Ontario Energy Board

EB-2010-0379

Report of the Board

Rate Setting Parameters and Benchmarking under the Renewed Regulatory Framework for Ontario's Electricity Distributors

Issued on November 21, 2013 and as corrected on December 4, 2013

The Board first described the components of an X-factor in its 3rd Generation IR report as follows:

> The productivity component of the X-factor is intended to be the external benchmark which all distributors are expected to achieve. It should be derived from objective, data-based analysis that is transparent and replicable. Productivity factors are typically measured using estimates of the long-run trend in TFP growth for the regulated industry.
>
> The stretch factor component of the X-factor is intended to reflect the incremental [efficiency] gains that distributors are expected to achieve under IR and is a common feature of IR plans. These expected productivity gains can vary by distributor and depend on the efficiency of a given distributor at the outset of the IR plan. Stretch factors are generally lower for distributors that are relatively more efficient.[12]

The RRF Report stated that X-factors for individual distributors under this next version of IR ("Price Cap IR") will continue to consist of an empirically derived industry productivity trend (productivity factor) and a stretch factor.

PEG made specific recommendations in its May 2013 Updated PEG Report for the productivity and stretch factor components of the X-factor. These recommendations provided the basis for stakeholder consultations. PEG updated its analyses to include 2012 electricity distributor data and presented the results in a report released on September 6, 2013, entitled "Empirical Research in Support of Incentive Rate setting: 2012 Update" (the "2012 Update PEG Report"). PEG's final recommendations to the Board are set out in its report released on November 21, 2013, entitled "Empirical Research in Support of Incentive Rate Setting in Ontario" (the "Final PEG Report")[13].

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[12] Ontario Energy Board. EB-2007-0673 Report of the Board on 3rd Generation Incentive Regulation for Ontario's Electricity Distributors. July 14, 2008. p.12.
[13] Pacific Economics Group Research, LLC. Empirical Research in Support Of Incentive Rate Setting in Ontario. November, 2013. (http://www.ontarioenergyboard.ca/OEB/_Documents/EB-2010-0379/EB-2010-0379_Final_PEG_Report_20131111.pdf)

Filed: 2016-05-27
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Exhibit A1-3-2
Attachment 1
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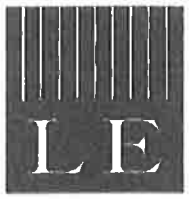
EMPIRICAL ANALYSIS OF TOTAL FACTOR PRODUCTIVITY TRENDS IN THE NORTH AMERICAN HYDROELECTRIC GENERATION INDUSTRY

Prepared for

Ontario Power Generation Inc.

By



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February 19, 2016

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6.2 Industry TFP results

6.2.1 Industry TFP results using the average growth method

The results for the industry TFP study over the 2002-2014 period using the average growth method suggest a TFP growth rate of -1.01%, as summarized in Figure 23.

Figure 23. Key TFP study results using the average growth method

Average index growth rates (2002-2014)		
Input Index	Output Index	TFP Index
0.38%	-0.64%	-1.01%

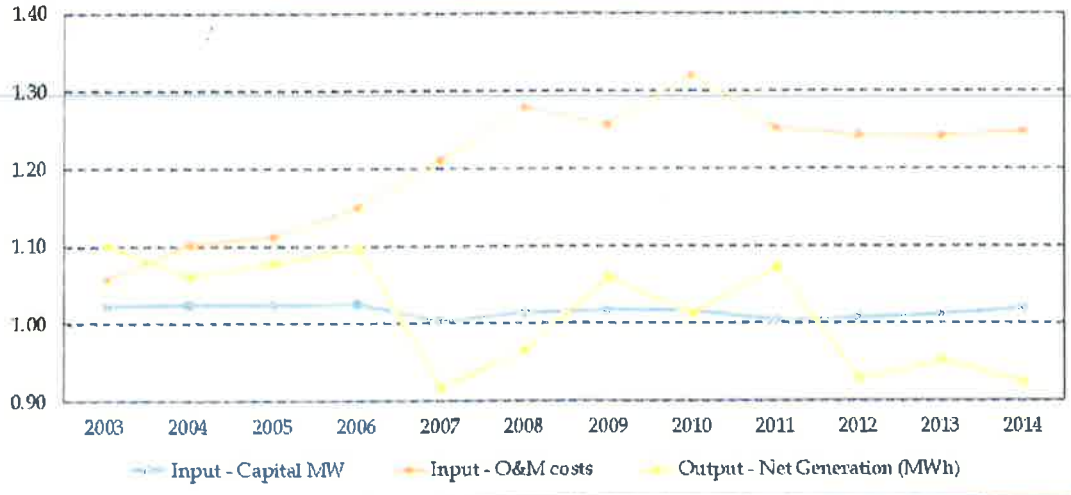

Figure 26, average growth rate for capital inputs measured in MW was 0.15% over the 2002-2014 period, with little year over year fluctuations. This result is to be expected for a mature hydroelectric industry as construction of new generation facilities is infrequent. O&M input growth was higher than capital input at an average rate of 1.85% over the study period, and year over year fluctuations were greater. LEI calculated capital's share of input for this peer set to be on average 80%, and O&M share of input to be 20% (see Section 4.2.2 for more background information on input shares); annual input weights are listed in Figure 24. With more weight assigned to capital, the total input index growth rate is estimated to be 0.38% using the average growth method, and year over year fluctuations are small, as seen in Figure 26.

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Figure 27. Input, output and TFP index growth rates using the average growth method

Year	Quantity Sub-Index Growth Rates		
	Input Index Growth	Output Index Growth	TFP Index Growth
2002-2003	2.69%	9.80%	7.11%
2003-2004	0.66%	-3.69%	-4.35%
2004-2005	0.07%	1.64%	1.58%
2005-2006	0.62%	1.79%	1.17%
2006-2007	-1.00%	-17.98%	-16.98%
2007-2008	1.78%	5.18%	3.40%
2008-2009	-0.21%	9.40%	9.61%
2009-2010	1.20%	-4.65%	-5.85%
2010-2011	-2.27%	5.69%	7.97%
2011-2012	0.04%	-14.38%	-14.42%
2012-2013	0.34%	2.55%	2.22%
2013-2014	0.61%	-3.00%	-3.60%
AVERAGE	**0.38%**	**-0.64%**	**-1.01%**

LEI believes that negative TFP trends can be "expected" for mature hydroelectric businesses, because of the fixed production capability, fixed capital stock and rising costs of maintenance through the life cycle of a hydroelectric resource. As discussed earlier in Section 3.1, common drivers of productivity include technological innovation and improved economies of scale. However, for a mature hydroelectric business, great leaps forward in technology are extremely rare and economies of scale are generally fixed as soon as the asset is built and put into operation (although occasionally, refurbishments and other capital programs can increase energy production due to advances in new equipment). In general, it should be expected that output levels would be stable over time;[69] capital inputs are constant (once a hydroelectric plant is put into service); and OM&A would likely be increasing over time (in order to maintain asset operational capability as the asset ages).

[69] Assuming constant water flow levels over the course of the study and given generator design is fixed once the asset is brought into service, unless there are refurbishments that increase output.

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EP Interrogatory #31

Issue Number: 11.1
Issue: Is OPG's approach to incentive rate-setting for establishing the regulated hydroelectric payment amounts appropriate?

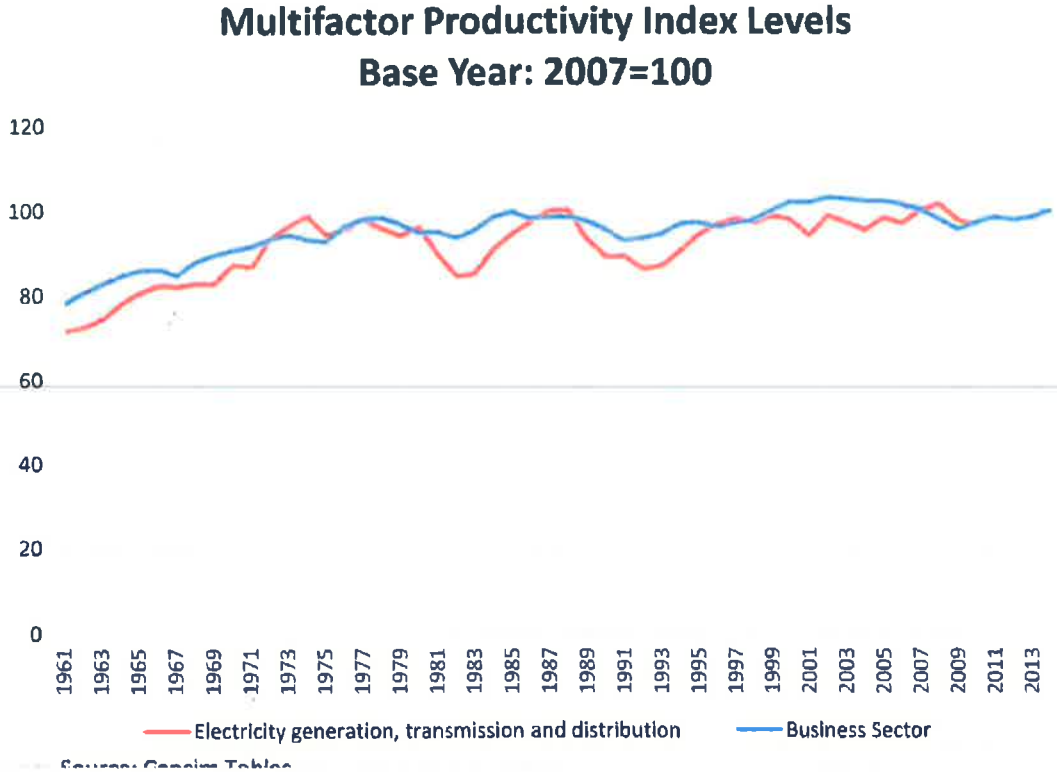
Interrogatory

Reference:
Application Ex A1-Tab 3-Sch 2 and Attachment 1

CANSIM Table 383-0021: Multifactor productivity…in the Canadian business sector

CANSIM Table 383-0032: Multifactor productivity…in Electric power generation, transmission and distribution

Statistics Canada maintains and updates the Canadian Productivity Accounts, and has multi-factor and other productivity data for years going back to 1961. Data in CANSIM Table 383-0021 indicate that levels of multi-factor productivity in the Canadian business sector fell in eight of the eleven years 2000-2010 inclusive. In the industry category "Electric power generation, transmission and distribution", data in CANSIM Table 383-0032 productivity levels fell in seven of those years. The following chart is based on the CANSIM tables referenced above.



Source: Cansim Tables

The LEI Updated Report used a study period of 2002-2014. According to Figure 27 of the Updated Report, total-factor productivity growth was negative in five of those years.

The CANSIM data tend to support LEI's conclusion of declining productivity growth in the study period used in its Updated Report. In the overlapping eight years, the CANSIM series has 5 negative growth years and the mean annual growth rate is -0.25%; the Updated Report (Figure 27) has 3 negative growth years and the mean annual growth rate is -0.54%.

In the Report of the Board in EB-2010-0379, the Board refers to the "long-run productivity of the sector" (at p.15).

1. Please confirm that the study period used in the Updated Report was selected, in part, because LEI could not obtain comparable data for earlier years.

2. Does OPG regard LEI's study period as providing evidence on the "long-term productivity growth rate" to which the Board has referred?

Witness Panel: Overview, Rate-setting Framework

3. Do the charted CANSIM data suggest that the long-term productivity growth rate for hydroelectric generation would be more accurately measured by examining a much longer time period if the relevant data were available?

4. Do the charted CANSIM data tend to support the conclusion that the long-term productivity growth rate for hydroelectric generation would be negative or zero if the relevant data were available?

5. Might the fact that levels of multi-factor productivity in the Canadian business sector fell in eight of the years 2000-2010 plausibly suggest that the negative growth rate for hydro reported by LEI had much more to do with factors and events external to OPG rather than those factors suggested by LEI?

6. Please confirm that for the 49 years from 1961-2010 inclusive, the mean productivity growth rate for the industry category "Electric power generation, transmission and distribution" was 0.668% per year with a standard deviation of 3.347%. Energy Probe will provide the charted data from CANSIM Table 383-0032 on annual productivity levels.

Response

The following response was provided by LEI, except for part 2, which was prepared by OPG.

1. Yes, while FERC Form 1 data is available going back to 1994, data for non-FERC jurisdictional entities, such as Seattle City & Light and Southeastern Power Administration, is not readily available going back for earlier years.

2. Yes, OPG believes that LEI's study and the period on which it was based provide evidence on the long-term productivity growth rate of the North American hydroelectric generation industry.

   In the context of studying the productivity of the electricity distribution industry, Pacific Economics Group observed dramatic changes in TFP results when 2012 data was added to their 2002 to 2011 data set.[1] PEG identified three unusual and one-time events that appeared to create the largest impact, and updated the analysis to exclude those events. In contrast, when two additional years of data were included in LEI's TFP study, the negative 1 percent TFP values did not change (Ex. A1-3-2, p. 16). The consistency of the TFP result supports the conclusion that the study period provides evidence of a long-term trend.

3. No. The CANSIM data from Table 383-0032 is for the broad electric utility industry and therefore includes productivity trends associated with other electric utility operations,

[1] Report of the Board: *Rate Setting Parameters and Benchmarking under the Renewed Regulatory Framework for Ontario's Electricity Distributors*, EB-2010-0379, Issued on November 21, 2013 and as corrected on December 4, 2013, p. 15.

such as transmission and distribution, as well as non-hydroelectric generation. As such this data is not specific to hydroelectric generation. It is worth noting that this data series has been terminated by Statistics Canada and no data is available subsequent to 2010.

4. Without analyzing the CANSIM data further, it is difficult to draw concrete conclusions with respect to correlation. That said, the data on multifactor productivity trends in the two data series are showing a negative growth trend as implied in the question over the 2002-2010 period. Indeed, the CANSIM data shows a negative average MFP trend even if we go back to the late 1990s.

5. LEI has not investigated the CANSIM data and drivers of the productivity trends presented in the data series that have been highlighted in this question. On the other hand, LEI has specifically calculated a total factor productivity growth trend for the hydroelectric generation industry using actual operating data from North American peers of OPG and OPG, itself. It is clear in LEI's Report that the negative TFP trend estimated for the hydroelectric industry is wholly based on drivers specific to inputs and outputs for the industry and not external factors as presupposed in the question

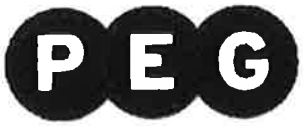
6. LEI confirms that taking the average of year over year productivity growth rates for the 1961-2010 period results in 0.668% with a standard deviation of 3.347%. As noted in Ex. L-11.1-6 EP-30, the data cited in this question is for the electric power generation, transmission and distribution industry, of which hydroelectric generation is only a small part.

PRODUCTIVITY AND BENCHMARKING RESEARCH IN SUPPORT OF INCENTIVE RATE SETTING IN ONTARIO:

FINAL REPORT TO THE ONTARIO ENERGY BOARD

November 2013

(Issued on November 21, 2013 and as corrected on December 19, 2013 and January 24, 2014)



Pacific Economics Group Research, LLC

Turning first to the output quantity results, it can be seen that overall output quantity grew at an annual rate of 1.30% per annum. Customers grew by an average of 1.55% annually. In contrast, kWh deliveries and system capacity demand grew more slowly, with each growing by 0.92% per annum. The fact that customers grew more rapidly than either deliveries or peak demand means that volumes per customer and peak demand per customer have declined, on average, over the sample period. Some of these declines clearly result from the severe recession that took place in 2008-09; for example, kWh deliveries fell by 1.3% and 4.3% in these respective years. However, some of the decline in volumes and demand per customer may be attributed to energy conservation policies that have been pursued in Ontario over the sample period.[32] Output declines appear to be especially pronounced after 2006.

In Table 10, it can be seen that OM&A inputs grew at an average rate of 1.70% over the sample period. In 2012, OM&A input quantity grew by 9.58%. This is nearly three times the 3.28% growth in OM&A input quantity in 2011 and is by far the most rapid annual change in OM&A input in any of the sample years. This increase is due to an 11.14% increase in OM&A expenses in 2012.

Table 11 shows that capital input quantity grew at an average rate of 1.56% between 2002 and 2012. Capital investment grew by 3.58% in 2012 as compared to 1.30% in 2011. The 2012 increase in capital input is more rapid than the trend in previous years.

Table 12 shows the change in overall input quantity. Overall inputs grew at an average rate of 1.63% between 2002 and 2012. The 5.99% increase in input quantity in 2012 is more than twice as large as the annual change in input quantity in any year in the 2002-2011 period.

---

[32] On May 31, 2004, the Minister of Energy granted approval to all electricity distributors in Ontario to apply to the Board for an increase in their 2005 rates by way of the third instalment of their incremental market adjusted revenue requirement ("MARR"). This approval was conditional upon a commitment to reinvest in CDM an equivalent of that amount. Consequently, in 2005 distributors brought forward, and the Board approved, $163 million in CDM funding for distributors, an amount related to the third tranche of their MARR. Subsequently, electricity distributors were permitted to apply for CDM funding as part of 2006 and 2007 rates. Beginning in 2008 CDM funding was available to distributors through the OPA. In 2010, in accordance with a directive from the Minister of Energy and Infrastructure, dated March 31, 2010, the Board was required to take certain steps to establish targets for the reduction of electricity consumption and peak provincial electricity demand to be met by certain licensed electricity distributors, as a condition of licence. Currently, to facilitate achievement of those targets, distributors may access funding from the OPA and through distribution rates.

PART 1

Please find below the annual productivity growth rate that LEI has calculated for each utility in the sample of LEI's industry TFP study. OPG is the only Canadian peer.

Chart 1 - TFP index Growth - Average growth method (%)

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	AVG
OPG	-3.2	5.9	-5.3	1.1	-4.2	11.1	-1.7	-16.7	6.6	-6.6	6.1	0.8	**-0.49**
AB Power	33.6	-27.0	0.4	-37.4	-82.8	50.2	97.0	-51.4	-12.0	-19.2	72.5	-40.9	**-1.41**
AP Power	50.7	-17.7	-15.2	-7.0	-5.2	-12.1	19.6	-6.4	-3.3	6.2	13.8	-33.3	**-0.82**
Ameren MI - Union	-8.8	30.4	2.7	-76.7	46.8	6.2	2.6	8.0	-6.1	-26.6	21.0	-23.7	**-2.02**
Avista	-14.8	6.5	-5.9	12.4	-11.3	3.9	-3.2	-6.9	24.3	-9.6	-14.2	15.1	**-0.30**
Duke	21.5	-26.7	8.8	-12.8	-6.6	4.7	-1.3	-2.9	-10.8	-6.3	26.5	-3.1	**-0.76**
GA Power	50.7	-35.7	8.0	-35.0	-18.2	-36.5	110.3	-22.2	-13.4	5.8	65.1	-38.1	**3.41**
ID Power	1.7	-2.9	2.8	39.4	-40.4	11.0	16.3	-10.0	40.6	-32.6	-34.5	9.4	**0.06**
PacifiCorp	5.5	-16.1	-3.5	36.5	-21.7	0.0	-7.0	8.3	21.4	-4.7	-32.8	20.4	**0.53**
PG&E	10.3	-7.4	14.5	17.8	-61.0	-0.3	9.6	16.1	13.3	-50.1	-2.3	-25.8	**-5.44**
Portland	-1.3	3.3	-9.4	23.2	-14.9	0.1	-1.1	6.2	7.7	-9.8	-14.9	-4.9	**-1.32**
SCE&G	28.9	-12.2	12.2	-26.5	8.0	-13.9	-3.7	0.8	-13.4	6.7	2.5	-28.4	**-3.26**
Seattle	-12.9	-1.1	-7.5	19.1	-4.2	-4.2	-6.9	-2.9	28.3	-9.7	-16.8	17.1	**-0.15**
SEPA	50.2	-10.8	12.2	-58.7	-0.9	-17.2	28.4	14.8	-13.9	-11.4	34.6	-5.7	**1.80**
SoCal Edison	14.2	-13.2	37.2	-2.5	-70.1	2.1	33.5	11.3	9.6	-48.7	-20.8	-24.3	**-5.98**
VA Electric	6.6	-14.3	-20.6	9.5	15.0	-40.5	30.3	19.8	-12.5	48.1	-38.9	-1.7	**0.08**

February 28, 2017

EB-2016-0152
ENERGY PROBE RESEARCH FOUNDATION
NOTE ON DATA AGGREGATION

Energy Probe Research Foundation ("Energy Probe") has reviewed the expert reports of London Economics International ("LEI")[1] and Pacific Economics Group ("PEG")[2], and their respective responses and revised responses to its interrogatories and those of other intervenors. Energy Probe seeks further clarification on the experts' calculation and reporting of their respective productivity growth rates and intends to question LEI and PEG at the upcoming hearing about, inter alia, the matters raised in this Note.

Energy Probe provides this Note to assist the Board's understanding of how LEI and PEG have obtained their estimates of the long-run productivity growth rate in hydro-electric generation. Energy Probe hopes that this Note will reduce the time devoted to questions on this material at the hearing.

1. Analysis of LEI Growth Rates

At Figure 27 of the LEI Report, LEI presents the percentage changes in its Output and Input Indexes for each year from 2003 to 2014 and the resulting yearly Total-Factor Productivity ("TFP") growth rate which is the difference between the two. Averaging over these twelve yearly changes, LEI reports that the average growth rate of TFP is -1.01% per year.[3]

Using the data as shown in Figure 27, Energy Probe confirms LEI's calculation of the -1.01% average TFP growth rate, but notes that it may be sensitive to the rounding-off of the various data that LEI has used in its calculation and reporting.

The LEI Report does not present the output, input and TFP growth rates for individual companies in LEI's sample. This is perhaps because, as it appears, LEI has adopted an index methodology and has constructed a TFP Index for each company in its sample. Its research problem was therefore to combine these indexes into an industry (or sample) index and compute the annual growth rates of that aggregate TFP index.

Energy Probe sought to understand how the -1.01% average TFP growth rate reported in Figure 27 relates to company-level data. Further to Undertaking JT3.24, OPG provided in hardcopy the annual productivity growth rates that LEI had calculated for each company in its sample of 16 companies for each year in the 12-year period 2003-2014 using its "average growth method".[4] Energy Probe thanks OPG and LEI for their time and effort in responding to its request.

Energy Probe manually entered this hardcopy company-level TFP growth rate data into an Excel spreadsheet, and reviewed and analyzed these data in order to confirm/disconfirm LEI's -1.01%

[1] EB-2106-0152. Exhibit A1-3-2, Attachment 1. Empirical Analysis of Total Factor Productivity Trends in the North American Hydroelectric Generation Industry, February 19, 2016. (the "LEI Report")
[2] EB-2016-0152. Exhibit M2. IRM Design for Ontario Power Generation, November 23, 2016. (the "PEG Report")
[3] See LEI Report at p.44.
[4] EB-2016-0152. JT3.24. Chart 1 – TFP Index Growth – Average growth method (%), at p. 2 of 4

growth rate in Figure 27. To this end, it has conducted various statistical calculations and analyses. In addition to the company growth rates provided by OPG, Table 1 below shows:

- an additional column labelled COMPANY AVG which shows the average of the yearly TFP growth rates for each company, and
- an additional row labelled YEARLY AVG which shows, by year, the average of company TFP growth rates

All of Energy Probe's calculations below used the LEI hardcopy data as received.[5]

It is instructive to examine the data in Table 1. The data can be averaged in three ways: over that entire sample, by company, and by year.

- In the first, there are 12x16=192 observations of the annual TFP growth rate. Energy Probe has calculated the average annual TFP growth rate thereof as approximately -1.01% with rounding. Energy Probe has also calculated the standard deviation of 26.40%.[6]
- In the second, there are 16 rows in Table 1, one for each company in LEI's sample, each row displaying 12 annual TFP growth rates for the years 2003-2014. Averaging over the 12 years for each company, the COMPANY AVG annual growth rates shown in Table 1 range from 3.40% (GPA) to -5.98% (SoCal). The mean of the 16 COMPANY AVG's provides information on the "average company" in LEI's sample; that mean is -1.01% with rounding and the standard deviation is 2.37%.
- In the third approach, Table 1 contains 12 columns of yearly data, each displaying the TFP growth rates of the 16 firms for each year in the period 2003-2014. Averaging over the 16 firms' growth rates in each year, the YEARLY AVG shown in the final row of Table 1 ranges from 20.17% (2009) to -16.98% (2007). The mean over the 12 YEARLY AVG's provides information on the "average year" in LEI's sample period; that mean is -1.01% with rounding and the standard deviation is 10.77%.

Energy Probe concludes that the -1.01% average annual TPF growth rate reported in the LEI Report at Figure 27 (presumably derived from LEI's aggregate TFP index) is confirmed by its own analysis of the company-level data.

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[5] Energy Probe notes that LEI has formatted and displayed the percentage TFP growth rates to two decimal places in Figure 27 of its Report. In Chart 1 of its response to Undertaking JT3.24, LEI formats and displays the percentage company growth rates to one decimal place and the company averages (AVG) to two decimal points. Since Excel stores numbers to 15 decimal places and calculations in Excel are performed on the numbers as stored, not as formatted, it could be that LEI's calculations are based on its data as stored, not as formatted and reported. Energy Probe worked with the hardcopy data as received. Accordingly, where LEI and Energy Probe have performed the same calculation, there may be differences in the result.

[6] Energy Probe used the Excel functions AVERAGE (.) and STDEV.S(.) for these calculations.

Energy Probe invites LEI to confirm/disconfirm Energy Probe's above calculations of the averages and standard deviations from the annual TFP growth rate data provided by OPG in response to Undertaking JT3.24.

TABLE 1

Annual Total Factor Productivity Growth Rates in LEI Sample
Source: LEI Response to Technical Conference Undertaking JT3.24

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	COMPANY AVG
OPG	-3.20%	5.90%	-5.30%	1.10%	-4.20%	11.10%	-1.70%	-16.70%	6.60%	-6.60%	6.10%	0.80%	-0.51%
AB Power	33.60%	-27.00%	0.40%	-37.40%	-82.80%	50.20%	97.00%	-51.40%	-12.00%	-19.20%	72.50%	-40.90%	-1.42%
AP Power	50.70%	-17.70%	-15.20%	-7.00%	-5.20%	-12.10%	19.60%	-6.40%	-3.30%	6.20%	13.80%	-33.30%	-0.83%
Ameren	-8.80%	30.40%	2.70%	-76.70%	46.80%	6.20%	2.60%	8.00%	-6.10%	-26.60%	21.00%	-23.70%	-2.02%
Avista	-14.80%	6.50%	-5.90%	12.40%	-11.30%	3.90%	-3.20%	-6.90%	24.30%	-9.60%	-14.20%	15.10%	-0.31%
Duke	21.50%	-26.70%	8.80%	-12.80%	-6.60%	4.70%	-1.30%	-2.90%	-10.80%	-6.30%	26.50%	-3.10%	-0.75%
GPA	50.70%	-35.70%	8.00%	-35.00%	-18.20%	-36.50%	110.30%	-22.20%	-13.40%	5.80%	65.10%	-38.10%	3.40%
ID	1.70%	-2.90%	2.80%	39.40%	-40.40%	11.00%	16.30%	-10.00%	40.60%	-32.60%	-34.50%	9.40%	0.07%
PacifiCorp	5.50%	-16.10%	-3.50%	36.50%	-21.70%	0.00%	-7.00%	8.30%	21.40%	-4.70%	-32.80%	20.40%	0.53%
PG&E	10.30%	-7.40%	14.50%	17.80%	-61.00%	-0.30%	9.60%	16.10%	13.30%	-50.10%	-2.30%	-25.80%	-5.44%
Portland	-1.30%	3.30%	-9.40%	23.20%	-14.90%	0.10%	-1.10%	6.20%	7.70%	-9.80%	-14.90%	-4.90%	-1.32%
SCE&G	28.90%	-12.20%	12.20%	-26.50%	8.00%	-13.90%	-3.70%	0.80%	-13.40%	6.70%	2.50%	-28.40%	-3.25%
Seattle	-12.90%	-1.10%	-7.50%	19.10%	-4.20%	-4.20%	-6.90%	-2.90%	28.30%	-9.70%	-16.80%	17.10%	-0.14%
SEPA	50.20%	-10.80%	12.20%	-58.70%	-0.90%	-17.20%	28.40%	14.80%	-13.90%	-11.40%	34.60%	-5.70%	1.80%
SoCal	14.20%	-13.20%	37.20%	-2.50%	-70.10%	2.10%	33.50%	11.30%	9.60%	-48.70%	-20.80%	-24.30%	-5.98%
VA	6.60%	-14.30%	-20.60%	9.50%	15.00%	-40.50%	30.30%	19.80%	-12.50%	48.10%	-38.90%	-1.70%	0.07%
YEARLY AVG	14.56%	-8.69%	1.96%	-6.10%	-16.98%	-2.21%	20.17%	-2.13%	4.15%	-10.53%	4.18%	-10.44%	**-1.01%**

2. Analysis of PEG Growth Rates

At page 49 of the PEG Report, PEG states that "over the featured period 1996-2014 sample period, the average annual growth rate in the MFP of all sampled US hydropower generators was about 0.29%." Table 3 of the PEG Report presents the yearly MFP growth rates that PEG has averaged.[7]

It appears that, similar to LEI, PEG adopted an index methodology and constructed an MFP Index for each company in its sample. Its research problem was therefore to combine these indexes into an industry (or sample) MFP Index and compute the annual growth rates of that aggregate index.

Energy Probe submitted interrogatories on the PEG Report on December 2, 2016.[8] In its interrogatory #2 i), Energy Probe requested that PEG provide its calculated productivity growth rate for each company in each year of its sample.[9]

In its response to Energy Probe, PEG referred to several working papers and Excel workbooks that it had provided in response to an interrogatory from Ontario Power Generation which, it noted, contained the information that Energy Probe had requested. PEG did not indicate which working paper or part thereof contained the information that responded to Energy Probe's interrogatory.[10]

From Energy Probe's review of PEG's working papers, it appeared that the information it sought was in Excel workbook M2-11.1-OPG-Attachment PEG-WP-1_20161214.XLSX. That Excel workbook contains a spreadsheet named "Indexes". The Indexes spreadsheet contains the heading "Productivity Calculations". Columns AC, AD and AE thereof contain productivity growth measures by company and by year for "O&M", "CAPITAL" and "MFP" respectively.

On January 8, 2017, Energy Probe requested that PEG clarify certain of its interrogatory responses. In particular, Energy Probe requested that PEG confirm that the Indexes spreadsheet was the document that PEG intended as its response to Energy Probe's Interrogatory #2 i). Energy Probe further requested that PEG confirm that the data in Column AE of that spreadsheet were the data PEG itself used to calculate its 0.29% MFP growth rate, and if not, then to indicate the data source for that number.

On February 8, 2017, PEG filed its revised responses.[11] It did not confirm that the Indexes spreadsheet was the document that PEG intended as its response to Energy Probe's interrogatory.

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[7] See PEG Report at p.49 and Tables 3 and 4.

[8] EB-2016-0152. Interrogatories of Energy Probe Research Foundation, December 2, 2016

[9] ibid, at p. 4:

> i) As LEI had done, please provide PEG's estimates of annual productivity growth for each company in its sample and for each year in its sample.

[10] EB-2016-0152. OEB Staff IRR, Exhibit M2/Tab 11.1, December 14, 2016. Schedule EP-002 at page 3 states:

> h) The working papers provided in response to M2-11.1-OPG-1 contain year-by-year productivity growth rates for the individual companies in the sample.

[11] EB-2016-0152, OEB Staff M2 11.1 Energy Probe 002 Revised IRR OPG 20170208

PEG did not indicate the location of the company-level data that it used to calculate its 0.29% average annual MFP growth rate.

a. PEG's Indexes Spreadsheet: Analysis of Column AE growth rates

Energy Probe has downloaded the MFP growth rate information for PEG's "larger sample" of twenty U.S. companies[12] from Column AE of the Indexes spreadsheet for the years 1996-2014 (its "featured sample period"[13]) to an Excel spreadsheet. The information is displayed in Table 2 in a format that facilitates comparisons with the LEI data provided by OPG.

For comparability with Table 1, Table 2 also shows:

- an additional column labelled COMPANY AVERAGE 1996-2014 which shows the average of the yearly MFP growth rates for each company, and
- an additional row labelled Yearly Average which shows, by year, the average of company MFP growth rates

Similar to the LEI data in Table 1, the data in Table 2 for PEG's featured sample period can be averaged in three ways: over that entire period, by company, and by year.[14]

- In the first, there are 20x19=380 observations of the annual productivity growth rate. Energy Probe has calculated the average annual MFP growth rate thereof as 0.088…%. Energy Probe has also calculated the standard deviation of 6.38%.

- In the second, there are 20 rows in Table 2, one for each company in the larger sample, each row displaying 19 annual growth rates for the years 1996-2014. Averaging over the 19 years for each company, the annual growth rates shown in the COMPANY AVERAGE 1996-2014 column range from 3.37% (Virginia Electric and Power) to -3.75% (Puget Sound). The mean thereof provides information on the "average company" in the larger sample; that mean is 0.088…% and the standard deviation is 1.56%.

- In the third approach, Table 2 contains 19 columns of yearly data, each displaying the growth rates of the 20 firms for each year 1996-2014. Averaging over the 20 firms' growth rates in each year, the Yearly Average row shown in the table ranges from 2.46% (1997) to -2.62% (2009). The mean of the 19 Yearly Averages provides information on the "average year" in the featured sample period; that average is 0.088…% and the standard deviation is 1.35%.

[12] See PEG Report at p.46
[13] ibid.
[14] Energy Probe notes that PEG has formatted and displayed the MFP growth rates in Column AE of the Indexes Excel spreadsheet to two decimal places. In Table 2, Energy Probe displays the same data to three decimal places. This is possible because Energy Probe downloaded PEG's Excel data as stored (i.e.to 15 decimal places).

As these averages drawn from the data in Table 2 differ from PEG's 0.29% figure, all that can be concluded is that PEG's approach to aggregating company-level MFP data differs from LEI's approach thereto.

Energy Probe invites PEG to confirm/disconfirm Energy Probe's above calculations of the averages and standard deviations from the annual MFP growth rate data from Column AE of the Indexes spreadsheet.

TABLE 2

Annual Multi-Factor Productivity Growth Rates in PEG Sample
Source Workbook: M2-11.1-OPG - Attachment PEG-WP-1_20161214.XLSX
Spreadsheet: Indexes
Based on Output Capacity
Logarithmic Annual Growth Rates

YEAR	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	COMPANY AVERAGE 1996-2014
Alabama Power	0.787%	2.034%	0.330%	1.471%	1.799%	3.481%	0.712%	0.853%	8.300%	1.046%	0.514%	-0.786%	2.353%	4.582%	-3.029%	3.625%	0.436%	4.501%	-3.409%	1.558%
Union Electric	-0.888%	3.158%	-0.493%	1.902%	0.976%	0.535%	0.485%	1.140%	-1.543%	4.435%	0.975%	-2.143%	-2.574%	-2.499%	-6.512%	-5.074%	2.485%	-2.824%	2.465%	-0.273%
Appalachian Power	5.959%	-0.076%	1.609%	0.059%	2.355%	-2.640%	4.015%	2.931%	-1.168%	-0.029%	1.791%	-2.569%	7.071%	-9.387%	3.434%	-0.861%	3.534%	-3.364%	-2.853%	0.516%
Avista	-1.719%	2.022%	1.534%	0.617%	-2.935%	6.449%	2.009%	1.355%	0.812%	1.072%	2.599%	3.733%	-0.421%	-9.018%	-1.649%	-3.313%	1.331%	-1.078%	2.697%	0.321%
Duke Energy Progress	-5.687%	5.632%	0.055%	1.234%	0.229%	2.651%	-0.010%	-7.123%	3.097%	1.824%	-0.790%	-1.535%	4.426%	-5.085%	7.778%	0.759%	-1.601%	2.559%	-7.119%	0.068%
Duke Energy Carolinas	3.227%	-1.539%	2.607%	2.125%	-0.101%	4.141%	-0.165%	0.789%	-0.096%	0.735%	3.944%	-0.635%	1.202%	-0.526%	1.169%	0.311%	-5.302%	16.301%	2.134%	1.596%
Georgia Power	-31.228%	8.347%	1.587%	-0.754%	3.661%	-2.747%	5.445%	2.826%	0.338%	0.461%	2.393%	3.397%	-0.638%	6.676%	-4.107%	2.703%	1.754%	1.674%	-4.414%	-0.138%
Green Mountain Power	0.780%	1.491%	0.389%	-2.922%	6.551%	-2.047%	3.016%	-2.047%	3.461%	-0.842%	-4.116%	1.482%	-5.500%	7.568%	-0.528%	13.499%	0.170%	4.058%	2.630%	1.426%
Idaho Power	-3.838%	3.108%	2.783%	-0.053%	2.550%	2.243%	2.989%	1.406%	0.157%	1.422%	0.773%	-0.005%	-1.288%	0.935%	0.457%	1.539%	0.637%	1.423%	1.160%	0.863%
ALLETE (Minnesota Power)	1.400%	8.336%	1.366%	-2.739%	6.157%	0.939%	2.427%	-0.004%	-0.431%	1.826%	-0.469%	2.325%	-3.238%	4.824%	-6.221%	-1.050%	-2.388%	5.384%	-3.884%	0.766%
New York State Electric & Gas	-3.742%	7.567%	3.543%	-8.843%	2.465%	2.065%	2.948%	3.471%	-0.530%	0.453%	4.065%	-3.105%	3.879%	-1.852%	1.061%	0.619%	0.375%	0.143%	2.750%	0.871%
Pacific Gas and Electric	-2.206%	5.820%	1.292%	-1.884%	2.995%	2.713%	0.571%	-0.639%	2.291%	1.289%	3.482%	-3.117%	-0.343%	1.101%	0.151%	-2.362%	-3.461%	-3.089%	-0.312%	0.221%
PacifiCorp	-0.940%	-0.266%	2.079%	2.025%	-0.947%	2.004%	-0.854%	1.321%	-6.125%	1.249%	3.432%	1.782%	-0.540%	-0.265%	-0.999%	-3.147%	-0.969%	-8.258%	1.526%	-0.415%
Portland General Electric	-3.810%	-1.090%	2.172%	-7.218%	3.456%	6.996%	-8.483%	0.099%	2.457%	-0.564%	0.822%	-2.508%	-12.577%	-4.293%	8.608%	-9.447%	-1.435%	-3.457%	14.990%	-0.804%
Public Service Company of Color	-1.449%	3.047%	2.430%	-1.890%	1.410%	-5.949%	2.721%	0.828%	-0.539%	-8.126%	5.857%	-7.442%	6.583%	-14.439%	4.703%	-0.504%	-6.228%	4.748%	-1.065%	-0.806%
Puget Sound Energy	3.147%	-2.253%	1.899%	-0.957%	-2.925%	2.934%	0.828%	0.436%	-21.094%	8.490%	3.890%	-5.651%	-1.246%	-22.190%	1.205%	-1.627%	2.122%	13.232%	-51.532%	-3.752%
Rochester Gas and Electric	5.066%	-2.136%	1.124%	2.604%	1.689%	-0.700%	3.571%	4.087%	-20.736%	0.332%	0.104%	-0.238%	4.834%	-8.367%	-2.940%	-6.772%	4.267%	-50.595%	7.961%	-2.992%
South Carolina Electric & Gas	2.422%	2.467%	1.771%	1.853%	2.280%	0.012%	2.042%	1.326%	0.859%	0.323%	-44.639%	2.033%	0.402%	0.746%	2.816%	2.532%	2.370%	1.948%	1.530%	-0.785%
Southern California Edison	-0.774%	1.145%	4.384%	0.980%	0.490%	-1.229%	0.839%	1.725%	0.318%	1.899%	-2.414%	-1.452%	2.137%	-3.269%	-3.267%	-3.839%	4.171%	-5.174%	5.617%	0.147%
Virginia Electric and Power	3.780%	2.397%	1.455%	1.892%	8.087%	-0.877%	3.518%	2.180%	2.242%	1.246%	1.921%	24.532%	0.495%	2.356%	2.875%	1.380%	3.025%	2.730%	-1.123%	3.374%
Yearly Average	-1.446%	2.460%	1.726%	-0.525%	2.012%	1.049%	1.286%	0.848%	-1.396%	0.922%	-0.793%	0.405%	0.251%	-2.620%	0.250%	-0.552%	0.265%	-0.957%	-1.512%	0.088%

b. PEG's Aggregation Spreadsheet: Cost-Weighted Growth Rates

Based on Energy Probe's review of PEG's working papers, it appears that PEG has used the information in its "Aggregation" spreadsheet that is contained in Excel workbook M2-11.1-OPG-Attachment PEG-WP-1_20161214.XLSX. Column I contains the MFP growth rates by company and by year for its featured sample of twenty companies over the years 1996-2014.[15] These growth rate data are identical to the data in Column AE of the Indexes spreadsheet referred to above.

Column F of the Aggregation spreadsheet contains PEG's calculated total cost by company and by year, and Column G contains each company's share of the annual aggregate cost of all sample companies in each year.

PEG uses these cost shares as weights for the MFP growth rates it reports in Column I. More precisely, it calculates the average of the current-year cost share and the previous-year cost share and multiplies by the current-year growth rate.

To illustrate using the data as displayed for PEG's company #2's (apparently, Alabama Power), the MFP growth rate in 1996 was calculated as follows:

MFP growth rate: 0.79%
1995 Cost share: 8.12%
1996 Cost share: 6.08%
Weighted MFP growth rate: 0.79% x (8.12% + 6.08%)/2 = 0.056%

Energy Probe has extracted PEG's cost-weighted MFP growth rates for each company and each year of its sample from Column I of the PEG's Aggregation spreadsheet[16] and reported same in Table 3 below. The Table contains 20x19=380 observations of the annual MFP growth rate. Note the weighted MFP growth rate for company #2 in 1996 shown in Table 3 is 0.056%, confirming the calculation immediately above.

As with Table 2, Table 3 also shows an additional column labelled COMPANY AVERAGE in which Energy Probe has calculated the average growth rate for each company over the 1996-2014 period. Table 3 also has an additional row labelled YEARLY AVERAGE in which it has calculated the average of the company growth rates in each year. Once again, the mean COMPANY AVERAGE, the mean YEARLY AVERAGE and the average of all 380 observations are the same and equal 0.014%. The associated standard deviations are 0.085%, 0.086% and 0.374% respectively.

The final row of Table 3 shows Energy Probe's calculation of the year-by-year sums of PEG's calculated growth rates. For example, the sum of all company growth rates for 1996 was found

[15] In its Indexes spreadsheet, PEG refers to MFP. In its Aggregation spreadsheet, PEG refers to TFP. Energy Probe agrees that the two terms have identical meanings and uses MFP consistently in discussing and analyzing PEG's data.

[16] In extracting the data from the Aggregation spreadsheet, Energy Probe followed PEG's practice and extensively used the advanced Excel data-handling function SUMIFS.

to be -5.034%. These growth-rate YEARLY SUMs in Table 3 are the same as the growth rates reported in Table 3 of the PEG Report.[17]

Averaging across the row of YEARLY SUMs, Energy Probe finds that the mean is 0.288% which, upon rounding, becomes 0.29% which, as noted above, is the PEG Report's "average annual growth rate in the MFP of all sampled US hydropower generators"[18]. The standard deviation of the YEARLY SUMs is 1.711%.

Energy Probe invites PEG to confirm/disconfirm Energy Probe's above calculations of the averages and standard deviations from the annual MFP growth rate data in the Aggregation spreadsheet.

3. Interim Comparisons

Subject to confirmation from PEG, Energy Probe believes that its analysis of the PEG data has replicated the procedures that PEG followed in obtaining its 0.29% average annual MFP growth rate as reported in the PEG Report.

More importantly, Energy Probe has shown that LEI and PEG appear to have aggregated their sample data into a final estimate of long-term industry MFP growth in very different ways. LEI has obtained its estimated -1.01% average annual MFP growth rate by *averaging* over its calculated growth rates of each company in each year of its sample. PEG, on the other hand, has obtained its 0.29% estimate by *summing* its calculated weighted annual growth rates of the companies in its sample in each year and then averaging those annual sums.

As suggested immediately above, Energy Probe feels that it may be premature to conclude that LEI and PEG have undertaken very different approaches to deriving their final aggregate estimate from their underlying sample growth rate data. This hesitation springs, in part, from Energy Probe's limited understanding of LEI's sample data. It is not yet clear whether LEI has weighted its sample growth rates in a manner similar to (or different from) PEG's weighting as discussed above. Similarly, the fact that Energy Probe has not identified aggregation by summing in LEI's company-level data does not indicate that LEI has not done so.

[17] See PEG Report at p. 50, Table 3.
[18] See PEG Report at p.49.

TABLE 3

Weighted MPP Growth Rates by Company and by Year

pegid	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Company Average
2	0.056%	0.144%	0.027%	0.118%	0.155%	0.303%	0.057%	0.068%	0.658%	0.081%	0.041%	-0.063%	0.193%	0.389%	-0.254%	0.283%	0.034%	0.343%	-0.253%	0.125%
8	-0.003%	0.092%	-0.016%	0.064%	0.035%	0.019%	0.017%	0.040%	-0.056%	0.159%	0.033%	-0.073%	-0.093%	-0.094%	-0.263%	-0.219%	0.103%	-0.115%	0.100%	-0.014%
9	0.117%	-0.001%	0.086%	0.001%	0.060%	-0.067%	0.091%	0.063%	-0.026%	-0.001%	0.037%	-0.054%	0.137%	-0.167%	0.066%	-0.019%	0.078%	-0.075%	-0.065%	0.011%
12	-0.051%	0.067%	0.056%	0.022%	-0.105%	0.206%	0.065%	0.052%	0.033%	0.043%	0.102%	0.145%	-0.017%	-0.406%	-0.079%	-0.158%	0.063%	-0.051%	0.119%	0.006%
20	-0.044%	0.045%	0.001%	0.012%	0.002%	0.027%	0.000%	-0.074%	0.034%	0.019%	-0.008%	-0.015%	0.045%	-0.054%	0.083%	0.007%	-0.015%	0.023%	-0.064%	0.001%
47	0.362%	-0.170%	0.338%	0.281%	-0.014%	0.566%	-0.021%	0.095%	-0.012%	0.093%	0.474%	-0.074%	0.134%	-0.055%	0.125%	0.034%	-0.586%	1.780%	0.228%	0.188%
64	-4.946%	1.353%	0.094%	-0.044%	0.224%	-0.172%	0.316%	0.155%	0.018%	0.025%	0.130%	0.188%	-0.036%	0.369%	-0.223%	0.145%	0.091%	0.084%	-0.220%	-0.129%
67	0.006%	0.011%	0.003%	-0.024%	0.059%	-0.019%	0.025%	-0.016%	0.030%	-0.007%	-0.035%	0.013%	-0.050%	0.066%	-0.004%	0.118%	0.002%	0.039%	0.024%	0.013%
73	-0.198%	0.164%	0.167%	-0.003%	0.154%	0.124%	0.056%	0.088%	0.010%	0.088%	0.047%	0.000%	-0.074%	0.058%	0.028%	0.087%	0.034%	0.077%	0.064%	0.051%
109	0.013%	0.072%	0.013%	-0.027%	0.063%	0.009%	0.022%	0.000%	-0.004%	0.018%	-0.005%	0.023%	-0.032%	0.047%	-0.060%	-0.011%	-0.024%	0.052%	-0.037%	0.007%
124	-0.038%	0.077%	0.036%	-0.091%	0.032%	0.028%	0.024%	0.035%	-0.005%	0.005%	0.042%	-0.028%	0.030%	-0.014%	0.009%	0.005%	0.003%	0.001%	0.027%	0.009%
142	-0.505%	1.277%	0.307%	-0.454%	0.615%	0.562%	0.144%	-0.162%	0.564%	0.296%	0.865%	-0.782%	-0.084%	0.248%	0.034%	-0.548%	-0.811%	-0.719%	-0.073%	0.042%
143	-0.048%	-0.014%	0.121%	0.112%	-0.057%	0.124%	-0.050%	0.079%	-0.388%	0.080%	0.213%	0.111%	-0.035%	-0.017%	-0.059%	-0.192%	-0.062%	-0.561%	0.107%	-0.028%
148	-0.109%	-0.033%	0.073%	-0.230%	0.138%	0.240%	-0.237%	0.003%	0.067%	-0.015%	0.022%	-0.067%	-0.363%	-0.129%	0.247%	-0.274%	-0.044%	-0.108%	0.476%	-0.019%
153	-0.010%	0.022%	0.020%	-0.015%	0.013%	-0.054%	0.022%	0.007%	-0.005%	-0.068%	0.049%	-0.067%	0.064%	-0.143%	0.048%	-0.005%	-0.864%	0.048%	-0.010%	-0.008%
158	0.065%	-0.045%	0.043%	-0.022%	-0.076%	0.078%	0.019%	0.010%	-0.496%	0.197%	0.089%	-0.128%	-0.032%	-0.554%	0.038%	-0.051%	0.064%	0.412%	-2.059%	-0.134%
159	0.021%	-0.009%	0.006%	0.013%	0.009%	-0.004%	0.017%	0.018%	-0.116%	0.002%	0.001%	-0.001%	0.026%	-0.043%	-0.018%	-0.048%	0.036%	-0.544%	0.094%	-0.029%
167	0.063%	0.060%	0.050%	0.052%	0.068%	0.000%	0.058%	0.037%	0.024%	0.009%	-1.597%	0.037%	0.017%	0.032%	0.121%	0.107%	0.103%	0.083%	0.061%	-0.030%
169	-0.045%	0.072%	0.152%	0.068%	0.034%	-0.088%	0.066%	0.141%	0.024%	0.136%	-0.166%	-0.118%	0.171%	-0.273%	-0.269%	-0.304%	0.328%	-0.400%	0.429%	0.007%
195	0.263%	0.161%	0.111%	0.145%	0.636%	-0.066%	0.247%	0.145%	0.150%	0.083%	0.118%	1.403%	0.029%	0.159%	0.192%	0.082%	0.179%	0.159%	-0.063%	0.218%
Yearly Average	-0.252%	0.167%	0.092%	-0.001%	0.101%	0.091%	0.047%	0.039%	0.025%	0.062%	0.023%	0.023%	0.001%	-0.034%	-0.012%	-0.048%	-0.024%	0.026%	-0.056%	0.014%
Yearly Sum	-5.034%	3.345%	1.835%	-0.025%	2.024%	1.816%	0.940%	0.782%	0.506%	1.241%	0.452%	0.504%	0.029%	-0.682%	-0.239%	-0.959%	-0.489%	0.530%	-1.116%	
																	Yearly sums average			0.288%

4. Other Issues

Energy Probe intends to raise the following related matters at the upcoming hearing.

a. Logarithmic and Simple Growth Rates

PEG and LEI have constructed productivity indexes for each firm in their samples. These indexes differ in important conceptual ways, but it is also important to understand how the experts have calculated and reported growth rates from their respective indexes.

The PEG Report points out in several places that the growth rates it has reported are logarithmic growth rates.[19] This raises the possibility that PEG and LEI have calculated and reported growth rates in different ways. If LEI's reported growth rate is a simple growth rate, it will only be comparable to PEG's corresponding logarithmic rate where the former is close to zero. However, some reported growth rates in both expert reports exceed 25% so the differences may be substantial.

Accordingly, Energy Probe seeks to determine whether LEI's reported growth rates are logarithmic rates in order to determine their comparability with PEG's reported rates.

b. Variability and Statistical Significance

Energy Probe Interrogatory #1, parts f) and g) asked PEG to perform tests of statistical significance on certain of LEI's and PEG's estimates of annual average MFP growth. PEG concluded that on the basis of these tests, the null hypothesis that the population productivity growth rate differed from zero could not be rejected.[20]

PEG's response to Energy Probe's Interrogatory #1, part f) also includes the statement:

> "However, we note that the small sample can lead to inaccurate results when performing the requested test."

In its expert report, PEG argues for a longer sample period because it "more effectively smooths the effects of volatility in the sample. ...".[21] It appears that PEG is asserting a relationship among sample size, variability of sample data, and the accuracy of tests of statistical significance.

Energy Probe wishes to pursue this asserted relationship with the experts and to seek their view on an alternate explanation for the lack of statistical significance: i.e., that there is too much

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[19] If the one-period growth rate is g, then the logarithmic growth rate is $ln(1+g)$. If g=0.15 (15%), then the logarithmic growth rate is $ln(1.15)$=0.13976..., which, after rounding, might be reported as 14%. The logarithmic growth rate is equivalent to the continuously-compounded growth rate.

[20] EB-2016-0152, Exhibit M2, Tab 11.1, Schedule EP-001, p.3. Energy Probe had calculated the 8.40% standard deviation using the data for LEI's TFP Index Growth in Figure 27 of the LEI Report. PEG confirmed Energy Probe's calculation.

[21] See PEG Report at p.60.

variability in the data, hence increasing the sample size would not necessarily reduce that variability.

Energy Probe also wishes to have the experts' further view on the proper interpretation of a failure to reject the null hypothesis in a conventional statistical test. In particular, does the failure to reject the null hypothesis provide evidence that the true population parameter is in fact zero? Alternately, does the failure to reject simply mean that, on the available evidence, there is no basis for making any conclusion at all about the true value of that parameter?

c. The Research Question

If LEI and PEG have indeed pursued the very different data-aggregation methods discussed above, Energy Probe suggests that they may have interpreted the basic research question differently. It appears that LEI has understood the goal of its research (providing "the industry TFP growth over the study period"[22]) as determining the average productivity performance of the companies in its sample of peer-group hydro generators, i.e. of a typical hydro generator.

It appears that PEG has understood the research question as asking for the aggregate productivity growth of the hydro generation industry over a particular time period. From this perspective, summing the growth rates of the companies in its sample is one way to estimate that aggregate MFP trend.

d. Other Measures of the MFP Growth Rate?

Because of the substantial variability in the annual productivity growth data used by both PEG and LEI, Energy Probe suggests that other growth-rate measures and statistical tests should be considered for determining the appropriate long-run growth MFP rate in North American hydroelectric generation.

One such alternative is the conventional compound annual growth rate ("CAGR"). The CAGR calculation requires only two data points: the value of a company's productivity index at the very beginning of the sample period, and the value of that index at the end of that period. Because the CAGR involves only the endpoints of the sample period, its calculation is unaffected by the intermediate year-to-year variability that contributes to the lack of statistical significance of virtually all of PEG's and LEI's calculated growth rates.

Neither PEG nor LEI report these productivity index levels in their expert reports. An alternate but equivalent CAGR calculation can be made using the annual MFP growth rates from the data already provided.[23]

Using sample data again raises the question of how CAGR's of individual companies should be aggregated into a measure of central tendency. Energy Probe suggests that the *median* CAGR is a better indicator of productivity growth than the arithmetic average thereof. Firstly, it is less

[22] See LEI Report, footnote 1 *supra* at p.48.
[23] As PEG and LEI are undoubtedly very familiar with CAGR calculations, it is not necessary to discuss the relevant mathematics in this Note.

affected by extreme values than the average. Secondly, it requires only the endpoints of the sample period and is unaffected by the inherent variability in the data. Thirdly, a negative average productivity growth rate is unacceptable to the policymaker.

Table 4 below shows Energy Probe's CAGR calculations for each company in PEG's larger sample and both the arithmetic average and the median CAGR for the sample. The average is -0.154% but the median is 0.147%. On Energy Probe's further tests, neither estimate is statistically significant.[24,25,26]

Energy Probe is interested to have the experts' views on whether the use of the median CAGR or any other particular measure would be an improvement that would assist the Board in determining the appropriate long-term MFP growth rate in this and future cases.

It is apparent to Energy Probe that statistical significance is not, and cannot be, the sole or even the most important criterion for deciding which long-term MFP growth rate the Board should adopt for the purposes of incentive regulation. Indeed, Energy Probe agrees with the Board's policy of rejecting proposed negative growth rates even if the supporting research could demonstrate statistical significance in the conventional manner.

Since, as it appears, neither of the experts' MFP growth estimates are statistically significant, Energy Probe is of the view that the parties and their experts should put forward other criteria that the Board could consider in evaluating the two experts' recommended long-term MFP growth rate.[27]

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[24] The sample average is tested on a conventional one-sample two-tailed t-test with a 5% significance criterion.
[25] The sample median is tested with a sign test. Of the 20 CAGR's, 10 are above the median and 10 below. The binomial probability of observing this outcome is approximately 17.6%. With a 5% significance criterion, the null hypothesis is not rejected.
[26] **CORRECTION March 14, 2017:** The test described in footnote 25 incorrect because it tests the wrong null hypothesis. The correct null hypothesis states that the true CAGR is zero. Of the 20 CAGR's, 11 are positive (+) and 9 are negative (-). The binomial probability of observing 11 +'s and 9 -'s in 20 trials is 16.02%. With a 5% significance criterion, the null hypothesis is not rejected.
[27] For example, having regard to its discussion of issues surrounding sample size, Energy Probe suggests that, in this case, larger sample size would not be a good criterion.

TABLE 4

YEAR	Compound Annual Growth Rate
Alabama Power	1.525%
Union Electric	-0.312%
Applachian Power	0.446%
Avista	0.269%
Duke Energy Progress	-0.013%
Duke Energy Carolinas	1.519%
Georgia Power	-0.526%
Green Mountain Power	1.335%
Idaho Power	0.851%
ALLETE (Minnesota Power)	0.702%
New York State Electric & Gas	0.809%
Pacific Gas and Electric	0.190%
PacifiCorp	-0.456%
Portland General Electric	-1.010%
Public Service Company of Color	-0.955%
Puget Sound Energy	-5.092%
Rochester Gas and Electric	-4.162%
South Carolina Electric & Gas	-1.551%
Southern California Edison	0.105%
Virginia Electric and Power	3.251%
Average	-0.154%
Median	0.147%

Excel Descriptive Statistics for COMPANY AVG

	COMPANY AVG
Mean	-0.010057292
Standard Error	0.005923107
Median	-0.006291667
Mode	#N/A
Standard Deviation	0.02369243
Sample Variance	0.000561331
Kurtosis	0.943096795
Skewness	-0.616698577
Range	0.09375
Minimum	-0.05975
Maximum	0.034
Sum	-0.160916667
Count	16
Confidence Level(95.0%)	0.012624805
Confidence Level-Upper Bound	0.00257
Confidence Level-Lower Bound	-0.02268

Excel t-Test of Significance 5% for COMPANY AVG

	COMPANY AVG
Mean	-0.010057292
Variance	0.000561331
Observations	16
Hypothesized Mean Difference	0
df	15
t Stat	-1.697975569
P(T<=t) one-tail	0.055077416
t Critical one-tail	1.753050356
P(T<=t) two-tail	0.110154832
t Critical two-tail	2.131449546

Excel Descriptive Statistics for LEI Sample

	LEI TFP
Mean	-0.01006
Standard Error	0.019053
Median	-0.027
Mode	-0.042
Standard Deviation	0.264006
Sample Variance	0.069699
Kurtosis	2.781212
Skewness	0.453311
Range	1.931
Minimum	-0.828
Maximum	1.103
Sum	-1.931
Count	192
Confidence Level(95.0%)	0.037581
Confidence Level-Upper Bound	0.02752
Confidence Level-Lower Bound	-0.04764

Excel t-Test of Significance 5% for LEI Sample

	LEI TFP
Mean	-0.01006
Variance	0.069699
Observations	192
Hypothesized Mean Difference	0
df	191
t Stat	-0.52786
P(T<=t) one-tail	0.299105
t Critical one-tail	1.652871
P(T<=t) two-tail	0.598211
t Critical two-tail	1.972462

Energy Probe Interrogatory #1

Issue Number: 11.1
Issue: Is OPG's approach to incentive rate-setting for establishing the regulated hydroelectric payment amounts appropriate?

Interrogatory:

Reference: Exhibit M2

The parties appear to agree that methods of statistical inference can be usefully applied in this case. For example, in its econometric cost analysis, the PEG report states:

> Results of the econometric work for the cost model are reported in Table 7. The table also reports the values of the *t* statistic that correspond to each parameter estimate. A parameter estimate is deemed statistically significant if the hypothesis that the true parameter value equals zero is rejected. This statistical test requires the selection of a critical value for the test statistic. (p.75)

Regarding its analysis of output quantity specification, the PEG report concludes that

> The estimated cost elasticities for the generation capacity and volume were 0.906 and 0.009, respectively. The parameter estimate for the volume variable was not statistically significant. (p.48)

Both PEG and LEI base their estimate of annual total factor productivity growth from samples of hydro generators over certain time periods. Figure 27 in LEI's expert report shows that the average TFP Index Growth for the years 2002-2003 to 2013-2014 was -1.01%. In response to Undertaking JT3.24 following the Technical Conference, LEI confirmed that the standard deviation of the annual TFP Growth rate in Figure 27 was 8.40% on a sample basis and 8.06% on a population basis.

Table 3 of the PEG report provides multifactor productivity ("MFP") growth rates for the years 1996-2014. For the 1996-2014 period, the mean annual MFP growth rate was 0.29% based on capacity and -2.03% based on volume. PEG did not provide the standard deviation for either estimate.

Table 3 of the PEG report also shows that MFP growth for the period 2003-2014 averaged 0.05% per year based on capacity and -1.83% based on volume. Again, PEG did not provide the standard deviations.

a) On page 48 of the PEG report, PEG reports that the parameter estimate for the volume variable was not statistically significant. Is this, as it appears, a regression-analysis result? Please provide the full estimated regression equation, the statistics typically calculated for the purpose of hypothesis-testing in a regression analysis, and the summary statistics typically calculated for the purpose of assessing the variance accounted for by the exogenous variables and the unexplained variance.

b) Please confirm/disconfirm that with a standard deviation of 8.4% in LEI's sample, the population mean, if it lies within one standard deviation would lie between -9.41% and 7.39%

c) To make the above more precise, please confirm/disconfirm that it is conventional in statistical inference (relying on the Central Limit Theorem) to characterize the sample mean as a normally-distributed random variable. Please additionally confirm/disconfirm that on LEI's data, the population mean inferred therefrom lies between -9.41% and 7.39% with a probability of 2/3.

d) Please calculate and confirm/disconfirm that the standard deviations for PEG's MFP growth rates (i.e. capacity and volume) for the 1996-2014 period are 1.71% and 13.56% respectively.

e) Please calculate and confirm/disconfirm that the standard deviations for PEG's MFP growth rates (i.e. capacity and volume) for the 2003-2014 period are 0.74% and 15.62% respectively.

f) The large standard deviation in LEI's sample of 8.4% suggests that the true population mean growth rate may not be statistically different from zero. Please perform the conventional one-sample statistical test of significance on LEI's sample data in Figure 27 of its report. Please use a 2-tailed test and a 5% significance criterion. Show all calculations and state the conclusion that PEG arrives at, along with any qualifying remarks that PEG feels are important.

g) Are PEG's mean annual MFP estimates for capacity and for volume for 1996-2014 and for 2003-2014 statistically significant? Please perform a 2-tailed test using a 5% significance level as was requested in the previous question e. Please show all calculations needed to compute the relevant test statistic and state the conclusion that PEG arrives at, along with any qualifying remarks that PEG feels are important.

Response:

The following response was provided by PEG:

a) Yes, this estimate was obtained econometrically and subjected to a standard statistical significance test. Please see Table 7 of the report for further details of the econometric work.

b) Confirmed.

c) It is confirmed that conventionally the sample mean is characterized as a normally-distributed random variable. Assuming all of the assumptions of the central limit theorem are satisfied, then the population mean inferred from LEI's data lies between -9.41% and 7.39% with a probability approximately equal to 2/3.

d) Confirmed. The standard deviations of PEG's average annual MFP growth rates using capacity and volumes as output are 1.71% and 13.56%, respectively. Please see Attachment M2-11.1-EP, Tab 1.

e) Confirmed. Please see Attachment M2-11.1-EP, Tab 1.

f) Please see Attachment M2-11.1-EP, Tab 2. The t-statistic is -0.42 and the critical value for the requested test is 2.201. Since .42 is less than 2.201, we cannot reject the null hypothesis that the population mean is 0. However, we note that the small sample can lead to inaccurate results when performing the requested test.

g) Please see Attachment M2-11.1-EP, Tab 1. The t-statistics for the 1996-2014 period are 0.73 and -0.65 using capacity and volume as the output measures, respectively. The t-statistics for the 2003-2014 period are 0.27 and -0.51 using capacity and volume as the output measures, respectively. The critical value for the requested test is 2.101. Since the absolute values of all four t-statistics are less than 2.101, we cannot reject the null hypothesis that the population mean is 0 in any of the four scenarios.