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(Sent by email to iec@toronto.ca)

Dec. 1, 2021

From: Martin Green, PhD
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Re: Item IE26.16: **TransformTO - Critical Steps for Net Zero by 2040**
Infrastructure and Environment Committee, Dec. 2, 2021

Dear Councillors,

The greenhouse gas (GHG) emissions reduction targets of the TransformTO Net Zero Strategy (hereafter, the Strategy) are laudable. Whether they will be achievable in practice has not yet been addressed in the Strategy, which leaves me very uneasy.

My comments focus primarily on the proposed measures to reduce the GHG emissions of existing houses. Where there is synergy, my comments extend to other elements of the Strategy.[1]

I have four key messages:

- **Net Zero, as defined in the Strategy, is not what science demands.** Climate change is driven by the **total** GHG added to the atmosphere, not just the rate of emissions in 2030 or 2050. Earlier emissions cause greater harm.
- The plan to reduce GHG emissions of existing houses to target levels by **implementing deep energy retrofits** and converting residential water and space heating to heat pumps is **unlikely to succeed**, for several reasons detailed below.
- Implementation of a **City-wide green district energy utility** that serves all houses would be a much less costly and more viable alternative way of achieving the same GHG reductions. Because of its potential, and I believe likely, advantages this district energy alternative should be seriously investigated and considered for adoption in place of the deep retrofit approach.

1 With only one week between publication of the 360 page Strategy (Report and Appendices) and its consideration by the I&E Committee, insufficient time was available for meticulous reading, analysis and preparation of comments. These comments thus represent a best effort without the benefit of careful checking and correction. The author would welcome questions and the opportunity for more substantive conversations with Councillors.

- The resources allocated to develop the proposed Strategy have not been commensurate with the task. This should not be misconstrued as impugning those involved, who have put in their best effort. Quite simply, **an undertaking that will entail societal investment greater than $100 billion warrants much greater investment in people and capability** to plan, in a transparent manner, an optimized, viable path forward, with solid processes to manage risks and make adjustments as needed.

1. What Science Demands

Climate change is driven by the total GHG added to the atmosphere, not just the rate of emissions in some target year, e.g., 2030 or 2050. Earlier GHG emissions cause greater harm.

The Strategy acknowledges "that embodied emissions in construction materials can account for up to 80 per cent of a large building's total emissions from extraction to decommissioning." Researchers have estimated that for highly efficient houses, embodied emissions, mostly incurred prior to first occupancy, may account for over 50 percent of total lifecycle emissions. The magnitude and significance of embodied emissions from building retrofits and electric power system capacity growth, as entailed by the Strategy, are unknown.

An action proposed in the Strategy for 2022-25 is "Evaluate and limit impacts of embodied carbon in construction." Quantifying embodied carbon is a challenging research problem that experts around the world have been working on for many years. It is not credible that EED and CP will be able to complete this action, even if the work is contracted out.

In spite of the great significance of embodied emissions, the Strategy proposes no mechanism to determine and minimize the total (i.e., embodied plus operational) GHG additions to the atmosphere. For example, the unmeasured GHG emissions in the course of completing deep energy retrofits of some houses may exceed the total future GHG savings achieved – we don't know. The proposed Strategy may thus avoid potential future GHG emissions by incurring even greater emissions up front, causing net harm to the environment!

The Strategy also states: "Currently, lifecycle (or consumption-based) emissions from the products and services consumed by residents, businesses and institutions in Toronto are not included in the GHG inventory." Without inventories of embodied emissions and

lifecycle emissions, it is not possible to know the full extent of Toronto's GHG emissions, or what fraction of those emissions the proposed Strategy might address.

2. Deep Retrofits of Existing Houses

In my comments[2] and deputation to the I&E Committee in July, 2021 I argued that the Net Zero Existing Buildings Strategy failed to establish a credible business model for implementation of the proposed deep energy retrofits of existing houses within the required timeline. The present Strategy proposes to accomplish by 2040 what had previously been proposed for 2050. Simply stating that the timeline will be shortened will not enable or cause the retrofits to be done more rapidly.

2.1 Physical Implementation of Deep Energy Retrofits

Specifically regarding existing houses, but also applying more broadly, there is no evidence that analysis has been done to obtain reasonable assurance that implementation of the Strategy is feasible – that the targets and objectives can actually be achieved using the stated approach. The effort, resources, time and expertise required to complete recommended actions have not been stated, but in some cases they are clearly far in excess of what is implied.

There is no analysis and no proposed credible path for completion of the required number of proposed deep energy retrofits of houses, reducing thermal energy demand by 75 percent, and conversion of space and water heating to heat pumps. Based on my own research and analysis, I believe that the GHG reduction approach chosen for existing houses is not viable because the costs are unacceptable and scaling the capacity to perform the required retrofits will not be possible in the available time.

The Strategy alludes to "Industrialization of retrofits" being adopted elsewhere, but proposes no specific action in Toronto. I have studied extensive research on those "one-stop shop" (OSS) approaches, mostly in Europe, and they are indeed a good way of proceeding. But start-up times are typically 6 to 8 years, substantial government support is needed, and the scales achieved through the start-up period have been fewer than 5,000 homes. With no present plan, it seems very unlikely that a credible path could be created for Toronto to retrofit over 18,000 houses per year, every year from 2023 to 2040. Major barriers the Strategy fails to address include lack of adequate, skilled workforce, lack of organizational capability, and an uncertain and possibly inadequate supply chain.

2 http://www.toronto.ca/legdocs/mmis/2021/ie/comm/communicationfile-134333.pdf

2.2 Affordability

The $73 billion estimated total costs for existing houses imply $166,600, on average, for each of the City's 430,000 houses. That is **far beyond what most homeowners can afford**. The Net Zero Existing Building Strategy report gave no indication that deep energy retrofits of houses would save money in the long term.

The present Strategy, under the heading "Financial Impact on Toronto households", claims as a benefit: "energy services (home heating, electricity, and transportation) could decrease by an average of 70 per cent as we move to net zero, with an average reduction of nearly $1,200 per household per year compared to the status quo." Payments on a loan of $166,600 at 3 percent for 30 years would be $8429 per year – seven times the energy cost reduction. **Even if the retrofit cost could be reduced by a factor of four, or with equivalent subsidy, deep energy retrofit of most houses cannot be monetarily justified!**

The Strategy's Equity Impact Statement includes: "Building to this level of performance and retrofitting existing buildings will cost money up front. While these costs can save money in the long term, the upfront costs can be out of reach for some small businesses and low-income households." The paragraph above shows that **the costs will not save money in the long term**. By my calculation, an adequate federal subsidy program to defray costs for house retrofits would cost more than $500 billion if applied equitably across the country.

Given the above, reducing costs should be a major priority to make the Strategy viable. But there is no evidence of efforts to find alternate paths that could achieve the necessary GHG reductions in more efficient manner.

2.3 Embodied GHG emissions

The proposed deep energy retrofits to achieve 75 percent reduction of thermal energy needs of existing houses would entail substantial embodied GHG emissions. No estimate is given for the magnitude of those emissions, nor is there any evidence that they would not be comparable in scale to the future lifetime reductions of operational GHG emissions. The full lifecycle GHG emissions and climate impact of the deep energy retrofit approach are thus unknown.

Further complicating analyses and decisions regarding embodied carbon is the fact that different houses will have different future life expectancies. Investing significant embodied carbon in a building with a short lifetime could worsen overall GHG emissions.

2.4 Homeowner Resistance

It should be expected that many homeowners will resist deep retrofits because of unwanted financial expenses, disruption, and significant impacts on the look and feel of their houses. "Anti-retrofit" groups are bound to emerge and may succeed in organizing the defeat of politicians who support the retrofit program. If more than 10 percent of the population is willing to resist free COVID-19 vaccines that could save their lives then it is quite likely that 20 percent or more of homeowners would oppose very-costly deep retrofits. Such resistance, which the Strategy has not considered, could cause the entire program to fail.

3. City-wide Green District Energy Utility

District energy systems (DES) are for thermal energy the analog of electric power systems. A DES uses water in pipes to transfer thermal energy between heat (and cold) sources, thermal storage systems, and connected buildings. Toronto already has numerous district energy systems, most notably those managed by Enwave, and conversion of large buildings to DES is part of the Strategy. But the existing and planned systems target only large buildings. Modern, low-temperature DES technology can also efficiently provide heating and cooling services to urban and suburban detached houses.

Through extensive research, analysis, and technical guidance from some of Canada's best experts, I have come to the conclusion that **Toronto could meet the heating and cooling needs of all its buildings – large and small – with a green DES service, using a utility model**. Heat (and cold) would be collected from a multitude of existing sources such as Lake Ontario, waste industrial heat, sewage effluent, skating rinks, supermarkets, and large buildings. Ground borehole heat exchangers (GHXs) and large water reservoirs (tank, well, pit) would be used to store heat until needed. Ample solar energy can be economically captured with solar thermal collectors to maintain suitable reserves and annual balance in thermal storage facilities. About 6 sq. km of solar collectors (on rooftops, over parking lots, etc.) could collect enough heat for all Toronto houses. Solar PV panels could provide enough electricity to power the DES.

The world does not have an energy problem; we are just not making wise use of solar energy that is a thousand times more abundant than we will ever need.

The DES would extend along all streets using uninsulated plastic pipes to which houses would connect very much as they do to potable water pipes. Each house would have a DES-owned "substation", installed in the house, to draw heat from or reject heat into the

DES according to its heating or cooling needs. A small, highly efficient heat pump would deliver the heat within the house at the required temperature(s). Implementing such a DES network would be the 21st century equivalent of the implementation of the natural gas distribution network in the 1960s. Indeed, it should replace the natural gas network.

Implementation of a DES utility would be far more efficient and less costly than performing deep energy retrofits on existing houses and converting space and water heating to heat pumps. It could be completed, and all houses connected, before 2040. Shallow building retrofits that give the most cost-effective efficiency improvements would still be economically advantageous, but the low cost of green district energy would eliminate the need for more costly building retrofit measures and reduce the retrofit-related GHG emissions (embodied carbon).

Because solar thermal energy is available almost everywhere, a DES need not be dependent on upstream infrastructure. It can be built to serve a small neighbourhood and then joined to other DESs as the opportunity presents. But our objective should be to have DES as a utility service, available for any building to connect to.

4. Resourcing Commensurate with Scale

The Existing Buildings component of the proposed Strategy, approved by Council in July of this year, was estimated to cost building owners $300 billion, including $73 billion for existing houses. Other Strategy components will have additional costs. Whatever viable strategy is eventually adopted, the total societal investment to achieve net zero GHG in Toronto will almost certainly exceed $100 billion before 2050. That is comparable to, and possibly much greater than, the replacement cost of all of Ontario's nuclear power stations.

Planning and designing those 21 nuclear stations required many thousands of highly qualified engineers and scientists working over a period of decades. Their work was subjected to rigorous independent review and much of it was published in academic journals. Even then, there were major problems that cost tens of billions of dollars to fix. By contrast, the City's directory for the Environment and Energy Division, which had primary responsibility for developing the Strategy, lists three staff members with Engineer in their title and no scientists. Whether any of the staff have PhD degrees in science or engineering or have published in academic journals is not evident. Such qualifications and experience are important.

While I recognize that many outside individuals and organizations have been consulted and contributed to development of the Strategy, the details of the those contributions are not disclosed. There is no evidence that any of the work has been subjected to the kind of rigorous, independent review that would be the norm in science and engineering for an undertaking of this magnitude and importance. The concerns that I raised above suggest that a rigorous review would identify many deficiencies and determine that the Strategy is not acceptable in its present form.

It would be irresponsible for the City to pursue implementation of a strategic program with cost implications exceeding $100 billion without allocating adequate resources with all appropriate competencies to ensure that the strategy is viable and the return on investment will be optimized. Without any desire to impugn those involved, who have put in their best effort, **the resources allocated to develop the proposed Strategy have simply not been commensurate with the task**.

At least ten times and perhaps a hundred times as many people, including engineers and physical scientists with advanced research education and experience, and working as an integrated team, will be needed to develop a full strategy commensurate with the contemplated societal investment. The investment in that team might be $500 million per year – less than 0.5 percent of the eventual societal cost, or 3 percent of the City's annual budget. But that investment can be expected to yield a strategy that is viable, with strong risk management processes, and that will likely lower societal costs by more than $50 billion – perhaps much more.

Sincerely,

Martin Green
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