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Exhibit M2
Attachment 1

Response to LEI's Reply Memo

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1. Introduction

London Economics International LLC ("LEI") completed a memo on December 22, 2016 that responds to the report, entitled *IRM Design for Ontario Power Generation*, which Pacific Economics Research LLC ("PEG") prepared for Ontario Energy Board staff and entered into evidence in EB-2016-0152. LEI's memo provides interesting commentary on the economics of hydroelectric power generation. This commentary is portrayed as supporting the methodology that LEI used in its productivity research and undermining the methodology PEG employed.

We believe that LEI's Reply Memo does not materially substantiate the price-cap index proposed by Ontario Power Generation ("OPG") or undermine the productivity research undertaken by PEG. In particular, we take exception to the following contentions.

- PEG's monetary method for measuring the capital quantity trend, which assumes geometric decay ("GD"), is inappropriate because it fails to reflect the pattern of service flows from capital assets as they age. The end result of this failing is to overstate productivity growth.
- The alternative one-hoss shay ("OHS") monetary approach, as well as the "physical" approach that LEI used, are more appropriate.

We also believe that an effective response to these and other detailed criticisms in the LEI memo must be made in writing if the Board is to have a balanced record for its decisions on OPG's incentive regulation mechanism ("IRM").

2. Capital Cost and Quantity Specification

The capital cost specification is of central importance in studies of hydroelectric power generation input price and productivity trends. The business is unusually capital intensive. Dams and other civil structures account for a large share of capital cost. These structures have long service lives and are almost never replaced. The value of these structures gradually depreciates. Depreciation has a major impact on the capital cost and total cost trends of hydroelectric generators today. The impact of depreciation is especially great on the cost trend of OPG because the value of the Company's hydroelectric assets was marked up substantially in 1999 and customers continue to compensate the Company for these older assets at the revalued levels.[1]

[1] The revaluation is discussed in Mark Newton Lowry and David Hovde, *IRM Design for Ontario Power Generation*, November 23, 2016, Exhibit M2, p. 60 and the OPG Response to SEC Interrogatory 97, Exhibit L, Tab 11.1, Schedule 15 SEC-097, filed 2016-10-26.

PEG uses a "monetary" approach to calculating the capital quantity trends of hydroelectric generators in its productivity study. Monetary approaches use the deflated value of plant additions (and sometimes retirements) reported by utilities to calculate capital costs and quantities. These approaches require an assumption concerning the decay in the quantity of plant after it is added. The capital price should be consistent with this assumption. PEG has posited a geometric decay pattern for capital assets. This involves a *constant* rate of decay.

2.1 Geometric Decay

LEI's Critique

In its Reply Memo, LEI criticizes a GD specification on the following grounds.

> PEG has employed an accounting standard of depreciation (geometric decay) that is fundamentally inconsistent with the actual, physical performance of hydroelectric generation assets. These assets do not experience physical depreciation in pre-set increments every year of their service life, as estimated by PEG. If they are properly maintained, these assets should operate consistent with their initial design and physical capability year after year.[2]

Further,

> For hydroelectric generation assets, a “one-hoss shay” profile is a close approximation of the physical depreciation of the capital deployed as it assumes that the asset can produce the same level of outputs over its entire service life.[3]

and

> The use of the geometric decay depreciation profile creates a clear bias: with this method, the TFP index will be using a capital quantity that is decreasing over time (barring new investments), which then leads to a higher TFP growth rate, all things being equal. In other words, the methodology used in the PEG Report has a tendency to overestimate TFP trends as a result of under-representing the capital input being employed.[4]

These are serious contentions about an approach to productivity measurement that the Board has based its X factor decisions on for years. A thorough response is needed.

[2] LEI, Reply Memo, December 22, 2016, p. 3.
[3] LEI, ibid, p. 5.
[4] LEI, ibid, p. 15.

1. *The goal of productivity research in X factor calibration is to find a just and reasonable means to adjust rates between rate cases.*

Productivity studies have many uses, and the best methodology for one use may not be best for another. One use of productivity research is to measure the trend in a utility's operating efficiency. Another is to calibrate the X factor in a rate-cap or revenue-cap index.

Price-cap indexes in most IRMs for energy utilities, including the IRM proposed by OPG, are intended to adjust utility rates between general rate cases that employ a cost of service ("COS") approach to capital cost measurement. The COS approach to capital cost measurement typically involves an historical valuation of plant and straight-line depreciation. Absent a rise in the target rate of return, the cost of each asset shrinks over time as depreciation reduces net plant value and the return on rate base. The rate of depreciation on an individual asset increases with its age. We have noted that depreciation has an especially large impact on the cost trends of hydroelectric generators today. The design of the price-cap index for OPG should therefore reflect depreciation by some means.

2. *One-hoss shay is not preferable to geometric decay as the foundation for a monetary approach to capital quantity measurement.*

OHS is an alternative monetary approach to measuring capital cost which posits no decay in the flow of services from a plant addition until it is retired. The capital quantity index is essentially the inflation-adjusted (i.e., real) *gross* plant value. We discussed the relative advantages of the GD and OHS capital cost specifications in Attachment M2-11.1-OPG-2A. We provide here an expanded discussion.

The OHS assumption is sometimes argued to better fit the service flows of *individual* assets. OHS has been used in a few productivity studies filed in proceedings to determine X factors. For example, it has twice been used in proceedings to establish X factors in rate and revenue-cap indexes for energy distributors in Alberta.

Other evidence suggests that the OHS specification is disadvantageous. Here are some notable problems.

OHS is More Difficult to Implement than GD Implementation of GD and OHS both require a deflation of gross plant *additions*. This is straightforward since the dates of the additions are known. Implementation of OHS requires, additionally, deflation of plant *retirements.* The vintages of these retirements are unknown. Productivity results using OHS are quite sensitive to the assumption concerning the vintage of the assets being retired. This assumption is usually based on an estimate of the average service life of the assets being retired.

Seemingly reasonable service life estimates can produce negative capital quantities under the OHS methodology. See, for example, the discussion in Attachment M2-11.1-OPG-2A of our attempt to implement an established form of OHS for hydroelectric power generation. In recent power distribution productivity research for the Consumers Coalition of Alberta, PEG found results using the OHS capital cost specification to be much more sensitive to the assumed average service life of assets than those using geometric decay.[5] Negative capital quantities were once again encountered.

Sensitivity to service life assumptions under OHS can be reduced by using plant addition and retirement data that are itemized with respect to asset type. Itemization is especially desirable in studies of hydroelectric generation productivity because roughly half of all assets by value have unusually long service lives, while the average lives of most other assets are much shorter. Unfortunately, itemizations of FERC Form 1 plant addition and retirement data are not publicly available before 1994, while our methodology uses addition and retirement data back to 1964.

It should also be noted that the mathematical coding for GD is particularly intuitive and easy to implement and review. The OHS specification involves a complicated capital service price that lacks intuition. The service price is needed to construct the capital cost weight in the multifactor input quantity index (since cost = price x quantity).

Used Asset Values are Inconsistent with an OHS Assumption Alternative patterns of *physical* asset decay involve different patterns of asset value *depreciation*. Trends in used asset prices can therefore shed light on asset decay patterns. Several statistical studies of trends in used asset prices have revealed that they are generally not consistent with the OHS assumption.[6] Instead, accelerated depreciation patterns like GD appear to be the norm for machinery and are also generally the case for buildings.[7] One expert has concluded that "the empirical evidence is that a geometric depreciation pattern is a better approximation to reality than a straight line pattern [i.e., the pattern more consistent with OHS decay], and is at least as good as any other pattern."[8] [bracketed remark from PEG]

Hydroelectric Assets Do Not Exhibit a Constant Flow of Services Throughout Their Lives A common sign of decline in the flow of services from an asset is a rise in the expenses to operate and maintain it. PEG and LEI both reported substantial downward trends in the productivity of hydroelectric operation and maintenance ("O&M") inputs in their direct evidence. PEG, with its longer sample period, found that O&M productivity growth has become substantially more negative since 1974. The average annual growth rate of O&M productivity was 0.10% from 1975 to 1995 and -1.30% from 1996 to 2014.[9]

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[5]See, for example, Mark Newton Lowry and David Hovde, *PEG Reply Evidence*, Exhibit 468, AUC Proceeding 20414, revised June 22, 2016, p. 16. This is filed as Attachment M2-11.1-OPG-2B as revised on January 16, 2017.
[6] For a survey of these studies see Barbara M. Fraumeni, "The Measurement of Depreciation in the U.S. National Income and Product Accounts*," Survey of Current Business*, July 1997, pp. 7-23. A recent Canadian study is John Baldwin, Huju Liu, and Marc Tanguay, "An Update on Depreciation Rates for the Canadian Productivity Accounts," *The Canadian Productivity Review*, Catalogue No. 15-206-X, January 2015.
[7] OECD, *Measuring Capital OECD Manual 2009*, Second Edition, p. 101.
[8] Fraumeni, op. cit., p. 17.
[9] Mark Newton Lowry and David Hovde, *IRM Design for Ontario Power Generation*, November 2016, p. 51.

In contrast, negative O&M productivity trends are not typical of electric power distributors in our experience.[10] LEI states on page 9 of its Reply Memo that "OPG's hydroelectric assets are maintained to produce at steady (or improving) levels of expected output (although O&M costs will be rising with time to ensure that productive capability remains at adequate levels)."

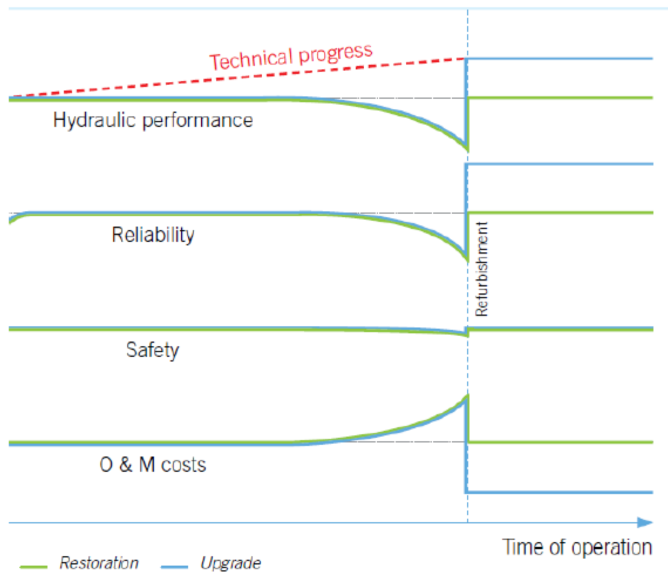
Another sign of a diminishing flow of services is a continual stream of "refurbishment" capital expenditures that do not boost volume or capacity. In this regard, OPG noted in its 2007 *Annual Report* that "Hydro's excellent availability over the years is the result of *ongoing investments and upgrades,* strong equipment performance, and shorter-than expected planned outage durations [italics added]."[11]

Figure 2 on page 7 of LEI's Reply Memo, replicated below, is apparently drawn from a Hydro Equipment Association publication. The figure shows that, after holding steady for many years, the hydraulic performance and reliability of hydroelectric generation assets decline while O&M costs rise. Refurbishments can then restore hydraulic performance and, with technological progress, improve it. This is not an OHS service flow pattern. Since the hydroelectric generation assets in the PEG study were far from new during the featured 1996-2014 sample period and O&M productivity was falling, it seems that the sampled utilities were typically operating in the period of declining capital service flows in LEI's figure. Holding volume and capacity constant required rising O&M expenses and "refurbishments".

A OHS Assumption Does Not Make Sense for Heterogeneous Groups of Assets In real-world productivity studies, capital quantity trends are rarely if ever calculated for individual assets. They are instead calculated from data on the value of plant additions (and, in the case of OHS, retirements) which encompass multiple assets of various kinds. Even if each individual asset had an OHS age/efficiency profile, the age/efficiency profile of the *aggregate* plant additions could be poorly approximated by OHS for several reasons. Different kinds of assets can have markedly different service lives. Assets of the same kind could end up having different service lives. Individual assets, in any event, frequently have components with different service lives. The alternator in a motor vehicle, for example, can need replacement before the body of the vehicle does. In this case, OHS doesn't fit the capital service flow of the composite asset. Alternative capital cost specifications such as GD can provide a better approximation of the service flow of a group of assets that individually have OHS patterns or which are composites of assets with OHS patterns.

[10] For example, a 0.76% average annual growth rate in O&M productivity is reported for a large sample of US power distributors from 1997 to 2014 in Mark Newton Lowry and David Hovde, *PEG Reply Evidence,* op. cit., p. 38.
[11] Ontario Hydro, *2007 Annual Report*, p. 9.

Figure 2. Illustration of increasing O&M costs to maintain a hydro plant's performance and reliability



Source: Hydro Equipment Association (HEA 2015). *Global Technology Roadmap*. 2015. Page 30.

Consistent with these remarks, the authors of a capital research manual for the Organization of Economic Cooperation and Development ("OECD") stated in the Executive Summary that

> In practice, cohorts of assets are considered for measurement, not single assets. Also, asset groups are never truly homogenous but combine similar types of assets. When dealing with cohorts, retirement distributions must be invoked because it is implausible that all capital goods of the same cohort retire at the same moment in time. Thus, it is not enough to reason in terms of a single asset but age efficiency and age-price profiles have to be combined with retirement patterns to measure productive and wealth stocks and depreciation for cohorts of asset classes. An important result from the literature, dealt with at some length in the Manual is that, for a cohort of assets, the combined age-efficiency and retirement profile or the combined age-price and retirement profile often resemble a geometric pattern, i.e. a decline at a constant rate. While this may appear to be a technical point, it has major practical advantages for capital measurement. *The Manual therefore recommends the use of geometric patterns for depreciation* because they tend to be empirically supported, conceptually correct and easy to implement.[12] [italics in original]

The OHS Approach is Rarely Used These disadvantages of the OHS specification help to explain why alternative specifications are more the rule than the exception in capital quantity research. For

[12] OECD, op. cit., p. 12.

example, GD is used to calculate capital quantities in the National Income and Product Accounts of the US and Canada. GD has also been used in numerous productivity studies intended for X factor calibration in the energy and telecommunications industries, including many studies prepared for utilities and entered into testimony. Statistics Canada uses GD in its multifactor productivity studies for sectors of the economy.[13] The U.S. Bureau of Labor Statistics, the Australian Bureau of Statistics, and Statistics New Zealand assume hyperbolic decay, not OHS, in their sectoral MFP studies.

3. *Depreciation can affect capital quantity trends even if the stream of capital services is constant.*

Depreciation can affect capital quantity trends even under constant capital service flows. To understand why, recall that increasing age causes the values of assets to decline in real terms. The decline in value is due to the shortening of the remaining service life.

The annual capital cost of a utility can then be calculated as the sum of the annual costs of assets of each vintage. The cost of each vintage is the product of a capital quantity and a price that is a function of construction costs and the rate of return. The price is lower for assets of older vintages.

The growth rate in the aggregate cost of capital can be shown to be the sum of the growth rates of a capital price index and a capital quantity index

$$\text{growth } Cost^{Capital} = \text{growth } Prices^{Capital} + \text{growth } Quantities^{Capital}. \qquad [1]$$

The growth rates of the capital price and quantity indexes are cost-weighted averages of the prices and quantities, respectively, of each vintage. The trend in capital prices is largely beyond utility control. Anything that slows capital cost growth more than it slows capital price growth therefore slows capital *quantity* growth and affects productivity growth.

1% growth in the quantity of an older vintage of assets has a lower impact on the growth of the capital quantity index than 1% growth in the same quantity of a newer vintage, since its lower capital price reduces its (cost share) weight. Growth in the average age of assets will thus tend to slow capital quantity growth and affect productivity growth. Under COS regulation, the cost impact of increasing age is magnified because assets are valued in historical dollars.

Mathematical support for these contentions can be found in the Appendix to this note.

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[13] For evidence on this see John R. Baldwin, Wulong Gu, and Beiling Yan (2007), "User Guide to Statistics Canada's Annual Multifactor Productivity Program," *Canadian Productivity Review*, Catalogue no. 15-206-XIE – No. 14., p. 41 and Statistics Canada, *The Statistics Canada Productivity Program: Concepts and Methods*, Catalogue no. 15-204, January 2001.

Consideration of analogous situations can help to elucidate this point. For example, a utility can slow labor quantity growth and bolster productivity growth if it can find a way to maintain output while replacing kinds of labor that have high wage rates with kinds of labor that have lower wage rates. Consider also that a household can cut its cost of capital by continuing to drive the family car for a few more years instead of buying a new one. The resale value of the car falls each year due to depreciation. The household has no control over trends in used car prices or the rate of return on alternative investments. Cost growth is instead slowed by (implicitly) reducing the *quantity* of cars that the household owns by choosing an older, less valuable car each year. Money freed up by not buying a newer car can be invested in the stock market or real estate.

Common OHS treatments, including the one undertaken by PEG at the request of OPG in Exhibit M2-11.1-OPG-2, gloss over the issue of vintaging by valuing all capital services by a "user cost" of capital methodology in which the capital service price is a function of prices of new assets. The derivation of this formula is on pages 7-9 of our Attachment M2-11.1-OPG-2A. This treatment is tantamount to treating capital services from all assets as purchases from a market in which prices of services do not depend on the age of assets. Capital service markets in which asset age doesn't matter greatly do exist for some assets (e.g., aircraft leases), but the cost and efficiency of firms that supply these markets depends very much on the vintages of their assets. OPG is chiefly a manager of assets rather than a renter of capital services.

To illustrate the importance of depreciation on appropriate X factors, we computed a possible X factor for OPG that is consistent with its hydroelectric revenue trend since 2006. X is calculated to be consistent with a selected inflation measure and the Company's revenue trend, which reflects cost of service accounting**.** Results are presented in Table 1.

Using LEI data, the 2007-2014 trends in the gross domestic product implicit price index for final domestic demand [GDP-IPI (FDD)] and the hydroelectric revenue and volume of OPG were +1.86%, -0.91%, and -1.43% respectively. The price growth of +1.86% given by the inflation index would by itself have provided price *increases* during a period when revenue/MWh averaged only 0.52% annual growth. The X-Factor that would have reconciled these trends is +1.34. A calculation using only the 2007-2013 results in an implicit X factor of +3.25%. This exercise suggests that a price-cap index with a positive X factor would have produced as much revenue as OPG actually received in the recent past.

4. *Conclusions*

In summary, there are many disadvantages to the use of the OHS specification in multifactor productivity research. The OHS approach seems especially *disadvantageous* in productivity studies of US electric utilities managing mature hydroelectric assets, not especially *advantageous*. That is because the requisite plant value data used in the calculations are insufficiently itemized; depreciation has an especially important impact on hydroelectric generation cost trends today, and hydroelectric generation

Table 1

X Factor Implicit in OPG's Revenue and Volume Trends[1]

	Generation Capacity[2] (MW)	Generation Volume[2] (MWh)	Revenue[2]	Revenue per MWh Level [A]	Revenue per MWh Growth Rate	GDP IPI FDD[3] Level [B]	GDP IPI FDD[3] Growth Rate	Implicit X Factor [B] - [A]
2002	6,899	33,977,759	2,126,290	0.063		90.2		
2003	6,926	33,202,786	2,068,079	0.062	-0.5%	91.7	1.6%	2.1%
2004	6,958	35,351,273	1,851,547	0.052	-17.3%	93.4	1.8%	19.2%
2005	6,924	33,487,118	1,837,930	0.055	4.7%	95.4	2.1%	-2.6%
2006	6,971	34,329,431	1,408,920	0.041	-29.1%	97.7	2.4%	31.4%
2007	6,971	32,986,718	1,378,521	0.042	1.8%	100.0	2.3%	0.5%
2008	6,999	37,423,326	1,615,589	0.043	3.2%	102.5	2.5%	-0.8%
2009	6,905	36,302,957	1,335,251	0.037	-16.0%	103.7	1.2%	17.2%
2010	6,906	30,568,258	1,125,926	0.037	0.1%	104.8	1.1%	0.9%
2011	6,422	30,359,921	1,099,541	0.036	-1.7%	107.3	2.4%	4.0%
2012	6,422	28,458,915	941,858	0.033	-9.0%	109.1	1.7%	10.7%
2013	6,433	30,347,392	1,127,001	0.037	11.5%	111.0	1.7%	-9.8%
2014	6,433	30,625,600	1,310,091	0.043	14.1%	113.4	2.1%	-12.0%
Average Annual Growth Rates								
2007-2014	**-1.00%**	**-1.43%**	**-0.91%**		**0.52%**		**1.86%**	**1.34%**
2007-2013	**-1.15%**	**-1.76%**	**-3.19%**		**-1.43%**		**1.82%**	**3.25%**

[1] Growth rates are calculated logarithmically.

[2] From LEI working papers "TFP_dataset" worksheet

[3] Source: LEI working papers "Can O&M price indexes" worksheet

assets of OPG and US power producers do not in any event seem to have conformed to an OHS service flow pattern in recent years.

The GD approach is preferable based on the data and other information available at this time. Most of these arguments also apply to power distribution. This helps to explain why PEG frequently uses the GD approach in its studies of power distribution productivity.

2.2 Physical Asset Approach

LEI Contention

LEI states on pages 13-14 of its Reply Memo that

> Ultimately, the core issue is which method provides the best overall approximation to the actual quantity of capital input used each year and allows for the most realistic measurement of productivity, given the characteristics of the assets and industry in

question. For the hydroelectric generation industry, where capital can be suitably measured using capacity ratings (in MW) and the physical decay in the capital assets over time is limited, the physical method is superior to the monetary approach. And indeed, academic studies typically show that practitioners favor this approach.

PEG Response

LEI's Reply Memo does not make a strong case for its use of generation capacity as the capital quantity index. This approach is problematic for several reasons.

- Efforts by utilities to reduce the capital cost of capacity are ignored. For example, under the OHS methodology, when an asset is retired it can be replaced with an asset that achieves the same level of capacity at lower cost.[14] A generator could also extend the service life of its assets. Both kinds of performance gains are ignored under LEI's approach --- a violation of common sense. There is thus an upward bias to the capital quantity trend using LEI's physical method that imparts a *downward bias* to the estimated MFP trend.
- Empirical research supports our viewpoint. PEG recalculated the capital quantity trends of OPG and our sampled US power distributors using an established OHS methodology. The resultant trends in the capital quantity indexes were materially *slower* than the trends in generation capacity. For example, it can be seen in Table 3A of Attachment M2-11.1-OPG-2A that the OHS capital quantity index for PEG's larger sample averaged a 0.19% average annual *decline* during the featured 1996-2014 sample period whereas generation capacity averaged 0.22% annual *growth*. Table 6A shows that, from 2003 to 2013 (before the NTP plant addition), the OHS capital quantity index for OPG averaged a 0.45% average annual *decline* whereas generation capacity averaged 0.07% annual *growth*.
- A monetary approach provides a ready means of aggregating multiple kinds of assets. LEI concedes this advantage of the monetary approach on page 13 of its Reply Memo when it states that "Conceptually, the monetary method can include capital equipment of all kinds, which may be important if a business uses many different assets that cannot be unified easily by using non-financial measures."
- In an application to power generation, a monetary approach frees up the MW of generation capacity to be used as an output variable. LEI concedes this advantage of the monetary approach as well, stating on page 13 of its Reply Memo that "the usage of MWs on the input side of the TFP equation precludes using capacity sales (also measured in MWs) on the output side of the TFP equation."

[14] LEI states on p. 17 of its Reply Memo, for example, that "The referenced statements relate to sustaining expenditures - transformers, generators, headgates, controls, etc. replaced at end-of-life to sustain the productive capability of the assets, not to upgrade the productive capability. Some new equipment is more efficient, but this is not significant in relation to productive capability."

- The OEB has rejected a physical asset approach in an application to power distribution.[15]

The monetary approach to capital cost calculation *is* complicated and requires many years of historical data on plant additions. However, the requisite data are available for US hydroelectric power generators. PEG has gathered plant addition data for hydroelectric power generators from 1964 to 2014.

These advantages of monetary approaches to capital cost measurement help to explain why they have been the norm to date in productivity studies used to calibrate the X factors of North American IRMs. For example, X factors for power distributors in Alberta, British Columbia, and Ontario are all based on productivity research that used monetary approaches to capital quantity measurement. Monetary approaches are also the norm in studies by government agencies of macroeconomic capital quantity trends and sectoral productivity trends. Generation capacity is typically used as a capital quantity variable only in studies where the requisite plant addition data are not available for all sampled companies.

2.3 GD Parameters

LEI Contentions

LEI states on page 15 of its Reply Memo that

> PEG has made many assumptions in conducting its monetary approach that appear to be arbitrary and not fact-based. LEI is particularly concerned that PEG's depreciation rate calculation may be biasing the results. It appears that they relied on U.S. Bureau of Economic Analysis ("BEA") parameters and methodology, and specific assumptions for different classes of assets that are not precisely related to actual hydroelectric assets. Moreover, PEG applied OPG-specific data on relative share of civil structures and electrical and mechanical components in determining the depreciation rates applied to all other peers in the industry.

PEG Response

Declining balance parameters are used in the calculation of the geometric decay depreciation rate. The BEA parameters used were 0.948 for structures and 1.65 for equipment.[16] The BEA uses the former value for electric light and power structures and the latter value for electrical transmission,

[15] OEB *Supplemental Report of the Board on 3rd Generation Incentive Regulation for Ontario's Electricity Distributors*, EB-2007-0673, September 17, 2008, pp. 11-12.
[16] M2-11.1-OPG Attachment PEG WP-2_2016-1214, Tab labeled Depreciation Rate. These were derived from Fraumeni, op. cit., p. 18.

distribution, and industrial apparatus. We consider both to be reasonable estimates of hypothetical values obtained from a study that only considered hydroelectric assets.

The data in Table 2 below on the cost shares of hydroelectric civil structures should allay concerns that the cost shares we assume are inappropriate. These data support the idea that the distribution of structure vs. equipment is very similar and stable over time.

3. Other Issues

We conclude this memo with brief responses to some of the other contentions LEI made in its Reply Memo.

3.1 Slow Productivity Growth

LEI Contention

LEI advances various arguments for why hydroelectric productivity growth should be unusually slow. These include the following.

- It is difficult for hydroelectric generators to boost volume.
- Extremely long replacement cycles limit technological change in civil structures.
- LEI states that "Machines deployed today have been perfected over more than 150 years. Many technical improvements have been harvested over the decades."[17]

PEG Response

- PEG has not found the MFP growth of hydroelectric power generators to be remarkably rapid. Accordingly, some limitations on productivity growth are to be expected.
- LEI's Figure 2 suggests that technological change can have a substantial impact on "hydraulic performance." Gains are especially likely to occur when assets are "refurbished". This is largely ignored in LEI's physical approach to capital quantity measurement.
- Figure 4 on page 10 of the Reply Memo does not indicate that hydraulic performance has stopped growing.
- Technological change can extend the service lives of assets, and we have shown that this slows capital quantity growth.
- Generators can boost the ability to serve loads in peak demand hours.
- Production technology at any point in time reflects the cumulation of past technological advances.

[17] LEI, op. cit., p. 10.

Table 2

Distribution of Hydro Plant by Plant Type, Annual Averages

	Structures	Dams, Reservoir, Waterway	Land	Generators	Miscellaneous	Road, Railroads	Accessory Equipment
1964	10.5%	51.8%	14.6%	18.3%	1.1%	0.5%	3.2%
1996	16.3%	46.2%	6.4%	22.5%	2.1%	1.3%	5.2%
1997	14.4%	47.1%	6.2%	23.2%	2.2%	1.3%	5.5%
1998	14.1%	47.1%	6.2%	23.0%	2.0%	1.5%	6.0%
1999	14.3%	46.2%	6.0%	24.0%	2.2%	1.3%	6.0%
2000	14.2%	45.9%	5.9%	24.3%	2.2%	1.4%	6.1%
2001	14.1%	45.5%	5.8%	24.8%	2.2%	1.3%	6.2%
2002	13.9%	45.1%	5.7%	25.4%	2.2%	1.4%	6.3%
2003	13.9%	45.0%	5.6%	25.4%	2.1%	1.4%	6.5%
2004	13.9%	44.7%	5.5%	25.6%	2.2%	1.3%	6.7%
2005	13.0%	47.1%	5.0%	24.7%	2.1%	1.3%	6.6%
2006	12.9%	47.1%	5.1%	24.6%	2.1%	1.3%	6.7%
2007	13.1%	46.7%	5.0%	24.7%	2.2%	1.3%	6.8%
2008	13.1%	46.4%	4.9%	25.2%	2.0%	1.3%	6.8%
2009	13.2%	45.8%	4.8%	25.8%	2.1%	1.3%	6.9%
2010	14.9%	45.6%	4.6%	24.5%	2.1%	1.3%	6.8%
2011	14.2%	45.6%	4.6%	25.0%	2.1%	1.3%	7.0%
2012	14.1%	45.7%	4.5%	25.1%	2.2%	1.2%	7.1%
2013	14.5%	44.8%	4.4%	25.5%	2.2%	1.3%	7.2%
2014	14.4%	44.1%	4.2%	26.1%	2.2%	1.3%	7.4%
Average:	**14.0%**	**45.9%**	**5.3%**	**24.7%**	**2.1%**	**1.3%**	**6.5%**
Classification	**Structure**	**Structure**	**Equipment**	**Equipment**	**Equipment**	**Equipment**	**Equipment**

Total	**U.S.**	**OPG**
Structure	**59.9%**	**60.5%**
Equipment	**40.1%**	**39.5%**

LEI Contention

The output of hydroelectric generation is multidimensional. Many generation productivity studies use volume as an output variable.

PEG Response

- PEG agrees that the output of hydroelectric generators is multidimensional. However, adding additional output variables greatly complicates analysis and may in the end do little to improve accuracy or aid in the establishment of an appropriate X factor.
- PEG does not propose to ignore the impact of volumes on MFP growth. It has instead proposed a "two-step" approach that considers any trend in the volume/capacity ratio that OPG expects. This permits the X factor to reflect Ontario hydrologic trends or efforts to boost volumes such as the Niagara Tunnel Project. However, OPG has not indicated that it expects such a trend.
- Unidimensional output indexes are widely used in X factor calibration exercises even though it is generally recognized that there are multiple scale dimensions to most utility services.
- LEI's X factor recommendation is also based on a unidimensional output index.
- Generation productivity studies that are not based entirely on US (and Ontario) data cannot use capacity as an output variable because they are using it as a capital quantity variable.

3.3 Sampled Companies

LEI Contention

The additional companies PEG added to the sample did not affect the industry trend very much.

PEG Response

PEG's role in this proceeding is to provide the Board with a more complete set of information to design an IRM. One of the tasks we were assigned was to consider a broader sample.

3.4 Including OPG in the Sample

LEI Contentions

LEI has made the following contentions.

Removing OPG from the peer group in LEI's analysis would not change the average TFP growth rate results materially: it only decreases the industry average TFP growth rate from -1.01% to a slightly more negative value of -1.11%.[19]

LEI continues to believe that the regulated company should be part of the industry that is being examined for purposes of setting an X factor for that company unless it can be shown that its productivity trends are truly outside the norm.[20]

PEG Response

- A ten basis point impact on the MFP trend is material.
- OPG's productivity trend should be calculated in this proceeding. However, due to its unusually large size, its inclusion in the productivity peer group would weaken OPG's performance incentives if done repeatedly.

3.5 Sample Period

LEI Contention

PEG has not justified its sample period.

PEG Response

A sample period should strike a balance between smoothing productivity fluctuations and reflecting current business conditions. LEI's 2003-2014 sample period is unusually short, especially considering its use of a volumetric output variable. The number of utilities in the sample is unusually small, and results are size-weighted. This makes results more sensitive to fluctuations in the productivity of individual utilities. It is by no means clear that a more recent sample period reflects a more appropriate system age for a study. For example, some utilities modernized their systems between 1996 and 2003. Meanwhile, the Niagara Tunnel Project reduced the average age of OPG's hydroelectric assets considerably in the last part of the period.

[19] LEI, op. cit., p. 21.
[20] LEI, op. cit., p. 21.

Appendix

Depreciation Can Affect Capital Quantity Trends Even With Constant Service Flows

This Appendix shows how depreciation reflects the capital quantity trend of utilities even if individual assets yield constant streams of service during their service lives. We focus here on results under cost of service accounting.

Cost Of Service Accounting

Ignoring taxes to simplify the analysis, the cost of capital in each period *t* ("CK_t") is the sum of depreciation expenses ("CKD_t") and the return on net plant value ("CKR_t"). Suppose also for simplicity that the service lives of all assets are added at the beginning of each year and have a service life of *N* years. Both kinds of capital costs can then be viewed as the sum of the cost of the assets of each vintage *s,* where *s* can assume any value in the range [0, 1, . . .N-1]. Then

$$CK_t = CKD_t + CKR_t \quad [2a]$$

$$= \sum_{s=0}^{N-1}(CKD_{t-s} + CKR_{t-s}). \quad [2b]$$

Here CKD_{t-s} and CKR_{t-s} are the depreciation and return on net plant value of assets of vintage *s*.

Assume now that, as in cost of service regulation, assets are subject to straight line depreciation and valued in historic dollars. The value of an asset acquired in year *t-s* is denoted VKA_{t-s}, while the nominal rate of return on capital is denoted r_t. Then

$$CK_t = \sum_{s=0}^{N-1}\frac{1}{N} \bullet VKA_{t-s} + \mathrm{r} \bullet \sum_{s=0}^{N-1}(VKA_{t-s} - s \bullet \frac{1}{N} \bullet VKA_{t-s}). \quad [3]$$

The value of a gross plant addition in each year *t-s* is the product of the *quantity* of the addition ("XKA_{t-s}") and the unit cost (or asset price) WKA_{t-s}. Thus

$$CK_t = \sum_{s=0}^{N-1}\frac{1}{N} \bullet WKA_{t-s} \bullet XKA_{t-s} + r_t \bullet \sum_{s=0}^{N-1}\left(WKA_{t-s} \bullet XKA_{t-s} - s \bullet \frac{1}{N} \bullet WKA_{t-s} \bullet XKA_{t-s}\right)$$

$$= \sum_{s=0}^{N-1}\left[\frac{1}{N} \bullet WKA_{t-s} + r_t \bullet \left(WKA_{t-s} - s \bullet \frac{1}{N} \bullet WKA_{t-s}\right)\right] \bullet XKA_{t-s} \quad [4a]$$

$$= \sum_{s=0}^{N-1}\left[\frac{1}{N} + r_t \bullet \left(1 - s \bullet \frac{1}{N}\right)\right] \bullet WKA_{t-s} \bullet XKA_{t-s} \quad [4b]$$

$$= \sum_{s=0}^{N-1} WK_{t-s} \bullet XKA_{t-s} \quad [4c]$$

The cost of the capital of each vintage *t-s* can be seen to be the product of the quantity of the gross plant addition in that year and a capital price ("WK_{t-s}") that is a function of WKA_{t-s}, the age of the asset, and the rate of return on capital. Under COS accounting, it follows that the capital price of assets of a certain vintage is lower the older is the vintage for two reasons: more depreciation and a lower initial acquisition price.

It can be shown using calculus that, for any cost that can be expressed as the sum of itemized costs, the growth rate of the cost is the sum of the growth rates of price and quantity indexes.[21] The weight for each itemized price and quantity in each of these indexes is its share of the corresponding cost in the aggregate cost. It follows from this result and the mathematics presented above that the growth rate of *capital* cost is the sum of the growth rates of a capital quantity index ("*XK*") and a capital price index ("*WK*") that are weighted averages of the growth rates of the capital prices and quantities (respectively) of each vintage.

growth CK = growth XK + growth WK. [5]

Please note the following concerning the capital *price* index.

- Growth in *WK* is driven chiefly by trends in the rate of return on capital and in the values of *WKA* that are applicable to the various asset vintages. For example, in 2016 the value of *WKA* that is applicable to the ten-year-old vintage is WKA_{2006}. In 2017 the applicable value is WKA_{2007}.
- A utility controls WK only indirectly through its effect on the cost share weights. That's true of any input price index.

Please note the following concerning the capital *quantity* index.

- Anything that slows capital cost growth more than it slows capital price growth slows capital *quantity* growth.
- 1% growth in the quantity of an older asset accelerates capital quantity index growth less than 1% growth in the same quantity of a newer asset because the older asset is less costly.
- Capital quantity growth is therefore slowed by depreciation (which boosts growth in the quantities of older assets relative to growth in the quantities of younger assets), although this force can be offset by new plant additions.

Thus, despite the assumption of constant flows of services from assets of each vintage during their service lives, an aging system tends to have slower capital quantity growth and bolsters productivity growth if output is maintained.

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[21] Here is a proof of this claim. The growth rate of aggregate capital cost can be written

$$growth\ CK = \frac{d \ln CK}{dT} = \frac{1}{CK} \bullet \frac{dCK}{dT} = \frac{1}{CK} \bullet \left(\sum_s WKA_s \bullet \frac{dXKA_s}{dT} + XK_s \bullet \frac{dWKS_s}{dT}\right) \quad [6a]$$

$$= \sum_s \frac{WKS_s \bullet XKA_s}{CK} \bullet \left(\frac{1}{XKA_s} \bullet \frac{dXKA_s}{dT}\right) + \frac{WKS_s \bullet XKA_s}{CK} \bullet \left(\frac{1}{WKS_s} \bullet \frac{dWKS_s}{dT}\right) = \sum_s sc_s \bullet \Delta XKA_s + \sum_s sc_s \bullet \Delta WK_s \quad [6b]$$

$$= growth\ XK + growth\ WK \quad [6c]$$

where sc_s is the share of itemized cost *s* in aggregate cost.