The Douglas Ruth Memorial Lecture

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The Future of Engineering Committee

Since the establishment of the Future of Engineering Committee (FEC) our overarching objective has been to enhance the profile of engineering in Canada and amplify the visibility and recognition of the CAE. The major focus has been on analysing the transition to net zero emissions recognizing the need to close the knowledge gap while providing more accurate insights to the urgent and decisive action needed.

The FEC embarked on hosting a series of webinars, developing position papers on both mitigation and adaptation, submitting an advisory brief to the Net-Zero Advisory Board, and establishing a net zero task force under the leadership of our incoming President, Soheil Asgarpour. FEC also reviewed the latest Canadian and International reports on the net zero challenge to assess the likelihood of decarbonizing current process technologies and replacement of high-emission processes and products with low emission ones at a sufficient large scale to have an impact on net zero emissions by 2050.

The work of the FEC can be summarized in three interrelated themes as detailed in Oskar Sigvaldason's excellent treatise "Canada's Challenge; Mitigating GHG Emissions," now on the CAE website:

- **The importance of engineering** in the delivery of major infrastructure programs essential for Canada to reach net zero "in a cost-effective, timely, socially acceptable and fiscally responsible manner;"
- **Effective project management and integrated planning** which is critical for large scale infrastructure and GHG reduction projects to come on stream in a timely and cost effective manner for the transformation of the energy systems; and
- **Turning aspirational targets into reality** by understanding the future trajectory of technologies such as solar panels, wind turbines, batteries, carbon capture utilization and storage (CCUS), nuclear fission and fusion and hydrogen in a rapid energy transition scenario.

Net zero by when?

Governments and companies worldwide are pledging to achieve net-zero emissions of greenhouse gases by 2050 in alignment with the IPCC studies to limit the rise in global temperatures to below 2^0C and approaching 1.5^0C. The April 2022 IPCC report on mitigation asserted that the technologies and policies necessary to limit global warming to near 1.5^0C already exist. However, GHG emissions must peak almost immediately and decline by about 44% by 2030 in order to reach net zero by

2050. This appears extremely unlikely more so because global GHG emissions have risen since 2010 (baseline used in the IPCC 2018 report) by 6.5 GtCO2eq reaching 59 GtCO2eq in 2019. In this regard, the IPCC stated, “Global net anthropogenic GHG emissions during the decade (2010-2019) were higher than any 2 previous time in human history”. From a technology perspective, the time frame required to, for example, double the number of nuclear reactors plus more than double the primary energy from biomass plus increase renewable energy by 5 -7 times all by 2050 from the 2019 baseline, is unrealistic. Equally unrealistic is the IPCC reliance on processes to remove carbon dioxide directly from the air; processes that are expensive, energy intensive and have extremely low efficiency. Professor Arthur Petersen from University College London, who was an observer in the IPCC approval session, put it bluntly “there are a lot of pipe dreams in this report."

Our assessment of Canada’s “2030 Emissions Reduction Plan” released in April 2022, is that it is aspirational with an unrealistic GHG emissions reduction goal of 40% in less than 8 years. The goal for at least 20% of new light-duty vehicle sales to be zero-emission vehicles by 2026, at least 60% by 2030 and 100% by 2035, is aggressive considering the deficit in charging station relative to Canada’s vast geography. The oil and gas sector is expected to achieve emission reductions of 42% below 2019 levels (reduction of 73 Mt of CO_2e). Depending on CCUS in large part to meet the oil and gas emission reduction objectives by 2030 is unrealistic. CCUS is not a quick ready-to-go technology and will take several years including geological work to select the reservoir strata to ensure the CO_2 once injected does not leak back; process testing of injection rates to estimate the number of wells to be drilled for the project and the power requirements; selection of a capture technology to minimize parasitic losses; and delineating the pipeline route from sources to sinks. Implementation of CCUS faces geotechnical, economic, institutional, environmental, and regulatory barriers that take several years to overcome and is unlikely to have an impact on oil and gas reduction levels by 2030. Compared to the oil and gas sector, CCUS is even less mature in the power sector, as well as in cement and chemicals production, where it is also a critical mitigation option. CCUS is likely to be significant technology for emission reduction in the 2040 plus timeframe and the CCUS Tax Credit offered by Canada in Budget 2022 is important to kick start ‘commercial’ applications.

Technology advances provides optimism

The world has made real progress in slowing GHG emissions in recent years with governments and businesses pouring billions of dollars into clean energy. Wind and solar power generated 10% of the world's electricity needs in 2021 and since 2015 when the Paris Agreement was signed, wind and solar share of global electricity generation has more than doubled. Electrification of public transport services is now feasible, scalable, and an affordable mitigation option to decarbonise mass transportation. Electric vehicles are also the fastest growing segment of the automobile industry, having achieved double-digit market share by 2020 in many countries. The viability of low carbon electricity, hydrogen, and CCUS technologies to decarbonize most industrial processes and the power sector have been demonstrated and are closing the cost gap.

The world is also placing considerable emphasis on methane emission reduction. Canada has recognized that this is a low hanging fruit that is needed to help reach 2030 goals and has committed to reduce methane emissions across the broader Canadian economy and oil and gas methane emissions by at least 75 percent below 2012 levels by 2030.

An example of a practical plan for hydrogen production is Air Products' world scale net zero hydrogen complex in Edmonton. It uses an auto thermal reforming (ATR) technology instead of steam methane reforming with the advantage that CO_2 capture can be near 100%. However, ATR requires an oxygen plant which adds to the capital costs. This project benefits from the already existing market in the refining and fertilizer sector which can be expanded to include transportation of freight trucks, road trains and passenger buses.

There is renewed hope for nuclear with a shifting emphasis on smaller and safer small modular nuclear reactors or SMNRs. Two demonstration projects of a macro-SMNR (300 Mwe) at Darlington is designed for grid-scale applications serving city-sized loads and micro-SMNR (5 Mwe) at Chalk River is designed for industrial applications – potentially for the oil sands steam generation. Recently it was announced that China has put into commercial operation its high temperature gas-cooled pebble bed reactor in Shandong province. This is the first unit of two with a generation capacity of about 200 MW. The revival of fission reactors and SMNRs are starting to see commercial daylight and along with fusion energy will be important near zero carbon free energy sources post 2040.

Attention on adaptation

In the adaptation brief on the CAE website, Heather Kennedy and Eddy Isaacs argued that it is time to put equal emphasis on adaptation as we are doing on mitigation to protect communities from extreme weather events. Warming in Canada is, on average, about double the magnitude of the average of global warming and this can lead to widespread extreme weather which has become evident in many parts of Canada. The design of infrastructure that can withstand and recover rapidly from climate disruptions and adapt to the changing conditions is critical. When feasible, infrastructure should be built that can assist the needs of both adaptation and mitigation.

In appreciation

Doug Ruth was a professor of thermodynamics, fluid dynamics and flow in porous media. He was a chair of the Research Committee, the predecessor of FEC and would have enjoyed being part of the revitalized FEC. Doug is missed.

My thanks to the members of the FEC for their enthusiasm and steady effort - Soheil Asgarpour, Ray Gosine, Anne-Marie Huynh, Axel Meisen, Emmanuel Nkwo, Nicole Poirier, and Oskar Sigvaldason. Thanks also to Robert Crawhall and Heather Kennedy for their ideas and contributions.