

4 Long-Run Price Elasticities from Selected Studies: EPRI

	Mean	Low	High
Residential	0.9	0.7	1.4
Commercial	1.1	0.8	1.3
Industrial	1.2	0.9	1.4

5
6 The EPRI survey is interesting because it includes estimates for commercial and industrial
7 customers, and their mean values imply that those groups are price sensitive. However, it is
8 important to stress that the selected studies underlying them are from various areas and not
9 from Newfoundland and Labrador. Both the industrial and commercial customers on the island
10 are likely to have very different characteristics than elsewhere, so significantly higher or lower
11 values for Newfoundland are possible.

12 Closer to Newfoundland in terms of both geography and climate, is Quebec. The result
13 of two analyses of residential electricity demand there are summarized in Table 3 below. In
14 both cases, the values are practically identical and greater than one. They indicate that
15 electricity demand in Quebec is price-elastic.

16 Table 3

17 Estimates of the Long-Run Price Elasticity:
18 Residential Demand for Electricity in Quebec

Authors	Estimate
Bernard and Genest-Lapante (1995) ⁸	1.33
Bernard, Bolduc and Yameogo (2011) ⁹	1.32

19
⁷ See EPRI (2008) "Price Elasticity of Demand for Electricity: A Primer and Synthesis," p.20. Available at <https://www.epri.com/#/pages/product/1016264/>

⁸ J.T. Bernard and E. Genest-Laplante (1995) Les élasticités-prix et revenu des demandes sectorielles d'électricité au Québec: revue et analyse. Rapport final de recherche soumis à Hydro-Québec.

⁹ Bernard, Jean-Thomas, Denis Bolduc and Nadège-Désirée Yameogo (2011) "A pseudo-panel data model of household electricity demand," *Resource and Energy Economics*, 33 (1):315-325.

1 It is possible to find many studies that present lower estimates of residential price
2 elasticities than in Tables 1, 2 and 3. However, the range of estimates in those tables provide
3 evidence that island residential customers may be quite price sensitive. A long-run elasticity
4 similar to that found for the south Labrador coast or in Quebec is a distinct possibility for island
5 residential customers.

6 (iii) Substitution Incentives and the Price of Electricity

7 The price elasticity of demand for a commodity depends on how important it is to the
8 consumer and on the availability of substitutes for it, and, in particular, on the net savings that
9 would result from substitution. Over a short period of time, a price increase may have little
10 impact on consumption. That is because there may not be enough time to switch to a
11 substitute or the consumer may be uncertain as to whether the price increase is permanent, in
12 which case if there is a cost of substituting then the consumer may wait until convinced that the
13 change is going to be long-lasting. Under the plan to incorporate Muskrat Falls costs into island
14 electricity rates, customers will perceive any significant increase in price as long-lasting. That
15 would provide an incentive for them to investigate alternatives. Generally, the more the
16 alternatives, the greater the price elasticity. Tables 4 and 5 illustrate the possible alternatives
17 for residential customers. The tables show the estimated annual costs of the different options
18 available to customers. The costs are solely for fuel and do not include the upfront costs of
19 installation/switching and maintenance or fixed charges.

20 Table 4 deals with space heating. It is based on the energy requirements for heating a 2,000
21 square foot house in St. John's built after 1990; the energy requirement is 80 million BTUs.¹⁰
22 The table is also adapted from Efficiency Nova Scotia's energy conversion ratios used in its cost
23 comparison methodology.¹¹ Table 4 shows the annual fuel costs of different types of space
24 heating sources based on three different prices of electricity for residential customers on the
25 island grid: the July 1, 2018 price of 11.4 cents per kWh, and then 17 cents, which is used as the
26 approximation for a mitigated price, and 23 cents, the price that would otherwise be

¹⁰ Natural Resources Canada gives 85 Gigajoules as being needed to heat such a dwelling, which is approximately 80.5 million BTUs. The calculations in Table 4 are based on 80 million BTUs.
http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/oeefiles/pdf/publications/Heating_with_Electricity.pdf
Table 3, p.37.

¹¹ See Efficiency Nova Scotia, <https://www.efficiencyns.ca/guide/heating-comparisons/> (For February 2018)

1 implemented following completion of the Muskrat Falls project. Other fuel costs are those that
 2 prevailed in St. John’s during mid-July 2018: 97.1 cents per litre for furnace oil and 79.6 cents
 3 per litre for propane.¹² Data on firewood costs was not readily available so prices from Nova
 4 Scotia were used: \$246.96 per cord of wood and \$312.99 per ton of pellets.

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Table 4
 Comparison of Annual Spacing Heating Fuel Costs (HST of 15% Included):
2,000 Square Foot Detached House Built after 1990 – St. John’s

	Electricity Price at 11.4 cents/kWh	Electricity Price at 17 cents/kWh	Electricity Price at 23 cents/kWh
Electric Baseboard heat	\$3,074	\$4,584	\$6,202
Electric Heat Pumps: Air-to-Air	\$1,618	\$2,413	\$3,264
Electric Heat Pumps: Mini-splits	\$1,230	\$1,834	\$2,481
Heat Pumps-Geothermal	\$1,025	\$1,528	\$2,067
Oil Furnace: old at 70% efficiency	\$3,497	\$3,497	\$3,497
Oil Furnace: new at 85% efficiency	\$2,880	\$2,880	\$2,880
Propane (fireplace) at 70% efficiency	\$4,305	\$4,305	\$4,305
Propane furnace at 80% efficiency	\$3,767	\$3,767	\$3,767
Wood stove/furnace at 55% efficiency	\$1,723	\$1,723	\$1,723
Wood stove/furnace at 70% efficiency	\$1,353	\$1,353	\$1,353
Wood Pellets at 75% efficiency	\$2,400	\$2,400	\$2,400

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Table 4 shows that, at 11.4 cents per kWh, electric baseboard heating is more costly in terms of annual fuel cost than wood fueled heating and the other electricity-fueled, but more efficient, heat pump options, but less costly than alternatives fueled by either oil or propane. However, at 17 cent per kWh, electric baseboard heating would have the highest annual fuel

¹² See Petroleum Pricing Order of July 12, 2018, <http://pub.nl.ca/orders/ppo/oil/HO-180712.pdf>

1 costs of all the options in the table. The margins are quite large. For example, while electricity
 2 for baseboard heaters would cost \$4,584 annually, the fuel cost for a new furnace would be
 3 \$2,880 and even electricity for a mini-split would be \$1,834. At 23 cents/kWh, as shown in the
 4 last column of Table 4, electric baseboard heating would be even more unattractive compared
 5 to all the other listed alternatives. In short, the figures in Table 4 suggest that even at 17 cents
 6 per kWh all the alternatives to electric baseboard heating offer large annual fuel costs savings,
 7 all of which being achieved through less consumption of electricity. At present, approximately
 8 70 percent of residential customers on the island of Newfoundland have electric space heating.
 9 Thus, there is considerable room for reductions in residential electricity consumption.

10 Table 5, which is also adapted from Efficiency Nova Scotia’s comparison tables. It is
 11 based on a four-person household shows that consumes 240 litres daily. The table shows
 12 electric hot water heating offers generally favourable annual costs compared to the oil or
 13 propane fired alternatives at 11.4 cent/kWh. However, at higher electricity prices, both
 14 propane and oil fueled alternatives offer annual fuel cost savings.

15
 16 Table 5

17 Comparison of Annual Hot Water Heating Fuel Costs: 240 Litres Daily

	Electricity Price at 11.4 cents/kWh	Electricity Price at 17 cents/kWh	Electricity Price at 23 cents/kWh
Electric Hot Water Heater (old) at 85% efficiency	\$701	\$1,046	\$1,415
Electric Hot Water Heater (new) at 90% efficiency	\$663	\$988	\$1,337
Oil Stand-alone water heater at 55% efficiency	\$ 868	\$868	\$868
Propane Stand-alone water heater at 55% efficiency	\$1,068	\$1,068	\$1,068
Propane stand-alone/on-demand/ heater-high at 93% efficiency	\$632	\$632	\$632

18
 19 Tables 4 and 5 illustrate that there are substantial annual savings from switching either
 20 to less electricity-intensive space and water heating or to non-electric alternatives but

1 customers will be aware that there are capital costs of doing so. The same observation applies
2 to new construction. If the annual savings are large and expected to persist then the customer
3 would have a very strong incentive to act. If the price increase is anticipated then the action
4 may be taken in advance. In such circumstances the long-run for the price elasticity of demand
5 may not be a lengthy period of chronological time, and that elasticity might be quite large.
6 Furthermore, substitution possibilities go beyond space and water heating. Better house
7 insulation and windows, and replacement of electric lights and appliances with more efficient
8 ones would also be actions that customers could take.

9 The focus of Tables 4 and 5 has been on residential consumption. However, commercial
10 (general service) customers of NL Hydro and NP as well as NL Hydro's industrial customers
11 would have similar incentives to find less expensive alternative sources of energy if the price of
12 electricity increases substantially for the long term. That would be especially so for those
13 businesses for which electricity is a major component of their cost structure.

14 c) Overall Assessment of Elasticity

15 The evidence in the preceding subsections is not sufficient to establish a single estimate
16 for the long-run price elasticity of demand for electricity on the island. However, based on that
17 evidence, that elasticity is likely more than 0.4 and possibly more than 1.0 at current prices.

18

19 **III. Implications**

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21 The range of values for the long-run price elasticity that has been suggested above has far-
22 reaching implications for the post Muskrat Falls period.

23 a) Electricity Consumption

24

25 In 2017, the total customer load for NL Hydro island interconnected system was
26 approximately 7 million megawatt hours (MWh), of which approximately 1.8 million were
27 provided by its oil-fueled generating plant at Holyrood. Nalcor and government statements
28 regarding Muskrat Falls have suggested that the price of electricity could rise by either 50
29 percent (to about 17 cents/kWh for residential customers) with rate mitigation or 100 percent

1 (to about 23 cents/kWh for residential customers) otherwise, relative to current rates. Even
2 values of the elasticity selected from the lower end of the range suggested herein have
3 substantial implications for future electricity consumption. Table 6 shows how much NL
4 Hydro’s customer load might change as a result of the price increases currently in the public
5 discourse and based on the long-run elasticity being either 0.4 or 0.6.

6

7

Table 6

8

Change in NL Hydro Customer Load Due to Electricity Price Increases,

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at Selected Values of the Long-Run Price Elasticity of Demand

	Elasticity of 0.4	Elasticity of 0.6
50% Price Increase	-1.4 million MWh	-2.1 million MWh
100% Price Increase	-2.8 million MWh	-4.2 million MWh

10

11 Even with the low value of 0.4 for the elasticity and the smaller rate increase of 50 percent,
12 Table 6 indicates that the reduction in customer load due to the price increase would be quite
13 large, at 1.4 million MWh. At a 0.6 elasticity, which might well be lower than the true value, a
14 50 percent price increase, implies a 2.1 million MWh decrease in consumption. Higher price
15 increases or greater elasticity would lead to even bigger reductions in customer loads. One
16 caveat here is that other considerations will also influence electricity consumption. For
17 instance, changes in income, prices of alternative fuels, technology and demographics would
18 come into play. Some might exert upward movement on consumption and others might tend to
19 lower consumption further. Those influences are not embodied in Table 6, which focuses
20 exclusively on the impact of price changes.

21 b) Muskrat Falls Energy

22

23 Table 6 implies that if electricity prices increase by the magnitudes that have been discussed
24 herein then the resulting fall in consumption could be nearly as large as or even much larger
25 than the amount of energy produced at the Holyrood generating facility, which was
26 approximately 1.8 million MWh in 2017. That is to say, the decline in consumption brought on
27 by the price increase would make Holyrood largely redundant. Winter demand might require

1 the plant to operate at times but, in net terms, the energy from Muskrat Falls could be largely
2 or even totally unneeded to displace Holyrood. The implication is that Muskrat Falls would
3 become primarily or entirely an export project. Practically all the energy that would be in
4 excess of what has already been committed to Nova Scotia would also have to be exported
5 since there would be no market for it on the island at high end-user rates. This is a perverse
6 result because the rationale for the project was to displace Holyrood and meet growth in island
7 electricity consumption.

8 Island customers would be consuming little or none of Muskrat Falls electricity, in net
9 terms, but would be paying much higher prices for the purpose of financing it. Additionally,
10 island consumers would be burdened with the cost associated with converting to other energy
11 sources and NL Hydro would experience little in the way of revenue increases from island sales
12 as customers there substitute away from electricity. Complicating the revenue challenges
13 would be low prices for exports of energy in accessible external wholesale markets if prices
14 there remain as low as they currently are. So the higher prices may also fail to generate
15 sufficient funds to pay for Muskrat Falls, even with the sort of price mitigation suggested in
16 Budget 2018.

17 c) Rate Design

18

19 The counterproductive impacts of raising electricity rates following completion of Muskrat
20 Falls are a signal that simply raising the price-per-kWh is an incorrect approach to rate design.
21 Setting prices in that way is not related to the core economic principle of marginal cost pricing
22 and, as demonstrated herein, it fails to take account of consumer response to higher prices.
23 The higher rates for island customers would push them away from consuming electricity even
24 though the benefits to island consumers from using that electricity may well exceed the export
25 revenue it earns.

26 **IV. Concluding Remarks**

27 This report has presented an assessment of relevant long-run price elasticities for electricity
28 and fuel substitution possibilities. Based on that assessment, it appears that a large increase
29 (e.g., by 50 percent or more) in the per-kWh price of electricity would be problematic. Not only
30 would it be a burden to all island interconnected customer groups, it would cause a large

1 decline in electricity consumption by those consumers. That would impede Nalcor's efforts to
2 raise revenue through Hydro's rates to pay for Muskrat Falls. Island consumption could fall by
3 so much that Muskrat Falls could become solely an export project. Since there has been no
4 indication that such pricing is based on economic principles, there is no reason to believe that
5 these outcomes are consistent with optimal economic use of the province's electrical energy.

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APPENDIX

Estimating the Price Elasticity of Demand for Electricity by Households in Newfoundland:
A Partial Adjustment Model

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1 **Introduction**

2 Table 1 of the report refers to a 0.42 estimate for the long-run price elasticity of residential
3 demand for electricity on the Newfoundland interconnected grid and indicates that it was
4 obtained from a partial adjustment model. This appendix explains the methodology that was
5 used to determine that estimate.

6 **The Data**

7 All interconnected residential customers on the island of Newfoundland face the same price
8 of electricity even though areas are served by two utilities; Newfound Power serves the vast
9 majority of customers while Newfoundland and Labrador Hydro serves the remainder. The
10 data on consumption that is used in this exercise corresponds to that for Newfoundland
11 Power's residential customers and was provided by Newfoundland Power on request. There is
12 little reason to expect the NL Hydro's own customers' consumption patterns to be much
13 different from NP's, given that they face the same prices and live on the same island.

14 In addition to consumption, expressed as average annual consumption per residential
15 customer, the other core variables used are the price of electricity, the price of heating fuel and
16 per capita personal disposable income (PDI). In the analysis that follows, the prices and
17 income are all expressed in real terms (i.e., 2002 constant prices) using Statistics Canada's
18 Consumer Price Index for Newfoundland and Labrador. The data for the price of heating fuel in
19 the province and personal disposable income were obtained from Statistics Canada as well.
20 While most of the data was available on a monthly basis, personal disposable income was
21 annual and thus annual data was used for this exercise. The years covered were 1992 to 2016,
22 inclusive. Table A1 describes the data.

23 Table A1
24 Core Data: 1992-2016

25 Variable Mean Std. Dev. Minimum Maximum

26 Weather –Adjusted

27 Average Consumption in kWh 15309 529.6 14588 16206

28

29 Real Price of Electricity in cents per kWh 8.55 0.54 7.7 9.2

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31 Real Price of Heating Fuel in cents per litre 62.9 18.4 37.9 95.7

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33 Real Personal Disposable income per capita \$18,447 \$3,979.5 \$13,886 \$24,945

1 Partial Adjustment Model

2
3 In general terms, a household's desired choice of electricity consumption Q^* is determined
4 by the price of electricity (P), the price of any substitute (PF), and income (I). Thus,

$$5 \quad (1) \quad Q^* = f(P, PF, I)$$

6 where f denotes the functional relationship between Q^* and the variables that determine it; the
7 other notation in the equation is as given in Table 1. That functional relationship may be
8 written as:

$$9 \quad (2) \quad Q^* = a + bP + cPF + dI + u$$

10 where a is a constant and b , c , and d are coefficients, while u represents the impact of other
11 possible factors and assumed to be a random error with a zero mean and constant variance.

12 In equations (1) and (2), Q^* denotes the household's choice but at any point in time
13 achieving it may not be feasible. If the price or some other relevant variable changes then it
14 may take some time for a household to fully adjust. Some actions can be undertaken fairly
15 quickly, e.g., turning down thermostats when the price increases. However, other reactions
16 take time because capital investment, e.g., switching from furnace to electric heat or
17 purchasing electricity-efficient appliances, is costly and may not be undertaken until the price
18 change is perceived as permanent. Such circumstances can be described by a partial
19 adjustment process as below:

$$20 \quad (3) \quad Q_t - Q_{t-1} = \lambda(Q_t^* - Q_{t-1}).$$

21 where the subscripts denote time periods. Equation (3) says that the actual change in
22 consumption over one period, $Q_t - Q_{t-1}$, is proportional to any gap between the desired level of
23 consumption and last period's actual consumption, $(Q_t^* - Q_{t-1})$. The Greek letter λ denotes the
24 adjustment parameter and would take the value of zero if complete adjustment takes place
25 instantly. When that is not possible the adjustment parameter must be a positive number. It is
26 assumed to be a fraction; otherwise the model would be unstable in the sense that
27 consumption would never converge to the household's desired level. By substituting the
28 expression for Q^* from (2) into (3), and simplifying yield the following:

$$29 \quad (4) \quad Q_t = \alpha + \beta P_t + \gamma PF_t + \delta I_t + \varepsilon Q_{t-1} + v_t$$

1 where $\alpha = a/\lambda$, $\beta = b/\lambda$, $\gamma = c/\lambda$, $\delta = \lambda d$, $\varepsilon = (1 - \lambda)$, and $v = \lambda u$.

2 Equation (4) is the basis for the estimation undertaken in the next section. A double-
3 logarithm specification is used; i.e., the variables in equation (4) are expressed in terms of their
4 logarithmic values.

5

6 **Results**

7 Table 2 provides the results of the Ordinary Least Squares (OLS) estimation using the 1992-
8 2016 dataset on the functional form given in equations (4). The results are quite good. All the
9 right-hand-side variables are statistically significant; see the corresponding t values, all of which
10 are statistically significant. Additionally, the regression test statistics are encouraging; the
11 adjusted R^2 implies a good overall fit, with the regression accounting for 96 percent of the
12 variation in consumption, and Durbin's h statistic suggests that the null hypothesis of no
13 autocorrelation cannot be rejected.¹³ Crucially the coefficient on the lag of consumption is a
14 positive fraction, which means the model is stable. Perhaps most importantly, the signs of the
15 coefficients are consistent with basic theory: the coefficient on the price of electricity is
16 negative, the coefficient on the substitute fuel is positive and the coefficient on income is both
17 positive and fractional, which is consistent with electricity being a normal necessity.¹⁴

18

¹³ With time-series estimation, as this is, there is always a concern that a strong fit may be the result of spurious correlation. That means that the variables move along similar time trends but there is no causal relationship in play. This does not appear the case here because even though the variables are not stationary i.e., do have trends, the residuals from the regression appear to be stationary. Additionally, going beyond the statistical issues associated with spurious correlation, economic theory provides a sound theoretical foundation for consumption varying with the right-hand-side variables of equation (4) in a pattern consistent with the regression results.

¹⁴ When an increase in consumers' income causes an increase in consumption of a good or service, but by less than the percentage increase in income, then that good or service is classified as a normal necessity.

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Table A2

OLS Estimation Results

	Double-log Function
Dependent Variable	(Q)
Explanatory Variables	Coefficients (t values)
Constant	2.98 (3.27)
Price of Electricity	-0.15 (-2.93)
Price of Fuel	0.023 (2.33)
Disposable Income Per Capita	0.073 (3.39)
Lagged Consumption	0.64 (5.70)
Regression Test Statistics	
Adjusted R ²	0.96
Durbin's h statistic	Prob> chi ² = 0.61

Based on the results in Table A2, it is straightforward to determine the implied short-run and long-run price elasticities of demand for electricity. These are presented in Table A3 below.

Table A3

Estimates of Price Elasticities from the OLS Results

Short-run Elasticity	-0.15
Long-run Elasticity	-0.417

The short-run price elasticity corresponds directly to the coefficient on the price of electricity as given in Table A2. (Analogously, the coefficient on income is the short-run income elasticity and the coefficient on the price of heating fuel is the short-run cross elasticity for that substitute.) Obtaining the long-run elasticity involves the coefficient on lagged consumption. When full adjustment is achieved, that lagged consumption and current consumption coincide so bringing like terms together and simplifying yields a long-run elasticity of $-0.15/(1 - .64) = -0.417$ or approximately -0.42.

1 Following a widely used convention, the short-run and long-run elasticities may be
2 expressed in their absolute values of 0.15 and 0.42, respectively. The latter figure corresponds
3 to the partial adjustment model estimate given in Table 1.