DOI:10.1111/1468-2427.70032

– ‘CLOSING THE CARBON LOOP’: Climate Policy Discourses and the Material Politics of Municipal Waste-to-Biofuel Programs

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Abstract

Waste-to-biofuel (WTB) programs have gained popularity as a municipal circular economy and an emissions reduction strategy. The upgrading of biofuels to renewable natural gas (RNG) has drawn particular interest, as RNG can displace conventional fossil fuels in any existing natural gas end use and be delivered through existing pipeline infrastructure. This article examines RNG produced at the City of Toronto’s waste facilities in partnership with Enbridge Distribution Inc. Toronto has framed its program as a strategy to ‘close the carbon loop’, recirculating waste as a new energy resource and, by extension, the carbon embodied in municipal waste. The article, first, examines the construction of the carbon loop policy narrative that draws from the technical work of emissions accounting. Second, it discusses how and why choices that shape energy systems are made as part of such programs. In Toronto, distributing through the Enbridge pipeline network has enabled the production of flexible environmental attributes that can be virtually assigned to a range of end uses and users. Understanding how policy narratives are constructed to describe municipal policy experimentation and situate municipal experiments within wider energy systems and energy system politics is critical to ensure experiments contribute to long-term net zero pathways.

Introduction

The circular economy now assumes a key role in the global urban sustainability agenda, where it is seen as a vital alternative to a ‘take, make, waste’ model of the linear urban economy (Ellen MacArthur Foundation and ARUP, 2019). Cities have conventionally been understood as spaces of consumption, where local government’s role to manage the efficient socio-spatial organization of urban environments has included the responsibility to manage wastes that typically must exit the urban system. The circular economy framework offers a rethinking of municipal waste services, where waste is no longer only a socio-spatial burden but a potential resource opportunity.

This is especially the case for waste-to-biofuel (WTB) programs. Not only are these programs seen as a policy innovation in the downstream management of material wastes, they are also an opportunity for cities to act as energy producers. Whereas gas collected at municipal landfills, or biogas produced at municipal organics facilities, can both be used directly for heat and electricity, the upgrading of these fuels to produce renewable natural gas (RNG) offers the opportunity to directly displace conventional natural gas in any existing end use, and can be directly injected into existing pipeline infrastructure.

The City of Toronto has recently begun experimenting with the installation of RNG upgrading facilities at its two municipal organics processing facilities and is in the late stages of expanding the program to the city’s largest operating landfill. An emphasis of the program has been on the utilization of RNG to fuel the City’s own waste collection vehicles, reflecting a closed-loop approach whereby ‘collection trucks can ultimately be powered by the waste product they collect’ (City of Toronto, 2020: 6) (see Figure 1).

Thank you to the two anonymous reviewers who provided very helpful feedback and suggestions in revising the article.

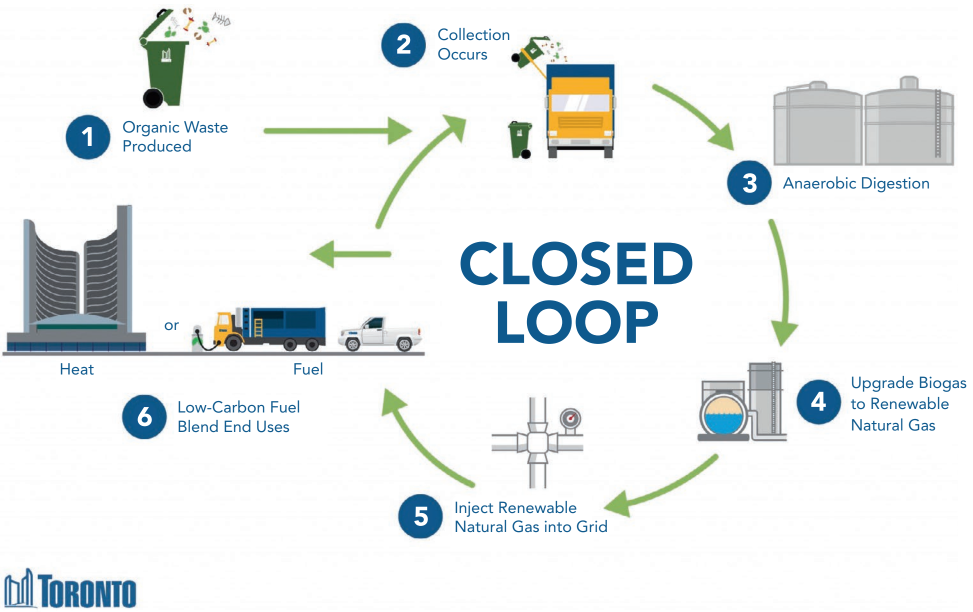

FIGURE 1 City of Toronto's 'closed loop' depiction of its organics RNG facilities (*source*: City of Toronto, https://www.toronto.ca/services-payments/recycling-organics-garbage/solid-waste-facilities/renewable-natural-gas/)

Undertaken in partnership with Enbridge Distribution Inc.—the largest natural gas distributor in Canada and the sole distributor in major franchise areas within the Province of Ontario—the program has been framed as both a key strategy to achieving the municipality's own net zero goals and an opportunity to advance City Council's circular economy aspirations (City of Toronto, 2018a).

This article explores the politics of municipal WTB programs with respect to net zero transitions. First, the article examines how a circular economy framework that focuses on the material recirculation of urban resources and wastes is being extended into a climate-positive discourse where such programs also serve to 'close the carbon loop'. This is based on the premise that the biogenic carbon embodied in municipal waste can be extracted as a source of green energy and recirculated within the local system, with such policy representations supported by the technical work of emissions accounting. Here, I discuss the accounting practices that enable carbon loop narratives of municipal waste-to-RNG programs, where physical flows of a material circular economy are made commensurate with flows of carbon territorialized at the local scale. The article argues that through technical abstractions, environmental contributions of RNG can become detached from the material, technological and geographic contexts that determine situated environmental outcomes.

Second, the article examines how and why physical infrastructure decisions are made in the development of municipal programs, drawing from the case study of Toronto to explore three important critical choices: the switch of the waste fleet from diesel to natural gas; the connection of RNG facilities with targeted end uses through Enbridge's pipeline system; and the utilization of surplus emissions reductions to lower emissions from City of Toronto buildings, facilitated through existing building connections to the grid. Many stakeholders, like Enbridge (2021), often emphasize opportunities to use fuel for heavy waste collection vehicles: a 'difficult-to-decarbonize' end use with no obvious non-fuel alternative at present. But as seen in Toronto, opportunities to scale up climate contributions often mean shifting toward using RNG's environmental attributes to decarbonize natural gas consumption of the building sector. Given that Toronto's program partner, Enbridge, derives its revenue almost exclusively through building-based connections to its grid, there are clear corporate interests in centering natural gas infrastructure as the material conduit through which such emissions reductions are attained.

Understanding the tensions between the material and representational dimensions of such programs, and their situation in long-term net zero planning, is important to resisting inertia toward the lock-in of infrastructures like the natural gas grid over the long term. The case study of Toronto should be seen as a valuable opportunity to explore how municipal experimentation with RNG is situated in wider energy transition and natural gas politics, and to consider the array of pathways to which such programs could contribute as they evolve over the long term.

Theoretical perspective

The first section offers a theoretical framework to explore these larger policy questions, beginning with insights from the sociotechnical systems literature. A sociotechnical systems approach to energy transitions emphasizes the interdependencies between infrastructures and technologies with the many social components that together form complex, evolutionary systems (Geels *et al*., 2017). As a research focus within this broad sociotechnical systems perspective, literature on *carbon lock-in* similarly describes how mutually reinforcing infrastructural, institutional, and behavioral dynamics create momentum toward the continued consumption of fossil fuels. In favoring the status quo, emissions-intensive systems often appear rigidly path-dependent due to the 'increasing economic returns to scale, and social and individual dynamics act to inhibit innovation and competitiveness of low-carbon alternatives' (Seto *et al*., 2016: 426). Carbon lock-in is thus a critical barrier to long-term transitions; understanding how carbon lock-in becomes strengthened among and across scales of energy systems can help illuminate where short-term emissions reductions may not necessarily lead to long-term transformational goals where lock-in dynamics are strengthened.

Despite the limited jurisdictional authority of local governments, their proximity to, and influence over the many social and physical infrastructures shaping urban environments justifies the growing focus on municipal policy in helping to stabilize or disrupt carbon lock-in inertia (Creutzig *et al*., 2016; Ürge-Vorsatz *et al*., 2018; Lwasa *et al*., 2022). Given the long lifespan of urban infrastructures, many climate responses in cities are particularly vulnerable to carbon lock-in (Ürge-Vorsatz *et al*., 2018). Local experiments can also influence energy systems pathways beyond their borders (Bulkeley *et al*., 2013). According to Bernstein and Hoffmann (2018), the interdependent, multilevel nature of carbon lock-in means that municipal climate experiments—which tend to be more nimble than policies implemented at other scales—may have catalytic impacts that can serve to disrupt carbon lock-in, even offering alternatives to established energy pathways from the bottom-up. At the same time, municipal climate experiments are structured by their surrounding political and economic contexts. Thus, it is important in examining the dynamics of municipal climate experiments to not flatten urban governance by focusing on the city alone: much wider energy regimes still serve to structure experimental possibilities and shape local experience (Hodson *et al*., 2017).

Path dependency and inertia are popular concepts used to explain the rigidities that emerge out of the interdependent infrastructural, institutional and social components of energy systems over time. Yet, while certainly subject to such stabilizing patterns, Rosenbloom *et al*. discuss the simultaneously important role of *critical choices* and *branching points* that permit the 'possibility of more radical change' (2018: 23). Foxon *et al*. (2013) define branching points as moments where openings in path dependencies lead to a materially significant critical choice that offers an opportunity to redirect inertia. In addition to the infrastructural and institutional rigidities that are often used to describe socio-technical path dependency, a focus on how opportunities to enact either change or stability underscores how 'contending material interests, frames of reference, and visions for the future are at least as important for critical choices around energy' (Rosenbloom *et al*., 2018: 22). Beyond 'entrenched structures, historical contingency and change in exogenous developments,' then, pathways are 'also endogenously influenced by contending actors as they leverage their resources (ideational and material) to frame problems and influence solutions' (*ibid*.: 23).

The carbon emissions inventory and related emissions accounting work are important sites of policy discourse creation that can both lend to and disrupt inertia of transition pathways. With a focus on the national level, Lövbrand and Stripple (2011) argue the establishment of standardized emissions inventorying practices has been critical to enabling the governance of climate change by state jurisdictions. Just as at the national level, subnational inventorying creates new territories of climate governance that establish the focus of local climate experiments around particular infrastructures and activities seen as critical to a territory's climate impact (Rutland and Aylett, 2008; Rice, 2010; Davey, 2025b). While a wide diversity of carbon accounting practices and procedures have been created as decision-making aides that go beyond just the physical, scientific measurement of carbon, it is quite common for all forms of carbon accounting to nevertheless be interpreted as objective practices of scientific measurement (Ascui and Lovell, 2011).

Yet in future-oriented decision-making contexts, the measurement of carbon is a more speculative exercise that is bound up in context-driven interpretations of political, social, economic and technical processes, with such interpretations ultimately necessary to make carbon evaluation a legible and meaningful policy resource (Davey, 2025a). Carbon accounting frameworks are valuable resources in decision-making when both the procedural assumptions and epistemic limits are well understood. This contextual knowledge is important because, inevitably, simplifications of energy system dynamics are intrinsic to this accounting process. For instance, the categorization of the urban emissions inventory according to the discrete policy sectors like energy, transportation, buildings and waste is a practical framework for conceptualizing the various components of an urban system; this sector-specific approach can also abstract from a long-term, cross-sectoral systems perspective that is based on a deep decarbonization of urban environments. Similarly, decisions to include or exclude upstream and downstream emissions from a given technology or activity are often a procedural standard used to avoid double-counting, maintain logical consistency, or establish a reasonable scope of the accounting world. Yet without understanding how quantifications of emissions are produced through certain accounting frameworks, even appropriately produced emissions data can still misrepresent the real emissions impacts of certain policies on global emissions. While accounting practices thus play a critical role in effective transition planning, they need to also be grounded in the real urban materialities they are being used to describe.

Foregrounding urban materialities can help recenter the focus on the more contested processes and practices of change, where seemingly prescribed 'policy goals, visions and actions can … be reinterpreted (or misinterpreted), reiterated and contested by the different groups and interests present according to what matters to them' (Rutherford, 2014: 1453). This approach suggests a turn toward the ongoing processes through which energy systems are negotiated, comprising a diverse set of actors and projects that mediate material flows through urban environments. Transition scholarship that adopts a material politics approach thus emphasizes going beyond popular policy discourses of municipal decarbonization to make sense of how such policy discourses are created to either positively or negatively frame a set of alternative pathways (Rutherford, 2014; Bulkeley *et al*., 2016; Tozer, 2019).

The article continues below first by exploring how RNG is constructed as a carbon neutral or carbon negative fuel through accounting-based assumptions. I then introduce the contemporary politics of natural gas in Ontario, and the key provincial stakeholder and partner in Toronto's RNG program: Enbridge Distribution Inc. An analysis of Toronto's waste-to-RNG facilities follows, focusing on the construction of the 'carbon loop' policy narrative and the physical transformations of the energy system that this policy discourse represents.

RNG: accounting for avoided emissions

Once more popularly referred to as biomethane, today RNG is being touted as a decarbonization solution and a viable alternative to electrification as an energy transition strategy. Chemically identical to natural gas, one of its most attractive benefits is that it can be consumed through existing fossil fuel infrastructure.

While carbon emitted from conventional natural gas is recorded as emissions contributing to climate change, carbon emissions from RNG are considered biogenic, defined as 'CO_2 emissions directly resulting from the combustion, decomposition, or processing of biologically based materials other than fossil fuels, peat, and mineral sources through combustion, digestion, fermentation, or decomposition processes' (EPA, 2011: ix). Assumptions that biofuels like RNG are carbon neutral are based on the reasoning that biogenic carbon is already part of the natural carbon cycle. Fossil fuels, on the other hand, introduce 'new' carbon into the biosphere. This assumption that underpins nearly all emissions accounting practices is not without controversy, however, and has been described as an accounting flaw based on the premise that there will necessarily be a quantitative balance between the categories of energy and land use (Haberl *et al*., 2012). When this accounting principle is incorporated into inventorying work, the result can be a highly simplified policy guidance assuming RNG is carbon neutral and 1:1 displacement with natural gas can reduce combustion-based emissions to zero.

When calculating the emissions from RNG production and use, two distinct moments of *avoided emissions* are especially crucial. First is the prevention of methane from being vented into the atmosphere from disposal in landfill. Second is the direct displacement of fossil carbon when RNG is used in place of natural gas.

Claims that RNG might be carbon negative are only possible when using a lifecycle assessment (LCA) to quantify avoided emissions. LCA is based on a *counterfactual scenario*, where the avoided emissions from the chosen *policy scenario* are equal to the difference in emissions from the counterfactual. In cases where it is assumed there would otherwise be no policy to contain or limit methane, the resulting avoided emissions can be substantial. This is usually the basis for claims of carbon negativity and is typical of how gas utilities, like Enbridge, and industry associations often describe RNG as part of their own climate change portfolios.

But as Grubert argues, any methane that can be captured for RNG production can be 'captured for diversion to a flare, and it is unrealistic to assume that capturable methane would be vented under a GHG conscious policy regime' (Grubert, 2020: 5). Government institutions and non-industry researchers are often more conservative in their claims on RNG's emissions benefits, establishing counterfactuals that aim to incorporate more realistic policy alternatives. Similar to the assumptions made by the City of Toronto (see below), Cyrs *et al*. (2020) demonstrate this in their comparison of typical emissions performance of RNG produced from different feedstocks, including landfill gas, food waste, wastewater, animal manure and agriculture residuals, which also demonstrates the immense significance of feedstock in the overall environmental impacts of RNG. In their analysis, RNG from landfill gas is especially emissions intensive and reaches an intensity nearly two-thirds that of conventional natural gas (Cyrs *et al*., 2020: 7). Among other factors, landfill gas converted to RNG can be emissions intensive in part due to the significant electricity that scrubbers require to upgrade gas with currently available technology. RNG produced via anaerobic digestion of biogas from food waste is less emissions intensive because of the simpler upgrading process. Yet focusing on the United States, Cyrs *et al*. highlight that the volume potential of landfill gas (approximately 525–850 billion cubic feet per year) is far greater than that of food waste (approximately 25–50 billion cubic feet per year), the latter representing a quite marginal potential volume despite performing much better from an environmental perspective (*ibid*.: 8).

The sustainability of RNG is thus not only a simple ledger-based question that is often implied in popular policy discourse—where the biogenic carbon is simply free energy—but is a materially and technologically situated question related to the type of biogenic feedstock and processing methods used. This has become particularly evident in debates over RNG from animal waste. While often considered the most significantly *carbon negative* feedstock (Cyrs *et al*., 2020), some critics argue that these substantially negative emissions outcomes are the product of narrow policy counterfactuals that assume there are no alternatives to address methane emissions absent RNG production (Saadat *et al*., 2020; Waterman and Armus, 2024). The rapid growth of RNG incentives for dairy farmers has been instrumental in making RNG cost competitive but, according to these critics, has also indirectly penalized producers already using methane-reducing manure management practices, or who already own smaller herd sizes, as these producers do not have access to the incentives that disproportionately favor large-scale and environmentally intensive agriculture (Waterman and Armus, 2024).

While this article focuses primarily on municipal RNG programs that source feedstock from municipal landfills and organics facilities, this perspective of the broader technical and political controversies highlights the complexity of determining the degree to which a future based on RNG, alongside other alternative fuel supplements, offers a renewable and sustainable alternative to fossil fuels. This does not mean RNG does not offer real environmental opportunities, and indeed there are other benefits to displacing natural gas not considered here, like the avoidance of localized environmental and health risks common in the production of shale gas (Howarth, 2014; Jackson *et al*., 2014) or competition for water in the hydraulic fracturing process that, in Canada, most acutely affect Indigenous communities (Parfit, 2017). This complexity, however, should encourage deeper reflection on how futures that incorporate alternative fuels into a long-term net zero plan reflect the transition toward a more sustainable and just energy mix.

This also points to the need to consider the end uses for which RNG will be adopted and how these end uses will be networked into a larger energy system. Where RNG is imagined as a modest supplement used to replace fossil fuels in a targeted set of difficult-to-decarbonize end uses, a more conservative RNG worldview is established that still sees substantial social and infrastructural transformations as inevitable. These transformations are typically based on widespread electrification of end uses and growth of renewable electricity over the long term. Air travel, shipping and long-haul trucking are three sectors in particular where it is more conservatively assumed that alternative biofuels and hydrogen might play a more targeted role (Cunliff, 2019). A very different RNG worldview is based on a process of fuel blending where existing energy infrastructures are largely maintained over the long term, as are current volumes of natural gas consumption, which come to be gradually replaced with supposedly carbon neutral or negative fuel alternatives. This is the vision shared by Enbridge for Ontario's energy transition.

The politics of (renewable) natural gas: Enbridge, Ontario and municipal planning

An RNG worldview that sees the natural gas grid entirely decarbonized in the future is typically based on the principle of *fuel blending*. In this view, while marginal quantities of RNG may currently displace total natural gas consumed, such fuels may entirely replace current volumes of natural gas over the long term. The Canadian Gas Association (CGA) has been particularly active in promoting this transition narrative where natural gas infrastructure can maintain a role in Canada's energy sector while being 'decarbonized' in the long term with the growth of alternatives like RNG (CGA, 2021). The potential volume assumptions associated with this premise are, however, questionable. A 2020 study commissioned by Natural Resources Canada, for instance, concluded that only 3.3% of natural gas consumption in Canada could be displaced with viable and sustainable sources of RNG (Stephen *et al*., 2018).

The vision of fuel blending as a decarbonization strategy is tied to the much larger discussion over natural gas as a bridging fuel (Howarth, 2014; Delborne *et al*., 2020; Janzwood and Millar, 2022). The *bridge fuel* pathway has traditionally represented a 'least harmful' solution that bought time for more desirable, permanent solutions to be realized. The short-termism of the original bridge metaphor has evolved into a much more plural discourse that increasingly portends—optimistically or begrudgingly—a more permanent role for the bridging fuel itself. Alongside a general underestimation of natural gas' climate impacts, fuel blending strategies can become narratives that legitimate the maintenance and expansion of natural gas infrastructure thus adding momentum to infrastructural and carbon lock-in (Kemfert *et al*., 2022). The risks of policies that encourage an expansion of natural gas infrastructure include the potential crowding out of other low-carbon technologies, as well as risks that include financial losses of stranded assets or, alternatively, a lock-in of infrastructures that are potentially more emissions intensive than if alternative pathways had been chosen at an earlier stage (Brauers, 2022).

In Ontario, a bridge fuel narrative that highlights the role of RNG to heat homes has, according to Janzwood and Millar, helped to create opportunity for natural gas 'to entrench in new sectors of the economy by acting as a placeholder until the arrival of non-emitting alternatives' (Janzwood and Millar, 2022: 7). As the sole entity authorized by the Ontario Energy Board (OEB) to distribute natural gas in the Greater Toronto Area, Enbridge is a major stakeholder in the provincial energy transition as well as a major proponent of RNG as the means to decarbonize an expanding provincial gas grid. After two unsuccessful attempts in 2011 and 2017, the OEB—the independent regulator of Ontario's electricity and gas sector—approved Enbridge's application to implement a voluntary consumer RNG program in March 2020. The program, *OptUp*, now 'invites Ontario-based residential consumers to pay an additional two dollars a month to help green the natural gas supply and support the Ontario government's environment plan' (Enbridge, 2021: 23). The corporation describes RNG fuel blending as an immediate solution that is also a 'cost-effective, reliable and low-carbon alternative to electricity' (*ibid*.: 10). While such programs offer potential emissions reductions in the immediate term, the timeline for transition away from conventional natural gas is left notably ambiguous, and as with the deployment of many bridge frames in contemporary contexts, appears to extend decision-making timelines around natural gas infrastructure that could make transition more difficult and costly down the road (Net-Zero Advisory Body, 2021; Janzwood and Millar, 2022).

As a natural gas distributor, Enbridge does not supply fuel but rather draws its revenue from grid connection rates. Each building or other end use that draws natural gas from Enbridge's franchise system represents a connection. Connection rates are strictly regulated by the OEB, typical of any utility service monopoly to ensure affordability. Of Ontario's 6 million households, approximately 75% rely on natural gas connections for heat (CGA, 2021). Current plans to construct 1.5 million new homes in the province by 2031 to address the severe housing shortage represent an astounding number of potential new grid connections (Province of Ontario, 2022). This has placed the conflict over the natural gas grid's future directly within debates over the future of new and existing building sector transformations in Ontario.

While approving the 2020 application for its voluntary RNG program, in December 2023 the OEB rejected a rate rebasing proposal by Enbridge that would have adjusted consumer connection rates to incorporate the costs of new infrastructure and future maintenance (OEB, 2023). The rejection was based on the board's consensus that there was a high likelihood of new infrastructure becoming a stranded asset in either the short to mid-term (*ibid.*). Almost immediately, the Province of Ontario vowed to overrule the decision by the independent regulatory board, which was accomplished with the passage of Bill 165 in May 2024. Yet, the same month of the OEB's 2023 ruling, the province's own Electrification and Energy Transition Panel (EETP) made very similar conclusions: that there were 'growing indications that it is unlikely that the natural gas grid can be decarbonized while continuing to deliver cost-effective building heat' and that, because it is 'no longer clear that natural gas is the cheapest way to heat buildings … customers may begin choosing to disconnect from the natural gas distribution system in the mid-term' (EETP, 2023: 72). Given the parallel mounting concern that electricity demand may strain the capabilities of the existing grid, the challenge in Ontario was one of pacing the 'rate of increase in electricity demand with the rate at which new electricity supply can come on stream' (*ibid.*: 73). The provincial debate over whether, how and when to strategically focus on disconnecting current end uses from the natural gas grid remains contentious.

Many important decisions affecting Enbridge's corporate future are also decided at the local level, as municipal land use planning and regulatory decisions can both enable or constrain Enbridge's capacity to expand its gas grid and install new connections. In 2020, Enbridge established a dedicated team to support local governments in Ontario in creating and updating their climate change and energy plans (Syed, 2024). Ensuring existing connections remain and new connections are installed is existential to Enbridge's corporate survival. Whether the existing building stock and new buildings will be networked into the Enbridge franchise system or electrified also depends in many important ways on municipal planning decisions. While over 75% of Ontario households use natural gas for heating, the vast majority are in urban (or suburban) regions, making the infrastructural politics of natural gas a mostly urban energy problem.

Aside from sitting on municipal climate change committees across Ontario, Enbridge is also partnering with municipalities in a variety of ways to promote the expansion of natural gas grid connections and end uses (Enbridge, 2021). In Hamilton, Ontario, Enbridge is piloting a new 'turnkey, all-inclusive Municipal Transit program' to accelerate the conversion of diesel public buses to natural gas, where they have thus far helped the municipality convert 130 buses (*ibid.*). All but one of these buses as part of the pilot were fueled with connections to the natural gas grid; a flagship bus plastered with floating food waste, and the slogan 'Ontario's first carbon-negative bus' is the exception. Nearby, a more recent CAD 42 million project in Niagara Falls, Ontario, to convert municipal landfill gas to RNG will soon supply Enbridge's grid with enough 'green energy' to heat 8,750 homes (Enbridge, 2020).

Despite this rise in municipal partnerships, tensions between Ontario municipalities and Enbridge have become apparent in recent years, as the expansion of natural gas infrastructure has come into conflict with local net zero planning goals. Enbridge has actively tried to rally support among municipalities, particularly during the debate over Bill 165 (Enbridge Gas Inc, 2024). But climate teams in the cities of Toronto and Ottawa have both publicly argued that a business-as-usual approach to natural gas infrastructure development is not conducive to their climate goals (OEB, 2022; City of Toronto, 2024b). The direct challenge by such municipalities to Enbridge's RNG promotion—based on the decarbonization of an expanding natural gas grid—demonstrates that, despite the participation of Enbridge in the municipal climate action planning process, the corporation's direct influence over this realm of municipal planning remains limited even as they continue to expand partnerships with municipalities in other ways. The relationship between Enbridge and the City of Toronto is notably complex and fragmented. Within the City, the Energy, Climate & Forestry (ECF) division is responsible for natural gas and RNG purchasing for the City corporation, but also leads the TransformTO net zero planning process. Solid Waste Management Services (SWMS) has a newer relationship established with Enbridge only since the launch of waste-to-RNG programs. Municipal permits to install and/or repair gas infrastructure within the City limits represent another politically charged municipal–corporation interface (City of Toronto, 2024b).

The article now turns to the City of Toronto's waste-to-RNG program. Enbridge is the City's development partner, and thus how the corporation's interests are reflected in the program's design is explored below. Rather than collapse the City's program entirely with Enbridge's interests; however, the program itself must be simultaneously understood from the distinct perspective of the City and key municipal divisions that hold both short-term and long-term interests, and which contribute to momentum that shapes future pathway choices.

The City of Toronto's waste-to-RNG program

– History of the RNG facilities

The City of Toronto has a long history of taking action to reduce emissions through waste sector policies. In 1997, Toronto became the first city internationally to reduce its emissions, owing in large part to investments in landfill gas capture fittings (DeMara, 1997). By 2013, the dramatic overachievement of the 6% emissions reduction goal by 2012 (based on 1990 levels) with an impressive 24% emissions reduction owed, first, to the Province of Ontario's phase-out of coal in the electricity grid; the second most significant contribution came from the landfill gas capture and curbside organics program (Porter, 2013). While the City of Toronto made significant investments in gas capture for its large landfills in the 1990s and established its first anaerobic digestion facility as part of its novel organics program in 2002, it was not until 2009 that the prospect of upgrading biogas to biomethane was first discussed as a potentially viable local option.

At least two key incentives informed the early focus on the waste sector in addressing local emissions. First, few other sectors contributing to local emissions were under the direct jurisdictional control of the municipality. A 1998 report determined that of the 22 $MTCO_2e$ of emissions under municipal control in Canada, an astounding 18 MTCO2e was due to emissions (primarily methane) from landfills (Torrie, 1998: 18). Second, the technological investments to capture landfill gas or produce biogas at organics facilities were relatively low cost compared to more substantial investments in the built environment and building systems that would be necessary to realize significant reductions in other crucial sectors. Along with the higher global warming potential of methane, interventions in the waste sector could accrue substantial reductions.

Toronto had been one of the first cities (if not the first) in North America to roll out a curbside organics program in 2002, where facilities were equipped with anaerobic digestion technology that resulted in captured biogas. The resulting biogas was flared off at the first Dufferin organics facility. The second facility that became operational in 2007, Disco Road, was designed to use biogas on-site for heat and electricity. This made Disco Road Canada's first anaerobic digestion WTB facility (Gorrie, 2015). In their original scoping of the facility, the City highlighted the potential to not only sustain Disco's operations with biogas-based cogeneration for on-site use but also to sell off extra electricity to the grid for profit (City of Toronto, 2007). Selling to a third party was ultimately deemed too expensive and speculative in nature, bound up in complicated provincial energy regulations. Thus, any surplus biogas not used for on-site energy was flared off.

By 2010, the City began exploring options to upgrade biogas to biomethane, with a small pilot approved at Disco Road; this was ultimately abandoned due to unfavorable market conditions, which were factored by the low cost of natural gas and high cost of upgrading technology (City of Toronto, 2010). City Council's renewal of its emissions reduction commitments in 2016 with the launch of TransformTO opened a new window of opportunity to explore biomethane opportunities. Market conditions had become more favorable: despite the price of natural gas remaining quite low, the upgrading technology was now more affordable and proven applications were in use (City of Toronto, 2016). With the rising price of diesel, the City had already begun converting its waste fleet to natural gas: a switch initially raised in the context of Disco's biomethane potential in 2009 (City of Toronto, 2010).

Dufferin Organics was the first site commissioned for RNG upgrading technology, becoming fully operational in 2022. New upgrading technology, slightly different from the Dufferin pilot, was recently installed at Disco Road in 2024. WTB is seen as strategic to the City's Circular Procurement Framework for corporate consumption, which uses the City's own purchasing processes to establish leadership and work toward the goal of becoming 'Ontario's first circular city' (City of Toronto, 2018a). The City of Toronto currently purchases its own RNG as a means of reducing emissions from natural gas consumed by Toronto's waste fleet and City-owned buildings. Together, Dufferin and Disco Road have a combined expected annual RNG output of 6.3 million cubic meters of RNG, or about 4.1% of the City's total 155.2 million cubic meters of annual fossil gas usage, a total volume that includes all of the City's Agencies, Boards and Corporations (City of Toronto, 2024a: 5).

Currently the City is in the planning and design stage for RNG upgrading technology at the Green Lane Landfill (GLL) site. As discussed above, conversion of landfill gas to biomethane is a more energy-intensive and technically complex process than converting biogas from anaerobic digestion. Initially, a landfill gas-to-electricity system was preferred at GLL, and in 2010 the City had begun developing a project to generate and sell electricity to the grid following the launch of Ontario's feed-in-tariff program in 2009 (Hamilton, 2010). Provincial changes to the feed-in-tariff program later dramatically changed cost considerations and led to the project's cancellation (interview SWMS, May 2025). The City subsequently shifted toward an RNG option. Studies show that the biogas potential from GLL (24.7 million cubic meters) is significantly larger than the current organics capacity. In addition to applying RNG to offset City transportation and building emissions, opportunities to sell RNG on the market are now also being explored with the prospective GLL upgrading facility. While the option of selling RNG was discussed in the initial stages of the Dufferin facility, the City chose to self-consume the fuel following Council's declaration of a Climate Emergency in 2019. Proceeds from selling RNG in the future might be used to create a new 'revenue stream which could be reinvested in green infrastructure projects' (City of Toronto, 2023a: 6).

– Avoided emissions

In 2025, it is expected that RNG attributes from the organics facilities will displace 534 tCO_2e and 8,393 tCO_2e of emissions from the waste vehicle fleet and City-owned buildings, respectively (City of Toronto, 2024a: 18). These avoided emissions are based on the specific counterfactual scenarios established by the City. As the City's counterfactual scenario assumes natural gas would be combusted absent RNG production, the avoided combustion emissions in replacing fossil carbon (natural gas) with biogenic carbon (RNG) are included in the total savings. The counterfactual scenario also assumes that biogas produced at Dufferin and Disco would be flared off, thus accruing additional reductions in reduced or avoided biogas flaring. These emissions savings are, however, also offset with the emissions created by the electricity needed for the project and the emissions from venting, tail gas and any natural gas usage specific to the project (interview SWMS, May 2025).

Due to inefficiencies in the preprocessing technology at the Dufferin anaerobic digestion facility, current biogas and RNG output at the facility is about a third of expected output (City of Toronto, 2024c: 10). The City notes it is planning to make improvements to the Dufferin facility to increase the amount of organics that can be recovered and the amount of RNG produced (City of Toronto, 2024c).

As discussed above, the much larger quantity of electricity needed to upgrade landfill gas to RNG largely accounts for the more marginal emissions savings expected per cubic meter at the potential GLL facilities. Cyrs *et al.*'s (2020) study concluded that, from a lifecycle perspective and using the authors' own counterfactual and policy scenario assumptions, RNG from landfill gas was the most energy-intensive form of RNG and resulted in approximately two-thirds of total fossil emissions from the burning of conventional natural gas. But the exact emissions performance is also technology and geography-specific: technology because each process chosen among possible alternatives will have its own unique electricity requirement which could also be subject to increased efficiencies as the technology matures; geography because, when drawing from the electricity grid, all emissions from electricity consumption are factored by the emissions intensity of the grid. Notably, Ontario has a low grid factor, but the resulting emissions are still significant to the overall emissions performance of RNG from the prospective GLL facility. Current plans by the Ontario government to significantly expand the supply of fossil gas-powered electricity to meet rising demand in the province further complicate the potential emissions benefits.

– Interventions in the physical energy system

– WASTE FLEET CONVERSION

As a difficult-to-decarbonize end use, heavy vehicles are often cited as one of the most logical uses for RNG and other biofuels, at least in the short to medium term. One of the first reports to mention the conversion of the city's waste fleet to natural gas was the 2009 report on prospects for upgrading biogas at Disco Road, where the consultants recommended accompanying the biofuel upgrading technology with a 'corresponding plan to transition the solid waste collection vehicle fleet from diesel to compressed natural gas (CNG) fuel' and displace the 4.4 million litres of diesel fuel currently consumed by the fleet (City of Toronto, 2010: 6). While the initial RNG pilot stalled at Disco Road, the City continued with the conversion of its diesel fleet to natural gas. Even without RNG, there were still significant emissions and cost benefits from natural gas conversion.

Within an energy transition context, the logical alternative to natural gas conversion is electrification. Yet there are distinct challenges to electrification of heavy vehicles like waste collection trucks, including lower weight limits of collected waste due to the heavy on-board batteries. When decisions were made beginning in 2010, natural gas conversion was the only practical pathway (interview SWMS, May 2025). Progress in waste vehicle electrification remains slow and technology remains costly. Only recently have major cities like New York and Seattle begun to add full-sized electrified waste vehicles to their fleet, so far with the purchase of one or two vehicles as demonstration pilots. Together with its contractors, the City of Toronto operates a fleet of 300 plus solid waste collection vehicles.

The life expectancy of a waste collection vehicle on Toronto streets is 5 years, much shorter than other natural gas-related investments related to pipeline infrastructure, for example. This means that these end uses are not necessarily locked in, with opportunities in the medium term should cost and technology cases shift.

– PIPELINE INJECTION AND RNG DISTRIBUTION

Toronto's program remains highly flexible in its allocation of RNG because of the City's decision to inject renewable fuel into the Enbridge pipeline. Virtual relationships between sites of RNG production and RNG consumption are the result, as the physical RNG molecules are blended into the larger natural gas grid. Once RNG is 'in the grid, the City's options in terms of its end uses are numerous' (Redling, 2019).

With the initial focus on the RNG program's capacity to fuel waste vehicles, several factors related to fleet logistics informed the decision for pipeline injection. In other local WTB programs, like Sacramento, RNG is directly injected into waste vehicles as fueling stations are co-located with organics processes facilities (Tomich and Mintz, 2017). In Toronto, fleet fueling yards are not co-located with waste transfer stations, and thus connecting to the Enbridge pipeline was deemed most practical. Given that Dufferin and Disco Road organics sites already existed prior to the RNG program, options were more limited, though these are not impossible barriers to overcome should direct injection be considered as an alternative in the long term.

Because the total volume potential of RNG from Toronto's waste exceeds that required to fuel its waste fleet, injecting RNG into the pipeline means the environmental attributes can offset natural gas emissions from city buildings. This has been critical to the ability of the program to reduce the City of Toronto's overall emissions, as more emission reductions are expected to be applied to the City Corporation's building sector (8,393 tCO2e) than its waste fleet (534 tCO2e) in 2025. It is also by injecting RNG into the pipeline that the opportunity to sell RNG to third-party consumers is possible.

Finally, Enbridge's role as the contractor for the RNG conversion technology is also relevant to its design, where RNG distribution relies on the Enbridge franchise system. As established in the Biogas Service Agreement between the City of Toronto and Enbridge, Enbridge maintains responsibility for designing and constructing the biogas-to-RNG upgrading system, managing operation and constructing grid injection infrastructure (City of Toronto, 2018b). The contract with Enbridge is for 15 years: the expected lifespan of the upgrading technology (interview SWMS, May 2025).

– BUILDING DECARBONIZATION

Finally, and perhaps most contentiously, is the relationship between the RNG program and the city's plans for deep decarbonization of Toronto's buildings, a question closely connected to the future of the natural gas grid. Because Ontario's electricity mix has a low emissions grid factor, the vast majority of City and community-wide emissions in the building sector are from natural gas combustion (see Figure 2).

The official TransformTO strategy focuses primarily on building electrification as a pathway to net zero. The City of Toronto's own real estate portfolio plan establishes a goal for 80% of its buildings to be converted off natural gas by 2040; though it would 'temporarily rely on [RNG] produced in City facilities to heat the 20% of buildings that remain to be retrofitted after 2040, as well as an estimated 7% of buildings where electrification may not be feasible' (City of Toronto, 2021: 5). This parallels the community-wide net zero plan for the privately owned building stock to undergo deep energy retrofits, which includes electrification and energy efficiency upgrades. Across the Toronto community, this would entail approximately 450,000 home retrofits at an average pace of 27,000 per year, to meet the 2040 goal (City of Toronto, 2023b: 2). Since 2007, the city has also developed its own green standards for new building construction that have become progressively ambitious as Toronto's climate goals have progressed. While not banning the installation of natural gas connections outright, the standard does set overall sustainability goals for building performance that strongly encourage electrification of new buildings (City of Toronto, 2024d). These standards were legally challenged by the non-profit industry association, Residential Construction Council of Ontario, in December 2024; most recently, in May 2025, Bill 17 was put forward as legislation in the Ontario Provincial Parliament that would prevent Ontario municipalities from setting their own building standards.

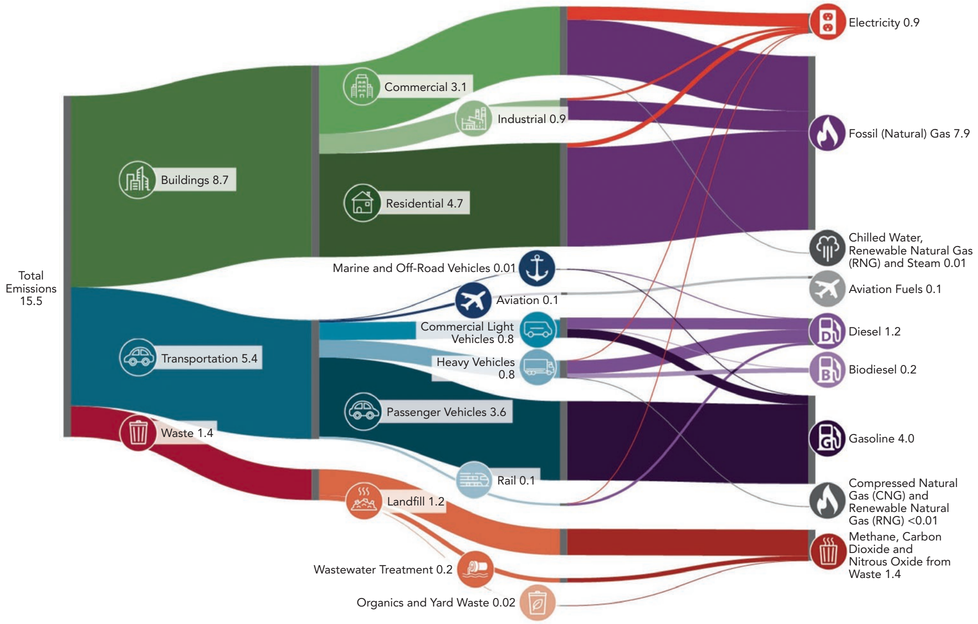

FIGURE 2 Sankey diagram of Toronto's 2022 community-wide emissions (MT) by sector and emissions source (*source*: City of Toronto, 2024a, https://www.toronto.ca/wp-content/uploads/2024/12/9270-2022-SBEI-Report.pdf)

While these challenges to Toronto's authority in creating its own green building standards play out, the City resides in a difficult spot in having to reconcile its commitments to emission targets with a hampered building decarbonization plan that is premised on widespread disconnections from the natural gas grid, and which faces difficult regulatory and financial barriers. Even in a scenario where Toronto's green building standards are upheld, existing private homeowners must still voluntarily disconnect from the grid at a substantial expense in order to reach 2040 goals (the City estimates CAD 100,000 each). The multifaceted relationship of Enbridge with the City of Toronto—not only as a contractor for the RNG program but as an essential service utility and a stakeholder existentially threatened by net zero strategies like those in Toronto—also complicates transition pathways. In any case, the chosen strategy to decarbonize city-owned buildings by assigning RNG to these end uses on the corporate inventory depends on continued connections to the natural gas grid.

Given this current dependence on physical grid connections, a long-term transition perspective that assumes decommissioning of the natural gas grid is the only practical pathway to net zero would seem to suggest this current strategy for corporate building emissions reductions would be considered a bridging solution. At the provincial level, timeframes for when disconnections from the natural gas grid should begin from both the provincial government and OEB remain undefined. While Toronto has official plans for deep decarbonization of the building stock according to its 2040 net zero goal, this seems increasingly unrealistic under current economic and regulatory conditions in the province for at least the privately owned building stock.

Discussion: the carbon loop policy framing and material politics of waste-to-RNG

The City of Toronto's RNG program is not only a material intervention in energy systems extending beyond municipal borders, but also a powerful policy discourse that must be situated in broader discussions around natural gas and RNG as part of province-wide transition politics. This does not mean the program is decidedly captured by the same natural gas bridging politics that animates a corporate entity like Enbridge's interests in expanding municipal RNG facilities. Deeper reflection on the policy narratives and material politics of the RNG program is, however, essential to consider how the current program is related to these other stakeholder interests, and to imagine how reinventions in the future could allow for RNG facilities to support energy pathways that support deep decarbonization of energy infrastructures.

If policy narratives are critical to legitimizing pathways of transition, and do important work in making short-term action meaningful to long-term goals, then the framing of waste-to-RNG as an innovation that 'closes the carbon loop' acts as a representative terrain within which to define the program as both climate-positive and a circular economy innovation. While the circular economy model implies a direct intervention in urban material metabolisms, the carbon loop further extends this frame to the urban–global carbon cycle through the technical work of emissions accounting.

The carbon loop policy narrative in Toronto has typically emphasized the use of RNG in the waste fleet. This clearly fits within a circular economy lens, where RNG produced from household organic waste is used to fuel the waste collection fleet that delivers waste to the RNG facilities and so on. These implied circular material flows are not real material flows, however, but nominally determined relationships that are managed through the emissions accounting process. The implication is of a direct physical connection between sites of RNG production and consumption, where the new renewable fuel replaces the entire energy basis of a particular end use like the city's waste fleet. But in a material sense, RNG is instead physically injected into the Enbridge franchise system where it flows through the province-wide grid as a blended fuel. While RNG is more proportionally significant by volume when quantified according to the city corporation's natural gas consumption, as a percentage of total natural gas consumed through the Enbridge system it becomes marginal.

This distinction—between direct end use injection and pipeline distribution—is politically, as much as materially, significant. Representations of RNG as the means of decarbonizing natural gas consumption in waste vehicles or targeted City buildings create a transition narrative where specific fuel end uses are isolatable from the grid and their energy basis entirely replaceable by a carbon neutral fuel. Yet the resource loops depicted in such narratives are really proxies for carbon loops produced through the technical work of carbon accounting. The fungibility of carbon as an entity that can be exchanged between sectors and across inventories—assignable to different end uses and/or commodified for exchange—is an abstraction of the real material flows from their socio-infrastructural contexts. In this framework, RNG could be applied to decarbonize any end use connected to the Enbridge grid without a physical intervention needing to take place.

Once environmental attributes are made fungible within the accounting-based framework, it becomes possible to move carbon around virtually to support a variety of policy framings. The sector-based inventory is already organized according to the discrete sectors of energy, buildings, transportation and waste. WTB programs cut across all these sectors and appear as a holistic approach to re-shaping energy systems from the local level. This framing reflects opportunities but also creates new risks, where energy systems planning could become a process of moving around quantities of emission reductions or environmental attributes, between sectors as opposed to long-term planning that engages with the co-evolving nature of sectoral infrastructures and their embeddedness in social, political and economic relations that exist outside the territorial accounting framework.

It is by relying on the Enbridge pipeline that new policy framings become possible without the need for physical intervention. The decision to distribute RNG through the natural gas pipeline reflects an inherently flexible and politically responsive program that appears to extend the timeframe within which decisions about natural gas infrastructure must be made, where continued emissions reductions can be realized while major infrastructure decisions are forestalled. Describing the possibilities of biofuel to reduce provincial emissions in Ontario, Rosenbloom *et al*. suggest this emphasis on low-carbon possibilities for natural gas infrastructure represents a stretching of existing branching points, where critical choices about natural gas infrastructure are being put off in order to keep other options open. In doing so, however, certain possibilities currently available may no longer be attainable in the future, and 'either an explicit acceptance of natural gas or a non-decision about the future of this fossil fuel would likely allow it to continue to gain market share' (Rosenbloom *et al*., 2018: 28).

The flattening of RNG attributes in emissions accounting also abstracts from the significance of material contexts within which fuels are produced and distributed. The City of Toronto's initial plan to use landfill gas as a fuel for electricity generation highlights the strained environmental performance of RNG produced from Toronto's landfill facilities compared to RNG produced from organics facilities. Given that 24.7 million cubic metres of RNG is expected from the GLL facility, compared to the 6.3 million from the organics facilities, the program's volume significance rests on the capacity to seize RNG opportunities from all of the City's waste-based feedstocks. The initial 2010 decision to follow an electricity generation pathway for landfill biogas offers a *road not taken* that was initially seen as more desirable than an RNG option. It also underscores that seizing the green energy potential of a municipality's waste stream should not be defined by RNG upgrading only. This electricity pathway was ultimately closed, at least temporarily, because of provincial policy changes. But the less-than-optimal environmental performance of RNG upgrading from Toronto's landfills, according to the City's current modeling, still underscores that RNG is not a generic solution on which to build a circular economy. As Blum *et al*. (2020) emphasize, just because something is circular does not make it sustainable, and decisions that support the circular urban economy must be evaluated based on their own context-specific merits. Just as grounding avoided emissions, or environmental attributes, in the material politics of natural gas systems is critical, so is grounding RNG in a material politics of relevant biological feedstocks, technical processes and energy geographies within which such fuel is produced.

Given the marginal quantities of potential RNG and other renewable fuels available to be produced in Canada, it is not possible for current natural gas infrastructure to remain intact while governing an effective transition toward a net zero future (Stephen *et al*., 2018). In contrast to claims made by corporations and organizations with interests in natural gas infrastructure, there is no viable strategy available at present to decarbonize this infrastructure over the long term via renewable fuels. The pacing of natural gas disconnections is a more practical debate around which Ontario's energy future might be explored. Ensuring such a process does not interfere with households' access to affordable and reliable energy is nevertheless paramount. There may be a role for RNG applied to a set of difficult-to-decarbonize transportation or industrial processes, but this future would certainly not resemble the socio-infrastructural relations of natural gas systems that we are familiar with today.

Conclusion

Programs like Toronto's RNG facilities are caught in a difficult position within a complex debate over natural gas grid infrastructure, which is characterized by a diversity of stakeholder interests and long-term planning visions. Within the City of Toronto, municipal divisions have their own situated interests and engage Enbridge in a wide variety of capacities. Enbridge acts as an essential service provider for Toronto residents and businesses, a major stakeholder affected by Toronto's net zero strategy and now a contract partner for RNG facilities. Alliances and interests are further shaped by the regulatory and political contexts determined by the provincial government and the OEB, among other interested parties.

In designing Toronto's current organics RNG programs, material decisions to connect RNG sites and vehicle fueling stations to the pipeline were, as described above, made for practical reasons. The shorter lifespan of RNG upgrading infrastructure and the waste fleet suggest flexibility in adapting the program's design to future conditions according to shifting economic, environmental and political conditions. This includes the possibility to shift away from the Enbridge franchise system as the physical intermediary that connects sites of RNG production with sites of consumption. However, the program also reflects inertia toward an energy pathway that realizes its contributions through the continued existence of the Enbridge system. How this inertia affects future pathway choices is an important question that goes beyond the analysis of municipal corporate decisions that are made among a set of short-term choices—where corporate fiscal responsibility and limited jurisdictional authority act as dominant constraints—but a longer term perspective on energy transitions as technical, political and social processes that will inevitably require more foundational regulatory and infrastructural innovation.

The City of Toronto's RNG experiment explores local level opportunities to reconfigure linear urban metabolisms and reduce local territorial emissions within the existing hierarchical and centralized energy systems and infrastructures that currently define modern economies. There remain transformative possibilities in local experimentation. Still, deeper consideration of the long-term and multi-scalar nature of net zero transitions, and the politics of infrastructure that are implicated in transition narratives, is critical.

This article has examined two important dimensions of municipal RNG programs. First, the article has interrogated the construction of a carbon loop policy narrative that has helped to extend a more conventional circular economy framework into a multi-sectoral climate discourse via the work of carbon accounting. Second, the article has scrutinized the physical interventions that accompanied these policy narratives and discussed the practical considerations that have shaped these program design decisions. Provincial actions by the Ontario government have significantly shaped local choices, first with the feed-in-tariff program, then with Bill 165 to facilitate the expansion of natural gas connections and most recently with Bill 17, among other examples. Decisions made by the City of Toronto in its own net zero planning process must be understood within this political context. However, municipal action is not merely reactive but actively helps shape future possibilities and pathways with long-term consequences. Of particular interest in Toronto has been the question of inertia with respect to natural gas infrastructure: Could reliance on the Enbridge system as the means of distributing a blended fuel and allocating reductions on the emissions inventory contribute to locking in natural gas infrastructure? Might it extend branching points—or strengthen bridge narratives—in service to more immediate reductions, while at the same time helping to forestall more fundamental infrastructure interventions under the coverage of meeting annual emission reduction goals? While the interests of Enbridge are important to consider as a program partner, the City of Toronto's program should not be viewed as solely in alignment with the corporation's long-term interests in maintaining a role for natural gas infrastructure. RNG can offer environmental benefits and there is value in the City of Toronto experimenting with its possibilities. However, ensuring that such programs lead toward transformative net zero pathways requires that fuel blending policy models be grounded with a much broader energy policy perspective.

The dominant discourse surrounding RNG is one that typically emphasizes the fuel as a singular entity: an abstract fuel switch that displaces fossil with biogenic carbon and makes consumption of (bio)methane irrelevant to the existential transformations of the global carbon cycle that we often call climate change. Policy discourses, like the carbon loop, that continue to encourage slippage between the technical work of inventorying and the real socio-material transformations involved in transition planning may ultimately undermine our ability to have difficult but necessary conversations over pathway choices and to think through energy transitions with the complexity such choices demand. Both encouraging local experimentation and fostering critical discussions on how urban programs can support long-term structural transformation are needed to ensure such experiments do not become captured by other interests over the longer term.

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