Before the Public Utilities Board of Manitoba

Manitoba Hydro

General Rate Application

2017/18 and 2018/19

Expert Testimony

of

Adonis Yatchew

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Executive Summary

Background

1. **Projected Rate Increases** In May 2017, Manitoba Hydro filed a General Rate Application seeking rate increases of 7.9% for 2017/2018 and 2018/2019. Manitoba Hydro was granted an interim rate of increase of 3.36% effective August 1, 2017. In a subsequent letter, dated September 5, 2017, Manitoba Hydro advised the Board that it projects rate increases of 7.9% for each of the upcoming six fiscal years followed by an increase of 4.54% in the seventh year. The cumulative effect would be to increase electricity rates by close to 50% in real terms over the coming decade.

2. **Purpose of Testimony** In broad terms, the purpose of this testimony is to assess the likely impacts on, and responses of various customer groups to rate increases of this magnitude, as well as the implications for the Manitoba economy as a whole.

3. **Manitoba Resources and GDP** From a resource perspective, the Province of Manitoba has the good fortune of being endowed with vast hydroelectric resources, very productive agricultural lands as well as deposits of some metals and minerals. Manitoba has a diversified economy. Much like most advanced economies, the dominant share of GDP – 71% – is in the service sector. Manufacturing comprises about 10% of GDP, construction 9%, agriculture 4%, mining about 2%. There is considerable variation in energy intensity and electricity intensity across the various sectors and sub-sectors.

4. **Sources of Energy** The dominant source of Manitoba energy (approximately 37% in 2015) is hydroelectricity. About 60% of energy consumed in the residential sector is electricity, the industrial sector electricity share is 50%, and the commercial sector share is about 40%. These shares are considerably higher than the corresponding Canada-wide electricity shares which are 42% for the residential sector, 19% for the industrial sector and 35% for the commercial sector. Manitoba's reliance on electricity has been largely the result of low-priced electricity over many years. It is also suggestive of the potential for substitution to other energy sources, for example to natural gas where it is available, in the event of large and sustained electricity price increases.

Key Energy Trends Affecting Manitoba and Manitoba Hydro

5. **Natural Gas Prices** Natural gas prices are low and are likely to remain low for the foreseeable future. The extraction of natural gas from shale using hydraulic fracturing ('fracking') has revolutionized North American natural gas markets leading to excess supply.

    a. In the U.S., low natural gas prices have led to increased reliance on natural gas for generation of electricity; the cost is approximately 5 cents U.S. per kWh for high capacity combined-cycle generation. This in turn has a direct impact on the competitiveness of Manitoba Hydro in export markets.

b. In Canada, low natural gas prices influence energy choices made by all classes of customers. The potential for substitution towards natural gas in the face of major electricity price increases is a significant risk for Manitoba Hydro.

6. **Oil Prices** The shale revolution has triggered profound change in world oil markets, not only because it has led to new sources of supply, but more importantly, because it is *scalable*. Shale oil can be brought on in tiny increments, allowing rapid response to increases in price and thereby reducing OPEC market power. Oil market analysts consider a return to the high oil prices (which exceeded $100 USD/barrel prior to 2014) unlikely. Continued low oil prices have a strong influence on the prosperity of Alberta and on future development of the oil sands, which indirectly affect the Manitoba economy.

7. **Exchange Rates** Canada's exchange rate has historically been closely linked to world oil prices. Exchange rates have an important effect on Manitoba's economy as they influence demand for, and revenues from exports, including those in the electricity sector. Expectations about future oil prices inform forecasts of Canada/U.S. exchange rates.

8. **New Energy Technologies** The costs of new key energy technologies have been declining rapidly. Since 2008, costs of wind generation have dropped by 41%; photovoltaic costs have dropped more than 50%; battery costs by 73%; and LED bulbs by a stunning 94%. Continuation of these trends could have an important impact on Manitoba Hydro domestic and export markets.

9. **Decentralization of Electricity Systems** Electricity systems are facing powerful decentralizing forces, in part as a result of the scalability of new generation and storage technologies, and the enabling effects of information technologies. On the other hand, Manitoba Hydro, because of its vast hydroelectric resources, continues to operate with a highly centralized model, relying on massive investments in generation and transmission. These large investments have long life-times, and face financial risks in a world of rapid technological innovation.

Demand Modeling and Elasticities

10. **Types of Energy Models** There is a voluminous literature on the estimation of energy models of supply and demand. Many of the papers pertain to the electricity sector. Broadly speaking, three types of data can be used to infer the impacts of prices and of many other variables.

    a. **Time-Series Models** By observing patterns of demand over time within a specific geographic area, one can infer impacts of price changes on demand, and how energy users adjust to such price changes. There needs to be sufficient variation in prices for such models to produce useful results.

    b. **Cross-Section Models** By observing patterns of demand across various geographical areas at a single point in time, one can infer how different locations have adapted to varying price points, the kinds of industries that have been attracted, and the response of residential and commercial customers.

c. **Panel Data Models** Time-series and cross section data can be combined into more comprehensive specifications which permit estimation of impacts across locations and through time.

Each approach has advantages and disadvantages, and each can inform the present discussion of the potential impacts of large price changes on demand.

11. **Types of Demand Elasticities** Two classes of response measures, or 'elasticities' are particularly germane to the current discussion: the responsiveness of electricity demand to changes in the price of electricity (the 'own-price' elasticity, or usually just the price elasticity of demand); and, the responsiveness of electricity demand to changes in economic activity, which in this case is Provincial GDP (the GDP elasticity).

    a. The price elasticity can be further refined to be sector specific, i.e., separate values may be estimated for the residential, commercial and industrial sectors.

    b. There is also a distinction between short-term (say one-year) and long-term elasticities. Energy use is determined to a large degree by capital goods which take time to replace. Thus, short-run responses are usually much more attenuated than longer-term ones.

    c. A separate critical objective of energy modeling is the identification of trends which are evolving over time, in particular energy intensity and electricity intensity trends.

12. **Estimates of Demand Elasticities** The vast demand modeling literature produces a *very* broad range of electricity demand elasticities. So-called meta-analyses seek to aggregate and distill the results from many papers into single estimates. Defensible, empirically based values which are relevant for the present Manitoba environment are presented below:

    a. a short-term price elasticity of -0.1 across all sectors; that is, an electricity price increase of 10% leads to a 1% decline in electricity demand in the short-term;

    b. a long-term overall price elasticity of -0.4; that is, an electricity price increase of 10% leads to a 4% decline in electricity demand in the long-term;

    c. long-term price elasticities of -0.35 for the residential and commercial sectors, and -0.5 for the industrial sector;

    d. a GDP elasticity of 0.8; that is, an increase in GDP of 10% eventually leads to an increase in electricity consumption of 8%.

Recent analyses suggest that long-term price elasticities are roughly three times short-term elasticities. Thus, impacts of price increases within the test period will not be fully realized for some time to come.

While elasticities proposed by Manitoba Hydro are not unreasonable, especially given the degree of uncertainty associated with estimation of demand parameters, those recommended above are better supported by the literature.

13. **Stagnant Electricity Demand** These recommended elasticities suggest that basic load (unadjusted for certain demand management activities) is likely to be stagnant over the coming decade. Suppose that cumulative increases in electricity prices are about 50% and that the economy grows at 2% per year, so that GDP is 22% larger ten years hence. Then the price increase reduces electricity demand by about 20% (-0.4 x 50%) and GDP growth increases demand by about 18% (.8 x 22%).

14. **Business Cycle Risks** The current economic expansion is in its ninth year, so that a recession may not be far off. This will have an adverse effect on electricity demand.

15. **Declining Energy Intensity** Over the last 25 years, energy intensity, that is the amount of energy used per dollar of GDP, has been falling by more than 1% per year in Canada, a figure comparable to the average for OECD countries. Manitoba energy intensity has been dropping more rapidly, at a rate closer to 2% per year.

16. **Electricity Intensity** Patterns of electricity intensity in Manitoba have been mixed. In the service sector, which is by far the largest, intensity dropped by about 25% between 2005 and 2012, but by 2015 it had recovered to 2005 levels. Intensity in the manufacturing sector peaked in 2005, and has been displaying a fairly steady decline since that time. Agricultural sector intensity remained high until 2005, but subsequently dropped significantly.

17. **Energy Poverty** Manitoba has a relatively low rate of energy poverty in comparison to some other provinces: about 7% of households spend 10% or more of their income on energy. However, the incidence of energy poverty varies significantly across the Province and is particularly high in remote communities where prices of many goods, among them energy, are high. The projected growth in electricity prices will increase rates of energy poverty.

18. **First Nations** The impact on energy poverty, which is already high in remote and First Nations communities, is likely to be especially acute given the limited possibilities for energy substitution. In addition, low incomes will hamper substitution of capital goods, such as improved insulation, and efficient windows and doors. Commercial and industrial establishments will also be adversely affected, particularly in the absence of energy substitutes such as natural gas.

Macroeconomic Issues

19. **Energy Price Shocks** Market economies have experienced major energy price shocks. Past experiences are helpful in bounding the likely effects of significant electricity price increases in Manitoba. The dramatic oil price shocks of the 1970s which were largely unanticipated, led to economic contractions of half a per cent or less. The cumulative impact on U.S. GDP of the oil price shock in the late 1970s is estimated to be about 3%.

20. **Risks Associated With Exchange Rates and Commodity Prices** Certain sectors of the Manitoba economy are subject to large, difficult-to-predict variations in key variables. Exporters are subject to exchange rate variations: over the last decade, the Canadian dollar has varied from below 70 cents/USD to well above parity. Wheat prices, which reached a post-recession high of

$9 US/bushel in 2012, have since declined to $4 - $5 US/bushel in 2017. Nickel, copper, zinc and gold prices have also exhibited large swings.

21. **Vulnerable Economic Sectors** Electricity prices affect all households, firms, institutions and agencies. The extent of response depends on the electricity intensity and alternatives available.

    a. In the manufacturing sector, the most vulnerable industries appear to be 'basic chemicals' and 'pulp and paper' where electricity comprises high shares of costs. Iron and steel mills, foundries and non-ferrous metal production also have significant electricity cost shares.

    b. In the agricultural sector, 'greenhouses' and 'animal production' have significant electricity cost shares.

    c. In the mining sector, 'support activities for oil and gas production' and extraction of metals also have significant electricity cost shares.

    Where natural gas is available, some of these industries may engage in fuel substitution. Others are likely to carefully consider, or reconsider future investment plans.

22. **Macroeconomic Impacts of Large Electricity Price Increases** In the event that large electricity price increases are approved over the coming years, the Manitoba economy will adapt.[1]

    a. The *net* effect on GDP may eventually be modest, but in the interim, there are likely to be significant adjustment costs.

    b. In some locations, particularly those which are heavily dependent on an industry that is sensitive to electricity prices, there could be large local impacts on employment, incomes and output.

    c. The projected rate increases are not of the same magnitude as the energy price shocks of the 1970s. However, given that in the short-term, demand for electricity is highly price-inelastic, the steepness of the projected rate increases will impose a significant burden, particularly on households, businesses and institutions that do not have access to substitutes, such as natural gas.

Concluding Observations

23. **Regulatory Signaling** The regulatory decision made in this proceeding, which ostensibly deals with rate increases over a two-year test period, will have an important impact on decision making by industry because it will signal the likely future path of rate increases. Approval of

[1] Ontario has experienced electricity price increases in excess of 50% since 2009. Notwithstanding these increases, and the fluctuations in exchange rates, the Ontario economy continued to grow and the manufacturing share remained steady at about 13% of Provincial GDP.

increases that are close to the proposed 7.9% will suggest the acceptance of Manitoba Hydro arguments, and its focus on the time profile of future financial ratios.

24. **Excess Capacity** Large increases will induce a price response, which in a period of excess capacity may be sub-optimal as it will erode revenues at a time when marginal costs of production are low.

25. **Cost Reductions** Manitoba Hydro operates under a 'cost-of-service' regulatory regime. (Many other jurisdictions have moved to a mode of incentive regulation in order to improve incentives for cost minimization.) Manitoba Hydro is implementing a "Workforce Reduction Plan" which would eliminate 900 positions (15% of the workforce) over the course of two to three years.[2]

26. **Intergenerational Fairness** One might ask whether the projected rate increases are equitable from an intergenerational standpoint.

    a. Expansion of hydroelectric systems, such as that in Manitoba, involves lumpy investments in generation (to exploit scale economies) and transmission (as supply sources are distant from load). They do not enjoy the beneficial scalability features of solar, wind and natural gas generation.[3]

    b. This leads to long-term cyclical pressures on rates. Current customers have benefited from past investments, particularly those that have been largely depreciated, but remain functional. Future customers will need to pay for current projects. The calculus of intergenerational fairness is therefore, at a minimum, complex, and may not lead to unequivocal answers.

    c. Rate-smoothing is a useful tool for promoting inter-generational equity. The projected profile is more in the nature of a step function over six years, followed by a rapid decline to increases close to the rate of inflation. A ramped sequence of increases, perhaps linked to a clear demonstration of efficiencies achieved by Manitoba Hydro, may provide a useful framework for promoting internal efficiencies, allowing time to adjust to electricity rates, and distributing costs more equitably over each generation of consumers.

27. **Mitigation of Rate Increases** The effects of the large projected increases, should they be approved, could in theory, be mitigated.

    a. Special industrial rates could be offered to those firms with large electricity cost shares. But this would be viewed as inequitable by other customers.[4] Alternatively, the Government might implement incentives to retain major industrial customers.

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[2] Manitoba Hydro, 2017/18 & 2018/19 General Rate Application, Integrated Financial Forecast, May 12, 2017, Tab 3, page 10 of 22.

[3] Or for that matter, shale oil extraction.

[4] Though rate design has inherent ambiguities. When there are significant common costs, there is no unique cost allocation based on the principle of cost causality.

b. There would be a substantial increase in the number of households facing energy poverty, however it is measured. To alleviate this effect will require funds either from other Manitoba Hydro customers, or from Government coffers.

28. **The Current U.S. Administration** In any discussion of Canada's economic circumstances, consideration of the effects of the current U.S. administration cannot be ignored. The North American Free Trade Agreement is being re-negotiated at the initiative of the U.S. At a minimum, this injects considerable uncertainty into trade relations with our largest trading partner. The U.S. administration has also altered direction on its decarbonization policies, disengaging from the Paris Agreement and making efforts to revive the coal industry. Together, these factors are likely to have a dampening effect on investment, and weaken prospects for long-term power sales agreements that are premised on clean hydro-electric power.

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A. Introduction

1. In May 2017, Manitoba Hydro filed a General Rate Application seeking rate increases of 7.9% for 2017/2018 and 2018/2019. Manitoba Hydro was granted an interim rate increase of 3.36%, effective August 1, 2017.[5] In a subsequent letter, dated September 5, 2017, Manitoba Hydro advised the Board that it projects rate increases of 7.9% for each of the upcoming six fiscal years followed by an increase of 4.54% in the seventh year.[6] The cumulative effect would be to increase electricity rates by close to 50% in real terms over the coming decade.

2. In broad terms, the purpose of this testimony is to assess the impacts on various customer groups and their likely responses; and to provide an analysis of the likely macroeconomic consequences of electricity price increases. We begin by situating the discussion within the context of Manitoba's economy, its patterns of energy and electricity use, critical trends related to energy, and the regulatory environment. In order to assess customer responses, we draw upon the large literature of energy modeling and in particular the estimation of price and income elasticities. Consideration is given to the incidence of energy poverty and the impacts on remote and First Nations communities. Subsequent sections discuss the likely macroeconomic effects of the projected rate increases.

3. In the concluding section, comments are provided relating the projected price increase to Manitoba's decarbonization agenda.

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[5] PUB Order 80/17, July 31, 2017, available at http://www.pubmanitoba.ca/v1/proceedings-decisions/orders/pubs/2017%20orders/80-17.pdf.

[6] Manitoba Hydro letter to the PUB, available at https://www.hydro.mb.ca/regulatory_affairs/pdf/electric/general_rate_application_2017/00.0000001_cover_letter_dated_september_5.pdf.

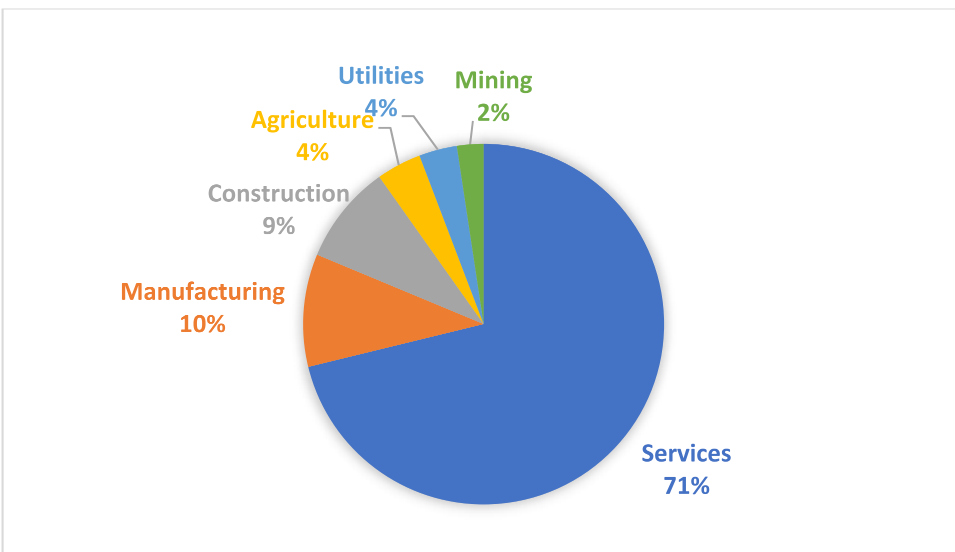
B. Background

B.1 Economic Setting[7]

4. Manitoba has a population of approximately 1.3 million. Its 2016 GDP was $67 billion with per capita output of $51,500. In part as a response to declines in commodity prices, Manitoba economic growth slowed during the 2014-2016 period, but is expected to have improved for the 2017 year. As a result of its industrial diversity, inter-provincial and international exports, high labour force participation and low per-capita debt, Manitoba's economic growth has been strong in comparison to a number of other provinces.

5. Manitoba is endowed with excellent fresh water and hydraulic resources, very productive agricultural lands, and a variety of deposits of metals and minerals. Its economy is well diversified. There is considerable variation in energy and electricity intensity across sub-sectors, making some firms more vulnerable to electricity price increases, while others more resilient to such price changes.

Figure 1: Manitoba GDP Shares 2016[8]

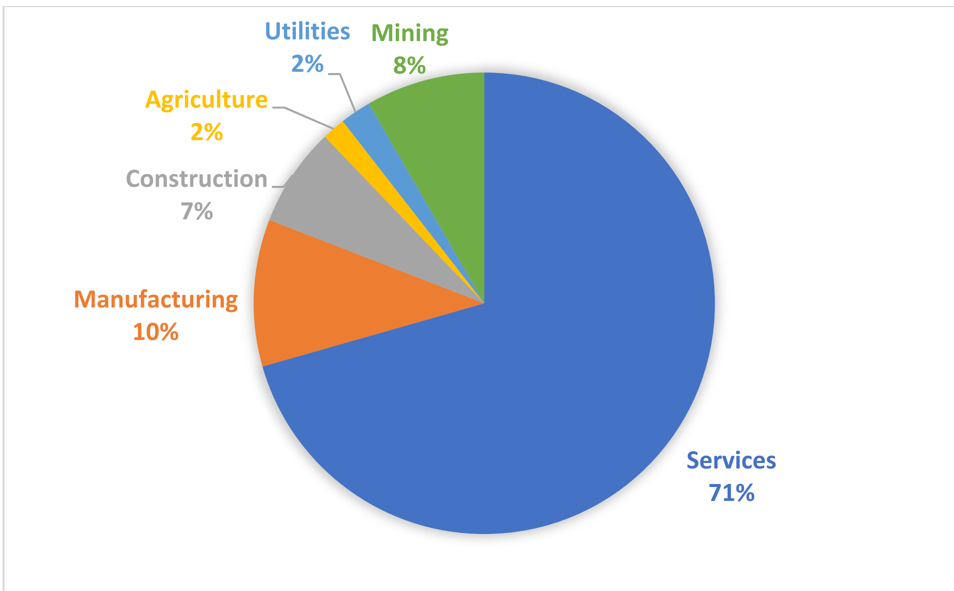


[7] See Manitoba Provincial Budget & Supporting Documents, available at http://www.manitoba.ca/budget2017/index.html and Manitoba Economic Highlights, https://www.gov.mb.ca/finance/pubs/highlights.pdf .

[8] Source: Statistics Canada, Table 379-0028 Gross domestic product (GDP) at basic prices.

6. Much like most advanced economies, the largest portion of Manitoba GDP -- 71% -- is in services. This sector comprises a virtually identical portion of Canada-wide GDP. (See Figures 1 and 2.) Major sub-sectors include real estate and rental and leasing (12%), wholesale and retail trade (11%), health care and social assistance (9%), public administration (8%), transportation and warehousing (6%), finance and insurance (6%), and educational services (5%).

Figure 2: Canada GDP Shares 2016[9]



7. Manufacturing comprises about 10% of Manitoba GDP. This sector consists of food processing, manufacture of transportation equipment (aerospace and motor vehicle), agricultural implements, chemicals (pharmaceutical and agricultural), metal and wood products and electrical equipment. Most manufactured goods are sold in other provinces or exported to the U.S. Export demand is sensitive to both exchange rates and economic activity in recipient countries.

[9] Source: Statistics Canada, Table 379-0031 Gross domestic product (GDP) at basic prices.

8. Exchange rates have an important effect on Manitoba's economy as they affect demand for, and revenues from exports, including those in the electricity sector. Canada's exchange rate has historically been closely linked to world oil prices, as we will discuss further below. Expectations about future oil prices inform forecast exchange rates.

9. In any discussion of Canada's economic circumstances, consideration of the effects of the current U.S. administration cannot be ignored. The North American Free Trade Agreement is being re-negotiated at the initiative of the U.S. At a minimum, this injects considerable uncertainty into trade relations with our largest trading partner. The U.S. administration has also altered direction on its decarbonization policies, disengaging from the Paris Agreement and making efforts to revive the coal industry.[10] Together, these factors are likely to dampen the Manitoba investment climate in the manufacturing sector, and weaken prospects for long-term power sales agreements that are premised on clean hydro-electric power.

B.2 The Manitoba Energy Sector

10. A particularly informative visual representation of energy sources and uses is provided by 'Energy Flow' diagrams, also known as Sankey diagrams. Figure 3 depicts this type of diagram for the Province of Manitoba. 'Pipe' diameters reflect the magnitudes of flows.[11]

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[10] Notwithstanding these developments, the U.S. Government released a major report confirming the anthropogenic nature of climate change. See "Climate Science Special Report", Fall 2017, available at https://science2017.globalchange.gov/chapter/front-matter-about/.

[11] Such diagrams have been in existence since the 1800s. They are widely used to depict energy flows, for example Lawrence Livermore National Laboratories (LLNL) produce such diagrams for all U.S. states, see https://flowcharts.llnl.gov/. LLNL also produces U.S. national carbon flow diagrams. The International Energy Agency produces Sankey diagrams at national and continental levels http://www.iea.org/Sankey/index.html#?c=World&s=Balance.

Figure 3 was produced using *e!Sankey* software, https://www.ifu.com/e-sankey/ based on CANSIM data.

For further discussion of uses of Sankey diagrams, see *Economist*, "Data Visualisation, Sankey or Harness?" July 4th,2011; A. Yatchew, "Economics of Energy: Big Ideas for the Non-Economist", *Energy Research and Social Science*, 1(1), 2014, pages 74-78; "Using Sankey diagrams to map energy flow from primary fuel to end use", Veena Subramanyam, Deepak Paramshivan, Amit Kumar, Md. Alam Hossain Mondal, *Energy Conversion and Management*, 91, 2015, pages 342–352; and A. Yatchew 2016: "Rational vs 'Feel-Good' Carbon Policy", *Energy Regulation Quarterly*, Vol. 4, Issue 3,

11. At the top left is the total 'primary' energy of all types which in 2015, the latest year for which comprehensive data are available, was 334 peta joules (PJ). The total is obtained by summing the values of the five primary sources of energy on the left (wind, hydro, natural gas, coal and petroleum).

12. The left side of the diagram represents the supply side, while the pink boxes on the right represent the demand side.

13. The largest source of energy in Manitoba is hydraulic, which comprises about 125 PJ, or 37% of total energy. Almost all electricity produced in Manitoba comes from hydraulic sources. The second largest source of energy is petroleum at 116 PJ, or 35% of provincial energy, the vast majority of which is used in the transportation sector. The third largest energy source is natural gas at 88 PJ or 26% of total energy.

14. Next consider the demand side, which is comprised of residential, commercial, industrial and transportation sectors.[12] Manitoba's successful development of cheap and accessible hydraulic electricity is reflected in its share of total energy, and its shares within each end-use sector.

    a. About 60% (30 PJ of 50 PJ) of energy used in the residential sector is electricity.
    b. For the industrial sector the share is 50% (33 PJ of 66 PJ).
    c. For the commercial sector the share is 39% (19 PJ of 49 PJ).

In short, Manitoba is an electricity intensive province where hydraulic energy represents the largest energy source. This is a price phenomenon, thanks to abundant hydraulic sources.[13]

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http://www.energyregulationquarterly.ca/articles/ rational-vs-feel-good-carbon-policy-transferability-subsidiarity-and-separation#sthash.GBtFuIOG.dpbs.

[12] There is also a non-energy sector which corresponds primarily to petrochemical feedstocks.

[13] A comparison with Canada-wide numbers illustrates the point. Natural gas is the dominant fuel in the residential, commercial and particularly the industrial sector where more than 50% of energy comes directly from this source (as well as a portion that comes indirectly through gas-fired electricity generation). See Canada-wide Sankey diagrams available at https://www.economics.utoronto.ca/yatchew/.

15. The Sankey diagram depicting energy flows in Manitoba (Figure 3) also provides a departure point for considering the impacts of changes in the price of electricity. Where natural gas is available, substantial increases in electricity prices could lead to substitution to gas in the residential, commercial and industrial sectors, particularly given the relatively low shares of natural gas there.

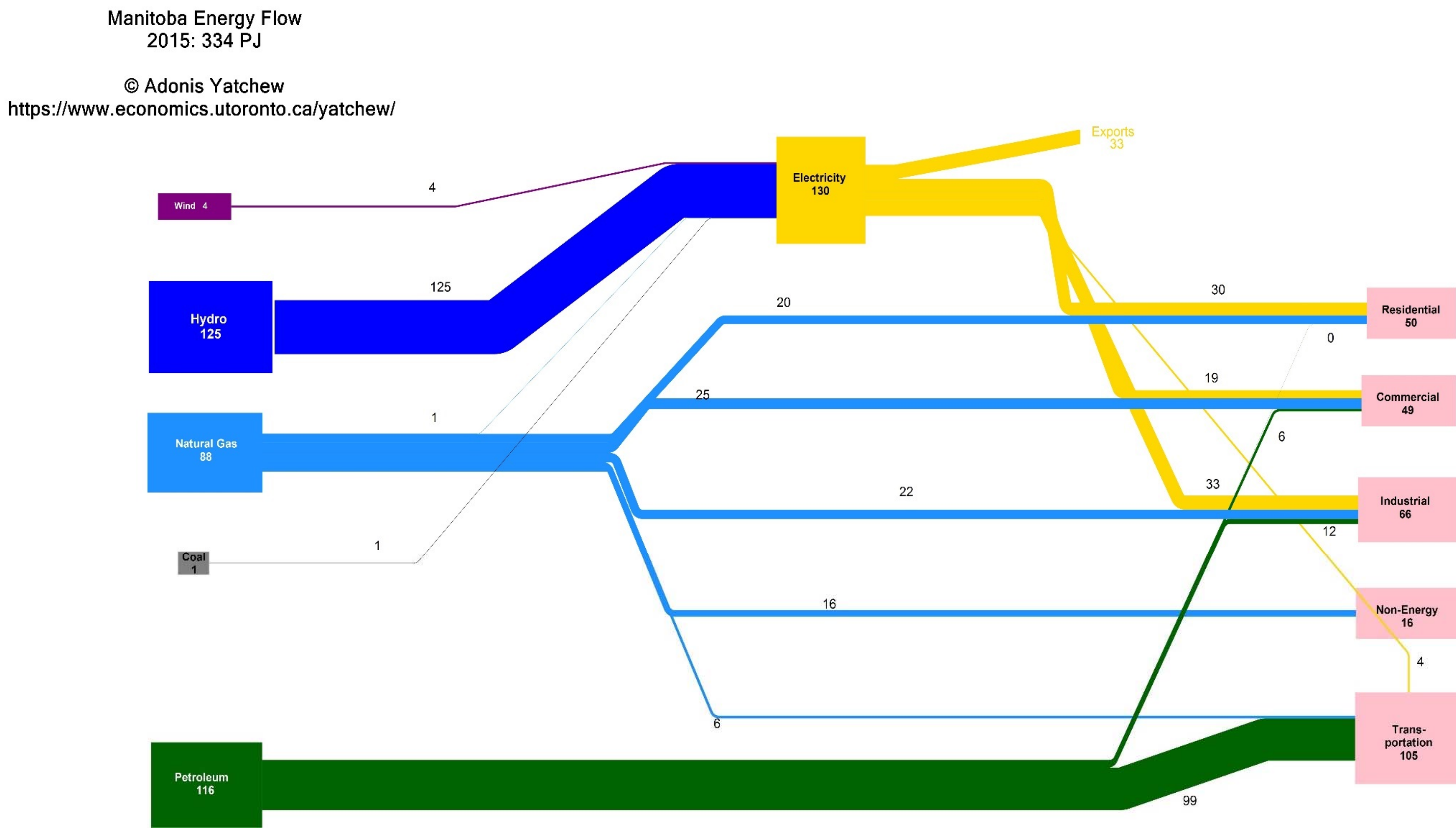
16. There is great potential for increased electricity consumption in the transportation sector, but a dramatic shift awaits further large drops in the costs and range of future generations of electric vehicles. In Manitoba, such a shift would contribute greatly to the decarbonization agenda as Manitoba has large supplies of clean hydraulic sources for the foreseeable future.

17. The energy in each sector either produces 'energy services' or is lost, usually in the form of heat. The least 'efficient' sector is transportation where 75%-80% of energy is 'rejected'. Depending on the source of energy and the types of uses, efficiency in the residential, commercial and industrial sectors ranges from 50% to 80%. While it might appear that we are very inefficient, 'wasting' well over half of the energy we produce, this is primarily a reflection of the state of technology and the second law of thermodynamics which states that whenever energy is transformed from one form to another, a portion is lost.[14]

18. The Sankey diagram is also useful for informing decarbonization discussions. Manitoba is very well positioned with such a large share of hydraulic source energy. Its use of coal is minimal and the remainder of non-transportation energy comes from natural gas, the hydrocarbon with the lowest carbon footprint (roughly half that of coal). The dominant share of energy-related carbon generated in Manitoba is in the transportation sector, which is the most difficult to decarbonize.

[14] Estimates produced by Lawrence Livermore National Laboratories suggest that roughly two-thirds of energy in the U.S. is 'rejected' and only one third produces energy services. See https://flowcharts.llnl.gov/content/assets/images/energy/us/Energy_US_2016.png.

Figure 3: Manitoba Energy Flow (Sankey Diagram)



B.3 Oil and Natural Gas Markets

19. An understanding of oil and natural gas markets and scenarios of their future price paths is important to the current analysis in several ways.

    a. First, natural gas competes with electricity in certain industrial, commercial and residential applications, particularly if the end-use is space heating or process heat. A large increase in electricity prices could lead to loss of electricity load to natural gas.

    b. Second, low-priced natural gas is the 'go-to' fuel for electricity generation in many parts of North America, including states neighboring Manitoba, and the MISO transmission system to which Manitoba belongs.[15] This in turn affects Manitoba Hydro export markets.

    c. Third, oil prices have an important impact on Canadian export revenues and on exchange rates. The precipitous decline in oil prices which began in mid-2014 has had a dramatic impact on the economy of Alberta and to a lesser degree on Saskatchewan and Manitoba. Canada has vast reserves of oil, mainly in the form of bitumen. But these reserves are among the highest priced in the world.

20. What is the outlook for natural gas prices? A decade ago, it was widely believed that the U.S. would need to begin importing natural gas. Liquid natural gas (LNG) terminals were planned and some were built.[16] Then came the shale revolution. By efficiently combining

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[15] Low natural gas prices have led to a significant shift away from coal-fired electricity generation in the U.S. towards natural gas generation. Roughly comparable amounts of electricity are generated from each of these two sources in the U.S.

[16] LNG shipping requires liquefaction terminals at the exporting site, and re-gasification at the importing site. Initially, the U.S. began to build re-gasification terminals. These sites have been largely converted to liquefaction. Qatar is the largest LNG exporter, followed by Australia. Floating storage and re-gasification carriers can serve as LNG importing terminals.

two technologies – horizontal drilling and hydraulic fracturing (fracking) – cost-effective North American gas reserves grew very rapidly.

Figure 4: Gas prices

USD/mmBtu

BP Statistical Review of World Energy 2017 © BP p.l.c. 2017

21. Natural gas prices worldwide dropped dramatically in 2009, as a result of the financial crisis. However, by 2012 they had recovered *except* in North America (Figure 4).[17] What we observed were the consequences of shale revolution. This in turn led to a reconfiguration of natural gas flows across North America as major natural gas supplies were developed, for example, in Texas and Pennsylvania, reducing the need for Canadian natural gas and leading to reduced use of the TransCanada Mainline.

22. In the past, natural gas markets have been continental (hence the separate benchmark prices in Figure 4). But recently, there has been a gradual globalization as LNG becomes

[17] LNG prices in Japan sky-rocketed in 2011 as a result of the Fukushima meltdown.

increasingly competitive in overseas markets. By 2015 about 40% of total natural gas trade moved by sea, and prices in distant markets began to converge.[18]

23. While globalization increases the demand for North American natural gas, there is little evidence to suggest that a dramatic price increase is likely; natural gas will continue to provide strong competition to electricity.

24. Though largely unanticipated, the revolution in natural gas would eventually lead to perhaps the most dramatic change in oil markets since the 1970s OPEC price increases.[19,20] One might think that the main effect of the fracking revolution on oil prices is through the increase in recoverable supplies. However, the peculiar features of the shale revolution have altered the nature of oil markets in another critical way. For the first time, additional oil can be brought online in tiny increments – the cost of a productive shale well is *three orders of magnitude* smaller than Arctic or deep-sea projects.

25. The ***scalability*** of shale has fundamentally altered the strategic behavior of OPEC. Whereas in the past OPEC might have coordinated a supply reduction to sustain prices, it is far more limited now in its ability to do so because shale producers (and others) can fill the gap. Shale has provided for a scalable response by many producers as market conditions change. This feature further limits unilateral or cartelized market power.

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[18] "Long Promised, the Global Market for Natural Gas Has Finally Arrived", Russell Gold and Alison Sider, *Wall Street Journal*, June 6, 2017. See also MIT Energy Initiative, *The Future of Natural Gas*, Cambridge: June 2011.

[19] Though in 2012, Berkeley physics Professor Richard Muller writes "Shale oil production could truly be a disruptive technology, with a large and positive impact on the US balance of trade, severe repercussions for the OPEC oil cartel, and a serious challenge to alternative-transportation technologies, particularly natural gas and synfuel. Shale oil could turn conventional oil into the new whale oil, replaced by a far more abundant source." Richard A. Muller, *Energy for Future Presidents: The Science Behind the Headlines*, 2012, (Kindle Locations 1679-1682). W. W. Norton & Company. Kindle Edition. In that same book, Muller sees $60 USD / barrel as a long-term limit price for oil. At the time of his writing, the world price of oil was well over $100 USD / barrel.

[20] The historic paths of oil and (North American) natural gas prices display a surprising degree of correlation. In fact, some have argued that the drop in world oil prices beginning in 2014 was signaled by the decline in North American natural gas prices which began in 2008. See, e.g., Dimitri Dimitropoulos, and Adonis Yatchew 2017, "Discerning Trends in Commodity Prices", *Macroeconomic Dynamics*, doi:10.1017/S1365100516000511.

Scalability of shale also reduces risks – wells do not last long, but capital requirements are low and lead-times short.

26. Not long ago, 'peak oil' meant that one day, in the not too distant future, we would reach peak production as supplies ran out. Now 'peak oil' refers to the day when demand levels off and begins to fall. Technological innovations to a post-carbon world are leading the way. Shale, bitumen and undersea resources are unlikely to run out, and the key question is what fraction of proven reserves will *not* be extracted. This in turn creates incentives for those with large cheap reserves (such as Saudi Arabia) to sell more today rather than saving reserves for an uncertain future.[21]

27. In the absence of innovation in electric vehicles which would lead to their wide spread adoption in growing economies such as China and India, demand for oil should continue to grow for a time. The question is when we will reach the tipping point in the sector that is the most difficult to decarbonize – transportation.

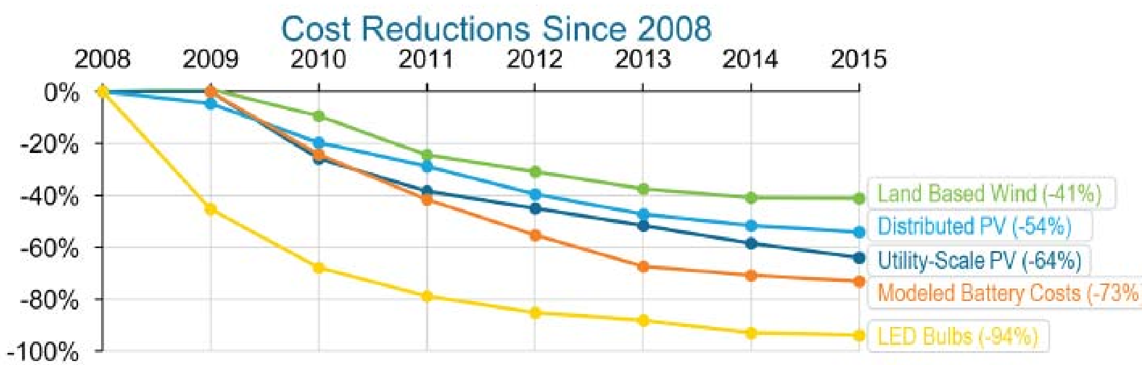
28. To summarize, low natural gas prices exert competitive pressures on Manitoba Hydro in domestic markets to the extent that they provide a viable alternative to electricity, and in export markets because they drive down electricity prices there. Low oil prices put downward pressure on the exchange rate, which enhances export competitiveness of Manitoba industries and improves Canadian dollar revenues of Manitoba Hydro electricity sales.

[21] See, for example, "Get Ready for Peak Oil Demand. There's a growing consensus that the end of ever-rising consumption is in sight. The big question that many oil companies are debating: When?", Lynn Cook and Elena Cherney, *Wall Street Journal*, May 26, 2017.

B.4 Costs of Key Technologies Have Been Dropping Dramatically

29. The costs of emerging technologies which are transforming electricity industries have been dropping at a rapid pace. Since 2008, costs of wind generation have dropped by 41%; photovoltaics have dropped more than 50%; battery costs by 73%; and LED bulbs by a stunning 94%. (See Figure 5 below.)

Figure 5 – Cost Reductions in Key Technologies[22]



30. Non-dispatchable generation such as on-shore wind is priced at about 5 U.S. cents/kWh for new installations at a capacity factor of 39%. Solar photo-voltaic is at 7 U.S. cents/kWh at a capacity factor of 26%. Combined cycle natural gas electricity generation for new installations costs about 5 U.S. cents/kWh if used at high capacity (87%), and conventional combustion turbine generation is at about 9 U.S. cents/kWh if used at low capacity (30%).[23]

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[22] Source: "Revolution … Now, The Future Arrives for Five Clean Energy Technologies – 2016 Update", U.S. Department of Energy, September 2016. Available at https://www.energy.gov/eere/downloads/revolutionnow-2016-update. "Notes: Land based wind costs are derived from levelized cost of energy from representative wind sites… Distributed PV cost is average residential installed cost... Utility-Scale PV cost is the median installed cost… Modeled battery costs are at high-volume production of battery systems, derived from DOE/UIS Advanced Battery Consortium PHEV Battery development projects. LED bulb costs are cost per lumen for A-type bulbs..."

[23] These are Levelized Cost of Energy (LCOE) numbers which embed assumptions about depreciation lifetimes, cost of fuel and, as indicated, utilization capacity factors. U.S. Energy Information Administration April 2017 *Table A1a. Estimated LCOE (weighted average of regional values based on projected capacity additions) for new generation resources, for plants entering service in 2019* ", available at https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf. Combined heat and power systems, because of their high efficiency, have the potential for

B.5 Decentralization of Electricity Systems

31. Historically, the centralized structure of electricity industries has been driven by three critical features. First, non-storability of electricity meant that supply and demand needed to be balanced virtually instantaneously. Second, scale economies in generation led to electricity being produced at a relatively small number of locations. Third, the essentiality of electricity to every-day life underscored the need for a very high degree of reliability.

32. Scale economies in electricity generation increased into the 1970's, at which time they began to level off. Minimum efficient scale declined. Electricity networks, both transmission and distribution, which would transport and distribute electrons, were and continue to be natural monopolies, but at different spatial scales.[24]

33. In many jurisdictions, as a result of scale economies, (and some have argued due to vertical economies of scope), the electricity industry was vertically integrated, as is the case in Manitoba. In other jurisdictions, the distribution segment of the industry was serviced by a number of distributors.

34. By the late 20th century, the centripetal forces which centralized electricity industry structure began to weaken. The generation segment in many instances was no longer seen as a natural monopoly.[25] In various jurisdictions, the separation of natural monopoly components (i.e., transmission and distribution) from potentially competitive segments (i.e., generation and energy services) took place. This 'unbundling' was intended to lead

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increasing market penetration. See *Combined Heat and Power Technical Potential in the United States,* U.S. Department of Energy, March 2016, available at https://www.energy.gov/sites/prod/files/2016/04/f30/CHP%20Technical%20Potential%20Study%203-31-2016%20Final.pdf; also *Many industries use combined heat and power to improve energy efficiency*, U.S. Energy Information Administration, July 27, 2016, available at https://www.eia.gov/todayinenergy/detail.php?id=27252.

[24] The power grid was named the greatest engineering achievement of the 20th century by the U.S. National Academy of Engineering. The main selection criterion was "how much an achievement improved people's quality of life". See "Great Achievements and Grand Challenges", *The Bridge*, September 1, 2000 Volume 30 Issue 3 and 4, pages 5-10.

[25] Previously, efficient scale for coal-fired and nuclear units was on the order of 1000 MW. The size of hydro-electric units depended critically on siting.

to increased competition, primarily in generation. In a few jurisdictions, industries were restructured and competitive forces were introduced, with varying degrees of success.

35. Still, the need for coordination, reliability and the natural monopoly characteristics of the grid, continued to be the fundamental centralizing drivers of the structure of the industry.

36. Transformation of electricity industries began gradually in the first decade of the 21st century. The information revolution had spawned new technologies, often called 'smart' technologies, which would improve responsiveness of the grid, facilitate more rapid identification and correction of faults, and eventually enable demand side response to grid or market conditions.

37. At the same time, the decarbonization agenda, which was being pursued most aggressively in Europe, began to drive innovation in renewables. Feed-in-tariffs and other stimuli were producing rapid cost declines and efficiency improvements in renewable technologies, particularly in solar and wind generation.[26] While one tends to associate successful implementation of solar technology with sun-lit locations and relatively little precipitation, grid parity is being achieved in some countries that are not endowed with either of these traits.[27]

38. Because solar and wind generation are non-dispatchable, i.e., intermittent, the value to the system is not fully reflected by the costs of production. Backup generation (usually natural gas) or electricity storage is required to ensure that sufficient electricity is available when needed.

[26] Between 2010 and 2016, average prices resulting from auctions have declined from about $90 USD/MWh to below $50 USD/MWh for wind generation. For solar, the decline for the same period has been from $250 USD/MWh to about $50 USD/MWh, a precipitous drop. See *Renewable Energy Auctions. Analysing 2016*, International Renewable Energy Agency, 2017, page 16, Figure 2.1, available at http://www.irena.org/DocumentDownloads/Publications/IRENA_Renewable_Energy_Auctions_2017.pdf.

[27] A 10 MW solar farm in the UK has recently been built without government subsidy. See "Solar Power Breakthrough as Subsidy Free Farm Open", by Nathalie Thomas, *Financial Times*, September 25, 2017, accessed at https://www.ft.com/content/8ea432e4-a1e9-11e7-9e4f-7f5e6a7c98a2. Note that this facility is two orders of magnitude smaller than conventional coal-fired stations of 1000 MW.

39. Storage technologies have also been experiencing major cost reductions, but have not yet reached a tipping point. Though, in some instances, solar-cum-battery installations have achieved unexpectedly low costs.[28]

40. Solar is extremely scalable (think solar powered calculators and parking meters) though larger facilities enjoy a significant cost advantage over small scale roof-top installations.

41. Scalability and storage, supported by innovative uses of information technologies, are combining to disrupt the conventional utility model. And that model is more susceptible to disruption if the price of electricity is relatively high. Residential and commercial customers are then more likely to invest in on-site solar to reduce their overall electricity costs.

42. Self-generation and 'net-metering' is posing a serious challenge to the conventional electricity utility model. In some jurisdictions this has led to a confrontation between utilities and their owners, and companies selling and installing distributed solar generation, and their customers.[29]

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[28] In January 2017, a Hawaii electricity cooperative signed an agreement paying $110 USD / MWh for dispatchable electricity from a combined solar and battery storage system. See "Hawaii co-op signs deal for solar+storage project at 11¢/kWh", by Gavin Bade, *UtilityDive*, January 10 2017, accessed at http://www.utilitydive.com/news/hawaii-co-op-signs-deal-for-solarstorage-project-at-11kwh/433744/ . A few months later, Tucson Electric signed a similar deal but at a much lower price. See "Updated: Tucson Electric signs solar + storage PPA for 'less than 4.5¢/kWh'", by Gavin Bade, *UtilityDive*, May 23, 2017, accessed at http://www.utilitydive.com/news/updated-tucson-electric-signs-solar-storage-ppa-for-less-than-45kwh/443293/ .

[29] Perhaps the most prominent clash has been between Warren Buffet, whose Berkshire Hathaway owns NV Energy, a Nevada electricity utility, and Elon Musk, whose SolarCity company installs solar panels. See "In a clash of titans, Warren Buffett beat Elon Musk in Nevada", Nick Cunningham, *Business Insider*, December 30, 2015, http://www.businessinsider.com/warren-buffett-beat-elon-musk-on-solar-in-nevada-2015-12?pundits_only=0&get_all_comments=1&no_reply_filter=1; "Warren Buffett controls Nevada's legacy utility. Elon Musk is behind the solar company that's upending the market. Let the fun begin", Noah Buhayar, *Bloomberg Businessweek,* January 28, 2016, https://www.bloomberg.com/features/2016-solar-power-buffett-vs-musk/; "Solar Showdown In The Nevada Desert: Warren Buffett Vs. Elon Musk?", Michael Lynch, *Forbes*, February 23, 2016, https://www.forbes.com/sites/michaellynch/2016/02/23/solar-showdown-in-the-nevada-desert-buffett-vs-musk/#5b845aed1766; "Buffett vs. Musk: The clash of old and new energy titans", Daniel Rothberg, *Las Vegas Sun*, May 2, 2016, https://lasvegassun.com/news/2016/may/02/buffett-vs-musk-the-clash-of-old-and-new-energy-ti/.

43. In a landmark study entitled *Utility of the Future,* a group at MIT has conducted a wide-ranging analysis of how the electricity utility business is changing, and how companies, regulators and policy-makers need to adapt.[30] That study argues that fundamental changes are underway in the supply and consumption of electricity. Among the major factors driving the change are "emerging distributed technologies -- including flexible demand, distributed generation, energy storage, and advanced power electronics and control devices". Rapidly decreasing costs in information technologies are enabling synchronization of various energy supply, demand and storage resources.

44. The MIT study identifies a series of core findings ranging from the importance of accurate price signals (locational and temporal), the need to improve regulatory models, the potential for cost savings arising out of more efficient use of existing assets, and even privacy and cybersecurity issues as interconnectedness increases (for example, through 'smart appliances').

45. While at first it might appear that the *Utility of the Future* study may bear little relationship to the main objectives of this proceeding, particularly as Manitoba Hydro is in a position of excess capacity for some time to come, there are at least two reasons why an appreciation of industry evolution is relevant.

    a. First, an understanding of how other utilities are adapting to the proliferation of new technologies and uses of electricity, can inform Manitoba Hydro's planning and forecasting. In the presence of sufficiently high rate increases, there may be significant risk of loss of load in one or more market segments, in ways that cannot be directly extrapolated from price elasticities based on historical data, but may be heralded by experience elsewhere.

    b. Second, understanding how electricity and energy industries are evolving, particularly in neighbouring jurisdictions, can provide insights into Manitoba's electricity export markets.

[30] *Utility of the Future. An MIT Energy Initiative response to an industry in transition*, MIT Energy Initiative, December 2016, available at http://energy.mit.edu/publication/utility-future-report/.

46. While generation will likely be progressively decentralized, some have argued that electrification of energy systems (think transportation sector in the Sankey diagram at Figure 3) will require modernization and even expansion of electricity grids.[31]

47. Finally, in a world where infrastructure security (including cybersecurity) is becoming an increasingly important issue, decentralization of electricity system may provide an important measure of protection.

B.6 Regulatory Considerations

48. Manitoba Hydro operates in what is essentially a 'cost-of-service' regulatory regime. This form of regulation, and its sibling 'rate-of-return' regulation, have been in existence since the late 19th century. Under these regimes, the regulator reviews the 'revenue requirement', that is the amounts required to meet costs, in some cases disallowing or trimming certain ones, then sets rates to each customer class.

49. Cost-of-service regulation prevailed for much of the 20th century. Keeping in mind that increasing returns to scale and productivity growth were driving down unit costs in North America until the 1970s, the task of regulators was easier as the objective was to determine how to allocate these benefits to customers and producing firms.

50. During the 1970s, oil price shocks led to upward pressure on electricity prices, particularly in jurisdictions where the generation mix relied to a significant degree on hydrocarbons. A significant portion of electricity in the U.S. was generated using oil. What is less understood is the indirect effects of oil price increases on natural gas and coal prices. The

[31] See "Utility Touts Electrification to Meet California Climate Goals" Russell Gold, *Wall Street Journal*, October 31, 2017, available at https://www.wsj.com/articles/utility-touts-electrification-to-meet-california-climate-goals-1509457320.

flight from oil by generators to these other hydrocarbons put upward pressure on those prices as well, spreading the impact.[32]

51. Pressure began to accumulate on regulators and policy-makers to control electricity prices. In some instances, accounting devices were used to mitigate rate increases. For example, asset lifetimes were extended, thereby reducing annual depreciation expense. In other cases, rate increases were delayed (so-called regulatory lag) to put pressure on electricity companies to reduce costs.

52. Theorists had already identified limitations of the prevailing regulatory model. Costs of regulated monopolies were not being disciplined by market forces, leading to inefficiency and 'gold-plating'.[33] Developments in the economic theory of regulation suggested new directions. The crux of the regulatory problem was that regulators, no matter how skilled, experienced and well-supported, were greatly disadvantaged in trying to assess what 'reasonable costs' should be. The mountains of data that one would need to process and evaluate represented a Herculean task. (This became known as the 'asymmetry of information' problem.)

53. Rather than relying exclusively on a regulatory process to discover the achievable minimum costs, theorists suggested that instead, the regulatory mechanism should enhance the incentives for regulated firms to minimize costs, and to reveal the savings and productivity gains to the regulator, at least over some period of time.

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[32] There is a surprising degree of co-movement of oil, natural gas and coal prices. See Dimitropoulos and Yatchew 2017, *op. cit.*

[33] For example, the so-called Averch-Johnson effect asserts that under rate-of-return regulation, firms expand capital expenditures in order to earn a higher volume of returns. This in turn leads to excess capital, and potentially inefficient input mix. Averch, Harvey; Johnson, Leland L. (1962) "Behavior of the Firm Under Regulatory Constraint", *American Economic Review*, 52 (5): 1052–1069.

54. These regulatory models fall under the general rubric of incentive regulation.[34] The most commonly applied version is price-cap regulation.[35] The emergence of incentive regulation coincided with the broad world-wide trends towards deregulation, privatization and an increased reliance on the market-place and individual choice.[36]

55. How are these regulatory considerations relevant to this proceeding?

a. First, Manitobans have been fortunate to have had the benefit of low electricity rates for many years. However, given current and future cost projections, there may be increasing pressure to shift towards a model which creates greater incentives for cost containment. This, at least, has been the pattern in other jurisdictions.

b. Second, the business community, particularly those segments for which electricity costs comprise an important share, are forming their expectations about future electricity prices in part based on whether the regulatory framework is well equipped to incentivize productivity growth and cost savings at Manitoba Hydro. Their decisions to expand or even situate themselves here are informed by these expectations.

c. Third, the financial community, which assesses debt worthiness, is carefully attuned to the regulatory model. The ability of Manitoba Hydro to service its debt and maintain healthy financial ratios, or at least to have them trending in the right direction, depends on Manitoba Hydro costs and rates, both of which are dependent on the regulatory

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[34] Though the idea comes in many flavours, e.g., performance-based regulation, yardstick regulation, and so on.

[35] Price-cap regulation was first applied in the telecommunications industry in the U.K. It then spread to other network and energy industries. Steven Littlechild is often associated with its earliest implementation, though many economists contributed to the development of the ideas.

[36] An admittedly over-simplified narrative would describe the 'market failure' known as the Great Depression of the 1930s leading to decades of increased regulation and government intervention. The 1970s, a period of high inflation and unemployment, was seen by many as a 'government failure' which in turn brought a period of deregulation and privatization. It is during this period that incentive regulation had its intellectual and practical roots. See Yatchew, A. 2014 "Economics of Energy: Big Ideas for the Non-Economist", *Energy Research and Social Science*, 1(1), 74-82.

model, the decisions of the regulator and the direction set by the Government and policy makers.

56. Governments are perpetually under pressure to influence electricity prices, particularly in jurisdictions where the utility is publicly owned, such as is the case in Manitoba.[37] This in turn, can lead to delays in cost recovery and inter-generational redistributions.[38]

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[37] The public complains when oil prices increase, but does not assign blame to the government. In fact, the variation in oil and gasoline prices has been far larger than the changes in electricity prices which are deliberately stabilized.

[38] The Ontario Government's financing of electricity rate reductions through debt flotation has come under heavy criticism from the Office of the Auditor General of Ontario, *The Fair Hydro Plan: Concerns About Fiscal Transparency, Accountability and Value For Money*, October 17, 2017, http://www.auditor.on.ca/en/content/specialreports/specialreports/FairHydroPlan_en.pdf

C. Demand Modeling

C.1 Energy Demand Modeling

57. In order to formulate a view on price elasticities of electricity demand, it is first helpful to understand how they are obtained. Elasticities are not estimated in isolation, but rather derived from more general models that try to incorporate various factors that influence the demand for electricity.

58. Numerous studies of energy demand have been conducted in many geographic locations. In the first instance, studies may be organized by the type and origin of data upon which they rely, such as
    a. geographical area
    b. individual data vs. aggregate data
    c. customer type -- residential, commercial, industrial
    d. time series, cross-section, or data that combine both time and spatial dimensions (i.e., panel data)
    e. sample period and frequency of data (e.g., monthly vs. annual)
    f. single equation vs multi-equation (e.g., electricity, natural gas and oil). [39]

59. Studies also differ by virtue of the econometric specification and their degree of sophistication. Distinguishing features include the flexibility that the model allows, for example, whether it captures potentially nonlinear responses to price changes; and whether key parameters evolve over time.

60. The work-horse of demand modeling is the log-linear model which in its very simplest form is given by $\log(y) = \alpha + \beta \log(x) = \varepsilon$ where x is price and y is demand. Such models are especially convenient because the coefficient β is the response elasticity. For

[39] There are also studies which focus on demand for energy services rather than energy types. Other models combine capital decisions with energy consumption. A classic, widely cited paper in this literature is "An Econometric Analysis of Residential Electric Appliance Holdings and Consumption" J. Dubin and D. McFadden, *Econometrica*, Vol. 52, No. 2, Mar., 1984, pp. 345-362.

example, if $\beta = -.1$ then a 10% increase in price leads to a 1% reduction in demand. Additional explanatory variables, such as prices of competing energy sources, GDP and characteristics of the purchasers can be readily added.[40]

61. Classical economic theory teaches us that prices adjust to 'clear the market', that is to bring supply and demand into balance. In most industries, this complicates modeling because the price variable cannot be treated as given (i.e., as being exogenous). This in turn requires either joint modeling of supply and demand, or the application of estimation techniques which correct for the problem. In much of the electricity demand estimation literature, this 'endogeneity' problem is moot because prices are set in advance and regulators ensure that there is sufficient supply to meet demand at expected prices.

62. A critical part of assessing the impacts of price trajectories requires distinguishing between short-term and long-term effects. For example, suppose there is the expectation that electricity prices will increase by 7% each year, roughly doubling in a decade. Next year, one might expect some response from residential, commercial and industrial customers, for example in the form of increased conservation. But adaptation takes time, mainly because processes and appliances that use electricity are costly to replace. Over time, more efficient appliances will be put in place, and there could be substitution to other sources of energy (such as natural gas). Thus, the short-run response is likely to be substantially smaller than the long-term response. Furthermore, the expectation of an increasing price trajectory may not only lead to efficiency improvements, migration to other fuels, and a more electricity efficient capital stock, but it may discourage future industrial investments, particularly in very electricity intensive industries.

63. At any given point in time, electricity prices vary widely across jurisdictions. Such 'cross-section' data are useful in identifying long-term effects of price changes (and therefore long-term elasticities). Locations with historically high prices are likely to have lower unit

[40] Richer but more complicated models which incorporate nonlinearities include *translog* and 'generalized Leontief' specifications. Semiparametric and nonparametric models allow the shape of price response to be fully data-driven rather than being imposed *ex ante*.

levels of electricity consumption, those with historically low prices are likely to have higher consumption levels, and a larger share of electricity intensive industries.

64. Time-series data are generally more useful in identifying short-term responses (and therefore short-term elasticities). Such models can be extended to try to capture long-term effects as well, though focusing on a single jurisdiction over time, usually limits the identification of larger and long-term price impacts. On the other hand, time series models enjoy the advantage of being able to capture smooth trends (e.g., resulting from efficiency improvements and technological innovation) as well as disruptive changes that eventually can result in a tipping point (such as we have seen in natural gas and oil markets).[41]

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[41] Within the class of time-series models, there are two important and large sub-classes: stationary and non-stationary models.

a. Stationary models apply to data in which the main characteristics (means, variances, covariances and so-forth) do not change over time, hence this model property is referred to as 'stationarity'. In the simplest versions, co-movement of variables is modeled using correlations and regression models (the latter are in effect partial correlations). Within the class of stationary models, time dependencies of observed variables (e.g., the effect of previous price changes on current consumption) are often estimated using so-called distributed lag models. Unobserved components (i.e., residuals) are typically modeled using autoregressive (AR) or moving average (MA) structures. Stationary models can be static or dynamic. In static models, variables respond contemporaneously to drivers. Dynamic models allow one to model impacts which take time to be fully realized. For example, consumers and businesses do not respond to price changes instantaneously, but rather adapt over time. Partial adjustment models constitute one type of dynamic specification which incorporates responses over a period of time.

b. Non-stationary models allow for evolution over time, such as through trends which can be deterministic or stochastic (i.e., random). Trends play an important role in energy and electricity demand modeling (and more generally in the modeling of commodity prices). For example, the study of trends in energy intensity has experienced rapidly growing interest as governments and policy makers try to address the challenges of decarbonization. In nonstationary settings, co-movement is typically modeled using cointegration techniques. One of the most common specifications in this literature is the error correction model which posits a long-term equilibrium relationship between variables and an adjustment mechanism that moves the system towards that equilibrium.

c. Models of energy use may also incorporate cyclical components, such as diurnal and seasonal effects. Cyclicality is especially important in modeling electricity and natural gas consumption.

d. Time-series models may contain stationary, non-stationary and cyclical components.

65. Panel data models combine both time-series and cross-section data. For example, a data-set of this type might contain say ten years of monthly data on electricity consumption in each of the 13 sub-national jurisdictions of Canada, that is the Provinces and Territories, (yielding 1,560 data points).

66. Energy industries continue to evolve, and in some areas technological innovation is a critical driver. Prominent among the changes, as noted earlier, are rapidly dropping costs of solar and wind generation. Electric vehicle research, design and manufacturing is attracting a growing list of participants. Innovation in (chemical) battery technology and more generally energy storage technologies, is also proceeding rapidly. Statistical models provide useful tools for projecting future time-paths of technology adoption.[42]

67. Individual papers in the literature on energy typically focus on one or another technique, determined largely by the structure of the data-set, (time-series, cross-section, panel data). How does one inform one's judgement about price elasticities from such a massive collection of results and approaches? One might be inclined to construct an architectonic model which incorporates data from multiple sources. In a sense, that is what meta-analytic papers are comprised of: meta-analyses are a genre of (usually academic) undertakings which assemble the results obtained in many other papers, then use statistical techniques to weight the various results that have been obtained therein, and thereby to arrive at an overall summary view.[43]

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[42] So-called 'convergence' models can be used to project adoption of LED lightbulbs and other energy saving devices, solar roof panels, and electric vehicles, to name a few.

[43] For example, suppose one has a dozen independent estimates of the price elasticity of electricity demand. One option would be to simply take the average of the estimates. A more sensible approach would be to give more accurate estimates (i.e., those that are estimated with greater precision as reflected by their lower standard errors) greater weight, and those that are estimated less precisely, less weight.

C.2 Price Elasticities

68. Given this very broad range of modeling techniques, data types, geographic locations and time spans, how does one organize one's thinking about the impacts of price changes on electricity demand in Manitoba and the trends in demand?

69. Our objective will be to inform the following questions:

    a. What are the short-term and long-term impacts of increases in the price of electricity on residential, commercial and industrial demand? To address these questions, we will focus on sectoral elasticities of electricity demand with respect to the price of electricity (known as own-price elasticities).[44]

    b. What is the relationship between economic growth and electricity demand? What electricity and energy industry trends can inform judgements about future electricity consumption? Here we will focus on the GDP elasticity of demand, and on energy intensity and electricity intensity trends.

    c. How can technological innovation be taken into account in constructing scenarios of future demand? Are there scenarios under which electricity demand could rise rapidly, or others under which it could fall?

70. Surveys of estimated demand elasticities reveal a very broad range of estimates.[45] It should be kept in mind that these ranges cover studies conducted over various time periods and in very different geographic locations. (Appendix 3 of this document contains a bibliography, focusing primarily on North American studies.)

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[44] A related elasticity measures the degree to which substitution to natural gas is likely to take place in the residential, commercial and industrial sectors. This is a known as a cross-price elasticity.

[45] K. Gillingham, R. Newell and K Palmer, in "Energy Efficiency Economics and Policy" *Annual Review of Resource Economics,* 2009, 1:597–619 summarize the ranges of estimates at Table 1. Short term residential electricity demand elasticities lie in the range -0.14 and -0.44; their long-run counterparts are between -0.32 and -1.89. Commercial and industrial elasticities also lie in very broad ranges.

71. A recent 'meta-analysis', which as indicated earlier, is a methodology which weights the results of various studies, arrives at empirical results which are useful to the present proceeding.

  a. The first is that the short-term elasticity of demand for electricity is -0.126; that is a 10% increase in the price of electricity results in a 1.26% decline in demand.

  b. The second is that the long-term average elasticity is -0.365; thus a 10% increase in price will eventually lead to a 3.65% decline in demand.[46]

  c. A third useful finding is that long-term elasticities of demand for various energy types are roughly three times short-term elasticities.[47]

72. In contrast, a recent study which uses state-level American data finds a comparable short-term elasticity of -0.1 in all sectors, but much higher long-term elasticities of approximately -0.5 for the commercial sector, -1.1 for the residential sector and -1.4 for the industrial sector. These results are likely driven by the cross-sectional nature of the data. The authors attribute the large industry price elasticity to concentration of electricity intensive industries in low-price states.[48] While these elasticity estimates are certainly large when compared to those in other studies, they serve to bound the range of reasonable estimates: in short, a price elasticity of -1 in the long-term is within the limits of empirical evidence.

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[46] Labandeira, X., Labeaga, J.M., López-Otero, X., 2017." A meta-analysis on the price elasticity of energy demand". *Energy Policy* 102, 549-568, Table 5.

[47] *Ibid.* p. 554 "Indeed, considering the papers that report both short (ST) and long-term (LT) price elasticities, the LT average elasticity slightly triples (3.08) the ST average elasticity. Moreover, all energy products are around that figure: electricity (3.04), natural gas (3.03), gasoline (3.05), diesel (3.20) and heating oil (3.73)."

[48] "The Price Elasticity of Electricity Demand in the United States: A Three-Dimensional Analysis", 2017, Paul J. Burke and Ashani Abayasekara, forthcoming, *The Energy Journal*.

73. A literature search for studies that estimated demand elasticities in a uniform fashion across the Provinces and Territories of Canada has turned up very little. [49]

74. **For present purposes, short-term sectoral elasticities of -0.1 and an overall long-term electricity price elasticity of -0.4 provide reasonable benchmarks. Long-term elasticities of -0.35 for the residential and commercial sectors, and -0.5 for the industrial sector would also provide reasonable reference points.**

75. These price elasticities are somewhat higher, in absolute terms, than those provided by Manitoba Hydro in its load forecast documents, as summarized in the table below. While elasticities proposed by Manitoba Hydro are not unreasonable, especially given the degree of uncertainty associated with estimation of demand parameters, those recommended above are better supported by the literature.

	2016 Electric Load Forecast[50]	2017 Electric Load Forecast[51]
Residential Basic	-0.29	-0.28
GS Mass Mkt Small/Medium	-0.18	-0.13
GS Mass Mkt Large	-0.47	-0.46
GS Top Consumers	-0.48	-0.37
Gross Firm energy	-0.32	-0.27

76. Manitoba Hydro is projecting rate increases of 7.9% through 2023/24 followed by 4.54% in 2024/25 for a cumulative nominal increase of about 65%. If realized, they will have a

[49] One report, however, summarizes the results of analyses conducted by researchers at the University of Alberta which was conducted on a Provincial basis. They find a short-term residential electricity demand elasticity of -0.57 for Manitoba; for the commercial sector, the elasticity is -0.44; and for the industrial sector, the estimated elasticity is effectively zero, signifying inelastic demand. See D. Ryan and N. Razek, 2012, "The Likely Effect of Carbon Pricing on Energy Consumption in Canada", Sustainable Prosperity Background Paper, available at http://institut.intelliprosperite.ca/sites/default/files/likely-effect-carbon-pricing-energy-consumption-canada.pdf. These estimates need to be interpreted with some caution, as they are obtained using historic Manitoba data. Electricity prices in Manitoba have displayed somewhat less variation than prices across many jurisdictions.

[50] Electric Load Forecast 2016, Manitoba Hydro 2017/18 & 2018/19 General Rate Application Appendix 7.1, page 57.

[51] Electric Load Forecast 2017, Manitoba Hydro, page 57.

significant impact on electricity sales in all residential, commercial and industrial sectors. Indeed, the *anticipation* of a succession of rate increases will likely have an impact on business investment decisions in the near future.

C.3 GDP Elasticities, and Energy and Electricity Intensities.

77. Numerous studies have analyzed the relationship between GDP growth, and growth in demand for energy in general, and electricity in particular. For many decades, these variables moved very closely together. [52]

78. However, in recent years, this relationship has been weakening in advanced economies. In earlier stages of growth, energy demand grows rapidly in part because manufacturing industries are intensive energy users. As their share of GDP increases, energy demand rises rapidly. In the post-industrial phase, the GDP share of service industries increases. As these industries are less energy intensive, demand for energy and electricity slows. These effects are due to the *composition of GDP*.

79. Increases in GDP which lead to increases in per-capita incomes, in turn drive household energy and electricity consumption. As incomes rise, families increase the size of their living space, they purchase more appliances, computers and entertainment systems, they acquire additional vehicles and they are likely to drive more. These are *income effects*.

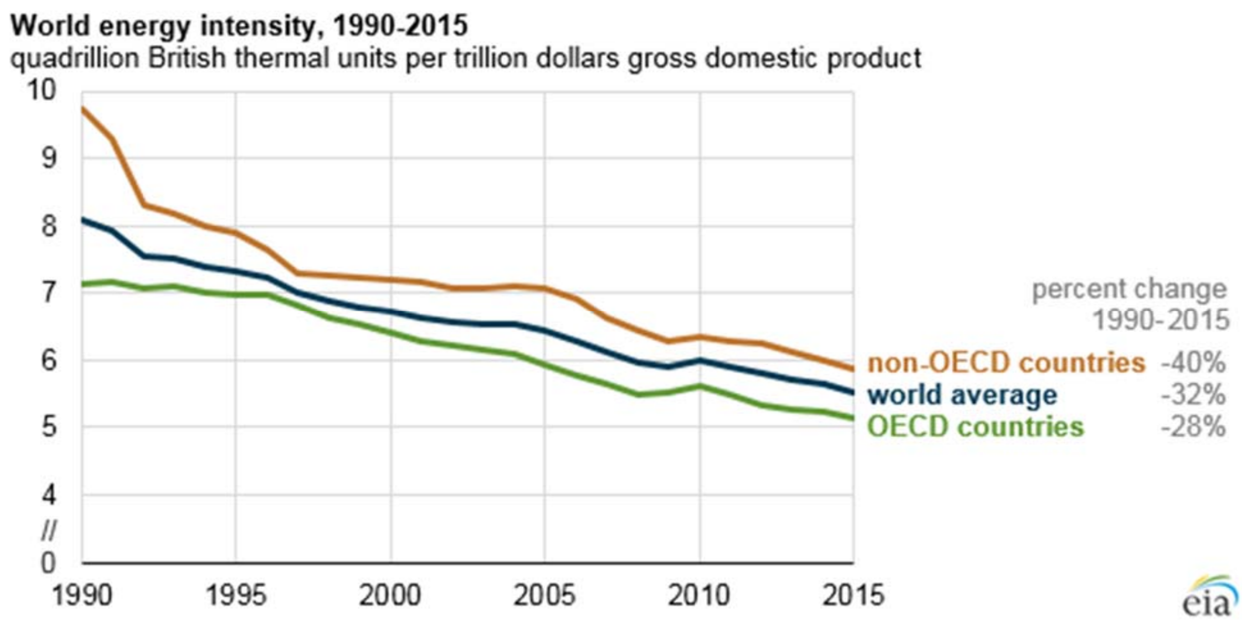
80. The decarbonization agenda also has impacts on energy demand. Energy efficiency programs reduce the energy or electricity required to produce a given level of service. Consider for example lighting where just a few years ago, incandescent light bulbs were the dominant source of light in homes; these used only about 3% of the energy input to produce light, the rest was lost as heat. Compact fluorescent light bulbs are four times as

[52] Standard models and tests assessed whether electricity demand and GDP were co-integrated. Causality testing was conducted to assess whether electricity demand led growth, or whether the reverse was a better representation of reality. The most convincing story is that causality runs both ways. See, e.g., "A survey of the electricity consumption-growth literature", J. Payne, 2010, *Applied Energy*, 87(3), 723-731.

efficient and LED efficiencies are six times higher and increasing.[53] Building envelopes are becoming progressively more efficient at conserving energy, and retro-fitting is common.

81. The net effect of these various forces is that energy intensity -- that is the quantity of energy used in producing say a dollar of GDP -- has been declining at over 1% per year for the last two decades in advanced economies.[54] See Figure 6 below. Over that same time period, energy intensity in Canada declined at a rate in excess of 1% per year, while per capita energy use remained flat.

Figure 6 – World Energy Intensity Trends[55]



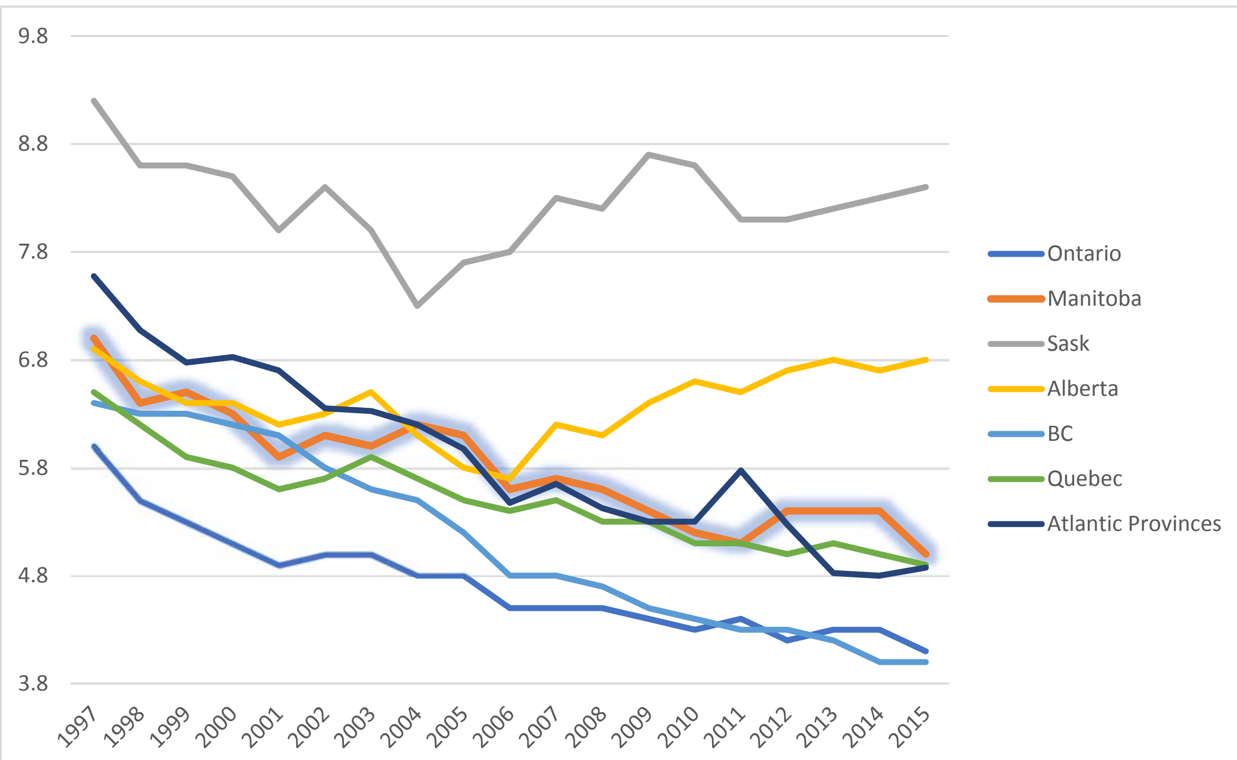
[53] For example, a standard Philips LED bulb, which replaces a 60W incandescent bulb required 9.5W.

[54] For OECD countries, energy intensity, declined 32% between 1990 and 2015.

[55] Source: EIA, International Energy Outlook 2016, International Energy Statistics, and Oxford Economics
Note: OECD is the Organization for Economic Cooperation and Development. GDP calculated in purchasing power parity terms. Available at https://www.eia.gov/todayinenergy/detail.php?id=27032.

82. However, the decline has not been uniform across provinces. Over the period 1997-2015 Manitoba energy intensity declined by close to 2% per year, a number very similar to Ontario. Alberta energy intensity first declined, then increased in large part because of the oil sands, so that overall its energy intensity in 2015 was at approximately the same level as in 1997. British Columbia had the most rapid decline over this period of about 2.6% per year.[56]

Figure 7 – Provincial Energy Intensity Trends



83. Energy intensity varies considerably by sector. As noted earlier, the service sector has relatively low energy intensity. The manufacturing sector can have an energy intensity five to ten times higher than the service sector, depending on the specific type of goods being produced.

[56] There have been few careful empirical analyses of the drivers underlying energy intensity trends at sub-national levels in Canada. For a recent detailed study, see Moshiri, A. and Duah N. (2016), Changes in Energy Intensity in Canada, *The Energy Journal*, 37 (4), 315-342, and references therein.

84. In Manitoba, the service sector has exhibited a steady decline in energy intensity over the period 1997 to 2015. The agricultural sector has exhibited a downward trend, though the pattern has been irregular. The mining sector has experienced an increase in intensity in recent years. And the manufacturing sector intensity increased from 1997 to 2005, but has been steadily decreasing since that time.[57]

85. Turning now to electricity (as opposed to energy) intensity, the patterns in Manitoba have been mixed.

    a. In the service sector, which is by far the largest, intensity dropped by about 25% between 2005 and 2012, but by 2015 it had recovered to 2005 levels.
    b. Intensity in the manufacturing sector peaked in 2005, but has been displaying a fairly steady decline since that time.
    c. Agricultural sector intensity remained high until 2005, but subsequently dropped by more than 50%.

86. Electricity demand continues to be very closely linked the level of GDP. Given the declining electricity intensity, a GDP elasticity of about 0.8 is a reasonable reference number for present purposes.

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[57] In the U.S., energy intensity in manufacturing has also been decreasing in recent years, but this has been largely attributed to a shift to less energy intensive industries within the manufacturing segment. "Intensity of U.S. energy use in manufacturing decreased as output outpaced fuel use", U.S. Energy Information Administration, October 18, 2017, available at https://www.eia.gov/pressroom/releases/press450.php.

D. Manitoba Hydro Electricity Prices

D.1 Rates, Costs and Intergenerational Equity

87. Manitoba electricity prices are low by national standards. Even the projected rate increases will not produce especially high rates compared to other provinces, with the exception of Quebec. It is possible that at low electricity prices, the response to an increase would be attenuated until the price crosses a certain threshold. The elasticities we are proposing should then be seen as an average response, keeping in mind that Manitoba Hydro projects a large cumulative increase in the coming years.

88. Consider the following simplified calculation. Assume an electricity price elasticity of -0.4 and a GDP elasticity of 0.8. Assume further that real electricity prices will increase by 50% over the next decade and that the economy grows at 2% per year, so that the economy is 22% larger ten years hence. Then the price increase will have a long-term effect of reducing electricity demand by about 20% (-.4 x 50%) and GDP growth will increase demand by about 18% (.8 x 22%). These calculations suggest Provincial electricity demand will be stagnant. While there will certainly be fluctuations in the short term, and economic growth may not be steady as a result of business cycles, the longer-term outlook for electricity demand growth is not favourable under the high price scenario.

89. This assessment is not unprecedented. In 2005, Ontario electricity demand exceeded 157 TWh. In subsequent years, prices increased by about 50%. Ontario demand declined to 137 TWh by 2016.[58]

90. Price induced impacts on electricity demand can come through many channels including:

    a. where natural gas is available, switching to natural gas in space heating and process heat applications, particularly as it is expected that natural gas prices are expected to remain low;

[58] Data available at http://www.ieso.ca/en/power-data/demand-overview/historical-demand.

b. improved energy efficiency of building envelopes: inexpensive measures include weather-stripping and caulking; more expensive measures include insulation and installation of efficient windows and doors to reduce heating costs in winter and cooling costs in summer;

c. purchase of energy efficient appliances;

d. accelerated migration from incandescent, to compact fluorescent and higher efficiency LED bulbs;

e. increased use of smart technologies such as programmable thermostats for heating and air conditioning, and motion-sensitive lighting;

f. increased use of low-flow shower-heads to reduce hot water use;

g. proliferation of solar panel installation by residential, commercial and even industrial customers.

91. There are significant risks to the forecast, for example, growth could be slower, or the price response could be stronger. But there are potentially upside risks as well.

a. In time, the current momentum towards decarbonization of transportation sectors will lead to accelerated adoption of electric vehicles. The price of electric vehicles, and particularly the cost of batteries has been declining.[59] This will increase demand for electricity. It is in this sector that electricity will play a "pivotal role".[60] However, the attractiveness of electric cars to Manitobans is unclear for at least two reasons. First, lower population density requires larger batteries to overcome range anxiety. Second, cold harsh winters have an adverse effect on battery output and electric vehicle range.

[59] Electric car batteries have dropped in cost by 80% in the last half dozen years. Tesla claims that its battery costs are around $190 US/kWh. Thus, a battery with say 80 kWh capacity would comprise about $15,000 US of vehicle costs. The Chevy Bolt now lists for $37,495 USD with a range of 380 kilometers, "Chevy Bolt: Meet the First Practical, Mass-Market Electric Vehicle", Dan Neil, *Wall Street Journal*, October 29, 2017.

[60] See "The technology path to deep greenhouse gas emissions cuts by 2050: the pivotal role of electricity", Williams, J.H., De Benedictis, A., Ghanadan, R., Mahone, A., Moore, J., Morrow, W.R., Price, S., Torn, M.S., 2012, *Science* 335, 53-59.

b. Increased emphasis on reducing carbon should stimulate demand for carbon-free electricity, such as hydro. The present U.S. administration however, is retreating on this issue, and instead promoting the use of hydrocarbons, including coal. Thus, increased U.S. demand as a result of decarbonization initiatives is unlikely to materialize in the near future.

c. Average residential rates in the U.S. in July 2017 were 13.12 cents U.S./kWh. For commercial customers they were 11.00 cents U.S. and for industrial they were 7.33 cents U.S. There is considerable variation across states. In neighbouring states and MISO members, electricity prices are much higher than in Manitoba, leaving room for potential growth in exports. [61]

92. As noted earlier, Manitoba Hydro operates under a 'cost-of-service' regulatory regime. (Many other jurisdictions have moved to a mode of incentive regulation in order to improve incentives for cost minimization.) Manitoba Hydro is implementing a "Workforce Reduction Plan" which would eliminate 900 positions (15% of the workforce) over the course of two to three years.

93. One might ask whether the projected rate increases are equitable from an intergenerational standpoint.

a. Expansion of hydroelectric systems, such as that in Manitoba, involves lumpy investments in generation (to exploit scale economies) and transmission (as supply sources are distant from load). They do not enjoy the positive scalability features of solar, wind and natural gas generation.

b. This leads to long-term cyclical pressures on rates. Current customers have benefited from past investments, particularly those that have been largely depreciated, but remain functional. Future customers will need to pay for

[61] U.S. Energy Information Administration, *Electric Power Monthly,* September 26, 2017, available at https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a.

current projects. The calculus of intergenerational fairness is therefore, at a minimum, complex, and may not lead to unequivocal answers.

c. Rate-smoothing is a useful tool for promoting inter-generational equity. The projected profile is more in the nature of a step function over six years, followed by a rapid decline to increases close to the rate of inflation. A ramped sequence of increases, perhaps linked to a clear demonstration of efficiencies achieved by Manitoba Hydro, may be a useful framework for promoting internal efficiencies, allowing time to adjust to electricity rates, and distributing costs more equitably over each generation of consumers.

94. The effects of the large projected increases, should they be approved, could in theory, be mitigated.

a. Special industrial rates could be offered to those firms with large electricity cost shares. But this would be viewed as inequitable by other customers. Alternatively, the Government might implement incentives to retain major industrial customers.

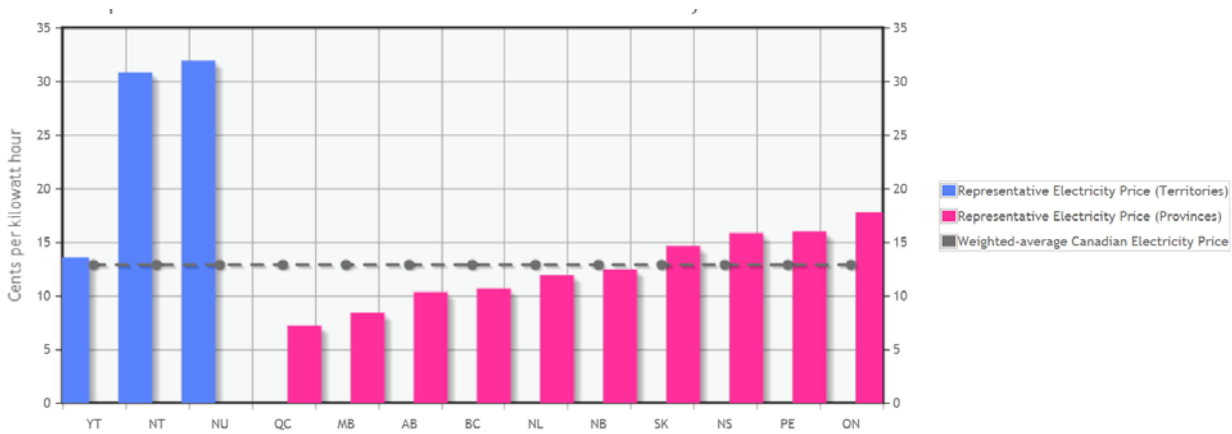
b. There would be a substantial increase in the number of households facing energy poverty, however it is measured. To alleviate this effect will require funds either from other Manitoba Hydro customers, or from Government coffers.

D.2 Bill Affordability and Energy Poverty

95. Electricity prices vary widely across the Canadian Provinces and Territories. Quebec and Manitoba have the lowest prices, mainly due to their hydroelectric resources. British Columbia, which is also overwhelmingly hydraulic has somewhat higher prices. Of the provinces, Ontario has the highest prices, due to a variety of factors including the nuclear program and feed-in-tariffs. But even Ontario prices, at about 18 cents per kWh, are far

below those in the North-West Territories and Nunavut, which are heavily reliant on diesel and oil to generate electricity. (Yukon Territory prices are lower because of hydraulic resources.) See Figure 8.

Figure 8 – Representative Electricity Prices 2016[62]



96. On average, Canadians pay about 3% of income on household energy (excluding transportation fuels). These expenditures are almost entirely on electricity and natural gas, with a relatively small portion of households still relying on heating oil.[63] The National Energy Board defines households to experience energy poverty if they spend 10% or more of income on energy. (Some others set a lower threshold of 6%.)

97. Generally, the share of income spent on essentials such as energy and food (another form of energy) declines with the level of household income.[64]

98. There is an extensive literature on energy poverty, and various critiques have been put forth of simple income thresholds (such as the 10% indicated above). For example, a family may be spending less than 10% of income on energy because it has more urgent

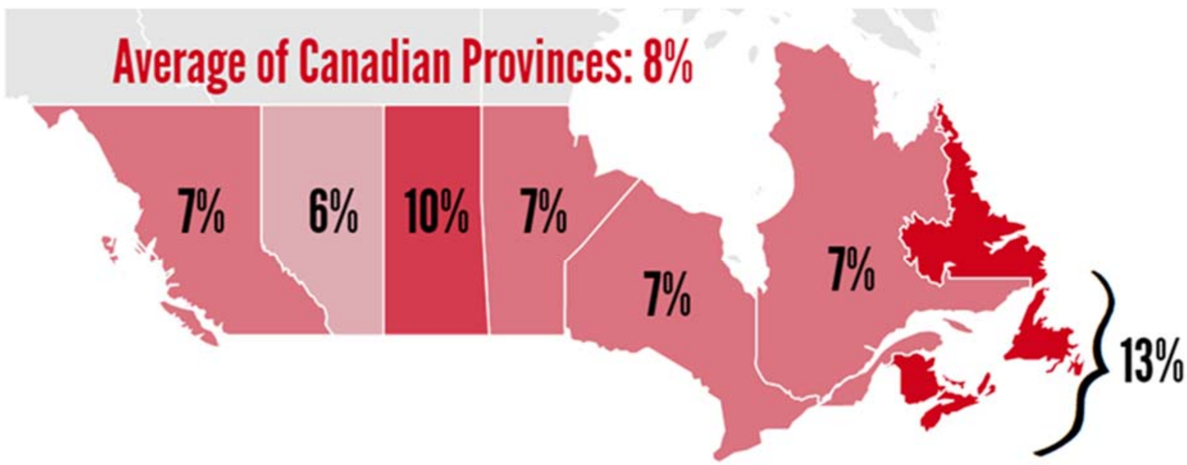
[62] "Explaining the high cost of power in northern Canada", National Energy Board, February 16, 2017, available at https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/snpsht/2017/02-03hghcstpwr-eng.html.

[63] See Canada Energy Flow Diagram 2014, (residential sector) available at https://www.economics.utoronto.ca/yatchew/ .

[64] Such relationships are called Engel Curves after Ernst Engel a 19th century statistician and economist.

demands on its income, and as a result, household temperatures are too cold. More sophisticated measures attempt to quantify how much a household *should* be spending on energy, and compares this to total income to determine whether the theoretical amount represents too large a fraction. Alternatively, one can subtract the required expenditures from household income and then assess whether the residual income places the family below the poverty line.[65]

Figure 9: Household Fuel Poverty Rates in Canadian Provinces in 2015[66]



99. Nevertheless, a 10% threshold provides a common departure point for the discussion. By this measure, 7% of Manitoba households experience energy poverty, a level comparable to British Columbia, Ontario and Quebec. Saskatchewan and the Atlantic Provinces have much higher levels. See Figure 9.

100. Lower income households face the additional hurdle of inadequate access to moneys to invest in energy efficiency improvements. The empirical evidence put forth by the

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[65] This is the methodology used in England, see https://www.gov.uk/government/collections/fuel-poverty-statistics. See also *Fuel Poverty, Methodology Handbook*, Department for Business, Energy and Industrial Strategy, UK Government, June 2017 Edition; and, "Special Section - Fuel Poverty Comes of Age: Commemorating 21 Years of Research and Policy", *Energy Policy*, Volume 49, October 2012.

[66] Source: "Market Snapshot: Fuel poverty across Canada – lower energy efficiency in lower income households", National Energy Board, https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/snpsht/2017/08-05flpvrt-eng.html.

National Energy Board suggests that higher income households have lower energy intensities, that is, they use less energy per square meter of dwelling size.[67] This may be partly due to implementation of more energy efficient measures.

101. Utilities across Canada are heavily involved in the development, administration and implementation of numerous energy efficiency programs ranging from informational initiatives, financial incentives and rebates, and energy management and monitoring. There are also programs available through various levels of government, municipal, Provincial, Territorial and Federal. Some specifically target low income households. A detailed listing is provided by the National Energy Board.[68]

102. Manitoba Hydro offers a wide range of energy efficiency and alternative energy programs targeting various segments of its customer base – residential, commercial and industrial. There are also programs specifically targeting First Nations and lower income households.[69]

103. The succession of proposed rate increases will have a particularly intense impact on low income households. In the short run, demand for electricity is highly inelastic. For low income households, facing constraints on cash flow and borrowing, expenditures on electricity saving alternatives may not be realistic. Households that heat with electricity, and therefore experience bills that are much higher than those that do not, are particularly vulnerable. Households in remote communities are especially vulnerable as there is little in the way of alternatives to electric heating. One of the likely consequences of rate shock will be greater 'uptake' of the various conservation programs that are available. However, investments that have multi-year payback periods, such as insulation,

[67] *Ibid.* Tables 3.5 and 3.7 provide data on electricity and natural gas intensity for households based on a Statistics Canada survey conducted in 2011.

[68] See "Directory of Energy Efficiency and Alternative Energy Programs in Canada", National Energy Board, available at http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/policy_e/programs.cfm.

[69] *Ibid.* "First Nations Program" and "Power Smart Affordable Energy Program".

thermal pane windows[70] and natural gas furnaces (where gas is available), may require greater incentives if they are to contribute to mitigating energy poverty.

104. The question arises as to where responsibility should lie for ensuring that high electricity prices do not drive low income households into poverty.

a. A valid case can be made that affordability of essential goods and services resides with governmental authorities. Supports should be designed to ensure sufficient income and to protect low income households from price increases of all essentials, electricity being one of them. Transfers come from the public purse, rather than from other ratepayers. Increases in electricity prices would be reflected in the escalation factors embedded in income supports, *if* these factors are properly calibrated.

b. A counter-argument can be put forth that in complex societies, multiple mechanisms are needed to protect the poor and disadvantaged. A social *safety net* which has multiple intersecting and reinforcing strands, is required to ensure that individuals and families do not 'fall through'.

105. Both arguments have validity. More recent sophisticated arguments based on behavioural economics suggest that individuals can be encouraged to make better decisions (for themselves and for society) if they are 'nudged' in the right direction. This year's Nobel Prize in economics was awarded to Richard Thaler, co-author with Cass Sunstein of the widely acclaimed 2008 book entitled *Nudge: Improving Decisions About Health, Wealth, and Happiness*. (At several points, the book discusses energy efficiency.) Arguably, many energy conservation programs may be seen as 'nudging' individuals, households and firms in a direction which serves both their individual interests as well as the public interest.[71]

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[70] Low cost alternatives, such as reducing window heat loss using plastic, are poor substitutes.

[71] The 'nudge' approach may be interpreted as a mechanism which bridges the differences between social models focusing on individual responsibility, and those that argue for a larger role for government and its institutions.

106. Ultimately, which approach prevails, is a matter of public policy. The first approach is *transparent and simple administratively*. It does not reduce the price of electricity to households, and places expenditure decisions at the level of the household. The second targets an essential good that needs to be directly supported.[72]

107. In many markets, prices that diverge from marginal costs lead to economically inefficient consumption levels. This argument has less weight in electricity industries where prices do not reflect marginal costs to begin with, as rates are regulated so as to recover average costs.

108. On the other hand, in remote communities, where electricity is generated by diesel, high unit costs serve the purpose of sending a price signal that more correctly reflects the (marginal) cost of the electricity that is consumed.

109. The Manitoba Public Utilities Board recently directed Manitoba Hydro to lead a collaborative process to study 'bill affordability'. The report contains simulations of impacts on energy poverty under alternative future rate scenarios. Even with rate profiles somewhat lower than currently projected, energy poverty is forecast to increase by 10% over the next decade.[73]

110. That report also reiterates a previous finding contained in the Manitoba Hydro's 2014 Residential Energy Use Survey which "suggests that energy poverty is greater among customers who identify as Indigenous (i.e. of First Nations, Metis or Inuit ancestry), customers with older homes and/or homes that are electrically heated, and households with either a single member or five or more members."[74]

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[72] Food stamp programs provide another example of support for a particular category of essential goods.

[73] "For example, if a rate increase scenario of approximately 8% for 4 years or 6% for 6 years and a 6% threshold is used, rates of energy poverty are projected to be approximately 24% higher in 2026. When the same rate scenario and a 10% energy poverty threshold is used, a 10% increase is observed. This underscores the degree to which potential rate increases could increase energy poverty in Manitoba." *Manitoba Hydro Bill Affordability Collaborative Process. Summary Report & Recommendations, January 2017*, page 26, available at http://billaffordabilitymb.ca/.

[74] *Ibid.* page 16.

111. The impact of large increases in electricity prices is likely to be especially acute in remote and First Nations communities, where the possibilities for energy substitution are limited and electricity is generated using diesel.[75] In addition, low incomes will hamper substitution of capital goods, such as improved insulation, and efficient windows and doors. While representative establishment level data do not appear to be available, commercial and industrial enterprises in these communities will also be adversely affected, particularly in the absence of energy substitutes such as natural gas.

[75] The 2017 Federal Budget allocates funds, beginning in 2018-2019 for the implementation of "renewable energy projects in off-grid Indigenous and northern communities that rely on diesel and other fossil fuels to generate heat and power", see https://www.aadnc-aandc.gc.ca/eng/1481305379258/1481305405115.

E. Macroeconomic Impacts of Electricity Price Increases

E.1 Energy Price Shocks

112. In order to provide a broader perspective, it is useful to reflect upon the impacts of changes -- even sudden and unexpected changes -- in key energy variables on economic activity.

113. A great deal of attention has been devoted to the impacts of oil prices on the macroeconomy. Many economists attribute several of the past recessions to oil price shocks, particularly those resulting from OPEC increases in 1973, and the subsequent increases in 1979 at the time of the Iranian Revolution. Between 1973 and 1974, oil prices *tripled*, from $17.77 to $56.39 USD (2016 dollars) per barrel; between 1978 and 1979, they *doubled*, from $51.51 to $104.50 USD (2016 dollars), see Figure 10 below. Both of these occurred at a time when western economies were in a state of stagflation (high inflation *and* high unemployment), and both were unanticipated.

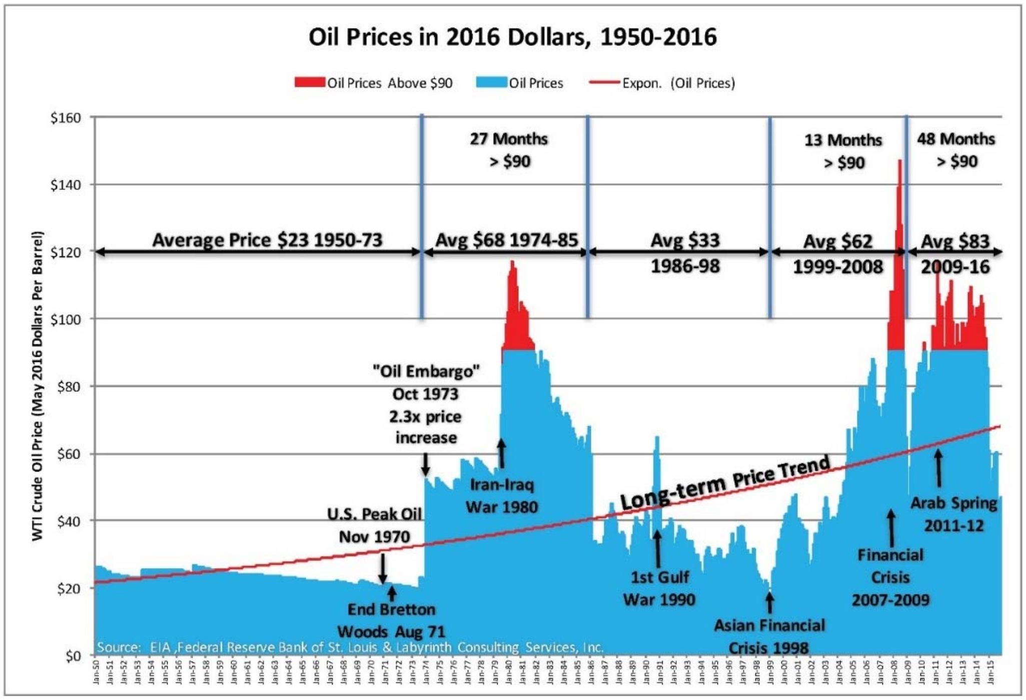
114. As may be seen from Figure 11, the two oil price shocks in the 1970s led to dramatic drops in GDP growth: from 5.6% in 1973 to -0.5% in 1974; and from 3.2% in 1979 to -0.2% in 1980. Kilian and Vigfusson estimate that US GDP is lower by 3% as a result of the doubling of oil prices in the late 1970s. [76]

115. Consider now oil prices in more recent years. Figure 10 reveals that oil prices increased from about $30 in 1998 to over $120 USD/barrel in 2008, a factor of four, which is much larger than the magnitude of the oil price shocks of the 1970s. During this period, U.S. real GDP growth averaged 3%, and the Great Recession which began in late 2008 was triggered by a financial crisis, not by the inexorable rise in oil prices. (In fact, many

[76] …"oil price shocks explain a 3% cumulative reduction in U.S. real GDP in the late 1970s and early 1980s and a 5% cumulative reduction during the financial crisis." See "The Role of Oil Price Shocks in Causing U.S. Recessions", by Lutz Kilian and Robert J. Vigfusson, The Federal Reserve Board, 2014 available at https://www.federalreserve.gov/pubs/ifdp/2014/1114/default.htm.

attribute the rise in oil prices to macroeconomic growth, particularly in China and the concomitant growth elsewhere.)

Figure 10: Oil Prices[77]



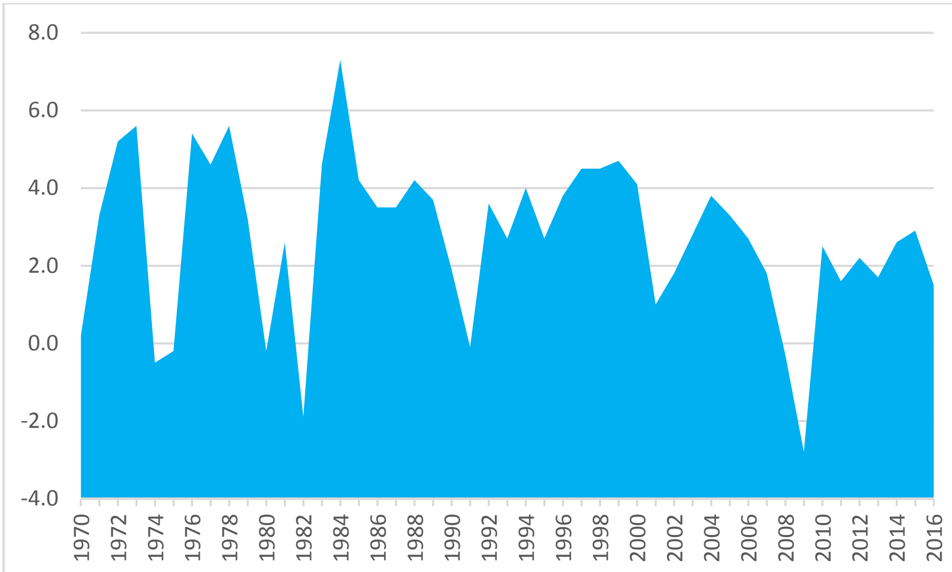
116. A key lesson from these contrasting macroeconomic responses to energy price increases is the critical difference between 'supply-push' and 'demand-pull' forces. The increases during the 1970s were supply shocks, resulting from decisions by major oil producing countries (OPEC). The increases in the 21st century were driven by increasing demand without sufficient opportunity or willingness on the part of suppliers to respond.

117. A second important lesson is that steady energy price increases, that are spread over a number of years, do not necessarily lead to disastrous adverse effects on aggregate economic activity. One of the reasons, of course, is that energy purchasers (consumers and producers) have some opportunity to adjust and to take the price effects into account

[77] Source: "Oil Prices Lower Forever? Hard Times In A Failing Global Economy" Art Berman, Forbes.com, July 25, 2016, http://www.artberman.com/wp-content/uploads/Oil-Prices-in-2016-Dollars-1950-2016-.jpg.

in their planning for the future. In contrast, large unexpected energy price changes can have a significant disruptive effect on the economy.

Figure 11: US GDP (% changes) [78]



118. Some who examine the data may also be surprised that, notwithstanding the *magnitudes* of the oil price increases in the 1970s, the contractions in both 1974 and 1980 were modest, half a per cent or less. In fact, the largest contraction over this period was 3% and it occurred as a result of the 2008 financial crisis.

119. Variations in oil prices have resulted in wide swings in gasoline prices. Between late 2008 and 2014, Manitoba pump prices increased from about 75 cents/liter to 128 cents/liter, an increase of about 70%.[79, 80]

[78] Source: Bureau of Economic Analysis, U.S. Department of Commerce, available at https://www.bea.gov/iTable/iTable.cfm?reqid=19&step=2#reqid=19&step=3&isuri=1&1910=x&0=-99&1921=survey&1903=1&1904=1970&1905=2017&1906=a&1911=0.

[79] Source: Gas Buddy, http://www.manitobagasprices.com/retail_price_chart.aspx.

[80] Natural gas prices have also experienced large changes since the turn of the century, driven in North America by the fracking revolution. The price declines have brought considerable benefits directly, to those households and businesses that have access to natural gas, and to a lesser degree to those that purchase goods for which natural gas is an input in the production process.

120. The implication for the electricity price increases, projected by Manitoba Hydro, is that they are not likely to have a disastrous impact on *aggregate* macroeconomic activity. This is further reinforced by the fact that over 70% of the Manitoba economy provides services, and electricity in this sector comprises a relatively small proportion of total costs.

121. However, that it not to say that certain industries will not be negatively impacted, possibly severely. As we discuss further below, some companies may choose to relocate or to scale back production. Some will consider very carefully whether to make major new capital investments in the Province. Indeed, the specter of increasing rates, in the near or more distant future, may have already discouraged investment. The risk of future price increases, that cumulate to 50% or more, must be part of the decision matrix for any electricity intensive firm in Manitoba.

122. Furthermore, there will be distributional effects that will be particularly felt by those in lower income brackets and those who do not have access to alternative sources of energy, in particular, natural gas.

123. In the past, electricity prices in Manitoba have increased steadily, but relatively smoothly over similar time-frames, largely due to regulatory decisions. The current proposal, for large increases over a sequence of years, is more in the nature of a rate shock.

E.2 Exchange Rates

124. The Manitoba economy is driven to a substantial degree by its exports markets, some of which involve sales to other Provinces and Territories (about 27% of Manitoba GDP), others involve international sales, primarily the United States (also about 27% of GDP).[81] Thus exchange rates have an important impact on the Manitoba economy.

[81] Budget Paper A, Economic Review and Outlook, page A14, Province of Manitoba, April 2017, available at http://www.manitoba.ca/budget2017/index.html.

125. Manitoba has a broad export base which includes grains and oilseed products (20.2%); transport equipment (12.7%); livestock and processed meats (10.7%); machinery and electrical equipment (9.5%); and chemical products (8.9%).[82]

126. The linkage between Canada's exchange rate and oil prices is illustrated in Figure 12 below; indeed the two series appear to be tethered to each other.[83]

Figure 12: Oil Prices[84] (blue) vs CAD/US Exchange Rate (orange)

127. In the early part of the 21st century, the exchange rate hovered around 80 US cents. As oil prices increased, the value of the Canadian dollar rose, achieving parity in 2007. The financial crisis of 2008 led to the 'Great Recession' through 2009, during which oil prices plummeted and the dollar returned to about the 80 cent level. As economies stabilized and recovered, oil prices rose once again. The Canadian dollar hovered around parity from

[82] *Ibid.* page A15.

[83] There is likely a co-integrated relationship between these series, as well as causality running from oil prices to the Canadian dollar value.

[84] West Texas Intermediate (WTI).

2010 to 2013. Then in 2014, oil prices collapsed and the Canadian dollar, which began its decline earlier, followed it down, at one point trading well below 70 cents US.

128. While oil prices have risen far above their lows of late 2015 when oil was trading below $30 USD/barrel, it is unlikely that they will return to $100 USD/barrel any time soon, if ever. As suggested earlier, the issue now is when worldwide demand (rather than supply) will reach its peak.

129. A stronger Canadian dollar has an adverse impact on the competitiveness of Canadian products on international markets. During the period of high oil prices, Western Canada benefited, while manufacturing industries in Ontario, and in other provinces, suffered the so-called 'Dutch Disease'.[85]

130. Presently, the dollar is near the 80 cent mark and Manitoba Hydro is projecting a gradual return to the 87 cent level over the course of the next few years.[86] Clearly much depends on the future price of oil.

131. But other factors may also have an important influence on the exchange rate. The NAFTA renegotiations are presently in limbo, and an adverse outcome for Canada will likely have a negative effect on Canadian and Manitoba exports to the U.S. and on the CAD/USD exchange rate.

132. To summarize, the exchange rate has important impacts on Manitoba and Manitoba Hydro.

   a. International exports are affected: as the dollar appreciates, the competitiveness of Manitoba exporting industries (agriculture, manufacturing, chemicals) is adversely affected. Those that are electricity intensive are particularly sensitive to the kinds of electricity price increases that are being proposed.

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[85] See, for example, "What Dutch disease is, and why it's bad", The Economist, November 5, 2014, available at https://www.economist.com/blogs/economist-explains/2014/11/economist-explains-2.

[86] Manitoba Hydro, GRA, Appendix 3.2 Revised, Economic Outlook, 2016-2037, Winter 2016, page 13.

b. Manitoba Hydro is also directly affected, in that its export sales to U.S. markets generate lower Canadian dollar revenues.

c. On the other hand, to the extent that some industries import inputs, particularly from the U.S., a stronger Canadian dollar is helpful.

E.3 Commodity Prices

133. Commodity prices are driven by a complexity of forces – depletion and discovery, innovation and obsolescence, competition and strategic behaviour, and of course, supply and demand. Each of these have played an important role in driving oil prices.

134. Metals markets are also driven by similar factors. The principal metals mined in Manitoba are nickel, copper, zinc and gold.[87] The first three exhibit both long term trends and cyclical behaviour. Gold prices are subject primarily to forces in financial markets, and are very much affected by market perceptions of risk and stability in geopolitical conditions.

135. The prices of each of these metals exhibit wide variations:

a. Nickel prices have dropped by a factor of two from $13 US/lb. in 2010 to less than $6 US/lb. in November 2017.

b. Copper prices also dropped by a factor of two between 2010 and 2016 (from $4 US/lb. to $2 US/lb.) but have since recovered to about $3 US/lb.[88]

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[87] Budget Paper A, Economic Review and Outlook, page A11, Province of Manitoba, April 2017, available at http://www.manitoba.ca/budget2017/index.html.

[88] The long-term paths of nickel and copper prices exhibit similar patterns. See Dimitropoulos and Yatchew.

c. Zinc prices were at about $2400 US/metric ton in 2009, declined to $1600 in 2015 and have since increased to $3200.

d. Gold prices peaked at $1800 US/ounce in 2011, but have since dropped to about $1300 US/ounce in 2017.

The purpose of these examples is to illustrate the degree of price variation that mining companies experience in metals markets. By comparison, electricity prices have historically been a source of stability for Manitoba metal extractors.[89]

136. Agricultural products also exhibit large price variations and are affected by growth conditions (such as droughts) in various parts of the world. Wheat prices, which reached a post-recession high of $9 US/bushel in 2012, have since declined to $4 - $5 US/bushel in 2017.

E.4 Electricity Intensity Varies Widely Across Some Sectors of the Manitoba Economy

137. It is helpful to put into perspective the share of electricity costs in various segments of the Manitoba economy. The most electricity intensive sectors are manufacturing and agriculture with electricity comprising 1.23% and 1.21% of inputs respectively. Mining is not far behind with a share of 1.12% The service sector (aggregated over a broad range of services and comprising 71% of GDP) has an electricity input share of 0.75%.

138. Based on these figures, one might be inclined to conclude that even substantial increases in electricity prices (on the order of 50% over the coming years) would have a minimal impact on decisions made by firms in these sectors. However, this level of aggregation masks those instances where sub-sectors and firms may be particularly vulnerable to electricity price rises. A more refined look by specific sub-sectors is required.

[89] There is a large literature which attempts to model commodity prices in terms of trends and 'super cycles', however such modeling exercises have little predictive value as the length and amplitude of cycles varies over time.

In the following paragraphs we highlight certain electricity intensive sub-sectors. Detailed tables are available in Appendix 4: Manitoba Electricity Cost Shares by Sub-Sector.

Electricity Shares by Major GDP Sector[90]		
	GDP Shares	Electricity as Share of Inputs
Services	71.2	0.75%
Manufacturing	10.1	1.23%
Construction	8.9	0.05%
Agriculture	4.0	1.21%
Utilities	3.4	0.01%
Mining	2.4	1.12%

139. In the manufacturing sector, the most vulnerable industry would appear to be 'basic chemicals' which has an 18% share for electricity costs. This is followed by pulp and paper which has an electricity share of 7%. Iron and steel mills, foundries and non-ferrous metal production have shares of about 3%. Fertilizer and pesticide has a 2% share. Motor vehicle, engine and electric lighting equipment manufacturing have shares of about 2%.

140. In the agricultural sector, greenhouses, nurseries and floriculture establishments have a 3% electricity share of total inputs. Animal production has a 2% share.

141. In the mining sector, support activities for oil and gas extraction have a 6% share. Copper, nickel, zinc and gold extraction have electricity cost shares of 2%-3%.

142. These sub-sectors of the manufacturing, agricultural and mining industries face competitive pressures in export markets. Their locational decisions are determined by various factors, including proximity to certain resources and inputs, and past capital investments. Manitoba may continue to be a preferred location for operations. However, future production and investment decisions by existing entities, and the attractiveness of

[90] The electricity input shares are based on 2013 data, the most recently posted data in CANSIM Tables 381-0033.

Manitoba to potential new enterprises, will be affected if electricity prices are expected to increase substantially in coming years.[91]

F. Concluding Observations

143. The regulatory decisions made in this proceeding, which deals with rate increases over a two-year test period, will have an important impact on decision making by industry because they will signal the likely future path of rate increases. Approval of increases that are close to the proposed 7.9% will suggest the acceptance of Manitoba Hydro arguments and its focus on the time profile of future financial ratios.

144. Large increases will induce a price response. Our review of the extensive modeling literature suggests an overall price elasticity of -0.4. In a period of excess capacity, such increases may be sub-optimal as they will erode revenues at a time when marginal costs of production are low.

145. From the standpoint of carbon emissions, Manitoba's energy sector is very well placed: 37% of all energy (including the transportation sector) comes from hydraulic sources, and 1% comes from wind generation (recall the Sankey diagram in Figure 3). Natural gas provides 26% of total energy, coal a miniscule 0.3%, and the remaining 35% consists of transportation fuels.[92] Other jurisdictions are focusing on decarbonizing the electricity sector, but Manitoba has already accomplished this.

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[91] There are also portions of the service sector that have high electricity cost shares. Social assistance and educational services have electricity shares in the 4% to 6% range. Dry cleaning and laundry services have an electricity share of 5%. Crude oil and other pipeline transportation have an electricity share of 2%. While these services will continue to be provided, large electricity cost increases will impact their bottom line.

[92] In total, about 60% of Manitoba energy is from hydrocarbons. Compare this to Canada-wide numbers where about 80% of domestic energy comes from hydrocarbons, see https://www.economics.utoronto.ca/yatchew/ . U.S. dependence on hydrocarbons is of a similar magnitude, see Lawrence Livermore National Labs Sankey diagrams at https://flowcharts.llnl.gov/content/assets/images/charts/Energy/Energy_2016_United-States.png.

146. Three decarbonization strategies suggest themselves.[93] The first involves reductions in energy intensity. While the energy intensity trends we have reviewed suggest that 2% annual reductions have been achievable in the past, this would just compensate for annual GDP growth rates of 2%. The second involves moving away from natural gas, which would be unappealing to residential, commercial and industrial consumers, especially when gas prices are expected to continue to remain low and electricity prices are increasing. The third involves decarbonization of transportation, which is by far the most difficult sector to decarbonize.

147. Increasing energy prices, whether in the electricity sector (for fiscal reasons) or in the natural gas sector (via a carbon tax), may be counter-productive for other reasons: if Manitoba's energy intensive industries decamp to other jurisdictions, the net effect on global emissions is likely to be negative. (To put it simply, how many industry-friendly jurisdictions are there with an energy mix as clean as that of Manitoba?) Reductions in carbon emissions may make Manitobans feel that they are doing 'their share' with respect to global warming, but it may not be rational unless the 'carbon leakage' problem is solved.[94]

148. The projected rate increases are likely to have a modest *net* effect on aggregate Manitoba output in the long-run, though there could very well be job losses and reduced output in the short-run. The immediate main effects will be distributional, impacting low income households and remote and First Nations communities more strongly. Such increases may also lead to structural changes in industry with the largest impacts on electricity intensive enterprises. Neither of these consequences constitute a basis for keeping rates inappropriately low for *all* purchasers, as there are superior mechanisms for handling distributional impacts in residential, commercial and industrial sectors.

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[93] The recently released Manitoba Government discussion paper outlines strategies for decarbonization, including of the energy sector. See "A Made-in-Manitoba Climate and Green Plan Hearing from Manitobans" available at https://www.gov.mb.ca/asset_library/en/climatechange/climategreenplandiscussionpaper.pdf, released on October 27, 2017.

[94] See, e.g., Yatchew, A. 2016, "Rational vs. 'Feel-Good' Carbon Policy – Transferability, Subsidiarity and Separation" Energy Regulation Quarterly, 4:3, 31-40, available at http://www.energyregulationquarterly.ca/articles/rational-vs-feel-good-carbon-policy-transferability-subsidiarity-and-separation#sthash.Kdjlk0vV.dpbs.

Appendices

Appendix 1: Scope of Work and Summary Responses

DR. ADONIS YATCHEW

(Summary responses in **bold**, report references in ***bold italics***)

For Microeconomic Issues:

1. Review, assess and comment on the reasonableness of the price elasticity information incorporated in Appendix 7.1 of Manitoba Hydro's General Rate Application.

   The elasticities proposed by Manitoba Hydro are not unreasonable, given the degree of uncertainty associated with estimation of demand parameters. However, based on the extant literature, more negative price elasticities and a substantially larger income/GDP elasticity are recommended. See sections *"C.2 Price Elasticities"* and *"C.3 GDP Elasticities, and Energy and Electricity Intensities"*.

2. Provide a review of the relevant literature on the price elasticity of demand for electricity, drawing from the North American experience in particular. This should distinguish between how different customer classes ("Residential," Commercial" and "Industrial") and how different sectors of the economy (including industry, small business, agriculture, manufacturing, and any other relevant sectors) respond to price changes in light of their different substitution possibilities and geographical mobility. This literature review should include consideration of any impacts on First Nations consumers, including residential and commercial and/or industrial First Nations ratepayers.

   The literature on demand modeling is voluminous and there are a variety of approaches, usually determined by the type of available data. These include time-series, cross-section, panel data, and meta-analyses. See section *"C.1 Energy Demand Modeling"*. The studies produce a very broad range of price elasticity estimates. Based on a review of the literature, the following elasticities are recommended:

   a. a short-term price elasticity of -0.1 across all sectors; that is, an electricity price increase of 10% leads to a 1% decline in electricity demand in the short-term;

b. a long-term overall price elasticity of -0.4; that is, an electricity price increase of 10% leads to a 4% decline in electricity demand in the long-term;

c. long-term price elasticities of -0.35 for the residential and commercial sectors, and -0.5 for the industrial sector;

d. a GDP elasticity of 0.8; that is, an increase in GDP of 10% eventually leads to an increase in electricity consumption of 8%.

The literature on estimation of sub-sectoral elasticities (such as manufacturing, agriculture) is limited. Some results are available on energy and electricity intensity trends at disaggregate levels. See sections *"C.2 Price Elasticities"* and *"C.3 GDP Elasticities, and Energy and Electricity Intensities"*.

Substitution possibilities are mainly in the form of natural gas, where it is available; capital investments, such as insulation, efficient windows and doors, LED lighting, and energy efficient appliances and equipment. Solar self-generation is progressively becoming a partial substitution option. Locational decisions for energy intensive industries are affected by energy prices. See sections *"B.2 The Manitoba Energy Sector", "B.3 Oil and Natural Gas Markets", "B.4 Costs of Key Technologies Have Been Dropping Rapidly"*, *"C.2 Price Elasticities"* and *"C.3 GDP Elasticities, and Energy and Electricity Intensities"*.

Unavailability of natural gas limits substitution options for remote and First Nations communities in all sectors (residential, commercial and industrial). Low incomes also hamper capital substitutions that require large investments. See section *"D.2 Bill Affordability and Energy Poverty"*.

3. Review

- Tab 9 and Appendix 9.13 (Survey of Canadian Electricity Bills) in Manitoba Hydro's General Rate Application; Manitoba Public Utilities Board's Needs For and Alternatives To Report with respect to ratepayer impacts;

- Available information regarding consumption patterns of Manitoba industries, including PUB/MH 1-54 and PUB 11-58 from Manitoba Hydro's 2015/16 General Rate Application.

Provide analysis and comment on what, if any, inferences can be drawn from the general literature on the price elasticity of demand for electricity to the Manitoba context, specifically given:

a) The history of the levels of electricity prices in Manitoba; and

b) substitution possibilities due to technological improvements in renewable energy sources.

Manitoba has a history of low electricity prices, which has shaped the patterns of energy consumption: very high reliance on electricity, compared for example to Canada-wide averages. Substitution to natural gas, where it is available, is likely to occur if projected electricity prices are realized. The costs of renewable technologies, such as solar and wind energy, have been dropping dramatically, and may gain penetration, particularly in areas where gas is unavailable.

The response to price increases may be nonlinear, with limited initial changes in patterns of consumption, but the response is likely to strengthen if rates reach substantially higher levels. (Since 2009, electricity rates in Ontario have increased by more than 50% and demand has been stagnant.) See sections *"B.2 The Manitoba Energy Sector", "B.4 Costs of Key Technologies Have Been Dropping Rapidly"* and *"D.1 Rates, Costs and Intergenerational Equity"*.

4. In light of Manitoba Hydro's request for an annual increase in average electricity rates of 7.9%, including for the fiscal years of 2017/18 and 2018/19, as well as the proposed rate trajectory over the next 10 years, provide comment on how various domestic customer classes might be expected to respond to an increase of the proposed levels.

See responses to 2. and 3. above, and 9. below.

5. Review, assess and provide an explanation of any implications for the economy of the Province of Manitoba arising from the impact of the proposed or alternative rate increases, including rate increases proposed for the years beyond the test years.

See responses to 8. and 9. Below.

6. Provide comment on issues of rate shock, pacing of rate increases and the intergenerational impacts of rate increases in the Manitoba context, including with reference to the rate increases sought by Manitoba Hydro in its General Rate Application.

Expansion of hydroelectric systems, such as that in Manitoba, involves lumpy investments in generation (to exploit scale economies) and transmission (as supply sources are distant from load). They do not enjoy the scalability advantages of solar, wind and natural gas generation.

This leads to long-term cyclical pressures on rates. Current customers have benefited from past investments, particularly those that have been largely depreciated, but remain functional. Future customers will need to pay for current projects. The calculus of intergenerational fairness is therefore, at a minimum, complex, and may not lead to unequivocal answers.

Rate-smoothing is a useful tool for promoting inter-generational equity. Rates projected by Manitoba Hydro are more in the nature of a step function lasting six years, followed by a rapid decline to increases close to the rate of inflation. A ramped sequence of increases, perhaps linked to a clear demonstration of efficiencies achieved by Manitoba Hydro, may be a useful framework for promoting internal efficiencies, allowing time to adjust to electricity rates, and distributing costs more equitably over each generation of consumers.

See section *"D.1 Rates, Costs and Intergenerational Equity"*.

7. Review and assess Manitoba Hydro's General Rate Application Appendices 10.4, 10.5, 10.6 and 10.7 (B ill Affordability). Provide comment on the issue of "Energy Poverty", including as the issue applies to Indigenous and Northern communities, and an analysis of the experience in other Canadian jurisdictions as to measuring the extent of this problem and potential remedies that have been suggested. What lessons can be learned from other Canadian provinces as to measuring the extent of this problem and potential remedies that have been suggested.

Manitoba has a relatively low rate of energy poverty in comparison to other provinces: about 7% of households spend 10% or more of their income on energy. However, the incidence of energy poverty varies significantly across the Province and is particularly high in remote communities where prices of many goods, among them energy, are high. The projected growth in electricity prices will increase rates of energy poverty.

The impact on energy poverty, which is already high in remote First Nations communities, is likely to be especially acute given the limited possibilities for energy substitution. In addition, low incomes will hamper substitution of capital goods, such as improved insulation, and efficient windows and doors. Commercial and industrial establishments in such communities will also be adversely affected, particularly given the absence of energy substitutes such as natural gas.

Review of energy program initiatives across Canada indicates that Manitoba has been pro-active in seeking to understand the structure and causes of energy poverty, and in developing remedies.

See section "D.2 Bill Affordability and Energy Poverty".

For Macroeconomics Aspects:

8. Given your findings with respect to demand responses by various customer classes and sectors of the economy to electricity price increases, review, assess and provide analysis on the potential or probable implications for the Manitoba economy as a whole.

Market economies have experienced major energy price increases. The dramatic oil price shocks of the 1970s which were largely unanticipated, led to economic contractions of half a per cent or less. The cumulative impact on U.S. GDP of the oil price shock in the late 1970s is estimated to be about 3%. These past experiences are helpful in bounding the likely effects of significant electricity price increases in Manitoba. See section *"E.1 Energy Price Shocks".*

The projected electricity rate increases are not of the same magnitude as the oil price shocks of the 1970s. However, given that in the short-term, demand for electricity is highly price-inelastic, the steepness of the projected rate increases will impose a significant burden, particularly on households, businesses and institutions that do not have access to natural gas. In some locations, especially those which are heavily dependent on an industry that is sensitive to electricity prices, there could be large local impacts on employment, incomes and output. See sections *"C.2 Price Elasticities", "C.3 GDP Elasticities, and Energy and Electricity Intensities", "D.2 Bill Affordability and Energy Poverty"* and *"E.1 Energy Price Shocks".*

The Manitoba economy is significantly affected by wide and difficult-to-predict fluctuations in other key variables, such as exchange rates and commodity prices. Notwithstanding wide variations in these variables, the Manitoba economy has continued to thrive. See sections *"E.2 Exchange Rates"* and *"E.3 Commodity Prices"*

The net effect on GDP may eventually be modest, keeping in mind that the electricity cost shares for major sectors of the economy (e.g., the service sector which comprises 71% of GDP) are low. However, in the interim, there are likely to be significant adjustment costs. See sections *"B.1 Economic Setting" and "D.4 Electricity Intensity Varies Widely Across Some Sectors of the Manitoba Economy".*

9. In the context of the proposed Manitoba Hydro rate increases, with the benefit of the latest Statistics Canada input-output tables for Manitoba (and/or other relevant sources), identify

and provide comment on the "electricity intensive" sectors of the Manitoba economy, including the following:

a. Whether the province would be at risk of losing major electricity-consuming firms to other North American jurisdictions;
b. In light of the heavily export-oriented nature of key sectors of the Manitoba economy, what the implications would be for producers.
c. Place these issues in some quantitative perspective, both in terms of the aggregate provincial GDP and income distribution effects by key sectors and customer classes.

Certain industries will be significantly affected if the projected rate increases are realized. In the manufacturing sector, the most vulnerable industries appear to be 'basic chemicals' and 'pulp and paper' where electricity comprises high shares of costs. Iron and steel mills, foundries, non-ferrous metal production, fertilizer and pesticide, and various equipment manufacturing industries also have significant electricity cost shares.

In the agricultural sector, 'greenhouses' and 'animal production' have significant electricity cost shares. In the mining sector, 'support activities for oil and gas production' and extraction of metals also have significant electricity cost shares.

While the consequences of high electricity rates in some of these industries will be quite significant, they need to be understood from the perspective of overall price variation and uncertainty associated with other key variables which affect them, such as exchange rates and commodity prices.

See sections *"B.1 Economic Setting", "E.1 Energy Price Shocks", "E.2 Exchange Rates", "E.3 Commodity Prices", "E.4 Electricity Intensity Varies Widely Across Some Sectors of the Manitoba Economy"* and *"Appendix 5: Manitoba Electricity Cost Shares by Sub-Sector".*

10. Provide a report on the Microeconomic Aspects and Macroeconomic Aspects to be placed on the public record that provides your findings and supporting information.

Appendix 2: Curriculum Vitae – Adonis Yatchew

Professor of Economics, University of Toronto
Editor-in-Chief, The Energy Journal
Senior Consultant, Charles River Associates

Department of Economics, University of Toronto

150 St. George Street, Toronto, Canada M5S 3G7

(416) 978-7128

adonis.yatchew@utoronto.ca
http://www.economics.utoronto.ca/yatchew/

Ph.D. Economics 1980
Harvard University

M.A. Economics 1975
University of Toronto

B.A. Mathematics and Economics 1974
University of Toronto

Adonis Yatchew's research focuses on econometrics, energy and regulatory economics. Since completing his Ph.D. at Harvard University, he has taught at the University of Toronto. He has also held visiting appointments at Trinity College, Cambridge University and the University of Chicago, among others. He has written a graduate level text on semiparametric regression techniques published by Cambridge University Press. He has served in various editorial capacities at The Energy Journal since 1995 and is currently the Editor-in-Chief. He has advised public and private sector companies on energy, regulatory and other matters for over 25 years and has provided testimony in numerous regulatory and litigation procedures. Adonis Yatchew currently teaches undergraduate and graduate courses in energy economics, graduate courses in econometrics and 'Big Ideas' courses on energy and the environment with colleagues in physics and classics.

ACADEMIC EXPERIENCE

Current Position	Professor of Economics, University of Toronto
2008	Visiting academic, Department of Mathematics and Statistics, University of Melbourne
2008	Visiting academic, School of Economics and Finance, Queensland University of Technology
2008	Visitor, National Center for Econometric Research, Queensland University of Technology
2005	Visiting Fellow, ARC Center of Excellence for Mathematics and Statistics of Complex Systems, Mathematical Sciences Institute, Australian National University
2001	Visiting Fellow, School of Mathematical Sciences, Australian National University

1986 to 2004	Associate Professor, Economics, University of Toronto
1989, 1990, 1991	Visiting Research Associate, Harvard University
1986	Visiting Fellow Commoner, Trinity College, Cambridge U.K.
1980 to 1986	Assistant Professor, Economics, University of Toronto
1984	Visiting Research Associate, National Bureau of Economic Research, Cambridge, Massachusetts
1982 to 1984	Visiting Assistant Professor, University of Chicago
1976	Lecturer, University of Toronto, Scarborough College

EDITORIAL AND PROFESSIONAL ACTIVITIES

Current

Editor-in-Chief, The Energy Journal (2006-present)
Member, Board of Editors, Economics of Energy and Environmental Policy
Member, Editorial Board, Foundations and Trends in Econometrics
Member, Council, International Association for Energy Economics
Member, National Center for Econometric Research, Econometrics of Energy and the Environment, Australia

Past

Editor, The Energy Journal, (2006)
Joint Editor, The Energy Journal (1995-2005)
Associate Chair for Graduate Studies, University of Toronto, 2006-2009
Joint Editor 1997, Distributed Generation, special issue of the Energy Journal
Advisory Editor, Economics Letters (1985-1997)
Member, Advisory Board, *Eurasia Foundation*, 1995-2007

AWARDS AND DISTINCTIONS

USAEE Senior Fellow Award, June 2014

SELECTED PRESENTATIONS

May 2016, Montebello Quebec: presentation entitled “Rational Carbon Policy and Regulation”, Canadian Energy Law Forum.

March 2016, Paris: Keynote Address “Subsidiarity and Separation”, 4th International Symposium on Energy and Finance Issues.

November 2015, Panelist, “Outlook on Oil”, University of Toronto Energy Network, University of Toronto.

June 2015, Milan: “Discerning Trends in Commodity Prices”, Invited presentation, Fondazione Eni Enrico Mattei, International Workshop on Recent Evolutions of Oil and Commodity prices.
April 2015, Bank of Canada, Workshop on Commodity Super-Cycles, “Discerning Trends in Commodity Prices.

September 2014, Beijing: Keynote address entitled “The Economics of Energy, Big Ideas for the Non-Economist”, Chinese Academy of Sciences, International Association for Energy Economics 4th IAEE Asian Conference.

June 2014, Hong Kong: Invited presentation entitled “Renewable Energy”, Hong Kong’s Electricity Future: Balancing Reliability, Environment and Cost, Hong Kong Baptist University.

July 2012, Hong Kong: Invited Speaker on “Climate Change and Electricity Generation”, Hong Kong Baptist University.

December 2010, Hong Kong: Invited paper on renewable energy, Fourth Asian Energy Conference.

October 2010, Berlin: Invited paper on quantile regression, Workshop on Quantile Regression Methods, Humboldt University.

October 2008, Gold Coast, Queensland: Keynote speaker, Australian Conference of Economists. Title of presentation: “Economics, Econometrics and Regulation”.

August 2007, Lisbon: Keynote speaker, Cemapre Conference on Advances in Semiparametric Methods and Applications. Title of presentation: “Data on Derivatives, Nonparametric Regression and the Curse of Dimensionality”.

BOOKS, EDITED VOLUMES

Yatchew, A., 2003, <u>Semiparametric Regression for the Applied Econometrician</u>, 213 pages, Themes in Modern Econometrics, Cambridge University Press.

<u>Chinese Energy Economics</u>, Special Issue of <u>The Energy Journal</u>, Edited by Ying Fan and Adonis Yatchew, 2016.

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OTHER PAPERS / STUDIES

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RECENT RESEARCH GRANTS

2011-2016 SSHRC grant "Nonparametric regression when data on derivatives are available".

2007-2011 SSHRC grant "Nonparametric and semiparametric estimation when data on derivatives are available".

2004-2007 SSHRC grant "Semiparametric demand modeling and testing".

CURRENT AND RECENT SUPERVISIONS

Ph.D.

Dhruv Sinha (2017): Essays in Energy

Dimitrios Dimitropoulos (2015): Three Essays in Energy Economics and Industrial Organization, Thesis Supervisor.

Adam Found (2014): Essays in Municipal Finance, Thesis Supervisor.

M.A.

Daniel Edgel (2017-2017): Fulbright Scholar, M.A. Economics

Nathan Warkentin (2015-2016): Masters of Science in Sustainability Management. "Integration of Renewable Wind Energy Sources in Ontario"

Sean Lemon (2013): M.Sc.Pl., Planning Program, Geography. An Evaluation of Ontario's Global Adjustment Mechanism (GAM). Thesis Committee.

Undergraduate

Wei, Max (2016-2017) Engineering Science. Undergraduate thesis: "Wind Energy Intermittency, Diversity and Interconnections in Ontario". Thesis Supervisor.

Shaker, Youssef (2016-2017) Engineering Science. Undergraduate thesis: "Analyzing the Effectiveness of Conservation Programs in Ontario". Thesis Supervisor.

Wilbur Li, (2012) Engineering Science. Undergraduate thesis: "Ontario's Feed-In-Tariff Program. Analysis of PV Solar Feed-In-Tariff Rates". Thesis Supervisor.

OTHER PROFESSIONAL EXPERIENCE:

(2017) Prepared expert testimony on regulatory costing of railway transportation services, filed before the *Canadian Transportation Agency*.

(2017) Prepared analyses on the degree of integration of natural gas hub prices in a major North American acquisition of pipeline and storage facilities.

(2016) Prepared analyses on price determination in West Coast gasoline and diesel markets as part of an asset acquisition evaluation.

(2016) Prepared statistical analyses of market power in the acquisition of MTS by Bell Canada.

(2016) Testified before the *Ontario Energy Board* on behalf of EPCOR Utilities Inc. in a proceeding relating to natural gas expansion in Ontario, EB-2016-04.

(2016) Conducted 'extent of the market' and market power analyses for a major hydrocarbon company seeking to acquire additional refining capacity.

(2015) Conducted analyses of utility benchmarking for a large electricity distributor as part of a regulatory rate proceeding before the *Ontario Energy Board*.

(2015) Co-authored study of integration of renewables for the *Alberta Market Surveillance Administrator.*

(2014) Conducted econometrics analyses of spot and forward prices in Alberta electricity markets in a major electricity acquisition evaluation.

(2013) Testified before the *Ontario Energy Board* on behalf of the Electricity Distributors Association on electricity rates and incentive regulation.

(2012) Prepared expert damages testimony in *Oracle America Inc. v. Micron Technology, Inc., U.S. District Court, Northern District of California, Oakland Division*.

(2011) Coauthored study for the *Alberta Market Surveillance Administrator* on electricity market transparency and bidding.

(2011) Prepared Ontario electricity sector review for the Electricity Distributors Association.

(2011) Appointed sole representative of a major Canadian electrical utility in infrastructure pricing negotiations with an incumbent telecom carrier.

(2011) Prepared testimony on behalf of Toronto Hydro on the pricing of attachment space for wireless facilities on joint-use-poles, filed before the *Ontario Energy Board*.

(2010) Prepared testimony on behalf of Noranda Aluminum, Inc. Filed before the *Public Service Commission of the State of Missouri*.

(2009) Prepared study for major generating company on sufficient competition tests for boundary entities in the Ontario electricity market.

(2009) Prepared testimony on worldwide paraxylene markets *Interquisa Canada L.P. and Parachem Chemicals L.P.*, International Court of Arbitration of the International Chamber of Commerce.

(2008) Prepared analysis of incentive regulation of capital and operating c osts and productivity growth for electricity distributors. Filed before the *Ontario Energy Board*.

(2007) Prepared analysis of distributor benchmarking of capital and operating costs on behalf of the Electricity Distributors Association. Filed before the *Ontario Energy Board*.

(2007) Prepared evidence on market power in Ontario electricity markets.

(2005-2007) Prepared analyses of pricing of investor communications services.

(2007) Prepared testimony on behalf of the Electricity Distributors Association on utility benchmarking of capital and operating costs. Filed before the Ontario Energy Board.

(2004-2007) Prepared various analyses in a class action and settlement proceeding involving billing of natural gas. Participated in settlement proceedings.

(2004, 2005, 2006) Prepared odds of winning prizes in promotions by a leading U.S.-based international fast-food chain.

(2006) Prepared testimony on incentive regulation. Filed before the *Ontario Energy Board*.

(2006) Prepared testimony on cost-sharing of capital and operating costs of joint-use power poles. Filed before the *New Brunswick Board of Commissioners of Public Utilities.*
(2005) Prepared testimony on cost-sharing of power poles by cable companies on behalf of Thunder Bay Hydro.

(2004) Prepared testimony on cost-sharing of capital costs of power poles by cable companies. Filed before the *Ontario Energy Board*.

(2003) Prepared testimony on behalf of large Ontario electricity distributors on distributor service area amendments. Filed before the *Ontario Energy Board*.

(2003) Prepared testimony on behalf of J.D. Irving Ltd. on rates of return, performance based regulation and benchmarking. Filed before the *New Brunswick Board of Commissioners of Public Utilities*.

(1982-1994) Participated in numerous Ontario Hydro rate hearings before the *Ontario Energy Board* on behalf of Ontario electricity distributors.

(1989-1991) Filed testimony before the *Ontario Environmental Assessment Board* in connection with the Ontario Hydro long-term demand supply plan.

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Appendix 4: Manitoba Electricity Cost Shares by Sub-Sector

Source: CANSIM Tables 381-0033 Supply and Use, Manitoba 2013.

Manufacturing	
Fruit and vegetable preserving and specialty food manufacturing [BS311400]	1.55%
Bakeries and tortilla manufacturing [BS311800]	1.01%
Textile and textile product mills [BS31A000]	1.28%
Sawmills and wood preservation [BS321100]	1.16%
Veneer, plywood and engineered wood product manufacturing [BS321200]	1.86%
Pulp, paper and paperboard mills [BS322100]	6.98%
Basic chemical manufacturing [BS325100]	18.10%
Pesticide, fertilizer and other agricultural chemical manufacturing [BS325300]	1.63%
Soap, cleaning compound and toilet preparation manufacturing [BS325600]	1.29%
Plastic product manufacturing [BS326100]	1.04%
Non-metallic mineral product manufacturing (except cement and concrete products) [BS327A00]	1.72%
Iron and steel mills and ferro-alloy manufacturing [BS331100]	3.33%
Non-ferrous metal (except aluminum) production and processing [BS331400]	2.51%
Foundries [BS331500]	3.04%
Forging and stamping [BS332100]	1.00%
Hardware manufacturing [BS332500]	1.11%
Coating, engraving, heat treating and allied activities [BS332800]	1.14%
Engine, turbine and power transmission equipment manufacturing [BS333600]	1.98%
Electric lighting equipment manufacturing [BS335100]	1.88%
Motor vehicle electrical and electronic equipment manufacturing [BS336320]	1.60%
Mining	
Gold and silver ore mining [BS212220]	2.76%
Copper, nickel, lead and zinc ore mining [BS212230]	1.97%
Other metal ore mining [BS212290]	3.40%
Stone mining and quarrying [BS212310]	0.37%
Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying [BS212320]	0.75%
Other non-metallic mineral mining and quarrying (except diamond and potash) [BS21239A]	0.71%
Support activities for oil and gas extraction [BS21311A]	6.30%
Support activities for mining [BS21311B]	0.03%
Agriculture	
Crop production (except greenhouse, nursery and floriculture production) [BS111A00]	0.86%
Greenhouse, nursery and floriculture production [BS111400]	2.78%
Animal production (except aquaculture) [BS112A00]	1.93%
Forestry and logging [BS113000]	1.09%

Fishing, hunting and trapping [BS114000]	0.44%
Support activities for crop and animal production [BS115A00]	0.20%
Support activities for forestry [BS115300]	0.04%
Services	
Furniture and home furnishings stores [BS442000]	1.08%
Building material and garden equipment and supplies dealers [BS444000]	1.03%
Gasoline stations [BS447000]	1.20%
Miscellaneous store retailers [BS453000]	1.05%
Non-store retailers [BS454000]	1.91%
Crude oil and other pipeline transportation [BS486A00]	2.06%
Radio and television broadcasting [BS515100]	1.02%
Non-depository credit intermediation [BS522200]	1.06%
Lessors of real estate [BS531100]	2.26%
Lessors of non-financial intangible assets (except copyrighted works) [BS533000]	1.27%
Educational services [BS610000]	2.12%
Offices of dentists [BS621200]	1.43%
Miscellaneous ambulatory health care services [BS621A00]	1.07%
Nursing and residential care facilities [BS623000]	1.83%
Social assistance [BS624000]	6.09%
Amusement and recreation industries [BS713A00]	1.18%
Traveller accommodation [BS721100]	1.45%
RV (recreational vehicle) parks, recreational camps, and rooming and boarding houses [BS721A00]	2.57%
Automotive repair and maintenance [BS811100]	2.42%
Repair and maintenance (except automotive) [BS811A00]	1.35%
Personal care services and other personal services [BS812A00]	1.27%
Dry cleaning and laundry services [BS812300]	4.48%
Professional and similar organizations [BS813000]	5.36%
Educational services [NP610000]	6.07%
Arts, entertainment and recreation [NP710000]	2.11%
Religious organizations [NP813100]	3.23%
Grant-making, civic, and professional and similar organizations [NP813A00]	2.60%
Other non-profit institutions serving households [NP999999]	1.18%
Community colleges and C.E.G.E.P.s [GS611200]	2.57%
Universities [GS611300]	1.17%
Other educational services [GS611A00]	4.36%
Other municipal government services [GS913000]	2.96%
Other aboriginal government services [GS914000]	1.93%
Utilities	
Natural gas distribution [BS221200]	0.12%
Water, sewage and other systems [BS221300]	0.61%

Construction	
Residential building construction [BS23A000]	0.04%
Non-residential building construction [BS23B000]	0.03%
Transportation engineering construction [BS23C100]	0.02%
Oil and gas engineering construction [BS23C200]	0.02%
Electric power engineering construction [BS23C300]	0.12%
Communication engineering construction [BS23C400]	0.25%
Other engineering construction [BS23C500]	0.10%
Repair construction [BS23D000]	0.04%
Other activities of the construction industry [BS23E000]	0.35%

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