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.

[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.

---

[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%	0.524%	-0.786%	2.353%	4.582%	-3.029%	3.625%	0.436%	4.501%	-3.409%	1.558%
Union Electric	-0.088%	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%
Applachian 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%	0.989%	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%	-0.466%	2.325%	-3.238%	4.824%	-6.221%	-1.060%	-2.388%	5.384%	-3.884%	0.766%
New York State Electric & Gas	-3.742%	7.567%	3.643%	-8.843%	2.465%	2.065%	2.048%	3.471%	-0.530%	0.453%	4.065%	-3.105%	3.879%	-1.852%	1.061%	0.619%	0.375%	0.149%	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%	1.189%	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%	-0.952%	-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%	4.884%	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%	0.0881%

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 MFP Growth Rates by Company and by Year																			Company
pegid	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	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%	0.036%	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%	0.146%	-0.017%	-0.406%	-0.079%	-0.159%	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%	0.885%	-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%	0.118%	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%	-0.064%	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%	-0.654%	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%	0.087%	0.017%	0.032%	0.121%	0.107%	0.103%	0.083%	0.061%	-0.030%
169	-0.045%	0.072%	0.352%	0.068%	0.034%	-0.088%	0.066%	0.141%	0.024%	0.136%	-0.186%	-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%	1.408%	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%	0.025%	0.001%	-0.034%	-0.012%	-0.048%	-0.024%	0.026%	-0.056%	**0.014%**
Yearly Sum	**-5.034%**	**3.345%**	**1.835%**	**-0.023%**	**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

[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]

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.[26]

[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] 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%**