## LEI memo responding to Pacific Economic Group's "IRM Design for Ontario Power Generation"

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Ontario Power Generation ("OPG") retained London Economics International ("LEI") in 2013 to perform a Total Factor Productivity ("TFP") study of the hydroelectric generation industry for purposes of setting an X factor for the hydroelectric business' future price cap plan.  $^{1,2}$  The Ontario Energy Board ("OEB") Staff engaged Pacific Economics Group Research LLC ("PEG") to review and comment on LEI's TFP study and OPG's proposed Incentive Regulation ("IR") plan. PEG filed its report, entitled "IRM Design for Ontario Power Generation," on November 23, 2016 (herein referred to as the "PEG Report").<sup>3</sup> LEI believes that PEG has not properly considered the key characteristics of the hydroelectric generation business in the design of its analysis. This brief memo identifies two major issues with PEG's analysis: (1) PEG assumed a geometric depreciation profile that does not accurately reflect the capital inputs of a hydroelectric generator, and (2) PEG employed an output measure that does not account for many of the actual productivity opportunities available to hydroelectric generators and the realities the of the price cap regime. This memo also addresses criticisms of LEI's TFP study in the PEG Report and identifies certain other concerns with PEG's analysis. LEI did not perform additional analysis for this brief memo given the time available for this response, but rather LEI relied on a comparison of LEI's analysis with the PEG Report and certain aspects of PEG's interrogatory responses.

<sup>&</sup>lt;sup>1</sup> In December 2014, LEI released the original TFP report, covering the 2002-2012 timeframe. Source: LEI TFP Study (2014). Frayer, J., Chow, I., Yakupova, K., and Hariri, A., Empirical Analysis of Total Factor Productivity Trends in the North American Hydroelectric Generation Industry. December 19, 2016. OEB, EB-2013-0321.

<sup>&</sup>lt;sup>2</sup> In February 2016, LEI provided an update of the TFP report extending the dataset through 2014. Source: LEI TFP Study (2016). Frayer, J., Chow, I., Leslie, J., and Porto, B., Empirical Analysis of Total Factor Productivity Trends in the North American Hydroelectric Generation Industry. February 19, 2016. OEB proceeding EB-2016-0152, Exhibit A1-3-2, Attachment 1, filed on November 10, 2016.

<sup>&</sup>lt;sup>3</sup> PEG Report (2016). Lowry, M. N., and Hovde, D., IRM Design for Ontario Power Generation. November 23, 2016. OEB proceeding EB-2016-0152, Exhibit M2.

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### **1** Executive Summary

LEI reviewed the PEG Report and the responses to interrogatories filed by OEB Staff regarding the PEG Report, as filed on December 14, 2016. LEI has reached three conclusions regarding PEG's analysis:

## 1. The PEG Report is based on assumptions that do not reflect the actual operating properties of hydroelectric generation assets.

PEG has employed an accounting standard of depreciation (geometric decay) that is fundamentally inconsistent with the actual, physical performance of hydroelectric generation assets. These assets do not experience physical depreciation in pre-set increments every year of their service life, as estimated by PEG. If they are properly maintained, these assets should operate consistent with their initial design and physical capability year after year. Indeed, OPG has assets that were built more than a hundred years ago, and they are continuing to operate at levels consistent with their design capability.

The PEG Report also failed to account for other properties of hydroelectric generation assets. These assets do not benefit from fast-paced technology improvements, compared to assets in other infrastructure industries, as only the electrical and mechanical components can be replaced over time to improve productivity, while their civil structures (e.g. dams) remain largely unchanged. In addition, an accurate productivity study should reflect the fact that these assets produce more than electricity and ancillary services. Hydroelectric generators also provide dam safety and watershed management services, balancing energy production requirements with environmental, commercial and recreational needs.

Finally, PEG has taken an approach that is inconsistent with how hydroelectric generating assets are paid. The OEB has consistently held that these assets are paid on the basis of their energy production, which implies that electric generation is a good proxy for other services that are produced. Moreover, the design of Ontario's energy market means that if these assets were not regulated, they would also be paid on the basis of energy production. If the TFP model that PEG proposes is used to calibrate the X factor in a price cap index, PEG's approach introduces risk of long-term capital insufficiency.

### 2. The PEG Report is based on several methodological errors and omissions.

The TFP growth estimate in the PEG Report is biased given the assumptions made. The most important methodological error is the use of the geometric depreciation profile, as also discussed above. By way of the basic math, the use of this assumption in the PEG Report leads to an over-statement of the estimate industry average TFP growth rate.

Since PEG's model explicitly excludes improvements in generation (MWh), it is unable to account for many productivity improvements that increase energy production but do not impact capacity. For example, PEG's methodology does not recognize any productivity impact from OPG's Niagara Tunnel Project, since that investment increased expected annual generation (MWh) but not capacity (MW) of the Sir Adam Beck generation facility.

PEG's average TFP growth estimate is also biased upwards because of the selected timeframe –by going back to the 1990s, PEG's industry average TFP results include outdated data that is no longer relevant to OPG's current and expected hydroelectric operations.

The analysis in the PEG Report includes some arbitrary assumptions and others that are not based on facts. For example, PEG arbitrarily used a single year of OPG data to calculate the share of civil structures to electrical and mechanical components, which PEG then used in determining the depreciation rates for all other peers in the industry for all years of the study. Given that other companies have different plant design parameters, using only OPG's fleet plant configurations in one year is a substantial assumption that may distort the results.

### 3. The PEG Report includes several wrongful criticisms of LEI's TFP study.

The PEG Report claims that the inclusion of OPG in LEI's study unduly affects results for the peer group. LEI's TFP study relied on industry peers that are relevant and representative of the industry and carefully checked for biases. With LEI's approach, inclusion of OPG does not create any biases that would require its exclusion from the industry grouping. Notably, the difference in the industry TFP average growth rate with and without OPG is just 10 basis points (with OPG, the industry average TFP average growth rate is -1.01%, while without OPG, the industry average TFP average growth rate is -1.11%). The bias that PEG identifies does not arise from the basic physical properties of OPG's hydroelectric fleet, but rather because of the various assumptions that PEG makes in computing their monetary approach (namely, depreciation assumptions).

PEG argues that LEI's 15-firm industry group<sup>4</sup> is insufficient. However, the 20-firm group in the PEG Report contains virtually the same list of peers. PEG's additions to the peer group represent 6% of their selected industry set in terms of installed capacity.<sup>5</sup> However, unlike LEI, PEG did not collect data to include municipal hydroelectric operators.

Lastly, PEG speculates that the timeframe of LEI's study may be insufficient. However, the length of LEI's study is consistent with industry practice and, importantly, is more applicable to the next regulatory period than the decades-old trends cited in the PEG Report. In fact, LEI's study uses the same timeframe that PEG did when evaluating TFP trends in the Ontario electric distribution sector in their 2013 report for the OEB,<sup>6</sup> plus additional two years to incorporate more recent data.

<sup>&</sup>lt;sup>4</sup> Excluding OPG

<sup>&</sup>lt;sup>5</sup> The added companies are Public Service Company of Colorado (395MW of installed capacity, 1.6% of PEG's sample by hydroelectric plant in service 2014), and 6 small companies making up 4.1%: Puget Sound Energy, Duke Energy Progress, ALLETE (Minnesota Power), Green Mountain Power, New York State Electric & Gas, and Rochester Gas and Electric. Source: PEG Report (2016), *op.cit*.

<sup>&</sup>lt;sup>6</sup> PEG used 2002-2012 timeframe for their recommended TFP growth trend. Source: PEG RRFE Report (2013). Productivity and benchmarking research in support of incentive rate setting in Ontario: Final report to the Ontario Energy Board. November 2013. OEB EB-2010-0379. Filed as part of the OEB's Renewed Regulatory Framework for Electricity Distributors ("RRFE").

# 2 Fundamental characteristics of a TFP study for the hydroelectric generation industry

Three fundamental issues make hydroelectric generation industry different from other industries that are typically regulated under IR schemes:

- Hydroelectric generating assets, if properly maintained, continue to deliver the same productive capability in the long-run. Unlike a battery or distribution poles, the majority of a hydroelectric generator's capital stock does not get "used up" or physically deteriorate in pre-set increments over time.
- The drivers of productivity growth are different than other regulated industries: since output is largely fixed when a facility is designed, productivity gains from output growth are not a driver of hydroelectric industry productivity trends. Generators do not experience demand growth as an electric distributor does. While a distributor may show productivity gains by adding new customers, hydroelectric generators do not. In addition, technology-driven growth is slow in the hydroelectric generation industry.
- Hydroelectric facilities provide a suite of services to consumers, including water management. Ideally, a TFP study should aim to capture these services. To the extent that one or more outputs from hydroelectric power plants are not directly captured, they must be considered in the interpretation of the TFP study results.

The PEG Report does not appear to recognize and reflect these specific characteristics of the hydroelectric generation industry.

## 2.1 Hydroelectric generation assets experience only minor physical deterioration if properly maintained

An accurate TFP analysis reflects how the actual, physical depreciation of the assets under study (inputs) translate into reduced ability to produce the services (outputs). This is entirely separate from the accounting depreciation used for financial reporting purposes. For hydroelectric generation, the primary input is the asset itself. A hydroelectric plant is composed of civil structures (like the dam, tunnels, and powerhouses) and electrical and mechanical components (like controls, transformers, generators, turbine runners and other turbine components).

Since the actual quantity of capital input used each year is not observable, any measure (physical or monetary) will be a proxy. Therefore, the critical question is the following: which proxy provides the best overall approximation? For hydroelectric generation assets, a "one hoss shay" profile is a close approximation of the physical depreciation of the capital deployed as it assumes that the asset can produce the same level of outputs over its entire service life.

### Backgrounder: Efficiency profiles for alternative depreciation profiles

PEG has listed three depreciation profiles used to establish the capital input quantity under the monetary method: geometric decay, "one hoss shay," and cost of service or straight-line.<sup>[1]</sup> PEG has also noted that regulators consider different capital input methodologies when calibrating X factors.<sup>[2]</sup> As such, it is important to understand the meaning of each deprecation profile.

- 1. <u>Geometric decay</u> uses a constant depreciation rate every year which creates an effect of a geometric decay in the productive capability of the asset in question.<sup>[3]</sup>
- 2. "<u>One hoss shay</u>" assumes no depreciation in the asset's physical capabilities until the end of its service life.
- 3. <u>Cost of service</u> or <u>straight line</u> depreciation assumes the same depreciation amount in each period.

There is also **hyperbolic depreciation**, which assumes largely no depreciation for the majority of the asset's lifetime, and close to the end of the lifetime, the deterioration is very rapid.<sup>[3]</sup> The hyperbolic depreciation profile is a current statistical agency practice used by many national statistical agencies (e.g., U.S. Bureau of Labor Statistics ("BLS"), the Australian Bureau of Statistics, and Statistics New Zealand)<sup>[4]</sup> that recognizes that most assets decay in physical terms closer to "one hoss shay" than geometric depreciation profile.





- Economic Insights (2013). Lawrence, D. and Kain, J. Inputs to be Used in the Economic Benchmarking of Electricity Network Service Providers. Briefing notes prepared for Australian Energy Regulator. February 27, 2013.
- [4] US BLS. A Prototype BEA/BLS Industry-Level Production Account for the United States. November 2012; ABS. Information paper: Experimental Estimates of Industry Multifactor Productivity. 2007; Statistics NZ. Productivity Statistics: Sources and methods. 2012; PEG is also aware that US BLS assumes hyperbolic depreciation in its multifactor productivity studies. Source: PEG's reply to OPG Interrogatory #9. EB-2016-0152, Exhibit M2, Tab 11.1, Schedule OPG-009, filed on December 14, 2016.

<sup>[5]</sup> John Baldwin. Estimating Depreciation Rates for the Productivity Accounts. 2005.

6 London Economics International LLC 390 Bay St, Suite 1702 Toronto, ON M5H 2Y2 <u>www.londoneconomics.com</u> A geometric depreciation profile, as assumed in the PEG Report, will not represent the physical performance of hydroelectric generating capital assets that are properly maintained. Indeed, in the experience of OPG and other companies in LEI's industry group for the TFP study, hydroelectric assets do not decline gradually – they operate consistent with their initial design and physical capability year after year, for many years. Furthermore, the geometric rate calculated by PEG relied on assumptions that do not reflect the experience of hydroelectric plants (see Section 3.1 for more details).

The productive capability of a hydro asset is "fixed" through its design and construction. For example, a hydroelectric plant's operating potential will typically be a function of the water flow, the dam design, and the turbines selected. The dam components, otherwise known as civil works, are fixed structures, made of concrete, and may last up to 150 years.<sup>7</sup> Such dam structures typically represent a majority of the invested capital (up to 70% of total project cost for a new construction)<sup>8</sup> in the hydroelectric generation business.



Hydroelectric generation assets are typically not "rebuilt" or "replaced" but rather are maintained to ensure that the productive capability is maintained. It would be impractical to tear up and rebuild a dam. According to the Hydro Equipment Association ("HEA"), Figure 2

<sup>&</sup>lt;sup>7</sup> Hydro Equipment Association ("HEA" 2015). Global Technology Roadmap. 2015. Page 14.

<sup>&</sup>lt;sup>8</sup> International Energy Agency ("IEA" 2012). Technology Roadmap: Hydropower. 2012. Page 47.

illustrates the trend in spending (labeled as O&M costs) required to maintain hydro equipment and "to ensure the plant's availability, reliability and safety"<sup>9</sup> remain on par with initial design as the asset ages.<sup>10</sup> As seen in Figure 2, reliability is fairly constant over time (commonly, a decline in reliability is expected at the end of life which is known as the "bathtub curve"<sup>11</sup>). At that point of decline, intervention is undertaken through a variety of maintenance programs to restore reliability. Some may involve refurbishment or replacement of electrical or mechanical equipment; if such equipment is replaced, there may be further opportunity to increase efficiency and production.



OPG has assets that were built more than a hundred years ago, and they are continuing to reliably operate at levels consistent with their design capability as a result of its asset management program.<sup>12</sup> As an example of the trends in reliability over an asset's service life, Figure 3

<sup>9</sup> HEA (2015), op. cit., page 30.

<sup>&</sup>lt;sup>10</sup> There may be times when an operator chooses to not maintain an asset to their original design – but those decisions arise as a result of economic considerations and typically only towards the end of service life.

<sup>&</sup>lt;sup>11</sup> O&M costs for hydroelectric generation assets follow a 'bathtub curve' in which the failure rate of equipment (and, therefore, the need to make repairs and additional maintenance/warranty work) is highest at the beginning of an asset's life, then stable once common start-up issues are resolved and steady state operations begin, and increase towards the end of asset's useful life. Source: EB-2016-0152, Exhibit L, Tab 11.1, Board Staff Interrogatory #226 (c).

<sup>&</sup>lt;sup>12</sup> For further information about OPG's hydroelectric asset management program, see EB-2013-0321, Ex. F1-1-1, pages 23-28.

demonstrates OPG's hydroelectric fleet's trend in equivalent forced outage rates ("EFOR"), which is the byproduct of the company's spending to maintain reliability levels. This chart shows that OPG's hydroelectric assets are maintained to produce at steady (or improving) levels of expected output (although O&M costs will be rising with time to ensure that productive capability remains at adequate levels).

The PEG Report does not reflect the actual experience of the hydroelectric power generation industry. Instead, it is based on the same assumptions and techniques that PEG used in previous TFP studies on Ontario's electric distribution industry (e.g., the assumption of decaying capital assets that need to be replaced at equal interval of time from day one of operations).<sup>13</sup>

## 2.2 Hydroelectric generation sector does not benefit from fast-paced technology improvements

There are a number of drivers to productivity in the hydroelectric generation sector.<sup>14</sup> Unlike electric and gas distribution sectors, hydroelectric power plant operators do not have the ability to take advantage of volume growth in their "output" over time to produce efficiency gains.<sup>15</sup> Nonetheless, the pace of technological improvements is relatively slow compared to other infrastructure industries, as civil work replacements are rare and only the mechanical components and electrical parts can be replaced over time to improve productivity. According to a recent Electric Power Research Institute ("EPRI") report, there are not significant "game changing" technologies on the horizon for commercial development. EPRI identified three new hydroelectric technologies; two technology applications consider incremental improvements in electrical and mechanical components, and one which considers pumped storage plants which are not applicable in Ontario.<sup>16</sup>

<sup>&</sup>lt;sup>13</sup> When discussing the theory of its index methods in Section 3.1-3.2, PEG provided examples mostly for the distribution sectors (for example, footnote 17, last paragraph on page 17, and footnote 19), with only one reference specific to power generation on page 15. While they have a small Section 3.3 on "application to hydroelectric power generation," PEG does not explain there, how their previous methods for distribution studies should be adjusted given critical differences in hydroelectric generation industry from electric and gas distribution industries. Source: PEG Report (2016).

<sup>&</sup>lt;sup>14</sup> Please refer to LEI TFP Study (2016), section 3.1; and PEG Report (2016), section 3.1.

<sup>&</sup>lt;sup>15</sup> PEG found in their TFP study of Ontario electric distributors for the RRFE, that customer growth was not just "statistically significant", but in fact the "largest" driver of productivity. Source: OEB RRFE (2013). Rate Setting Parameters and Benchmarking under the Renewed Regulatory Framework for Ontario's Electricity Distributors. Issued November 21, 2013, corrected December 4, 2013. Page 6, Table 8, and page 39.

<sup>&</sup>lt;sup>16</sup> The three new hydroelectric technologies that EPRI identified are: expand operating range with lower minimum load and higher peak operating capabilities; apply adjustable speed drive electronics in new and selected existing pumped storage; and design new pumped storage plants that minimize environmental impacts such as low profile or closed water supply loop to shorten licensing lead times and public approval process as compared to recent conventional experiences. Source: Electric Power Research Institute ("EPRI" 2013).

As both HEA and the International Energy Agency ("IEA") recognize in their hydroelectric technology roadmap reports, "hydropower is a mature technology,"<sup>17</sup> and "the machines deployed today have been perfected over more than 150 years."<sup>18</sup> Many technical improvements have been harvested over the decades. For example, the industry is believed to have already harnessed hydraulic efficiency of hydroelectric turbines to 95% (as seen by the flattening out of the curve in Figure 4).



Like many of its peers, OPG has already taken advantage of capturing technology improvements through runner upgrades to increase energy throughput, and in some instances, the maximum continuous rating ("MCR"). OPG has increased efficiencies and capacity at many plants by up to 12% since the plants went into service in the 1930s to 1950s.<sup>19</sup> Without an exceptional breakthrough in turbine runner technology, OPG expects that there will be far fewer such opportunities in the future.

<sup>17</sup> HEA (2015), op. cit., page 20. And IEA (2012), op. cit., page 8.

<sup>18</sup> HEA (2015), op. cit., page 20.

*Quantifying the Value of Hydropower in the Electric Grid: Final Report.* 2013 Technical Report. February 2013. Page 3-9.

<sup>&</sup>lt;sup>19</sup> For example, since 1998, OPG has automated most of its hydro plants and reduced the number of operating centres from nineteen to six. Since 2002, OPG has replaced the main output transformers at many of its regulated stations. Source: provided by OPG.

#### 2.3 Hydroelectric generation provides a diverse set of outputs

By design, hydroelectric generation assets deliver a multi-dimensional service, providing multiple products or "outputs" such as generation, ancillary services, supporting overall system reliability, firm capability, system support, water management for flood control, and recreational use.<sup>20</sup>

Recognizing the many services a hydroelectric generator provides, in LEI's TFP Study (2014), LEI evaluated a two-output model (generation and Availability Factor ("AF")<sup>21</sup>) for a subgroup of peers. LEI's conclusion was to use the generation output metric because "availability" as an output is already captured in generation data due to the interrelationship between production and overall annual availability.<sup>22</sup> Therefore, LEI's TFP studies used generation as the output metric because (1) it is the essential product of every power generator; (2) it is the most common metric used for measuring output for productivity studies on generation business;<sup>23</sup> and (3) it not only represents the measure of energy injected into the grid, but also indirectly represents the relative quantum of ancillary services and reliability provided to the system.

However, PEG recognized only some of the services that hydroelectric generators provide to customers (generation volumes, capacity, and ancillary services).<sup>24</sup> Moreover, PEG chose in its analysis to only measure capacity as an output of service. Yet, none of the previous TFP studies for power generation reviewed by LEI or by PEG used MW as the sole output measure; all of the studies used MWh and only a handful also used MW.<sup>25</sup> As such, PEG did not consider either the primary output – generation, or other important services that any hydroelectric asset provides.

Such services deliver benefits to customers (e.g., water management benefits arising from the dam and reservoir) and impose costs on generators, and therefore should be considered in the context of a TFP analysis. While the costs associated with providing these additional services are captured in the O&M costs (input-side), the benefits of these services are hard to measure on the

- <sup>22</sup> LEI TFP Study (2014), op. cit., Section 8, Page 48.
- <sup>23</sup> In all 18 productivity studies that LEI reviewed, conducted both for academic and regulatory purposes, energy generation in MWh was the most common output measure used in generation productivity studies. Source: LEI TFP Study (2016), page 55.
- <sup>24</sup> PEG's reply to OPG Interrogatory #10. Issue Number 11.1. EB-2016-0152, Exhibit M2, Tab 11.1, Schedule OPG-010, filed on December 14, 2016.
- <sup>25</sup> PEG listed 14 generation productivity studies, of which all used MWh as the output. Only 4 used MW as an additional output metric. Source: PEG's reply to OPG Interrogatory #3. Issue Number 11.1. EB-2016-0152, Exhibit M2, Tab 11.1, Schedule OPG-003, Table M2-11.1OPG-3, filed on December 14, 2016.

<sup>&</sup>lt;sup>20</sup> IEA (2012), op. cit., Page 9.

<sup>&</sup>lt;sup>21</sup> Availability Factor is defined by NERC as "The fraction of a given operating period in which a generating unit is available without any outages." Source: LEI TFP Study (2014), *op. cit.*, Section 8, Page 48.

output-side of the TFP analysis. Nonetheless, it is important to recognize that the demands on hydroelectric generators around these services have been increasing, constraining the productivity improvements that hydroelectric generators can achieve. For example, similar to many of its peers, OPG's costs of complying with safety regulations, cyber-security requirements, and water management have been steadily rising, as stated in OPG's Stakeholder Consultation Session on December 17, 2014.<sup>26</sup> This means that although safety and water management are being delivered, these costs are not improving MWh output – in fact, it may be reducing the output or constraining it.

In conclusion, PEG's use of capacity as the sole output measure in a TFP for the hydroelectric power generation services does not reflect the range of services that a hydroelectric power generator provides. In LEI's assessment, it is critically important that the output metric in a TFP analysis properly capture the services provided by the industry under study. Furthermore, it is important to recognize the limiting impacts on future productivity gains due to increasing external pressures on operations from such services as water management and flood control.

<sup>&</sup>lt;sup>26</sup> "Dam safety is an area of focus and will continue to drive costs and will require additional investment over the next ten years". Source: OPG Stakeholder Consultation Session Notes, Information Session, December 17, 2014.

## 3 Major issues

The two primary differences between LEI's TFP study and PEG's analysis are the approach taken for defining capital input quantities and output. There are multiple approaches for measuring capital input quantities, and none will be "perfect." PEG's analysis is based on an input measure that does not reflect the characteristics of the hydroelectric generation industry. The best approach is one that reflects the realities of the industry under study. LEI's physical proxy method accomplishes just that. Similarly, there are tradeoffs for selecting the output metric. PEG chose an output metric based on a conceptual assessment of the relationship between costs and outputs. In contrast, LEI's TFP study better reflects the actual services provided by hydroelectric operators and the practical realities of the market.

### 3.1 Measuring capital input quantities

TFP studies can use either a monetary or a physical approach to measure capital input quantities. The decision in favor of one approach over another requires evaluation using conceptual merits (e.g., which approach represents the industry best?) and practical merits (e.g., what data is available?). Both approaches have shortcomings and advantages.

Conceptually, the monetary method can include capital equipment of all kinds, which may be important if a business uses many different assets that cannot be unified easily by using nonfinancial measures. However, many more years of data are required and a depreciation assumption must be employed to approximate the capital input quantity. Therefore, a major weakness of a monetary approach is that, without depreciation assumptions that reflect the actual, physical depreciation profile of the assets, it can produce a misleading result.

In contrast, the physical method relies on physical measures of the quantity of capital deployed. In the electric generation industry, a physical method is straightforward, because the capital input quantity can be thoroughly represented by capacity ratings (in terms of MWs).<sup>27</sup> However, the usage of MWs on the input side of the TFP equation precludes using capacity sales (also measured in MWs) on the output side of the TFP equation.

Ultimately, the core issue is which method provides the best overall approximation to the actual quantity of capital input used each year and allows for the most realistic measurement of productivity, given the characteristics of the assets and industry in question. For the hydroelectric generation industry, where capital can be suitably measured using capacity ratings (in MW) and the physical decay in the capital assets over time is limited, the physical method is superior to the

<sup>&</sup>lt;sup>27</sup> LEI used MCR for OPG and demonstrated maximum generating nameplate ratings of power plants from FERC Form 1. This metric shows the productive capability of the asset without exceeding design thermal limits. It is a dynamic measure that explicitly reflects the performance of the capital equipment because utilities routinely test their asset's performance to develop these numbers.

monetary approach. And indeed, academic studies typically show that practitioners favor this approach.<sup>28</sup>

PEG's analysis used a monetary approach to measure capital input quantities. In and of itself, PEG's approach is not an issue. The problem arises in that the monetary approach requires a series of assumptions, the most important being the depreciation profile for the capital input quantities.<sup>29</sup> As an alternative to the geometric decay profile, PEG could have examined a hyperbolic profile (which most national statistics agencies now use) or a "one hoss shay" profile (which is a more accurate depiction of the physical depreciation of the majority of the capital stock in the hydroelectric generation industry, as already mentioned on Section 2.1).<sup>30</sup> PEG's analysis does not consider multiple depreciation profiles, as has been done for regulators in other jurisdictions.<sup>31</sup> Instead, PEG presented results using a singular assumption – a geometric decay profile – without addressing whether that assumption accurately reflects the reality of the industry.<sup>32</sup>

If it is prepared with proper inputs, reliable data, and credible assumptions, the monetary approach is not inherently 'wrong' for the hydroelectric industry. However, the geometric depreciation profile that PEG used is inappropriate, <sup>33</sup> because as discussed in Section 2, there will

- <sup>30</sup> PEG was asked to identify cases where utility X-factors were calibrated using each depreciation profile: geometric decay, "one hoss shay", and cost of service. In response to IR#8, PEG identified two cases of undergoing IRs that calibrate utility X-factor using a "one hoss shay" profile for capital measure: power distributors in Alberta (ATCO Electric, EPCOR, and Fortis Alberta) as well as all gas distributors in Alberta. For the remaining cases of undergoing IR, two were under cost of service and only one used geometric decay to measure capital quantity.
- <sup>31</sup> "[S]ome regulators may consider more than one capital input methodology when calibrating X factors". Source: PEG's reply to OPG Interrogatory #8. EB-2016-0152, Exhibit M2, Tab 11.1, Schedule OPG-008, filed on December 14, 2016.
- <sup>32</sup> PEG was asked to justify the application of the geometric decay profile of depreciation to generation assets in the discovery process and failed in this regard: in response to OPG's Interrogatory OPG-005, PEG reported that they were not aware of any TFP studies for X-factor calibration for application to generation. Source: Source: PEG's reply to OPG Interrogatory #5. EB-2016-0152, Exhibit M2, Tab 11.1, Schedule OPG-005, filed on December 14, 2016.
- <sup>33</sup> PEG also made statements that contradicted the adoption of a geometric depreciation rate notably, PEG stated in their report that "an important reason for the high capital intensiveness of hydroelectric generation is the

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<sup>&</sup>lt;sup>28</sup> LEI reviewed 18 academic and regulatory TFP studies and observed that the most common input used for generation related productivity studies was capacity as a physical measure of capital. A list of all studies analyzed by LEI can be found in LEI's reply to VECC Interrogatory #45. EB-2016-0152, Exhibit L, Tab 11.1, Schedule 20 VECC-45.

<sup>&</sup>lt;sup>29</sup> Other assumptions are needed as well: for example, the relative shares of different asset types in estimating the capital stock, and an identification of the specific depreciation rate itself. PEG made a number of assumptions that are questionable.

not be any appreciable physical decay in the structures that represent the majority of the capital asset base, if the plants are properly maintained. The use of the geometric decay depreciation profile creates a clear bias: with this method, the TFP index will be using a capital quantity that is decreasing over time (barring new investments), which then leads to a higher TFP growth rate, all things being equal. In other words, the methodology used in the PEG Report has a tendency to overestimate TFP trends as a result of under-representing the capital input being employed.<sup>34</sup> If a lower depreciation rate was more appropriate for the industry, it would have resulted in a lower TFP trend in PEG's analysis, holding all else constant.

Furthermore, PEG has made many assumptions in conducting its monetary approach that appear to be arbitrary and not fact-based.<sup>35</sup> LEI is particularly concerned that PEG's depreciation rate calculation may be biasing the results. It appears that they relied on U.S. Bureau of Economic Analysis ("BEA") parameters and methodology, and specific assumptions for different classes of assets that are not precisely related to actual hydroelectric assets.<sup>36</sup> Moreover, PEG applied OPGspecific data on relative share of civil structures and electrical and mechanical components in determining the depreciation rates applied to all other peers in the industry.<sup>37</sup>

In conclusion, LEI's choice to use a physical approach to measure capital inputs is grounded in two facts: (1) the profile of physical depreciation of hydroelectric assets does not decay geometrically and in fact has a "one hoss shay" profile, and (2) an asset's capacity rating, as measured by MW, represents a universal measurement of the capital deployed.<sup>38</sup> Through its preparatory research, as described in the LEI TFP Study (2016), LEI also identified a number of

- <sup>36</sup> BEA (2003). U.S. Bureau of Economic Analysis. Fixed Assets and Consumer Durable Goods in the United States, 1925-97. September 2003. Page M-6.
- <sup>37</sup> PEG's working paper PEG-WP-2, provided as part of PEG's reply to OPG Interrogatory #1. EB-2016-0152, Exhibit M2, Tab 11.1, Schedule OPG-001, filed on December 14, 2016.

<sup>38</sup> See footnote 27.

unusually high cost of civil structures such as dams and waterways that are needed to handle water. These structures have unusually long service lives." Source: PEG Report (2016). Page 10.

<sup>&</sup>lt;sup>34</sup> Using PEG's model provided in the interrogatory responses on December 14, 2016, LEI tested the model's sensitivity to the assumption of the depreciation rate. A lower depreciation rate yields a lower productivity growth estimate than that presented in the PEG Report (2016). Changing the depreciation rate that PEG used in their analysis from 2.63% to 2%, yields an average TFP growth rate of 0.05% for 1996-2014 period (instead of 0.29%) and -0.12% for 2003-2014 (instead of 0.05% in PEG's analysis). Although PEG refused OPG's interrogatory requesting they perform an analysis under the monetary approach assuming "one hoss shay" depreciation, this illustrative test is evidence that a depreciation profile closer to the actual physical capabilities of hydro generation assets would materially reduce the TFP estimates from those under a geometric decay profile.

<sup>&</sup>lt;sup>35</sup> PEG did not disclose the sources for these assumptions in their report, but noted BEA as a source in the working paper provided in reply to OPG's interrogatories. Source: PEG's working paper PEG-WP-2, provided as part of PEG's reply to OPG Interrogatory #1. EB-2016-0152, Exhibit M2, Tab 11.1, Schedule OPG-001, filed on December 14, 2016.

academic studies of TFP which suggested that the most common measure of capital input quantity was the capacity rating of the power plants (or the physical approach).<sup>39</sup> PEG's review of third-party studies also confirms the use of "one hoss shay" depreciation profile to calibrate utility X-factor.<sup>40</sup>

### 3.2 Output specification

As discussed in Section 2, hydroelectric generation plants provide a number of services or "outputs". The goal of a robust TFP study is to capture these various services in the output index, subject to available data. Generation (MWh) is the primary output of hydroelectric generation business "since the function of the plants is to supply electricity to meet demand."<sup>41</sup> The measurement of generation is accurate and robust across companies and jurisdictions. It is also important to keep in mind that OPG is paid based on the energy generated (MWh) and not on its installed capacity. As PEG themselves state, "generation volume is by far the most important billing determinant in OPG's hydroelectric generation invoicing."<sup>42</sup>

In addition, as this TFP study is being used for calibrating an X factor for an IR plan, it is important to keep in mind the form of IR regime. OPG has proposed a price cap rate-setting methodology for hydroelectric payment amounts, where the underlying billing determinants will not be changed from their previous cost of service price cap (although the year on year trends in the price cap will change). PEG agrees with the IR-based price cap in principal.<sup>43</sup> Under a pure price cap, output for the productivity calculation must be measured in the exact same way as the business charges its customers, and OPG is compensated only for energy produced and ancillary services, not for capacity.<sup>44</sup> PEG's analysis omits the very output metric which forms the basis of OPG's compensation. If PEG's estimated TFP growth rate is then used to calibrate the X factor for setting the price cap, the IR regime will jeopardize financial capital maintenance – in other words, the utility may not have an opportunity to recover its total costs of operation.

<sup>&</sup>lt;sup>39</sup> In LEI's research of pervious works (best practices) on TFP studies for power generation, LEI identified 10 power generation specific TFP studies which relied on the physical measure of capital approach. In contrast, PEG did not identify any power generation specific TFP studies which used monetary method (the examples that PEG provided in their interrogatories were all for electric distribution, gas distribution, or integrated utilities).

<sup>&</sup>lt;sup>40</sup> LEI also interviewed OPG staff in order to understand the functionality of the assets and their ability to provide the same level of services over their service life.

<sup>&</sup>lt;sup>41</sup> Hosseini. Evaluating the efficiency changes of the Thermal Power Plants in Iran and Examining its Relation with Reform using DEA Model & Malmquist Index. Iran: University of Payame Noor, 2011.

<sup>&</sup>lt;sup>42</sup> PEG Report (2016). Page 29.

<sup>&</sup>lt;sup>43</sup> PEG Report (2016), Section 6.2.1, Page 58.

<sup>&</sup>lt;sup>44</sup> OEB (2014). Decision with reasons EB-2013-0321. Ontario Power Generation Inc. Page iii. November 20, 2014.

As discussed in Section 2.3, LEI reviewed eighteen TFP studies on electricity generation companies and distribution utilities published from 1987 to 2013, and all generation industry specific productivity studies used MWh as their key output specification. PEG reports that it reviewed fourteen studies of hydroelectric generation, none of which used MW as the singular output metric. All the studies reviewed by PEG use MWh as an output metric and only four used MW as a secondary output.<sup>45</sup>

Despite these issues, PEG chose to use MW ratings as the output measure in its TFP analysis.<sup>46</sup> This decision has important implications for the TFP estimate. Certain forms of capital productivity may not be properly captured based on the output metric chosen. The PEG analysis cannot capture the productivity benefits of common runner upgrade projects where the incremental investment increases output as measured by MWh, as discussed further below.<sup>47, 48</sup> Moreover, if the X-factor is calibrated to PEG's distorted TFP growth rates, then the underlying logic for financial capital maintenance is broken, as discussed above.

LEI also notes that PEG appears to have confused or misinterpreted statements from OPG's Annual Report<sup>49</sup> regarding the opportunities available to OPG to increase productive capacity. The referenced statements relate to sustaining expenditures - transformers, generators, headgates, controls, etc. replaced at end-of-life to <u>sustain</u> the productive capability of the assets, not to upgrade the productive capability. Some new equipment is more efficient, but this is not significant in relation to productive capability.

PEG criticized LEI for using the MWh metric because annual energy production volumes will change year over year due to exogenous drivers (weather) and therefore are not fully within management's control. PEG, however, overlooked the fact that LEI took this issue into

- <sup>47</sup> PEG confirms that the NTP also depress productivity growth under their methodology. Source: PEG's reply to OPG Interrogatory #11. Issue Number 11.1. EB-2016-0152, Exhibit M2, Tab 11.1, Schedule OPG-011, filed on December 14, 2016.
- <sup>48</sup> Although LEI's approach has the potential to underestimate the productivity benefits of projects that increase a plant's capacity rating, in reality there are few opportunities for capacity rating upgrades in the future, as discussed in Section 2.1 above.
- <sup>49</sup> PEG's reply to OPG Interrogatory #7. Issue Number 11.1. EB-2016-0152, Exhibit M2, Tab 11.1, Schedule OPG-007, filed on December 14, 2016.

<sup>&</sup>lt;sup>45</sup> PEG's reply to OPG Interrogatory #3. Issue Number 11.1. EB-2016-0152, Exhibit M2, Tab 11.1, Schedule OPG-003, filed on December 14, 2016.

<sup>&</sup>lt;sup>46</sup> This preference for an "abstract" model is in stark contrast to PEG's other work in Ontario, where they have selected output metrics that are practical. For example, PEG used a volumetric output metric (kWh of deliveries) as part of their TFP study of Ontario LDCs for OEB's RRFE. Source: OEB RRFE (2013). *Rate Setting Parameters and Benchmarking under the Renewed Regulatory Framework for Ontario's Electricity Distributors*. Issued November 21, 2013, corrected December 4, 2013. PEG has also used volumes of gas delivered (retail gas throughput) for studying the TFPO trend in the gas distribution utility sector. Source: Pacific Economics Group Research, LLC. *Statistical Analysis of Public Service of Colorado's Forward Test Year Proposal*. December 17, 2010.

consideration as part of the TFP study and remedied the impact of a volatile output metric using three corrective actions:<sup>50</sup>

- 1. LEI checked for anomalies in hydroelectric output relative to the long-term average and excluded utilities who power generation fleet experienced unusual water conditions during the study timeframe that would bias the results
- 2. LEI used a relatively long timeframe that "averaged" out year over year oscillations in output and limited the impact of any single year's contribution to the calculated average TFP growth rates.
- 3. LEI used a trend regression method to re-estimate the average TFP growth rate from the annual TFP Index values in order to remove the bias associated with the TFP Index values at the endpoints of the study timeframe.

In addition, by using the capacity as the output measure, PEG's analysis is not able to capture such projects as the NTP, while LEI's methodology does.<sup>51</sup> The NTP featured prominently in the PEG Report and discovery questions for LEI.<sup>52</sup> This is not surprising given the size and cost of this project. This \$1.5 billion project provided a projected average annual production increase of OPG's Sir Adam Beck ("SAB") generating complex (stations 1 and 2) of 1.5 TWh. However, the NTP did not increase the capacity of the SAB complex and will have limited reduction in O&M costs going forward for the fleet.<sup>53</sup>

Although NTP is a unique opportunity, the general premise of efficiency projects to increase production is not unique. In fact, OPG implemented runner upgrades on 75% of its hydroelectric generating capacity in the last 40 years, and the majority of these runner upgrades boosted the volume of energy generated (MWh over the course of a year) rather than the capacity (MW).<sup>54</sup> In effect, PEG's chosen output measure does not account for the majority of the efficiency projects that have been implemented by OPG.

54 Source: OPG.

<sup>&</sup>lt;sup>50</sup> LEI TFP Study (2016). Page 18.

<sup>&</sup>lt;sup>51</sup> PEG confirms that "using their methodology, the NTP would depress productivity growth in both the short and long run because it affects the generation volume of the SAB units but not their capacity." Source: PEG's reply to OPG Interrogatory #11. EB-2016-0152, Exhibit M2, Tab 11.1, Schedule OPG-011. Page 1 of 1, filed on December 14, 2016.

<sup>&</sup>lt;sup>52</sup> It is also important to note that the Niagara Tunnel Project ("NTP") was a unique opportunity for OPG (details of which are discussed in Section 3.2), and that no similar opportunities are anticipated for OPG.

<sup>&</sup>lt;sup>53</sup> See EB-2016-0152, Exhibit L, Tab 11.1, Board Staff Interrogatory #225 (a).

### 4 Other issues in PEG's analysis

In addition to the representation of the capital input quantity and choice of output metric, PEG made a number of other criticisms of LEI's TFP study. PEG suggested that the timeframe used in LEI's analysis was "too short" and also claimed LEI's selection of peers as "too small." However, in the end, PEG's analysis was no more robust with respect to these two issues.

### 4.1 Study timeframe

While PEG suggested that the timeframe used in LEI's analysis was too short, PEG's analysis and PEG's interrogatory responses suggest that a shorter timeframe (similar to that used by LEI) would be more appropriate.

PEG does not provide any fact-based justification for its 1996-2014 timeframe. In fact, PEG's analysis shows that there is a trend within their study that follows closely the technical "bathtub curve" that hydroelectric engineers commonly expect for this industry, as discussed in Section 2 above. As can be seen in the figure below, a 10-year moving average of TFP changes has generally gone down with time. This is not surprising given the expected need for additional maintenance as the asset ages.



When asked why more recent average TFP trends are lower than the counterparts that contain more years of data, PEG responded by noting that "utilities are no longer realizing appreciable scale economies and, as their facilities age, maintenance and replacement capex has loomed larger".<sup>55</sup> This is consistent with LEI's reasoning for using a more recent time period. The trend in TFP growth rates over time is simply documenting the reality of the slow pace of technology improvements in this industry once opportunities for new hydroelectric construction have been exhausted, as discussed in Section 2 above. PEG also agrees that "as plant ages, it's productivity growth is slowed since O&M and capital inputs are needed to maintain capacity," which would imply that more recent trends are more relevant going forward than trends from decades ago.<sup>56</sup> Both these points would suggest recent periods' TFP trends are more appropriate and accurate for use in calibrating an X factor for the next generation of IR for regulating mature hydroelectric assets. As a reference point, from the PEG Report, the industry average TFP growth rate for their sample and under their methodologies for the last ten years was -0.07%. And we know, from the discussion in Section 3, that this is an over-estimate of the TFP trends because of the bias created by their assumptions on capital depreciation rates. So, the TFP trend is likely to be even more negative under PEG's analysis, once their approach to depreciation rates has been corrected and the output metric has been calibrated to use generation.

#### 4.2 Selection of peers

Despite PEG's criticism of the peer group used in LEI's TFP study (2016), the PEG Report is based on an industry sample that is nearly 80% of the sample used by LEI as measured by relative share of installed capacity, after removing OPG from the sample.

PEG expressed concern with the sample size in LEI's study (which included 16 utilities). However, while PEG uses an industry sample that has seven companies that LEI had not included, these seven additional companies are very small (fleet size between 56 MW and 325 MW) and represent less than 6% of the industry sample in terms of installed capacity.<sup>57</sup> Moreover, PEG's study does not include the two municipal utilities that LEI had included, which in LEI's TFP Study (2016) represented 17% of the industry in terms of installed capacity (without counting OPG) with fleet size above 1,900 MW. Furthermore, the federal and municipal companies included in the LEI's TFP study contributed to a higher industry average TFP growth trend (removing these companies would results in even more negative TFP growth trend: -1.34% (if we continue to include OPG in the industry sample), and -1.74% (without OPG)). So, on a net basis,

<sup>&</sup>lt;sup>55</sup> PEG Report (2016). Page 52.

<sup>&</sup>lt;sup>56</sup> PEG's reply to OPG Interrogatory #6. Issue Number 11.1. EB-2016-0152, Exhibit M2, Tab 11.1, Schedule OPG-006, filed on December 14, 2016.

<sup>&</sup>lt;sup>57</sup> The added companies are Public Service Company of Colorado (395 MW of installed capacity, 1.6% of PEG's sample by hydroelectric plant in service 2014), and 6 small companies making up 4.1%: Puget Sound Energy, Duke Energy Progress, ALLETE (Minnesota Power), Green Mountain Power, New York State Electric & Gas, and Rochester Gas and Electric. Source: PEG Report (2016), Table 2 on page 47. A noteworthy observation is that PEG's additional peers are also pulling down the average industry TFP growth rate - from 0.05% to 0.33\$ considering the 2003-2014 timeframe – indicating indeed that scale impacts TFP growth and so rationalizes our approach to focus on firms with larger plants. Furthermore, from LEI's review of eighteen TFP studies, the number of companies in the power generation studies was under 15 companies, while distribution businesses studies included a much larger data set. The reason for the distinction is straightforward - there are simply fewer companies that operate in the hydroelectric generation space.

### 4.3 Inclusion of OPG in the industry sample

Finally, LEI disagrees with PEG's recommendation to remove OPG from the industry average. PEG claims that OPG creates a distortion in the TFP results, but that allegation does not prove true in LEI's TFP Study. Removing OPG from the peer group in LEI's analysis would not change the average TFP growth rate results materially: it only decreases the industry average TFP growth rate from -1.01% to a slightly more negative value of -1.11%. In fact, OPG's presence in the peer group improves the average industry TFP growth rate and it would therefore be conservative to include it, as it would lead to a higher TFP growth rate, holding all else constant.

PEG's TFP results are affected in the other direction when excluding OPG – but that is not necessarily an indication of the underlying productivity bias. We believe that this outcome is a consequence of the various assumptions PEG has made in its study, including the depreciation assumptions, and its choice of output. In addition, given that PEG included seven small utilities, which are not practically appropriate peers to OPG's hydro business, mathematically this would have predisposed the PEG analysis to view OPG as an outlier, as OPG appears even larger than the other peers (especially, given that PEG calculated "<u>size-weighted</u> averages" of trends).<sup>58</sup>

Consistent with regulatory precedent, LEI continues to believe that the regulated company should be part of the industry that is being examined for purposes of setting an X factor for that company unless it can be shown that its productivity trends are truly outside the norm. LEI understands that in some instances, data is simply not available for any period of time to allow for the regulated company's TFP trends to be considered as part of the industry. In such instances, proxies need to be developed. However, this is not the case for OPG. Data is available and OPG's TFP trends are not outside the range of the rest of the industry, per LEI's TFP Study. Therefore, it is not necessary or appropriate to exclude it.

<sup>&</sup>lt;sup>58</sup> PEG Report (2016). Page 46.

## 5 Concluding remarks

LEI's primary concern with the PEG Report is that it is based on assumptions that do not reflect the reality of the hydroelectric generation industry, and therefore produces a result that does not reproduce the productivity trends in that industry. The PEG Report is based on an estimate of capital quantities derived from a geometric depreciation profile, which will have biased its TFP estimates upward. And although OPG is under a price cap regime where the price cap is a volumetric rate denominated in dollars per MWh, the PEG Report does not include the volume of annual electric production as an output. As a result, the TFP trends PEG proposes – if applied to calibrate the X factor – may lead to capital insufficiency over time.