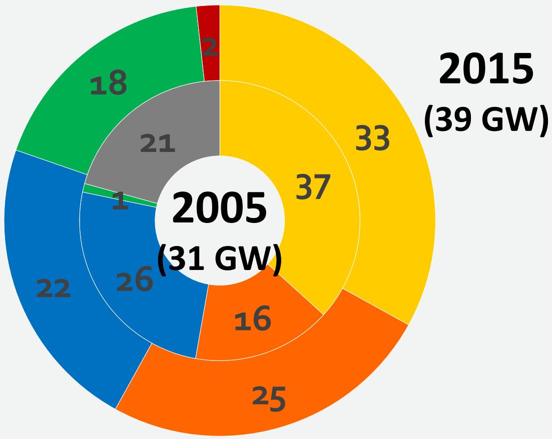
A LIFE CYCLE APPROACH TO ELECTRICITY SUPPLY IN ONTARIO

Nicholas Vantfoort, Jennifer M. McKellar, Marc A. Rosen
University of Ontario Institute of Technology
Oshawa, Ontario, Canada

Outline

- Ontario's Electricity System
- Objective
- Modelling Approach
- Preliminary Forecasts of Ontario's Electricity Future
- Preliminary Conclusions

Electricity Supply in Ontario



- Ontario's grid mix fairly diverse
- Projected GHG emissions intensity (2017): 3.8 -4.1 $Mt_{CO_2}E/y$
- Most IESO forecasts expect demand growth toward 2035
- Some generators nearing end-of-life

Data from: Independent Electricity Systems Operator, Ontario Planning Outlook 2016

Decision-Making Challenges

- Goals:
  - Meet the current and future demand
  - Electricity supply budget friendly
  - Compliant with provincial environmental regulations and emission goals
- Variables and uncertainty:
  - Demand
  - Market conditions
  - Environmental policy
  - Technology development
- Plus
  - Many technologies have long lead times

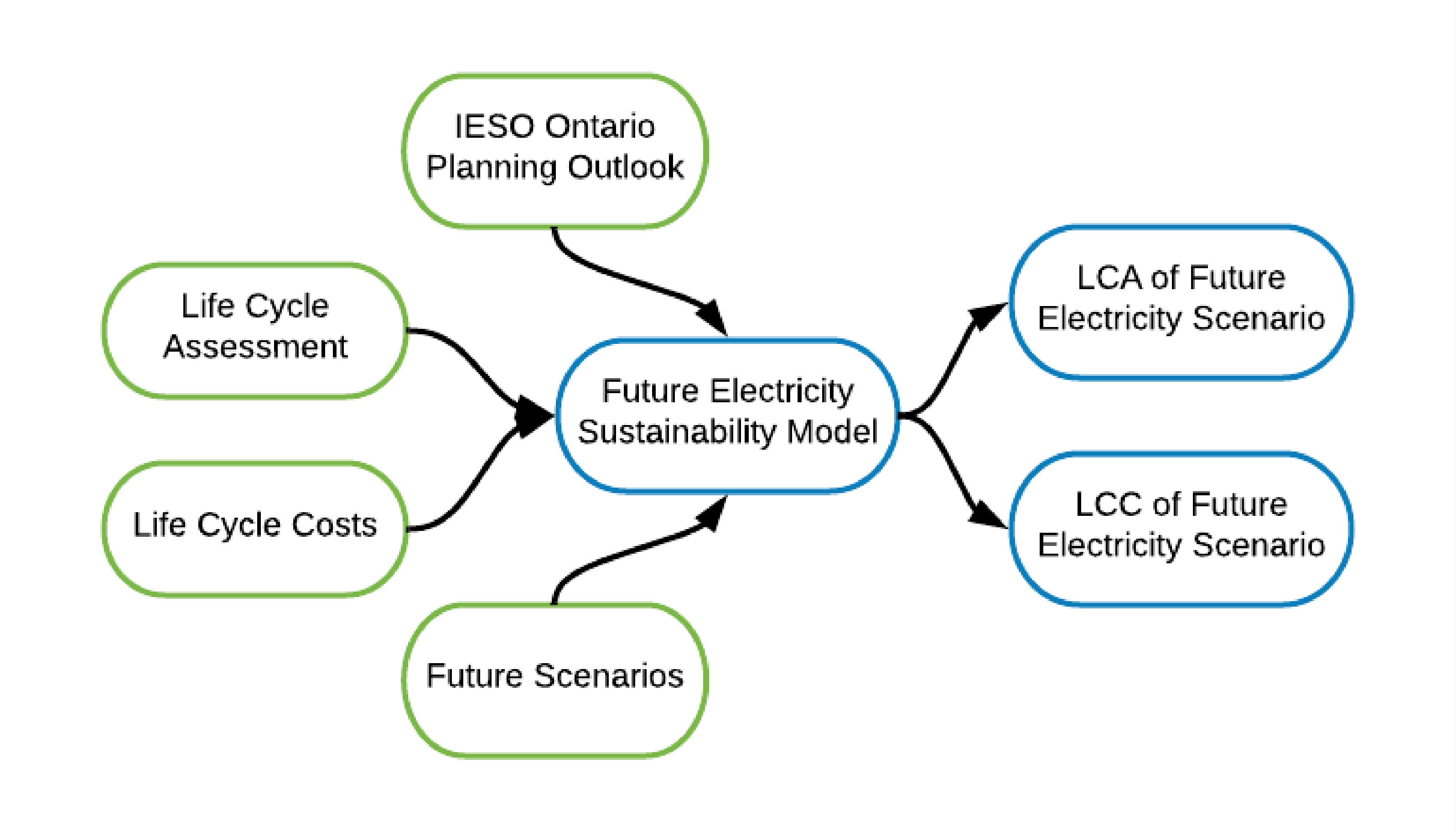
Literature Review

- Examples of Ontario Electricity Generation LCAs
  - Mallia & Lewis (2013) published *Life Cycle Greenhouse Gas Emissions of Electricity Generation in the Province of Ontario*
    - *Ontario's average GHG intensity 201 t CO_2e/GWh for 2008*
  - Zhang et al. compared the life cycle operational costs of coal, wood pellets and natural gas
    - *Good example of a combined LCA/LCC which determined the cost of GHG emission reduction ($/t CO_2e) for varying fuel types*

Objective

- To investigate which energy technologies can contribute to a cost-effective ($/MJ) and low life cycle greenhouse gas (GHG) emission (kg CO_2e/MJ) electricity grid mix for Ontario over a 20 year horizon
- Results are expected to aid government and industry decision-makers by identifying which technologies can be implemented advantageously now to meet future emission goals and energy demand

Modelling

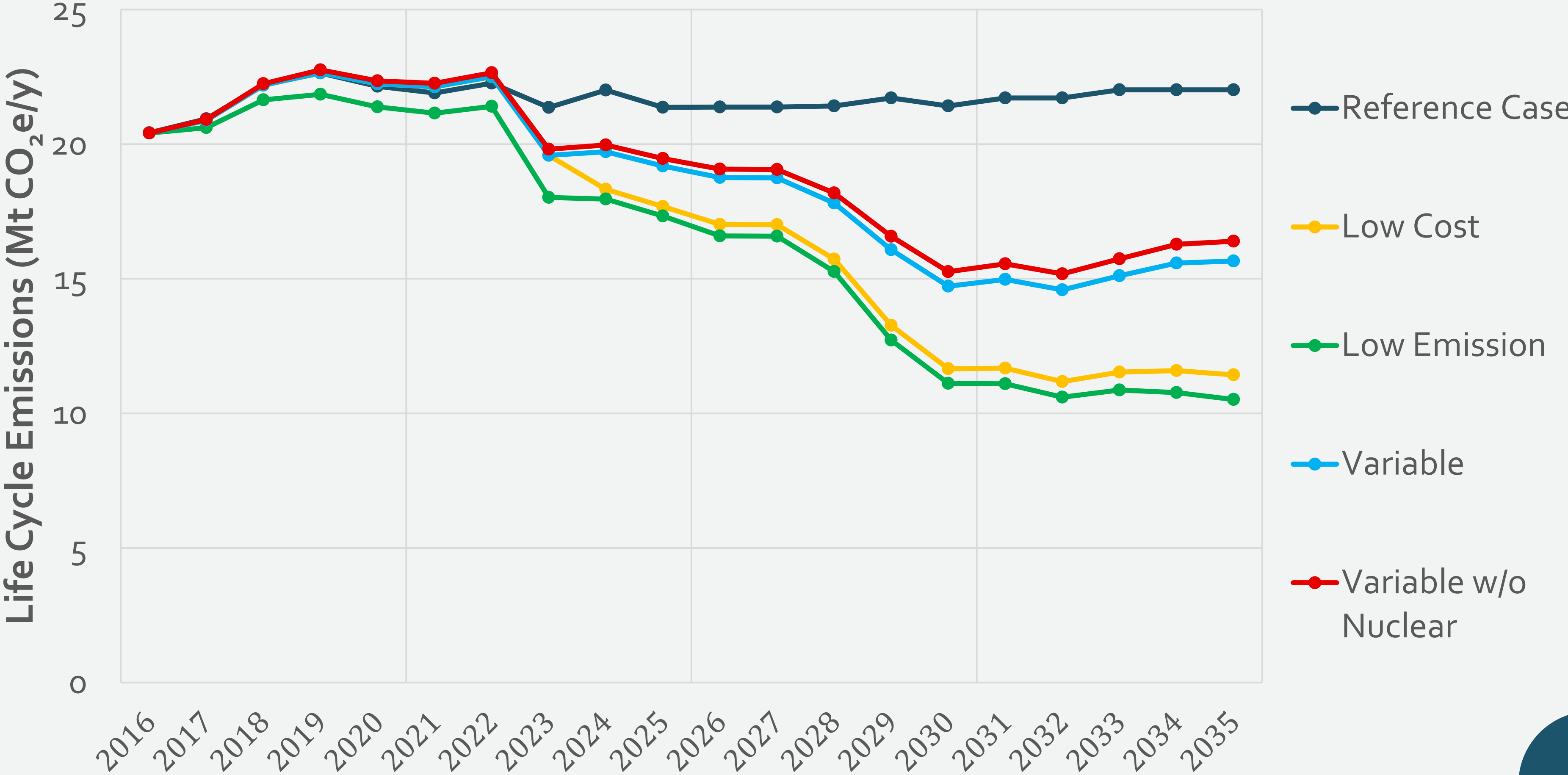


Data/Model References include: Murphy-Snow & McKellar (2015), IESO (2016)

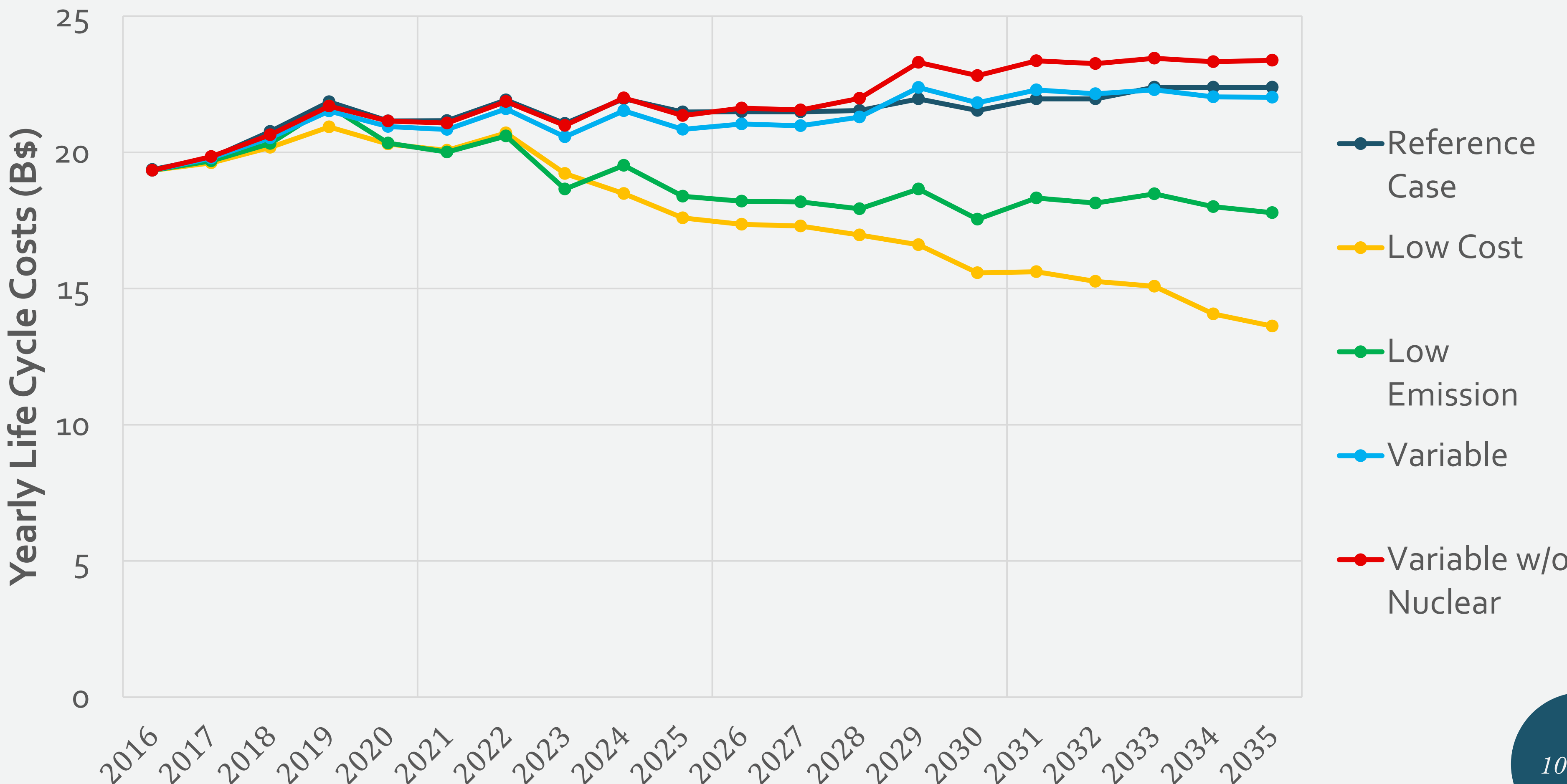
Modelling

- Reference case:
  - Utilizes the projected installed capacity from IESO's Ontario Planning Outlook [2016]
- Low cost:
  - Directed and Expiring capacity replaced by available energy technology with lowest cost
- Low emissions:
  - Directed and Expiring capacity replaced by available energy technology with lowest emissions
- Variable:
  - Directed and Expiring capacity replaced by energy technology based on user input
- Variable without nuclear:
  - Directed and Expiring capacity replaced by energy technology based on user input while excluding nuclear

Preliminary Results – GHG Emissions



Preliminary Results – Life Cycle Costs



Preliminary Conclusions

- Preliminary results suggest that emissions and costs can be reduced below the reference case
- Pending adjustments to the model
- The model being developed here is intended to provide insights into which technologies may meet low risk criteria

Acknowledgements

- Natural Sciences and Engineering Research Council of Canada

Jennifer McKellar, PhD, PEng
Faculty of Energy Systems & Nuclear Science
University of Ontario Institute of Technology

QUESTIONS?

References

Amor, M. B., Gaudreault, C., Pineau, P.-O., & Samson, R. (2014). Implications of integrating electricity supply dynamics into life cycle assessment: A case study of renewable distributed generation. *Renewable Energy*, *69*, 410–419. https://doi.org/10.1016/j.renene.2014.03.063

Ardani, K., O'shaughnessy, E., Fu, R., McClurg, C., Huneycutt, Joshua, & Margolis, R. (2017). *Installed Cost Benchmarks and Deployment Barriers for Residential Solar Photovoltaics with Energy Storage: Q1 2016*. Retrieved from http://www.nrel.gov/docs/fy17osti/67474.pdf

Astudillo, M. F., Treyer, K., Bauer, C., Pineau, P.-O., & Amor, M. B. (2017). Life cycle inventories of electricity supply through the lens of data quality: exploring challenges and opportunities. *The International Journal of Life Cycle Assessment*, *22*(3), 374–386. https://doi.org/10.1007/s11367-016-1163-0

Balzhiser, R. E. (1981). Shortening the Generation Lead Time. *IEEE Power Engineering Review*, *PER-1*(7), 1–1. https://doi.org/10.1109/MPER.1981.5511659

Barbose, G., Darghouth, N. R., Weaver, S., Feldman, D., Margolis, R., & Wiser, R. (2015). Tracking US photovoltaic system prices 1998–2012: a rapidly changing market. *Progress in Photovoltaics: Research and Applications*, *23*(6), 692–704. https://doi.org/10.1002/pip.2482

Curran, M. A., Mann, M., & Norris, G. (2005). The international workshop on electricity data for life cycle inventories. *Journal of Cleaner Production*, *13*(8), 853–862. https://doi.org/10.1016/j.jclepro.2002.03.001

EnergySage. (2016, June 16). The Top 10 Solar Panel Manufacturers | EnergySage. Retrieved July 30, 2017, from http://news.energysage.com/best-solar-panel-manufacturers-usa/

Fu, R., Chung, D., Lowder, T., Feldman, D., Ardani, K., & Margolis, R. (2016). *U.S. Solar Photovoltaic System Cost Benchmark: Q1 2016*. Retrieved from http://www.nrel.gov/docs/fy16osti/66532.pdf

Government of Canada, N. E. B. (2017). *NEB – Canada's Energy Future 2016: Update - Energy Supply and Demand Projections to 2040*. National Energy Board. Retrieved from https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016updt/index-eng.html

Government of Ontario. (2017). *Summary Results Report, Ontario Cap and Trade Program Auction of Greenhouse Gas Allowances June 2017 Ontario Auction #2*. Ontario. Retrieved from http://files.ontario.ca/summary_results_report_english_2017-06-09.pdf

Hendrickson, C. T., Lave, L. B., & Matthews, H. S. (2006). *Environmental Life Cycle Assessment of Goods and Services: An Input-output Approach*. Resources for the Future.

Independent Electricity Systems Operator. (2016). Ontario Planning Outlook - IESO. Retrieved May 29, 2017, from http://www.ieso.ca/sector-participants/planning-and-forecasting/ontario-planning-outlook

International Organization for Standardization. ISO 14040:2006 - Environmental management - Life cycle assessment - Principles and framework (2006). Retrieved from http://www.iso.org/iso/catalogue_detail?csnumber=37456

International Organization for Standardization. ISO 14044:2006 Environmental Management - Life Cycle Assessment - Requirements and Guidelines (2006). Retrieved from https://www.iso.org/standard/38498.html

Jazayeri, S., Kralovic, P., Honarvar, A., Naini, A., Rozhon, J., Shabaneh, R., & Walden, T. (2008). *Comparative Life Cycle Assessment (LCA) of Base Load Electricity Generation in Ontario*. Canadian Energy Research Institute. Retrieved from https://cna.ca/wp-content/uploads/2014/05/Comparative-Life-Cycle-Analysis-of-Base-Load-Electricity-in-Ontario.pdf

Kantor, I., Fowler, M. W., Hajimiragha, A., & Elkamel, A. (2010). Air quality and environmental impacts of alternative vehicle technologies in Ontario, Canada. *International Journal of Hydrogen Energy*, *35*(10), 5145–5153. https://doi.org/10.1016/j.ijhydene.2009.08.071

Lehmann, A., Zschieschang, E., Traverso, M., Finkbeiner, M., & Schebek, L. (2013). Social aspects for sustainability assessment of technologies—challenges for social life cycle assessment (SLCA). *The International Journal of Life Cycle Assessment*, *18*(8), 1581–1592. https://doi.org/10.1007/s11367-013-0594-0

Levasseur, A. (2010). Considering Time in LCA: Dynamic LCA and Its Application to Global Warming Impact Assessments. *Environmental Science & Technology*, *44*(8), 3169–3174.

References

Levasseur, A., Lesage, P., Margni, M., Deschênes, L., & Samson, R. (2010). Considering Time in LCA: Dynamic LCA and Its Application to Global Warming Impact Assessments. *Environmental Science & Technology*, *44*(8), 3169–3174. https://doi.org/10.1021/es9030003

Mallia, E., & Lewis, G. (2013). Life cycle greenhouse gas emissions of electricity generation in the province of Ontario, Canada. *The International Journal of Life Cycle Assessment*, *18*(2), 377–391. https://doi.org/10.1007/s11367-012-0501-0

McDonald, N. C., & Pearce, J. M. (2010). Producer responsibility and recycling solar photovoltaic modules. *Energy Policy*, *38*(11), 7041–7047. https://doi.org/10.1016/j.enpol.2010.07.023

Murphy-Snow, R., McKellar, J. (2015). Examining the Sustainability of Ontario's Energy Use. 65th Canadian Chemical Engineering Conference; Oct 4-7; Calgary, Alberta.

Murray, G. Bill 172, Climate Change Mitigation and Low-carbon Economy Act (2016). Retrieved from http://www.ontla.on.ca/web/bills/bills_detail.do?locale=en&BillID=3740

National Energy Board. (2016, October 26). Macro Indicators. Retrieved July 30, 2017, from https://apps.neb-one.gc.ca/ftrppndc4/dflt.aspx?GoCTemplateCulture=en-CA

Pehnt, M. (2006). Dynamic life cycle assessment (LCA) of renewable energy technologies. *Renewable Energy*, *31*(1), 55–71. https://doi.org/10.1016/j.renene.2005.03.002

(S&T)2. (2013). *GHGenius, Model Version 4.03*. (S&T)2 Consultants Inc. Retrieved from https://ghgenius.ca/

Treyer, K., Bauer, C., & Simons, A. (2014). Human health impacts in the life cycle of future European electricity generation. *Energy Policy*, *74*, S31–S44. https://doi.org/10.1016/j.enpol.2014.03.034

Turconi, R., Boldrin, A., & Astrup, T. (2013). Life cycle assessment (LCA) of electricity generation technologies: Overview, comparability and limitations. *Renewable and Sustainable Energy Reviews*, *28*, 555–565. https://doi.org/10.1016/j.rser.2013.08.013

U.S. Energy Information Administration. (2017). *Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2017*. Retrieved from https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

Weißbach, D., Ruprecht, G., Huke, A., Czerski, K., Gottlieb, S., & Hussein, A. (2013). Energy intensities, EROIs (energy returned on invested), and energy payback times of electricity generating power plants. *Energy*, *52*, 210–221. https://doi.org/10.1016/j.energy.2013.01.029

Zhang, Y., McKechnie, J., Cormier, D., Lyng, R., Mabee, W., Ogino, A., & MacLean, H. L. (2010). Life Cycle Emissions and Cost of Producing Electricity from Coal, Natural Gas, and Wood Pellets in Ontario, Canada. *Environmental Science & Technology*, *44*(1), 538–544. https://doi.org/10.1021/es902555a