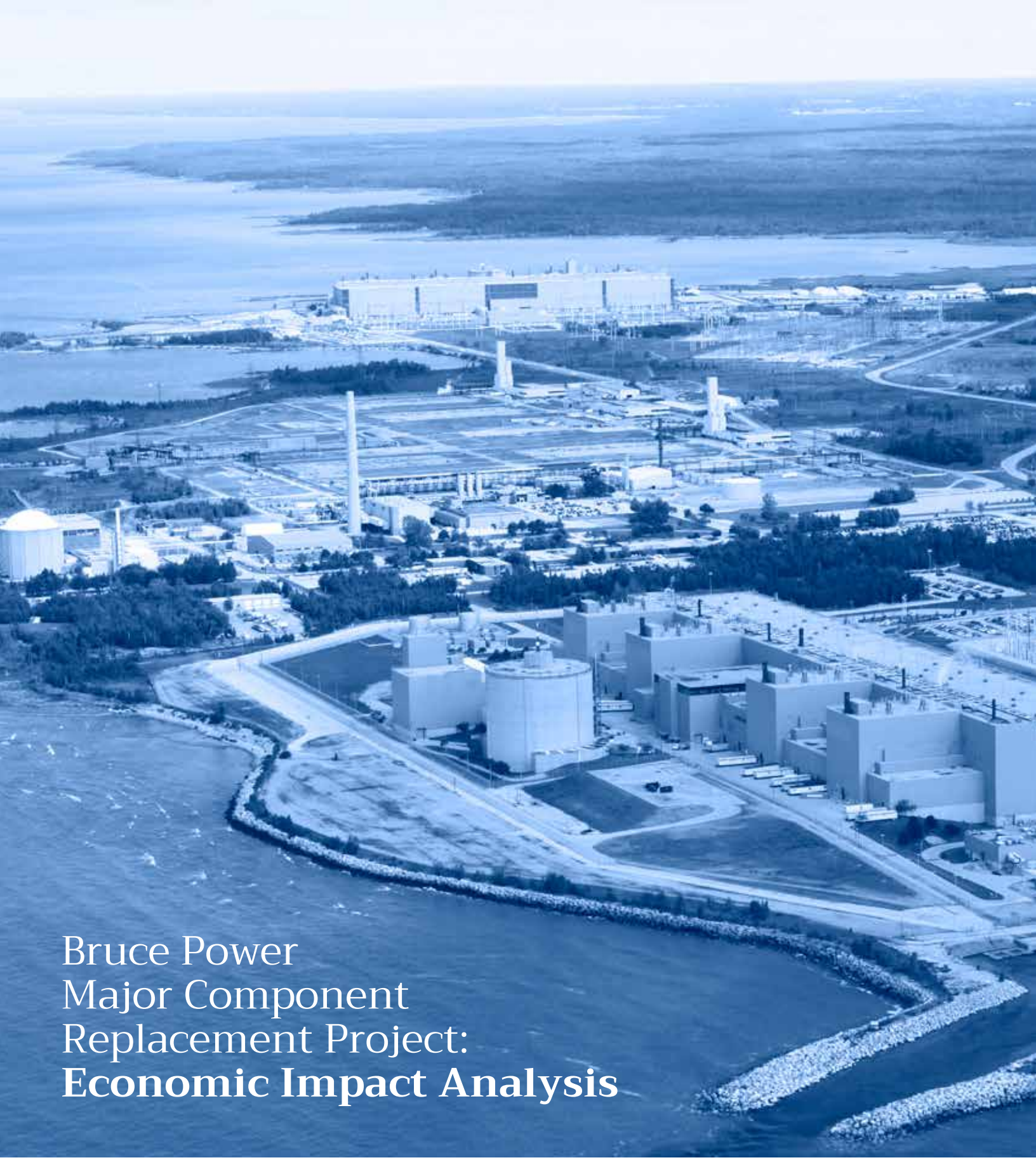


Bruce Power Major Component Replacement Project: **Economic Impact Analysis**

ontario chamber of commerce

Bruce Power™

Innovation at work

Table of Contents

Executive Summary

Bruce Power is a limited liability partnership between the TransCanada Corporation, OMERS Infrastructure, the Power Workers' Union, and The Society of United Professionals, making it one of the largest P3 partnerships in the world. Bruce Power is embarking upon one of the largest and most sophisticated construction projects in Canadian history: the Bruce Power Life-Extension Program.

A central component to Bruce Power's Life-Extension Program and the focus of this report is the Major Component Replacement (MCR) Project. The MCR project runs from 2020-33 and comprises all activity concerning refurbishment and replacement of six of Bruce Power's eight reactors. MCR will allow the Bruce site to operate to 2064, securing low-cost power for decades to come. As described by the FAO, "there is currently no portfolio of alternative low emissions generation which could replace nuclear generation at a comparable cost."[1]

In our quantitative analysis of the economic benefit derived from the labour and materials used in the 13-year-long MCR construction project, the Ontario Chamber of Commerce (OCC) estimates:

- Ontario economic impact to be between $7.6 and $10.6 billion;
- Canadian economic impact to be between $8.1 and $11.6 billion;
- Ontario GDP to increase between $4.8 and $7.1 billion;
- Canadian GDP to increase between $5.2 and $7.8 billion;
- Ontario labour to receive between $3.8 and $4.6 billion and Canadian workers located in other provinces to receive an additional $300 million;
- The federal government to receive $144 million in excise tax and $1.2 billion in income tax;
- The provincial government to receive $300 million in excise tax and $437 million in income tax; and
- Ontario's municipal governments to receive a collective $192 million in tax.

In addition, the size and scope of the MCR Project will prove fruitful for the province's workforce development prospects, both in the project's demand of advanced skills and unique work experience offered. The structure of the public-private partnership will provide continued employment and revenue to the over 200 companies and contractors directly involved in the project. Large and complex construction projects, such as the MCR, provide these participating firms the needed demand to push them to the leading edge of their respective industries. The highly skilled labour and technologically advanced goods and materials demanded by the MCR provide the valued impetus and revenue for local industry to elevate their offerings to that of the leading global standard, in turn expanding the market for their goods and services.

Our findings indicate that the construction-related activities associated with MCR Project provide a substantial return on investment to Ontario. This is both with respect to economic impact and within the context of the overall economic and environmental benefits of nuclear energy and the nuclear supply chain.

1 Financial Accountability Office of Ontario. 2017. *Nuclear Refurbishment Report*. https://www.fao-on.org/en/Blog/Publications/FAO-NR-Report-Nov-2017#C:%20Alternative%20Generation%20Options

Introduction

Commissioned by Bruce Power, this report is intended to provide an impartial economic impact assessment of the Major Component Replacement (MCR) Project being undertaken as part of Bruce Power's Life-Extension Program. The MCR encompasses all work required to replace the reactors and immediate componentry, whereas the Life Extension Program refers to the MCR and all other ancillary work, such as supporting infrastructure and organizational development. The assessment attempts to provide a quantitative analysis of the economic impact expected to be received by Canada, Ontario, and Bruce County, as well as presents a qualitative projection of the broader economic benefits that large, highly complex infrastructure projects, such as MCR, could potentially offer Ontario.

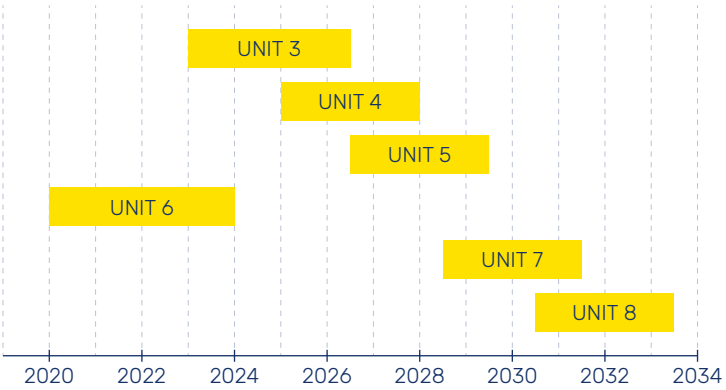
Bruce Power: Context Defined

Bruce Power is a limited liability partnership between the TransCanada Corporation, OMERS Infrastructure, the Power Workers' Union, and The Society of United Professionals, making it one of the largest P3 partnerships in the world. Located on the Bruce Peninsula at the southern shore of Lake Huron, Bruce Power is the licensed operator of eight nuclear reactors. Together, these eight reactors comprise the Bruce Nuclear Generating Station, the largest operating nuclear plant in the world, providing a maximum capacity of 6,400 megawatts.[2] In 2015, Bruce Power set its record for production, generating over 30 percent of Ontario's electricity at 30 percent less than the average cost to generate residential power and has continued to do so every year since.

In 2003, Bruce Power embarked on the Bruce A Restart Project—at the time considered to be the most sophisticated engineering project in Ontario's history—to restart reactor Units 3 and 4[3] which had lain dormant for nearly two decades at the Bruce site. Then, upon successful completion of the Bruce A Restart, and using what it had learned restarting Units 3 and 4, Bruce Power began refurbishment of Units 1 and 2 in 2005, finishing in 2012. With all four reactors completed, Bruce Power began providing 3,000 megawatts of electricity to Ontario's grid, contributing 70 percent of the power ultimately needed to permanently transition away from coal-fired electricity production in 2014.

In December 2015, Bruce Power amended its long-term agreement with the Independent Electricity System Operator (IESO), an arms-length crown corporation responsible for managing Ontario's electricity market, to secure 6,400 megawatts of electricity capacity through to 2064. Central to this agreement is the 13-year Major Component Replacement (MCR) Project, which aims to extend the life of Units 3 to 8 for an additional 30 years. Upon completion, the MCR will allow the Bruce Power site to produce electricity through to 2064.

FIGURE 1: MCR PROJECT TIMELINE



With Unit 6 slated to begin refurbishment in January 2020, preparations are well underway. As reactor units complete their refurbishment, others will begin the process. This chaining of reactor refurbishment affords the MCR Project long-term value by way of greater efficiency found through repetition and development of relationships with local contracting and supply partners.[4]

Bruce Power's focus on innovation, simplification and delivering efficiencies, while increasing site output and reliability, also means over $200 million in efficiency payments will be returned to Ontario electricity customers between 2019 and 2021.[5]

2 Bruce Power is currently pursuing measures to uprate the output if the site to 7000 MW and has increased the capacity for generation from 63400 MW to 64500 MW in the past year.

3 The reactor unit is the vessel, and immediate componentry, in which the nuclear fission reaction of uranium-238 and uranium-235, often referred to as 'natural uranium' due to its relatively unrefined form, split into smaller parts generating a thermal reaction which is used to spin turbine generators.

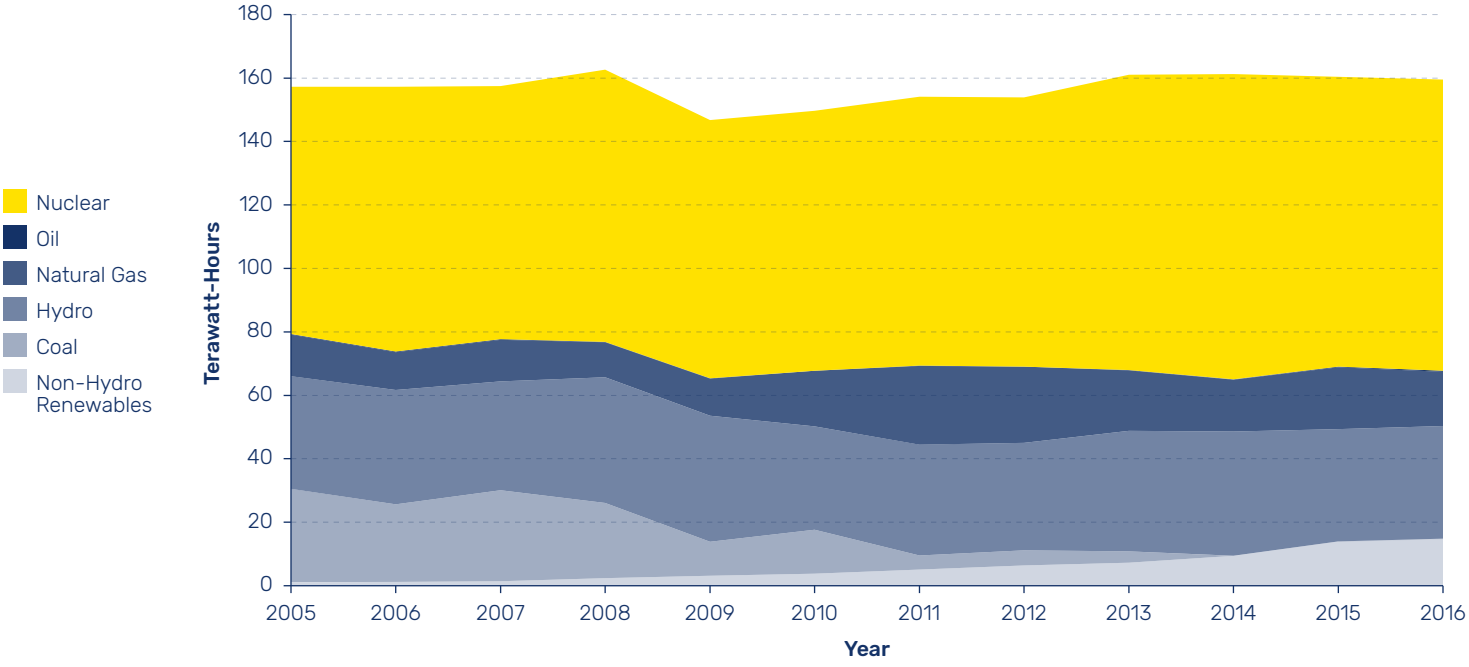
4 Harry Hall. 2016. *Long-Term Outlook*. Bruce Power.

5 Ministry of Energy, Northern Development and Mines. January 25th, 2019. *Bruce Power to Save Ontario Electricity Customers $200 million*. Government of Ontario. https://news.ontario.ca/mndmf/en/2019/01/bruce-power-to-save-ontario-electricity-customers-200-million.html

Nuclear Energy in Ontario

In shutting down over six gigawatts of installed coal-fueled electricity supply between 2005 and 2014, Ontario's electricity system has undergone a fundamental shift from an unsustainable, carbon-heavy energy supply to one that is nearly free of carbon emissions. Such a transformational shift would not have been possible without the use of nuclear power. As a result of the retirement of coal-fired generation, greenhouse gas emissions from Ontario's electricity sector have fallen by 80 percent since 2005, with clean energy—much of which is nuclear—now comprising 70 percent of the province's installed capacity.[6]

FIGURE 2: GENERATION IN ONTARIO (2005–2016)[7]



6 Installed capacity represents the amount of electricity the entire electricity system, or a particular generation system, is capable of generating. This is contrasted with electricity production, which references the amount of electricity produced over a given period of time.

7 National Energy Board of Canada. 2017. *Canada's Energy Future 2017: Energy Supply and Demand Projections to 2040*. http://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2017/index-eng.html

In all, Bruce Power generated over 46.6 TWh, enough electricity to power over 5.2 million Ontario homes for the full year in 2017.

70%

Bruce Power Nuclear Generating Station provided 70% of the energy needed to help Ontario achieve its coal-phase out in 2015.

60%

Nuclear energy provides 60% of Ontario's daily supply needs.

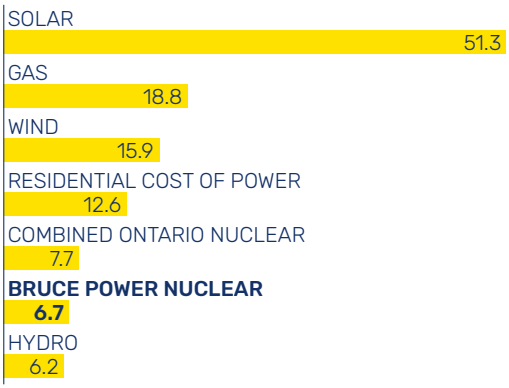
30%

Bruce Power supplies 30% of Ontario's electricity at 30% less than the average cost to generate residential power.

From 2003 to 2014, the share of Ontario's electricity generated from nuclear power stations increased from 42 to 62 percent, providing the province with enough sustainable generation capacity to replace all coal-fired sources of power with nuclear energy and a combination of natural gas and non-hydro renewables.[8] Carbon emissions from electricity generation now only comprise four percent of Ontario's total emissions.[9] Further, the transition away from coal has allowed for an estimated savings of $4.4 billion per year in health and environmental costs.[10]

In 2017, Ontario's nuclear generating stations generated 90.6 terawatt-hours (TWh) of electricity, which constituted 63 percent of the total electricity produced by the province and 35 percent of the installed generation capacity of the province.[11] In the same year, the nuclear sector yielded a $5 billion industry comprised of over 200 companies and more than 60,000 jobs, encompassing sectors such as operations, manufacturing, skilled trades, health care, and research and innovation.

FIGURE 3:
2017 ELECTRICITY PRICE[12] (¢/kWh)



In Ontario, nuclear generation currently costs 7.7 cents per kWh compared to the average cost to generate residential power of 12.6 cents per kWh, making it one of the least expensive sources when compared to other forms of electricity generation. The nuclear sector contributes to the Ontario economy by providing less costly electricity, supporting the province's climate change goals, creating jobs across its high-tech supply chain, and providing a critical supply of medical isotopes to the world's health care system.

Isotopes supplied by nuclear generation have a variety of medical uses, such as High Specific Activity Cobalt to treat brain tumors; and Cobalt 60, which can be used to sterilize medical instruments. The isotopes provided by Bruce Power not only provide the world's medical community with a valued, steady supply of medical isotopes, but also serve to aid in the advancement of Ontario's medical treatment practices and innovation.

8 National Energy Board of Canada. 2018. *Nuclear Energy in Canada Energy Market Assessment*. https://www.neb-one.gc.ca/nrg/sttstc/lctrct/rprt/2018nclrnrg/2018nclrnrg-eng.pdf.

9 Independent Electricity System Operator (IESO). 2016. *Ontario Planning Outlook: A Technical Report on the Electricity System*. http://www.ieso.ca/ Documents/OPO/OntarioPlanning-Outlook-September2016.pdf.

10 Independent Electricity System Operator (IESO). 2016. *Ontario Planning Outlook: A Technical Report on the Electricity System*. http://www.ieso.ca/ Documents/OPO/OntarioPlanning-Outlook-September2016.pdf.

11 Independent Electricity System Operator (IESO) 2018. *2018 Electricity Data*. http://www.ieso.ca/en/Corporate-IESO/Media/Year-End-Data.

12 Ontario Energy board. April 20, 2018. *Regulated Price Plan Supply Cost Report May 1, 2018 to April 30, 2019*. https://www.oeb.ca/sites/default/files/RPP-Supply-Cost-Report-20180501-20190430-correction.pdf

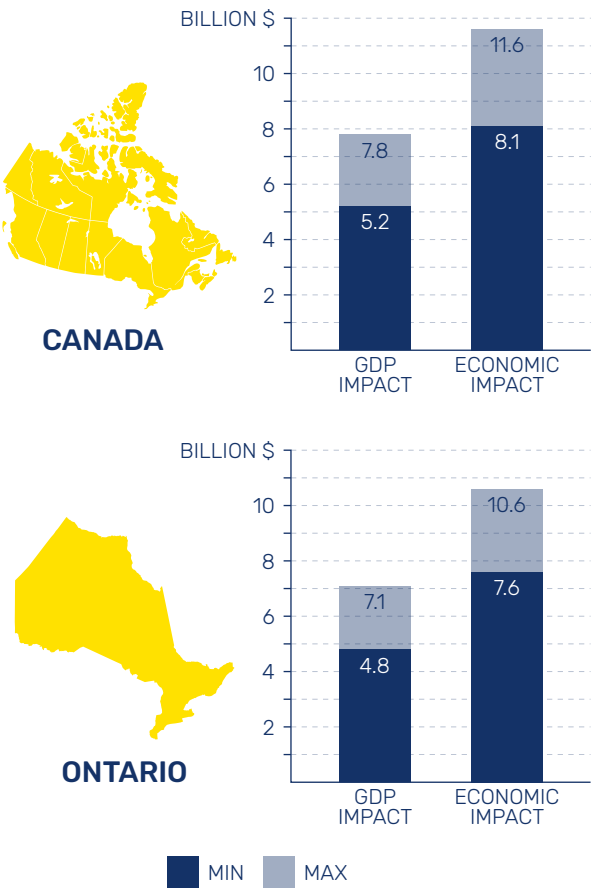
Economic Impact Assessment

By analyzing the expected capital expenditure needed to complete construction of Bruce Power's MCR Project, the OCC has arrived at the following assessment, which examines the economic impact the MCR Project is expected to have on the economy during its 13-year duration. All analysis was completed through use of Statistics Canada's robust Input-Output Model Simulations.[13]

It is important to note that this assessment only accounts for the immediate economic benefit realized by those industries directly and indirectly involved in the MCR construction project alone. The long-lasting macro benefits nuclear power generation offers Ontario's unique character—by way of low-cost electricity and niche labour demand, among others—are simply too obscure to account for from a quantitative viewpoint. As such, subsequent sections will attempt to do so from a qualitative or contextual perspective.

OBSERVATIONS ON GDP CONTRIBUTION & TAXES

FIGURE 4: GDP & ECONOMIC IMPACT



The construction industry is often referred to as a 'horizontal' industry as it relies on, and services, a vast array of other industry verticals. This is especially true for large construction projects such as the MCR, which rely on, and maintain robust commercial relationships with, a similarly broad array of other industries (e.g. manufacturing, transportation, and financial services). A large construction project's impact on GDP is, therefore, of a commensurate depth, extending far beyond the direct contribution to construction activity alone, generally thought of as raw materials processing, finance, and transportation, and so forth. In the context of the MCR Project assessment, this is evidenced by the large difference in GDP contribution and economic impact.

In measuring GDP[14] contribution, only expenditures used to realize the final value of a product are counted, meaning only the final dollar value of the product is recorded. In contrast, economic impact[15] measures the final value of all products and materials in addition to the value of capital bought by firms to grow the capacity needed to satisfy the demands of the products being assessed.

In our analysis of Bruce Power's MCR Project, the OCC estimates the impact on GDP to be between $4.8 and $7.1 billion for Ontario and between $5.2 and $7.8 billion for Canada. Comparatively, the economic impact is expected to be between $7.6 and $10.6 billion for Ontario; and between $8.1 and $11.6 billion for Canada.

13 All amounts are in 2015 dollars, as described by Statistics Canada's Input-Output model.

14 GDP measures the sum of all final goods and services purchased to meet the new demands of the MCR Project.

15 Economic impact measures the changes due to interindustry purchases as they respond to the new demands of the industries directly and indirectly affected by the MCR Project. This includes the chain reaction of output up the production stream since each of the products purchased will require, in turn, the production of various inputs.

OBSERVATIONS ON LABOUR DEMANDED

By nature, construction projects are a labour-intensive undertaking, with a significant portion of the investment flowing directly to on-site labour contracts. This is reflected in the OCC's analysis. Fig. 5 describes the amount of labour demanded by each industry, and Fig. 6 shows total labour as described by wages for both Canada and Ontario.

The Canadian Manufacturers and Exporters Association has estimated that the Bruce Power Life-Extension Program will directly and indirectly demand approximately 5,000 jobs per year.[16]

FIGURE 5: TOTAL FULL TIME EQUIVALENT JOBS DEMANDED BY THE MCR PROJECT

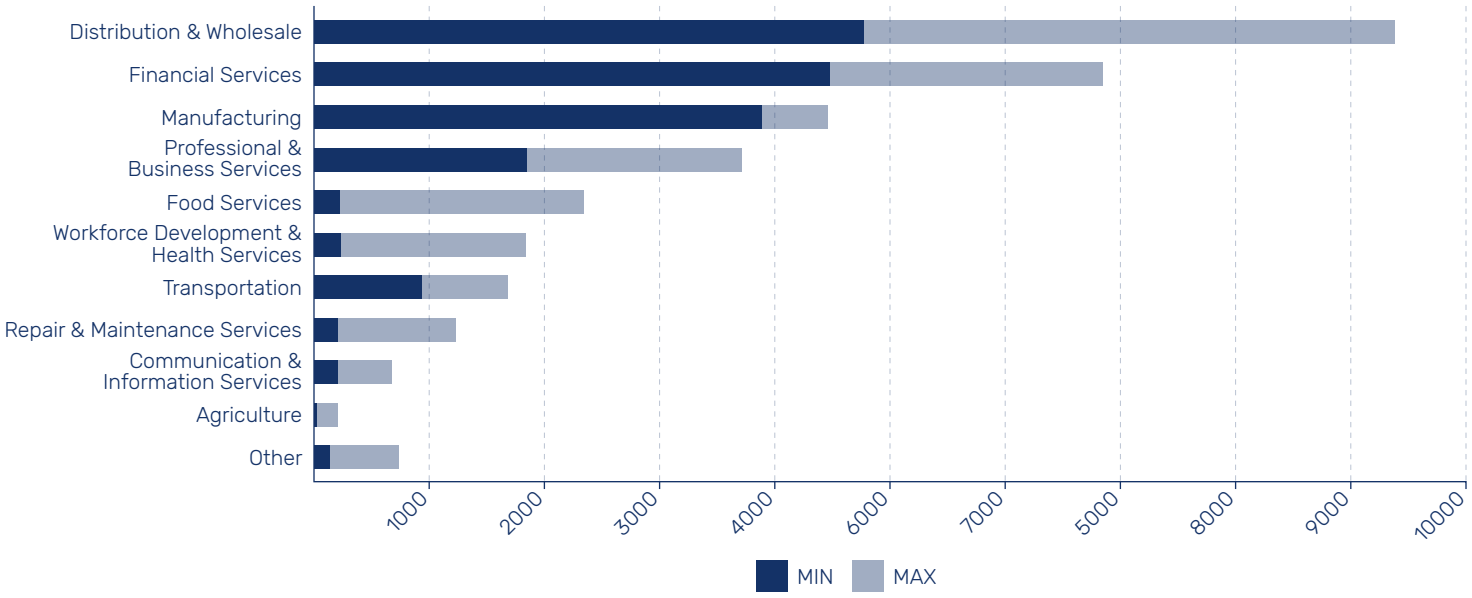
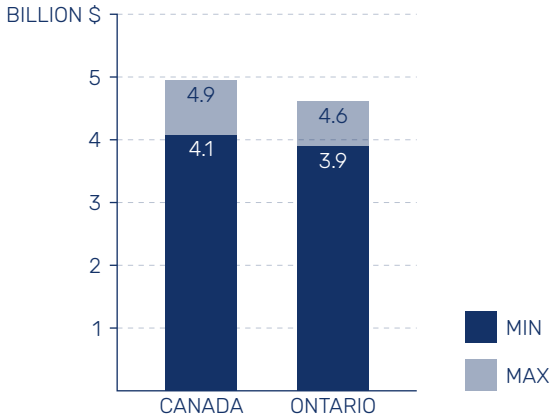


FIGURE 6: TOTAL WAGES DEMANDED BY THE MCR PROJECT



16 Canadian Manufacturers and Exporters Association (CME). 2014. *Affordable Power. Jobs & Growth. By the Numbers: Securing both affordable power and growing Ontario's economy from Bruce Power Site*. https://s14083.pcdn.co/wp-content/uploads/2015/09/140368_EconomicImpactStudy-5med-2.pdf.

LOCAL ECONOMIC IMPACT ON BRUCE COUNTY

Bruce Power collaborates with the County of Bruce on several initiatives to help drive economic growth in the region. This includes the Economic Development and Innovation Initiative, which has seen over 40 nuclear supplier companies either open local offices, create a new venture, or expand operations to Bruce, Grey, and Huron counties since it was launched in 2016.[17]

Bruce Region economic development by the numbers.

DEVELOPMENT

250,000 SQFT
of commercial and industrial spaces

10,000
residential developments approved

$100 MILLION
in new infrastructure

LABOUR DEMAND

40
nuclear suppliers opened in local counties

3000
overall jobs in the region

300
new small business start-ups[18]

Additionally, in 2018, Bruce Power and the County of Bruce announced a new partnership to establish Ontario's Nuclear Innovation Institute, an applied research facility that will enable researchers and industry to come together to identify new and innovative opportunities for the nuclear energy sector. The Institute will include a Skilled Trades and Training Secretariat, consisting of industry leaders who will be responsible for coordinating and increasing employment in the skilled trades to support building a strong, sustainable regional labour force.

17 Bruce Power. 2018. *Economic Summit outlines positive impact of nuclear industry on region*. https://www.brucepower.com/economic-summit-outlines-positive-impact-of-nuclear-industry-on-region/.

18 Bruce Power. 2018. Economic *Summit outlines positive impact of nuclear industry on region*. https://www.brucepower.com/economic-summit-outlines-positive-impact-of-nuclear-industry-on-region/.

Economic Specialization and Economic Development

In addition to supplying infrastructure to support Ontario's current and future interests, investment in Ontario's nuclear sector has the benefit of boosting the value local businesses can offer the global nuclear energy industry. The immense scope and complexity of large projects, such as the MCR, provide the demand needed to encourage cutting-edge labour specialization, and development of a valued, geographically centralized knowledge base.

As described in a recent World Economic Forum report, advancements in construction have long lagged those of the technology made available to the industry.[19] The nature of the disparate and localized projects that comprise the construction industry provide little incentive for construction firms and contractors to integrate costly technology advancements and/or contemporary organizational development practices into their workflow. The economies of scale able to be realized by adopting such innovation are simply too elusive given the limited scope, time, and ad-hoc nature of each construction project. The augmentation of vertical supply chain cooperation and coordination demanded by large, long-term, and sophisticated projects such as the MCR, therefore offers the construction industry the opportunity (and impetus) to integrate and utilize technical and organizational innovation.

As players within the global economy endeavour to advance and diversify their understanding of burgeoning technologies and ideas, industrial specialization becomes increasingly valuable. Specialization in advanced industrial sectors induces a shared knowledge development that is of increasing value in the world market. Similar to how an individual may spend years pursuing an advanced degree in an effort to become an expert worthy of a commensurate wage, localized industry too must endeavour to develop and maintain cutting edge insight and knowledge, which it can then offer the global market.[20] Knowledge of available economies of scale and other operational efficiencies within nuclear energy development are of ever-increasing value, as many countries turn to nuclear energy for the clean, stable, and inexpensive

19 Renz, A., Solas, M., Almeida, P. R., Buhler, M., Gerbert, P., Castagnino, S., & Rothballer, C. 2016. *Shaping the Future of Construction. A Breakthrough in Mindset and Technology. In World Economic Forum*. (Vol. 7, p. 2017).

20 Kemeny, T., & Storper, M. 2015. *Is specialization good for regional economic development?. Regional Studies*, 49(6), 1003-1018.

electricity it offers.[21] Of further benefit, localized industrial sectors that exhibit advanced development have been known to withstand economic downturns with greater ease than those which do not.[22] As the services and products offered by an industry become more specialized, cheaper alternatives or substitutes to such offerings become more scarce. In the Ontario context, the result is improved global competitiveness for businesses within the nuclear supply chain.

This relationship between knowledge and value is especially true for large projects; the International Monetary Fund estimates that for every one percent of GDP invested in a construction project, the economy can receive 1.5 percent in return.[23] Projects such as the MCR allow industries both central and peripheral to Ontario's nuclear sector to develop niche expertise, insights, and capacity, which are of increasing value in the global market. Evidence of the effect a large infrastructure project can have is already visible in the MCR Project's nascence, as firms such as Promation—a custom tool maker—look to make further investments in their manufacturing processes to both increase their market share abroad and to offer enhanced value to long-term initiatives like the MCR.

The level of skill demanded by large construction projects like the MCR Project also serves to provide a valued impetus for schools and technical institutions alike to offer and invest in cutting edge programs, which can produce students with the skillsets needed to complete the project. In completing one of the largest construction projects ever embarked upon in Canada,[24] Bruce Power will demand skilled labour of an unprecedented quantity and level of expertise.

"These large contracts provide a sense of stability for our workers, both longstanding and new hires," said Peter Bethke, Union President for USW Local 2859. "I think many of our longstanding employees are enjoying the opportunity to pass on their skills as they plan for retirement in the not so distant future. USW 2859 is proud to be supporting these major component projects and continues to work hard to see them through successfully."

Peter Bethke
President USW Local 2859

To help meet the demand for labour, Bruce Power has established partnerships with several universities and colleges across Ontario, to ensure that program offerings reflect the emerging needs of Ontario's nuclear sector. In addition, Bruce Power has created the Skilled Trades Secretariat as part of the Nuclear Innovation Institute. The Secretariat will provide an administrative and coordination function, bringing together industry leaders and local organizations to establish a collaborative mechanism for maximizing training programs and capitalizing on local assets, increasing the supply of high-demand skilled trades locally.

21 Lovering, J. R., Yip, A., & Nordhaus, T. 2016. *Historical construction costs of global nuclear power reactors. Energy Policy*, 91, 371-382.

22 Kalemli-Ozcan, S., Sørensen, B. E., & Yosha, O. 2001. *Economic integration, industrial specialization, and the asymmetry of macroeconomic fluctuations. Journal of International Economics*, 55(1), 107-137.

23 Abiad, A., Almansour, A., Furceri, D., Granados, C., & Topalova, P. 2014. *Is it time for an infrastructure push? The macroeconomic effects of public investment. World Economic Outlook: Legacies, Clouds, Uncertainties*, 75-114.

24 Top 100 Canada's Biggest Infrastructure Projects. https://top100projects.ca/2018filters/.

Observations Drawn from Public-Private Partnership

A public-private partnership (P3) can generally be referred to as a "cooperative arrangement between the public and private sectors that involves the sharing of resources, risks, responsibilities, and rewards with others for the achievement of joint objectives."[25] While a purely public approach risks falling victim to indecision and inefficient organization frameworks, a strictly private approach may cause inequalities in the distribution of resources.[26] The collaboration of private and public entities, therefore, enhances market access, opportunities for alternative financing methods, and operational efficiency.[27] Examples of such advantages pertinent to the MCR Project include the following.

ENHANCED SOCIAL CAPITAL PROVIDED THROUGH STRENGTHENED PARTNERSHIP WITH THE PUBLIC SECTOR

Social capital can be defined as the norms of trust and reciprocity that provide informal social governance over the dynamics of a relationship. As relationships with suppliers and contractors are cemented over the duration of a project, the need a more formal structure which defines the parameters of a commercial relationship, become less relevant. The prospect of continued, long-term business overrides the advantages that a more opportunistic, short-term strategy might offer.[28] In a P3, private firms are incentivized to maintain trustworthy relationships with the public entities with which they are partnered, as the prospect of the long-term business offered by such opportunities is of value.[29] Strengthening social capital has the added benefit of mitigating incentives for commercial opportunism, which reduces spending which would have been otherwise needed to monitor project progress and contractual obligations.[30]

Enhanced social capital can also create a sense of 'belonging' and shared action, in turn shifting the perspective of P3 participants from an individual basis to a collective one—incentivizing cross organizational, or perhaps vertical, collaboration in anticipation of enhanced mutual benefit. This identification with the project itself then presents opportunities for cross-organizational synergy and development of consensual strategic direction.[31] An example of such synergy may be increased procurement efficiency, as opportunities to expand supplier networks become more easily accessed as commercial relationships become stronger over extended periods of time.[32]

25 Kwak, Y. H., Chih, Y., & Ibbs, C. W. 2009. *Towards a comprehensive understanding of public private partnerships for infrastructure development. California management review*, 51(2), 51-78.

26 Kwak, Y. H., Chih, Y., & Ibbs, C. W. 2009. *Towards a comprehensive understanding of public private partnerships for infrastructure development. California management review*, 51(2), 51-78.

27 Tang, L., Shen, Q., & Cheng, E. W. 2010. *A review of studies on public–private partnership projects in the construction industry. International journal of project management*, 28(7), 683-694.

28 Onyx, J., & Bullen, P. 2000. *Measuring social capital in five communities. The journal of applied behavioral science*, 36(1), 23-42.

29 Ho, S. P. 2006. *Model for financial renegotiation in public-private partnership projects and its policy implications: Game theoretic view. Journal of Construction Engineering and Management*, 132(7), 678-688.

30 Bovaird, T. 2004. *Public–private partnerships: from contested concepts to prevalent practice. International review of administrative sciences*, 70(2), 199-215.

31 Erridge, A., & Greer, J. 2002. *Partnerships and public procurement: building social capital through supply relations. Public Administration*, 80(3), 503-522.

32 Falk, I., & Kilpatrick, S. 2000. *What is social capital? A study of interaction in a rural community. Sociologia ruralis*, 40(1), 87-110.

Finally, enhanced social capital and network creation allow P3s to more effectively address complex policy and regulatory challenges. The robust networked relationships between government and private firms formed in a P3 arrangement present all participants of the arrangement with the unique opportunity to work more closely together and set out common, and clear objectives and courses of action to address systematic problems. This in turn promotes the sharing and coordination of information regarding performance and quality standards and encourages cooperative action towards a collective goal.[33]

ENHANCED RISK MANAGEMENT

Some risks are better placed under the purview of the private sector, whereas others are best left within the public interest.[34] When placed within the context of a P3, many of the advantages of both the public and private model can be realized with few of the downside risks. P3 projects are relatively more sheltered from risks unique to projects placed within strict government control, such as those associated with political transition.[35] While public entities may be better suited for some risks, such as those associated with market demand and regulation, firms in the private sector may be better equipped to handle others, such as technical and operational risks.[36] Such sentiment is underscored in a recent report by the FAO, stating, "As Bruce Power is a private sector entity, any transfer of risk to Bruce Power reduces the exposure of ratepayers."[37] Use of P3s allows government to place greater focus on its core priorities, alleviating it of operational and supply chain concerns, which firms within the private sector are better equipped to manage.[38]

Within the context of the MCR, because the private entities in the partnership have significant responsibilities, which must be fulfilled in both the construction and operation of the plant, the consortium is incentivized to ensure the plant is optimally constructed in order to mitigate any near and future operational challenges.[39] Such a risk is largely restricted to public procurement, but wholly avoided in the MCR Project by way of a P3. Further, because the refurbishment of each reactor will either happen in concurrence with another or in succession, valuable economies of scale will be realized, through improvements in processes and establishment of long-term relationships with suppliers.[40]

33 Erridge, A., & Greer, J. 2002. *Partnerships and public procurement: building social capital through supply relations. Public Administration*, 80(3), 503-522.

34 Grimsey, D., & Lewis, M. K. 2002. *Evaluating the risks of public private partnerships for infrastructure projects. International journal of project management*, 20(2), 107-118.

35 Zhang, X. (2005). *Critical success factors for public–private partnerships in infrastructure development. Journal of construction engineering and management*, 131(1), 3-14.

36 Kwak, Y. H., Chih, Y., & Ibbs, C. W. 2009. *Towards a comprehensive understanding of public private partnerships for infrastructure development. California management review*, 51(2), 51-78.

37 Financial Accountability Office of Ontario. 2017. *Nuclear Refurbishment Report*. https://www.fao-on.org/en/Blog/Publications/FAO-NR-Report-Nov-2017#C:%20Alternative%20Generation%200ptions

38 Edkins, A. J., & Smyth, H. J. 2006. *Contractual management in PPP projects: evaluation of legal versus relational contracting for service delivery. Journal of Professional Issues in Engineering Education and Practice*, 132(1), 82-93.

39 Hart, O. 2003. *Incomplete contracts and public ownership: Remarks, and an application to public private partnerships. The Economic Journal*, 113(486), C69-C76.

40 Lovering, J. R., Yip, A., & Nordhaus, T. 2016. *Historical construction costs of global nuclear power reactors*. Energy Policy, 91, 371-382.

Environmental Benefit of Nuclear Energy

When considering the entire power generation life cycle, including construction, mining, operations and decommissioning, nuclear is found to be one of the cleanest technologies available.[41] A sizable portion of the environmental cost of a nuclear plant comes from the construction of the plant itself, as the process demands vast amounts of concrete and steel—materials which expel significant amounts of carbon when created. However, comparatively little is emitted during the plant's lengthy operation. Additionally, the nature of Bruce Power's Life-Extension Program negates much the environmental cost by way of re-using existing infrastructure.

The construction process also takes place in a highly regulated environment using skilled labour and advanced construction techniques which minimize environmental impact and ensure a high level of safety and efficiency. Further, as all six of Bruce Power's reactor refurbishments will either take place in succession of one another or in concurrence, construction efficiencies will be reaped through establishment of long-term supplier relationships and repetition, which will further minimize both financial and environmental costs.[42]

GHG emissions associated with a CANDU reactor[43] life cycle—the same reactors used at the Bruce site—are estimated at 15g CO2e/kWh. For comparison, gas is estimated to be between 410 and 650 g CO2e/kWh,[44] the majority of which is emitted during operation.[45] While there are alternatives to nuclear energy capable of generating a similar amount of baseload electricity and emitting a similar level of GHGs, such generating alternatives are estimated to cost 50 percent more than nuclear.[46]

41 Canadian Nuclear Association. 2017. *Nuclear Energy Fact Book*, 2017. https://cna.ca/wp-content/uploads/2017/01/2017-Factbook-EN-WEB-FINAL.pdf

42 Lovering, J. R., Yip, A., & Nordhaus, T. 2016. *Historical construction costs of global nuclear power reactors. Energy Policy*, 91, 371-382.

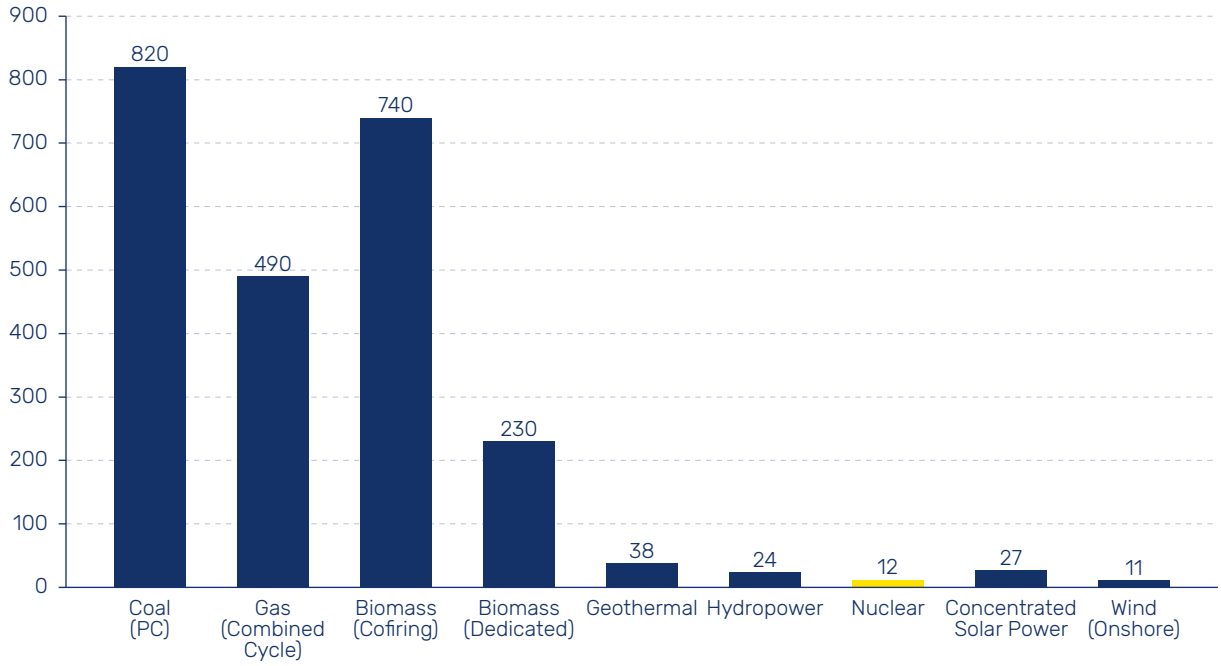
43 CANDU reactors refer to a heavy water reactor originally developed in partnership between Atomic Energy of Canada Limited (AECL), the Hydro-Electric Power Commission of Ontario, Canadian General Electric, among other firms.

44 S. Schlömer, T. Bruckner, L. Fulton, E. Hertwich et al. 2018. *Technology-specific Cost and Performance Parameters*, Annex III. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf

45 Gagnon, L., Belanger, C., & Uchiyama, Y. 2002. *Life-cycle assessment of electricity generation options: The status of research in year 2001. Energy policy*, 30(14), 1267-1278.

46 Financial Accountability Office of Ontario. 2018. *Nuclear Refurbishment An Assessment of the Financial Risks of the Nuclear Refurbishment Plan*. https://www.fao-on.org/web/default/files/publications/Nuc%20Refurb%20nov%202017/Nuclear-Refurb-EN.pdf

FIGURE 7: MEDIAN LIFECYCLE EMISSIONS OF SELECTED ELECTRICITY SUPPLY TECHNOLOGIES[47] (g CO_2e/kWh)



Bruce Power's reactors are also fueled in a more environmentally friendly way, as most of the uranium used as fuel is derived from non-open pit mines located in Northern Saskatchewan. The enclosed nature of the mines ensures a minimal environmental impact. The proximity of the mines to industrial centres also allows for the transportation of the uranium to use more efficient methods, such as rail car, as compared to long-haul trucking.[48] Furthermore, the uranium used for CANDU reactors requires significantly less processing (i.e., enrichment) than many of the world's other nuclear plants. The entire uranium supply chain for all eight of the Bruce Power reactors, from mining to fission, therefore carries one of the lowest ecological footprints of any nuclear reactor.[49]

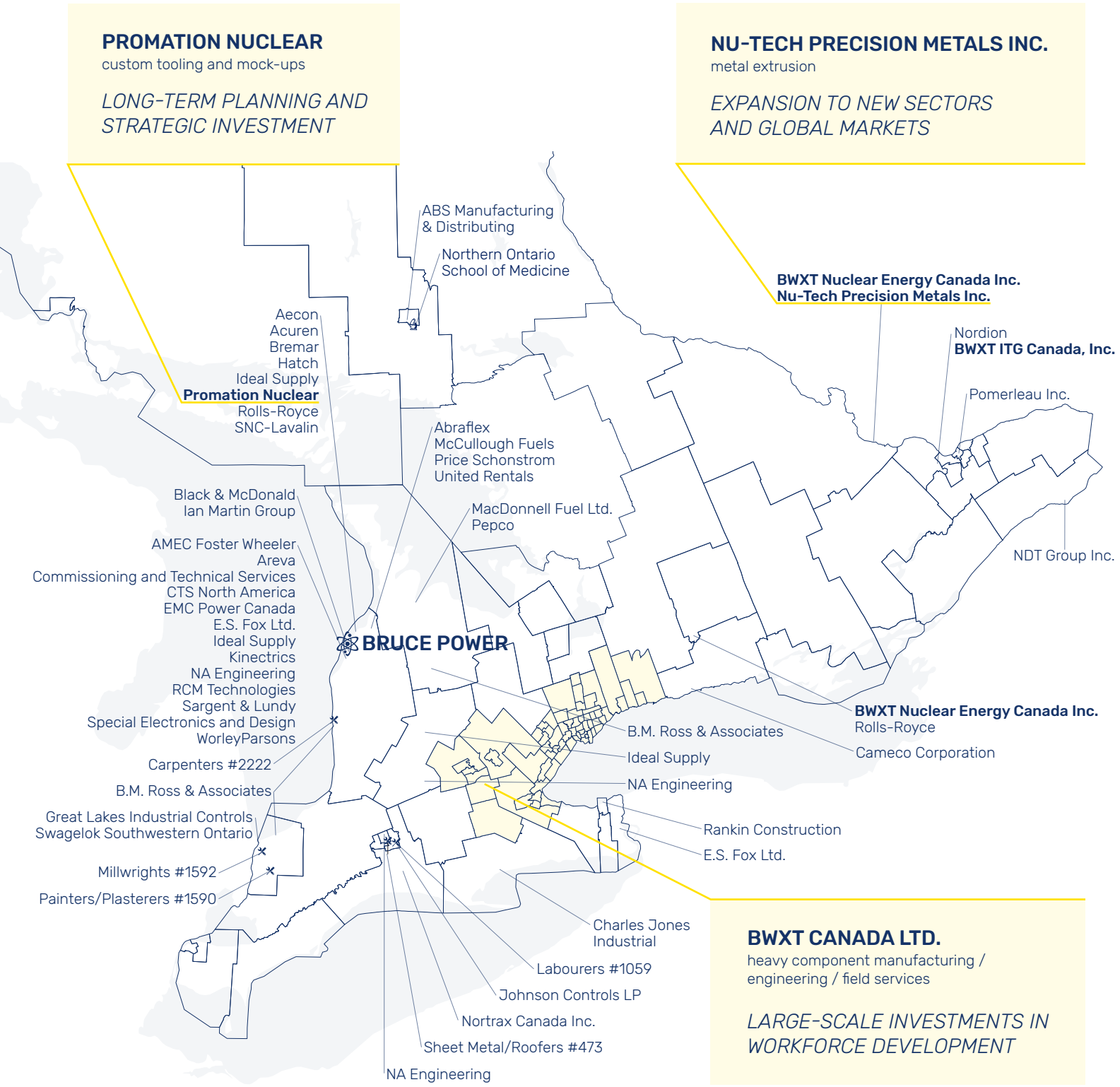
As Ontario's energy demand grows, political concerns related to capacity and generation origin will only become more prominent. As such, there are few alternatives Ontario is able to consider: those of a comparable long-term cost to nuclear generation rely on carbon-based natural gas, and more environmentally friendly alternatives rely on costly, renewable energy and importing energy fuels and electricity from other provinces or countries.[50] Therefore, the environmental and economic advantages of nuclear energy further support the investment in the MCR Project.

47 S. Schlömer, T. Bruckner, L. Fulton, E. Hertwich et al. 2018. *Technology-specific Cost and Performance Parameters*, Annex III. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf

48 Sovacool, B. K. 2008. *Valuing the greenhouse gas emissions from nuclear power: A critical survey. Energy Policy*, 36(8), 2950-2963.

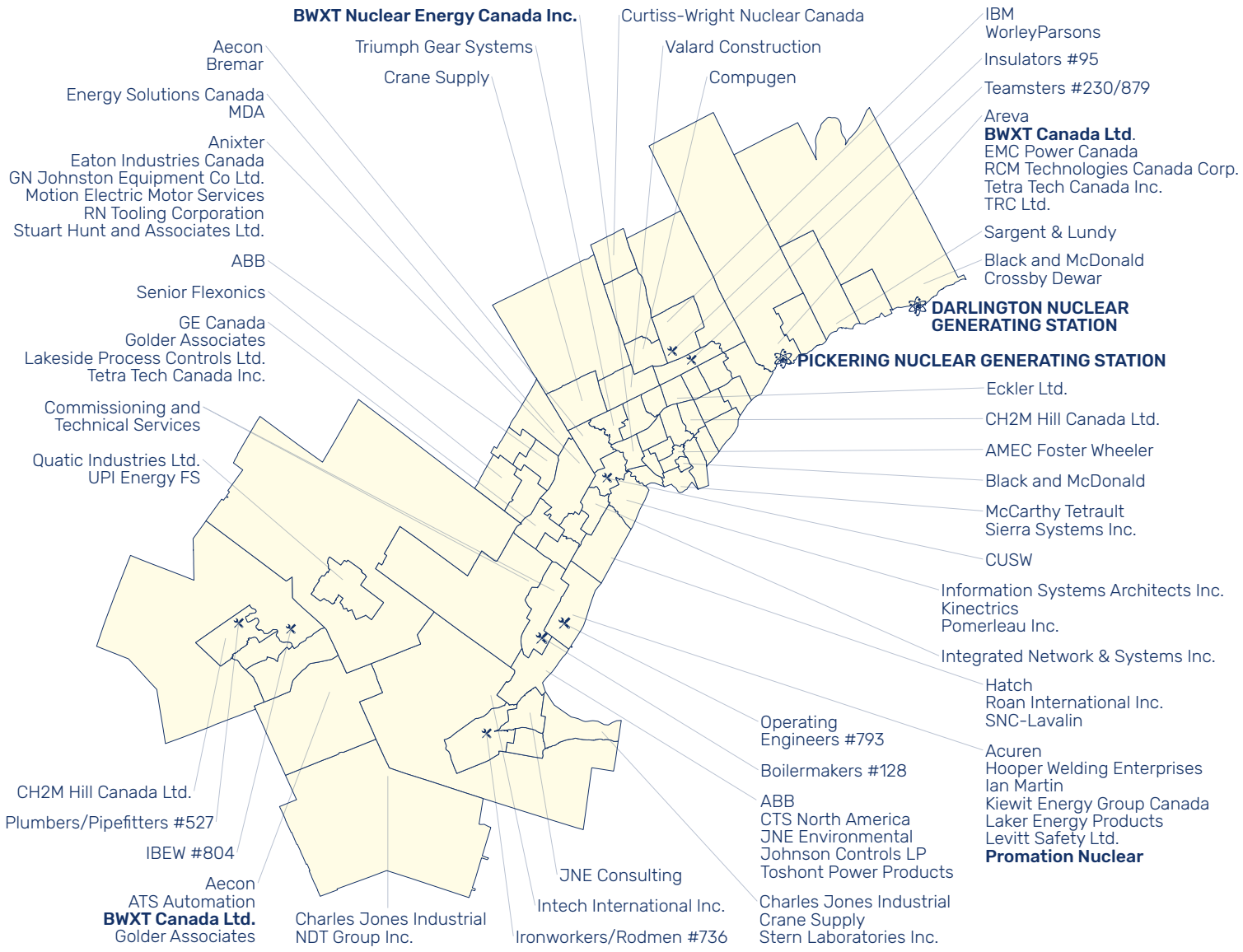
49 Siddiqui, O., & Dincer, I. 2017. *Comparative assessment of the environmental impacts of nuclear, wind and hydro-electric power plants in Ontario: A life cycle assessment. Journal of Cleaner Production*, 164, 848-860.

50 Financial Accountability Office of Ontario. 2018. *Nuclear Refurbishment An Assessment of the Financial Risks of the Nuclear Refurbishment Plan*. https://www.fao-on.org/web/default/files/publications/Nuc%20Refurb%20nov%202017/Nuclear-Refurb-EN.pdf



Value Chain

The MCR Project has had a profound impact on communities across Ontario, creating new economic opportunities for investment, job creation, workforce development, and export competitiveness. The following section will highlight a few examples of the organizations and individuals involved in the project—from the companies that manufacture core components to the construction workers that assemble them—and illustrate the value this project has and will create for them.



PROMATION nuclear

Promation is an engineering, design, and manufacturing company based in Oakville, with a supporting office in Port Elgin, with expertise in the nuclear, automotive, and industrial sectors. As a supplier to the MCR Project, Promation creates highly specialized custom tooling and mock-ups that are used inspect, remove, and install reactor components at the Bruce Power facility.

The MCR Project has had a considerable impact on Promation, as the multi-year nature of the contract has given the company a firm baseline of work that has partially shielded it from exogenous market fluctuations and allowed for long-term strategic planning and investments.

Internally, the project has led to opportunities for workforce development. Given the scope of the work involved, employees at Promation have developed new technical skills and broader project management expertise, and several individuals have been promoted from manufacturing technologists to project management roles as a result.

From an internal operations perspective, there has been greater inter-departmental collaboration with staff and other resources migrating across roles as the project evolves. This, in turn, has created synergies and operational efficiencies that will last well beyond the duration of the MCR Project.

BWXT Canada Ltd. (BWXT) was founded in 1844 as an independent foundry, and over its long history has adapted to serve numerous new markets within a changing global economy. Today, BWXT is the only manufacturer of large commercial nuclear components in North America and acts as a critical player in Bruce Power's Asset Management and MCR Project by supplying heat exchangers, steam generators, and primary heat transport motors through contracts totaling over 700 million dollars.

The MCR Project has afforded BWXT a myriad of opportunities. To staff the project, the company held three job fairs in 2018 and grew its employee count by over 100 and continues to recruit across all locations. In July 2018, BWXT opened its Owen Sound manufacturing facility to meet additional space requirements needed to manufacture components for Bruce Power. The Owen Sound facility is a strategic growth opportunity for both the company and the local community; BWXT estimates that over time, this location could employ 30 to 50 full-time personnel, representing approximately 5 - 10 million dollars in annual payroll. The company also leased and locally staffed a new sales project office at Port Elgin to meet MCR Project needs.

"In my role, I supervise the inspection and maintenance of critical components at Bruce Power, largely those supplied by BWXT," said Ana Aquino de Colley. "As BWXT is a significant contributor to the MCR Project in the supply of critical components, it also gives BWXT and my team the opportunity to continue investing in and supplying these services for decades to come."

Ana Aquino de Colley
Eddy Current Supervisor,
Field Services at BWXT Canada Ltd.

Recognizing the present and future demand for skilled labour arising from the MCR Project, BWXT has made considerable investments in skills development within Ontario. For example, the company recently collaborated with Georgian College to hold weld tests for applicants in advanced nuclear welding positions and has sponsored three bursary awards, including categories for an exemplary female and indigenous student. Looking ahead, the company will continue to explore ways in which it can communicate its labour market needs for critical skills such as rigging, valve testing, quality inspection and maintenance.

Labour market opportunities stemming from the MCR Project have also enabled BWXT to increase its investments in workforce diversification. This includes a multi-year sponsorship of University of Ontario Institute of Technology (UOIT) Women for STEM program, active participation in Bruce Power's Indigenous Relations Supplier Network, and commitments to hire growing numbers of women and indigenous workers throughout its operations.

In a broader economic sense, government investment in the Bruce Power refurbishment is helping Ontario strengthen its nuclear advantage and positioning the province as a global leader. Around the world, there is growing demand for Small Modular Reactors (SMRs)—cheaper, smaller, and simpler technologies that promise to assist in the global transition to clean energy. Once the MCR Project ends, resources and expertise previously engaged in the project will be well placed to transition to serve emerging markets, including producing and exporting SMRs, to help solve global energy poverty. The economic implications of Ontario's nuclear leadership are tremendous.

Based in Arnprior, Ontario, Nu-Tech Precision Metals supplies fuel channel pressure tubes made from zirconium. These tubes serve as a critical component in the MCR Project.

Since the CANDU program's inception in 1955, Nu-Tech has been the sole supplier of fuel channel pressure tubes to every CANDU reactor in the world. To date, the company has manufactured over 20,000 pressure tubes.

Continued investment in the sector has enabled Nu-Tech to become a major driver of economic activity in the Ottawa Valley. In particular, nuclear refurbishment contracts—including the MCR Project—have given the company the financial stability, technological skills, and competitive edge needed to successfully expand its Ontario business to other global markets. Today, Nu-Tech supplies titanium hollows and structural shapes to all models of Boeing's commercial airplanes, military aircraft, as well as zirconium for the construction of research reactors around the world.

Within the Ottawa Valley, Nu-Tech provides stable, high-quality jobs that have helped the region weather recent business closures and financial pressures. In understanding the commercial opportunities arising from Ontario's continued investment in nuclear energy, Nu-Tech has reaffirmed its commitment to the province and made significant infrastructure investments—such as $1 million paid to local contractors to replace the roof of one of its plants—and numerous donations to community organizations including the Arnprior hospital, library, and fire department.

Investment in large capital infrastructure projects, such as those in the nuclear sector, has allowed companies like Nu-Tech to invest in the local economy, create jobs, and elevate Ontario's competitiveness in industries critical to the global economy, such as high-tech manufacturing.

Conclusion

This report has demonstrated that large, sophisticated infrastructure projects generate value for industry, communities, and governments. The Bruce Power MCR Project has the potential to positively contributing billions of dollars to the Ontario and Canadian economies through economic impact, GDP increase, tax revenue, and opportunities for local workers and industry.

In addition, projects such as the MCR give Ontario's nuclear supply chain impetus and capacity to elevate its offering within the global market, as the experience and operational knowhow gained through such an undertaking is of value to other jurisdictions pursuing nuclear energy. The skills demanded, and experience offered, by the MCR have the potential to improve the competitiveness of Ontario's nuclear industry, as well as of firms in peripheral sectors of the economy.

As Ontario's energy demand grows, questions of capacity and generation origin will only become more prominent. As such, there are few alternatives Ontario is able to consider: those of a comparable long-term cost to nuclear generation rely on carbon-based natural gas, and more environmentally friendly alternatives rely on costly, renewable energy as well as importing fuels and electricity from other provinces or countries.[51]

Taking into consideration both the quantitative analysis of the MCR Project construction and our qualitative overview of the value of nuclear energy and the nuclear industry in Ontario, we conclude that the MCR project provides a substantial return on investment to Ontario.

Author: Reid McKay, Economic Analyst
reidmckay@occ.ca

51 Financial Accountability Office of Ontario. 2018. *Nuclear Refurbishment An Assessment of the Financial Risks of the Nuclear Refurbishment Plan*. https://www.fao-on.org/web/default/files/publications/Nuc%20Refurb%20nov%202017/Nuclear-Refurb-EN.pdf.

Appendix A: List of Figures