BUILDINGS & CITIES

Canadian cities: climate change action and plans

SPECIAL COLLECTION: TRANSFORMATIONAL CLIMATE ACTIONS BY CITIES

RESEARCH

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ABSTRACT

The individual and collective decarbonization pathways of 26 Canadian cities are assessed by evaluating data gathered from the implementation of a unique energy model, CityinSight. Although many cities in Canada have declared a climate emergency and plans are at various stages of implementation, development path change is mostly incremental. They are at the very beginning of transforming development paths that necessitate climate action planning which embraces a systems perspective and whole-city planning. The present data reveal that there are very different starting points for Canadian cities, and considerable asymmetries between municipalities, as well as the collective impact of their plans on national targets. The latency of municipalities for on-the-ground implementation of their plans means that ongoing assessments will be required to determine the impact of efforts by cities to achieve their targets.

POLICY RELEVANCE

Cities are on the front line of implementing climate change adaptation and mitigation. Many climate researchers and practitioners have called for fundamental change and new governance arrangements to achieve even a 2°C limit to rising global temperatures. At the same time, researchers argue that Canadian cities do not have the ability to raise revenue other than through continuous development: an incentive therefore exists to keep 'growing' regardless of other sustainable imperatives. Transformational change is required through policy instruments and more appropriate incentives harmonized across macro-, meso-, and microlevels to create carbon-neutral development paths in the next decade. Policy harmonization, coherence, and alignment are necessary and sufficient conditions for meeting the international commitments to reducing greenhouse gas emissions. This also requires action at multiple scales with multilevel partnerships and unprecedented degrees of government collaboration and leadership.

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1. INTRODUCTION

Climate change adaptation and mitigation can be seen as a messy, wicked problem (Rittel & Webber 1973) implicating multiple levels of government in the search for solutions that necessitate unprecedented levels of collaboration and innovation. Although the focus of much current research has been on multilevel governance and changing current development paths (Dale *et al.* 2018, 2020), the continued lock-in of urban development to high-carbon development paths presents a major challenge for national, provincial, and local governments everywhere.

Many scholars argue that 'cities' are central to realizing meaningful climate solutions as they are at the forefront of reducing greenhouse gas (GHG) emissions (Bulkeley & Betsill 2005; van der Heijden 2021). The latest dire warnings from the Intergovernmental Panel on Climate Change (IPCC) underscores their role as they are the source of 70% of anthropogenic emissions (Skea *et al.* 2022). The Sustainable Development Goals, particularly the place-based content of the Urban Goal and the new urban agenda in global policy, locates cities at the center of development debates (Barnett & Parnell 2016).

Yet, cities differ tremendously in the resources they have to address this critical imperative in terms of place-based variations (Barnett & Parnell 2016): asymmetries of scale, financing, access to critical expertise, to name only a few (Bulkeley & Betsill 2013). And most importantly, they vary tremendously in the degree their elected officials place on its urgency and political will to act that determines their commitment to change—whether incremental, transitional, or transformative. And in some cases, depending upon their size, their administrative staff can vary in their understanding and expertise, as well as, more critically, their planners (Albrechts *et al.* 2019; Whitehead 2013). Given the urgency of both the climate imperative and biodiversity loss (Watson *et al.* 2019), only transformational change to a carbon-neutral economy and society (Bulkeley 2015; Dale *et al.* 2020; O'Brien & Sygna 2013) will realize the IPCC's aspirational goal of limiting to a 1.5°C increase.

This paper investigates how Canadian cities are performing with respect to GHG reductions and embedding climate change into municipal decision-making processes, particularly focusing on energy efficiency planning. There are, of course, multiple and diverse pathways for addressing climate change adaptation and mitigation other than energy. However, greater emissions reductions have been associated with plans targeting energy efficiency (Hsu *et al.* 2020). Data from 26 Canadian cities across Canada are examined on multiple scales. The data were gathered through the implementation of a unique energy model, *CityinSight*, employed by the case study cities. Three components of a city's carbon neutrality were considered relevant. First, a city's path towards carbon neutrality starts with a commitment and climate action plan. This resembles the planning component or initiation phase. Second, implementation of activities and decarbonization measures that are relevant for the realization of the urban carbon neutrality targets. Third, impacts play an important role, since all decarbonization efforts are linked to the higher goal of reaching net zero emission (Damsø *et al.* 2016).

The paper is structured as follows. The next section briefly describes the methods used to model the data. Following a discussion of the data, the paper provides a series of recommendations based on the authors' previous climate change research (Burch *et al.* 2015; Dale 2015; Dale *et al.* 2018; Shaw *et al.* 2014) that would propel Canadian cities towards transformative change of their current development paths (Jost *et al.* 2020; Moore *et al.* 2021). Additional detailed data, including a description of the CityInSight model, are provided in the supplemental data online.

2. METHODS

Efforts to examine patterns in urban GHG emissions have included the analysis of the GHG profile of multiple municipalities (Harris *et al.* 2020; Kanemoto *et al.* 2020; Markolf *et al.* 2017; Newell & Robinson 2018; Singh & Kennedy 2015), but the authors are not aware of other bodies of work that include a consistent, replicable approach to developing integrated, spatial energy, and emissions scenarios for multiple, diverse communities.

This paper surveys this previously unpublished assembly of climate actions plans and subsequent implementation efforts to distil insights using qualitative and basic quantitative methods. The CityInSight modelling methodology used to develop the pathways for each municipality is detailed in Appendix C in the supplemental data online, as it is the foundation on which the macro-analysis is based, and the evidence on which cities are basing their implementation approaches.

Data from 26 Canadian cities ranging in population (2016) from 8753 (Bridgewater) to 2.9 million (Toronto) spanning eight provinces were available from analysis undertaken for individual municipalities between 2016 and 2021. Cities were chosen from (1) a body of work completed by the authors and (2) for which data were either publicly released and/or for which decarbonization pathways had been approved by councils. Collectively these municipalities represent 8.9 million people, a quarter of Canada's total population of 34.5 million (2016). In each case the municipal council has approved a climate action plan that includes low carbon pathways developed in CityInSight. See ***Figure S1*** in the supplemental data online for a graph of the participating cities by population.

2.1 MODELLING A CITY'S ENERGY AND EMISSIONS

Energy and emissions modelling at the city scale is increasingly common, a product of cities requiring robust analysis to support their policies and programs and of the recognition of the importance of cities in global GHG mitigation efforts (Stevenson & Gleeson 2019). Models help cities to operationalize long-term GHG reduction targets into capital planning and policy development, to understand the scale of programs and financing required, to consider path dependency in investment decisions, and to evaluate trade-offs between technologies or delivery platforms (Epstein 2008; Scamman *et al.* 2020).

An urban energy model is defined as:

> a formal system that represents the combined processes of acquiring and using energy to satisfy the energy service demands of a given urban area.
>
> (Keirstead *et al.* 2012: 6)

A focus on GHG emissions requires an expanded definition; a formal system that represents the GHG emissions resulting from energy and non-energy sources which result from activities within a given urban area. Non-energy sources of GHG emissions include land-use change, agriculture, solid waste, and wastewater.

CityInSight uses a systems dynamics modelling approach to describe the urban system and evaluate the impacts of change of components of the system on the system as a whole. Developed in the early 1960s (Forrester 1997), systems dynamics has been applied to a diverse array of problems (Pruyt 2013). It first came to prominence when Meadows *et al.* (2013) evaluated the relationship between social, economic, and ecological systems.

Systems dynamics exposes the latency inherent in the turnover of physical stocks, critical to assessing and overcoming carbon lock-in (Brown *et al.* 2008). The approach is liberated from the exogenous financial assumptions that drive optimization models; such inputs are difficult if not impossible to project in the context of an energy system transformation (Holtz *et al.* 2015; Huovila *et al.* 2022; Lund *et al.* 2017; Papachristos 2019).

CityInSight is used to develop one or more decarbonization pathways for each community, a process which is described in detail in Appendix C in the supplemental data online. A pathway is defined by a:

> sequence of sectoral changes in the physical infrastructure, deployment of technologies [...], investment and consumption patterns—all based on available and anticipated technologies.
>
> (Bataille *et al.* 2016: 8)

A data-collection process involves compiling geospatial data for each sector and calibrating energy consumption to observed energy data. An iterative scenario design process blends expert insights with community engagement tactics such as focus groups, surveys, and workshops and ensures that each pathway is grounded in the culture, asset base, and economy of the community. The analysis for each municipality involves between 600 and 1000 hours of expert work, over a period of 1–1.5 years. The outcome is generally a technical and/or public-facing report, which, once adopted by a council, becomes the policy of the municipality.

2.2 LIMITATIONS

The primary purpose of CityInSight is to evaluate physically coherent pathways to decarbonize a city/community by 2050 or earlier. These pathways analyses do not evaluate the physical impacts of climate change and adaptive measures that will be required, specify specific policies or incentives required to implement the actions, seek to optimize pathways for lowest cost, evaluate individual actions from the perspective of a specific stakeholder, such as an investor or household, quantify the impact of decarbonization pathways on hourly demand, or evaluate consumption-based emissions or the economy-wide impacts on employment, prices or gross domestic product (GDP) of the scenarios. Each of these considerations, while important and insightful, is a subsequent piece of work that can begin once a municipality has commenced its action plan.

3. RESULTS

3.1 PATHWAYS FOR EACH CITY

Figure 1 illustrates net zero pathways that have been formally approved by a selection of Canadian municipalities from nearly every province. Nearly every major municipality and many smaller municipalities have formally adopted net zero pathways of their own volition (Huovila *et al.* 2022; Tozer & Klenk 2018).

The analysis indicates that while the share of emissions for each sector is different, transportation generally dominates, particularly in provinces with relatively clean electricity (*i.e.* Courtenay, Caledon, and St. John's) but not in cities with major industries (Hamilton, Sudbury, and Regina). The rate and depth of reductions also vary, with some cities having much steeper emissions reductions (Edmonton, Ottawa, and Halifax), while others are more gradual and do not get as close to zero (Courtenay, Moncton, and Saskatoon). The trajectory of emissions is a function of aiming to achieve earlier and more ambitious targets.

The varying place characteristics of each community are apparent when the results are presented on a per capita basis. The analysis revealed that Banff's per capita emissions are disproportionately high because the accounting protocol captures inbound vehicular trips, which are particularly high in Banff because it is a tourist destination. Bridgewater's per capita emissions are the result of the predominance of heating oil for heating and a major tire manufacturing factory within its boundary. Regina's high per capita GHG emissions are the result of relatively dirty provincial electricity and a major refinery within its boundary. Similarly, the per capita emissions of Thunder Bay, Edmonton, and Hamilton are also higher because of the presence of energy-intensive industries: pulp and paper, oil and gas, and steel, respectively. The ratio between the highest and lowest per capita emissions in Banff and North Vancouver, respectively, is 10 to 1 in 2016; by 2050, this ratio increases as most municipalities converge at near zero emissions but a few lag behind. Each community has its unique story but, as Figure 2 demonstrates, they are all adopting pathways that trend towards zero emissions.

While the end GHG target is determined by science, the large differential between the starting points gives rise to questions of justice (Garvey *et al.* 2022), a microcosm of the dilemma that plays out between Northern and Southern countries in the United Nations' climate negotiations. Rather than framing GHG emissions reductions as a burden, an alternative and more constructive framing is that reductions are an opportunity from which everyone can gain, irrespective of their starting point with critical potential to opening pathways for avoided cost savings and future innovations.

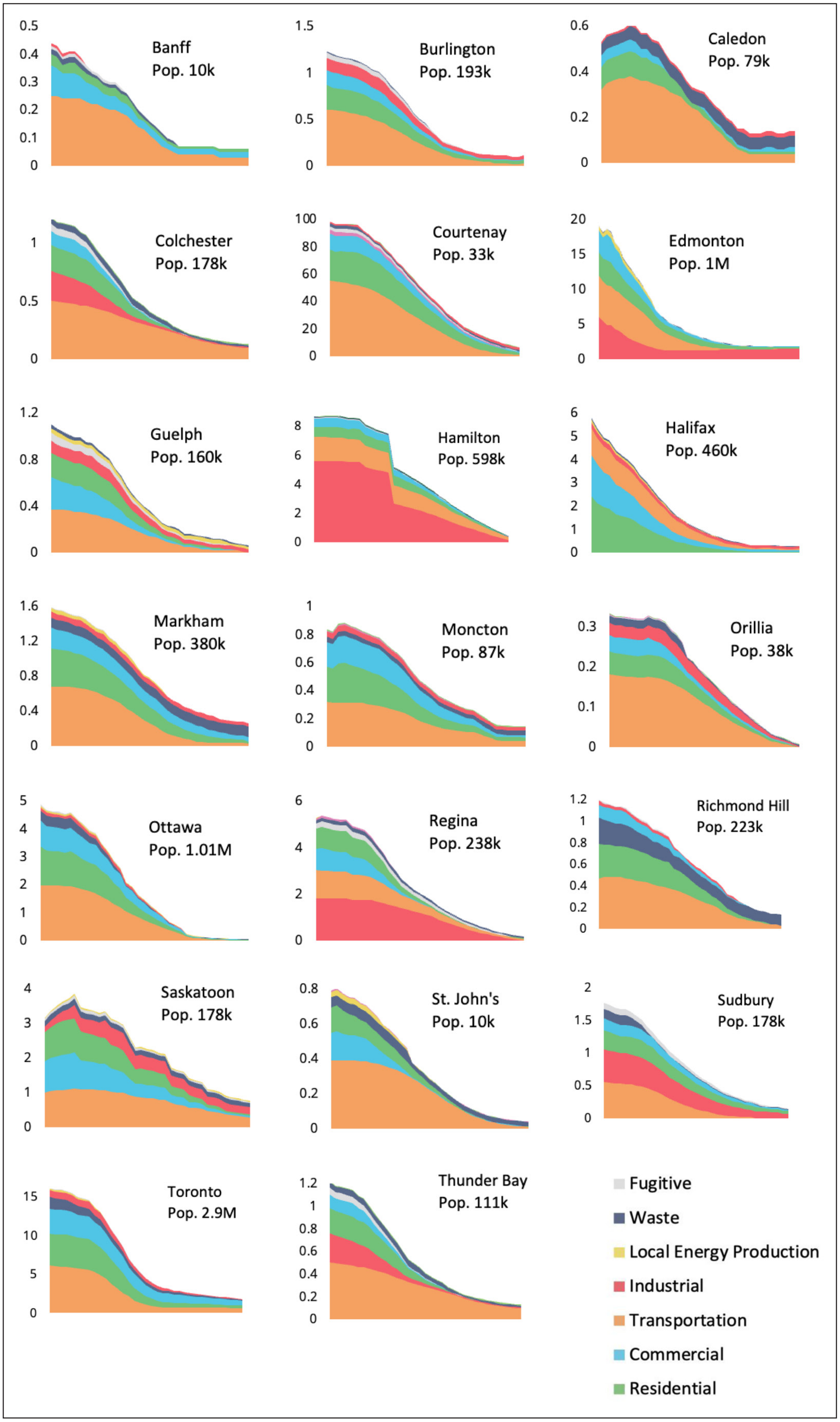

Figure 1: Low carbon pathways for selected Canadian municipalities, by sector, 2016–50.

Note: The *x*-axis is time (consistently from 2016 to 2050) and the *y*-axis is greenhouse gas (GHG) emissions ($MtCO_2e$).

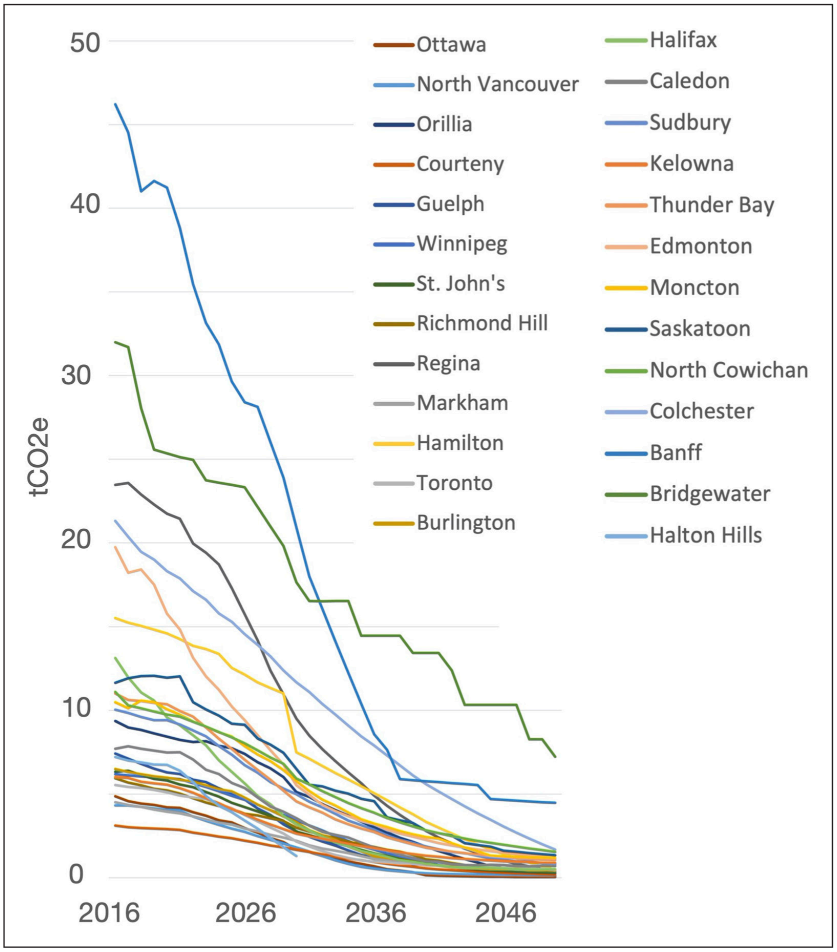

Figure 2: Per capita greenhouse gas (GHG) emissions for the selected municipalities, low carbon scenario, by municipality, 2016–50.

The decarbonization actions and policies that are identified as a result of the technical analysis and engagement are generally consistent in each community (see Appendix B in the supplemental data online), but the pathway is unique to each community according to its starting point, its emissions profile, with the implication that the social, cultural, political, and economic considerations are also context dependent.

These results emphasize the IPCC's conclusion (Skea *et al.* 2022) that every community has a unique GHG profile and decarbonization trajectory, the product of the spatial configuration of the community, the composition of industrial activity, the emissions intensity of fuels, and the energy source of heating (*e.g.* heating oil is used extensively in Halifax versus natural gas in other jurisdictions). As a result, the principle of subsidiarity holds (Howarth *et al.* 2022): urban climate policies must also be determined locally in order to address local conditions, but within a broader framework that empowers communities and aligns their efforts with a collective, global, and fair effort (Science-based Targets Network 2020).

3.2 THE COLLECTIVE IMPACT

The 26 cities considered in this paper account for just over 80 $MtCO_2e$, or 12% of Canada's 707 $MtCO_2e$ total reported to the United Nations Framework Convention on Climate Change (UNFCCC) (Environment and Climate Change Canada 2021). Two cities, Toronto and Edmonton, account for 43% of these emissions, and despite a population ratio of 1 million to 2.8 million, Edmonton's total GHG emissions are higher than Toronto's in 2016 (Figure 3).

By 2030, these pathways have achieved reductions of 47% over 2016, and by 2050 a 90% reduction, predicted to exceed Canada's 2030 target and aligned with the net zero by 2050 target, but not aligned with a fair share reduction (Heath & Foyer 2021).

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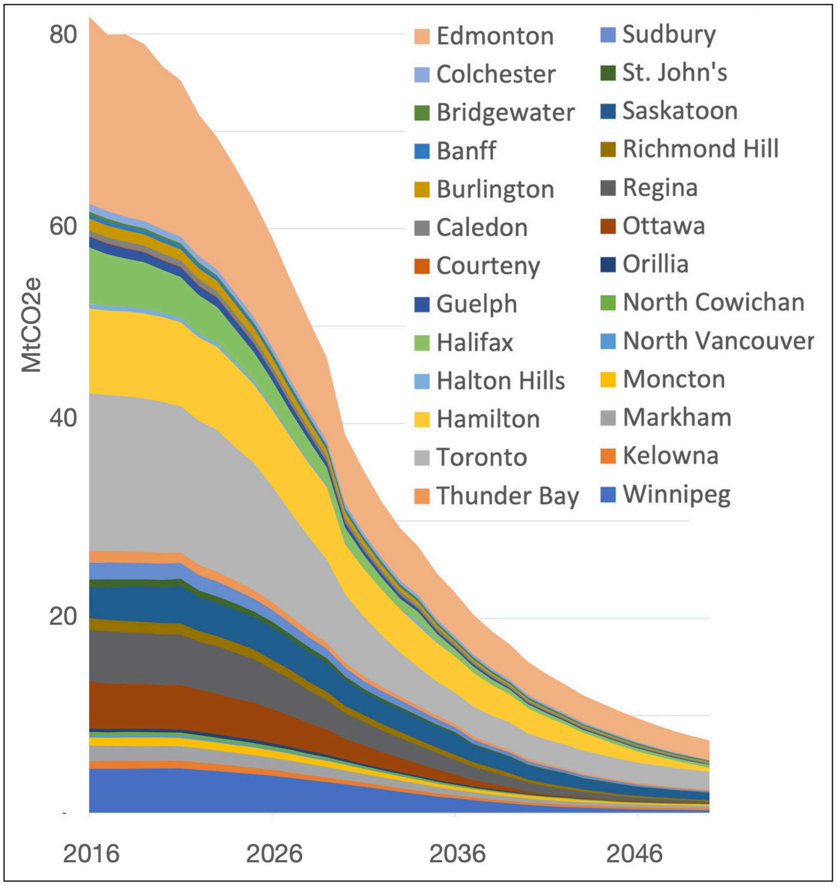

Figure 3: Greenhouse gas (GHG) emissions for the selected municipalities, low carbon scenario, by municipality, 2016–50.

This opportunity is borne out in the financial analysis undertaken in each project. The net present value (NPV) of the capital expenditures, energy costs, carbon price, and maintenance and operation costs are summed up over the period 2020–50 and divided by the GHG reduction to calculate an abatement cost (C$/t$CO_2$e) for each city analysed. In all cases except Toronto, the NPV is negative, indicating that the decarbonization pathway saves money relative to the reference scenario. A social discount rate of 3% is used.[1] There are net savings of –C$38/t$CO_2$e in Banff to –C$435/tCO_2e in Halton Hills. The City of Toronto's cost is positive because it envisions free transit as an equity component of its climate action plan and therefore transit revenue is reduced relative to the reference scenario (Figure 4).

The present value of the investments across the cities evaluated totals C$318 billion, a per capita investment of C$35,700. For reference, if the C$318 billion investment were averaged over the 28 years between 2022 and 2050, it would represent approximately just under 3% of GDP, assuming the 2016 GDP is distributed equally on a per capita basis (Statistics Canada n.d.). The NPV totals –C$111 billion, or –C$12,500 per capita, which includes the sum of costs and savings at a 3% discount rate.

The investments are lumpy in each of the city's pathways, which requires an enhanced effort to mobilize capital in the next decade. Figure 5 illustrates the annual undiscounted capital investment for the City of Toronto's Net Zero Strategy on a cash basis, which peaks at over C$10 billion in 2028 and again in 2030. The capital costs can be amortized, which reflects how other major infrastructure projects, for example, in the electricity sector, are financed, reducing the capital requirements in the near term as they are spread out until nearly 2080.

These are highly consequential plans touching on every aspect of their operations and policy. And in the last year or so, many of these pathways have been passed unanimously, including London, Regina, St. John's, and Orillia, indicating that there is a level of consensus at the local level that does not exist at the national scale.

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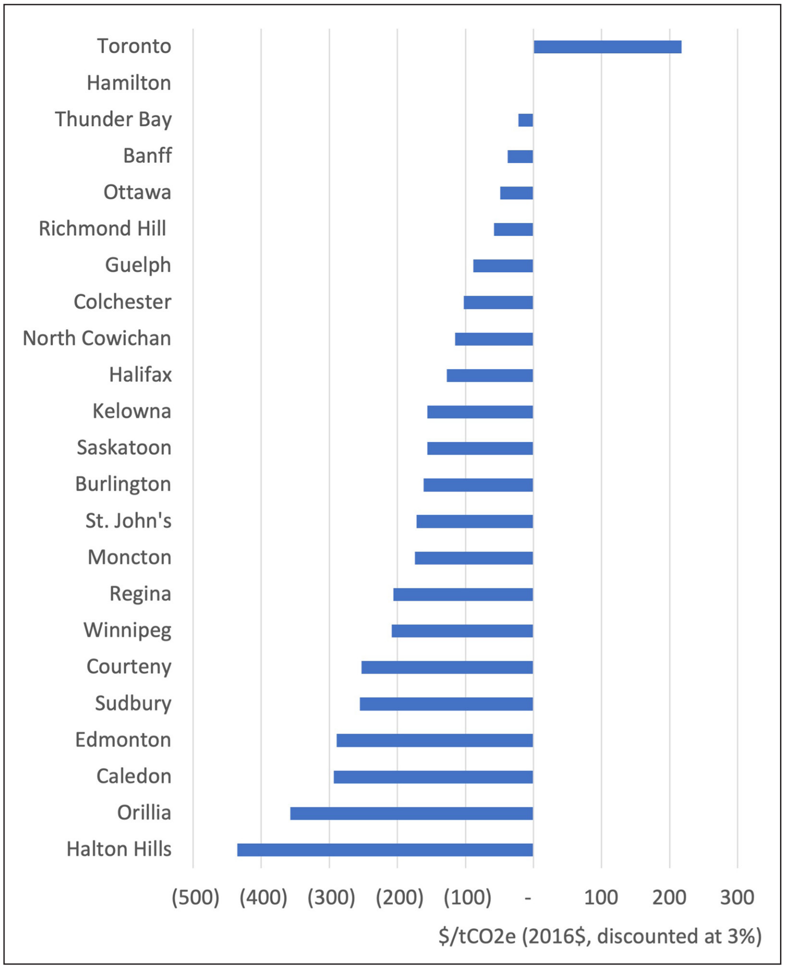

Figure 4: Abatement cost of the low carbon pathways for the selected municipalities, low carbon scenario, by municipality, 2020–50.

Note: The basis for the calculation of these costs is available in public reports from each city's climate action plan; see Appendix B in the supplemental data online.

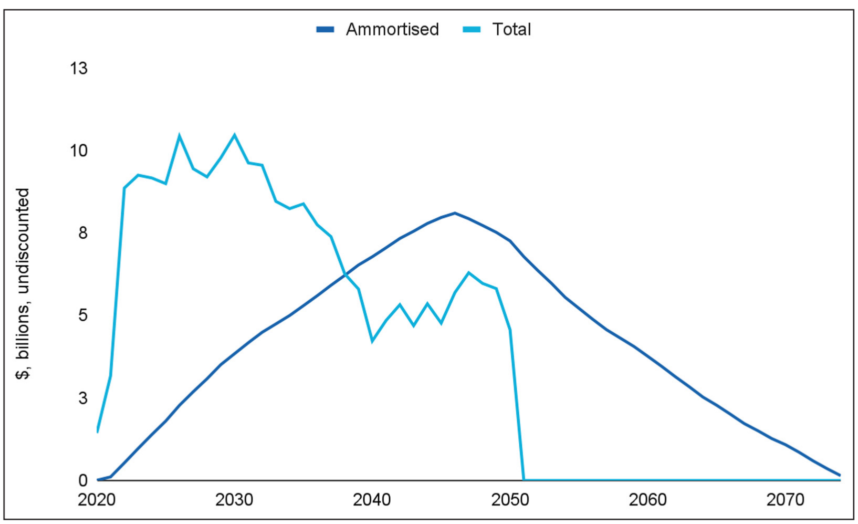

Figure 5: Impact of amortizing the investments on total capital requirements: City of Toronto's Net Zero Strategy.

4. DISCUSSION

4.1 A NEW GENERATION OF CLIMATE ACTION

The climate action plans in this analysis constitute a step change in the approach taken by municipalities; they are characterized here as the third generation, arguably born of the UN Conference of the Parties in Paris. These plans, and the pathways contained within, are about whole-city planning, transformation, equity, and implementation (Fitzgerald 2022; Moore *et al.* 2021; Ravetz *et al.* 2021). Climate action has graduated to a core service area for municipalities of all sizes, alongside more traditional functions but with an overarching mandate.

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In contrast, the first generation was focused on building awareness and setting initial targets, and resources and city policies were not aligned with the scope of the challenge (Wheeler 2008). In the second generation, climate action became more mainstream, as networks such as ICLEI, the Global Compact of Mayors, and others increased the profile and developed the practice, including creating planning processes such as the five milestones (inventory, target, plan, implementation, reporting). In this generation, climate action planning and implementation occupied a marginal niche within municipalities, with few staff and small budgets. GHG reductions, if any, were the result of actions from other levels of government (Millard-Ball 2018), for example, in Ontario, when coal-fired electricity generation was phased out.

The transnational municipal 'ecosystem,' while primarily aspirational (Bansard *et al.* 2017), has given rise to the key ingredients of systematic climate action. Methodologies align city targets with the latest science (ARUP & C40 n.d.: 40), standardize GHG inventory protocols (Fong & Doust 2014), daylight leading municipalities (C40, ICLEI, Global Compact of Mayors, Race to Zero), lend the cache of the UN (Non-State Actor Zone for Climate Action (NAZCA) platform) and track progress (CDP and Global Compact of Mayors).

The third-generation climate action planning process distils these ingredients into evidence-based pathways, which have been instrumental in securing political consensus and translating political will into work plans, bridging ambition, and operations, while acting as a rallying cry for engaged citizens (Ravetz *et al.* 2021). The approval of the plans by councils reviewed in this paper has empowered staff to enlarge their efforts and ambition to more closely align with science-based targets.

Translating this momentum into GHG reductions is, in relation to the urgency for action, an incremental process (Neij & Heiskanen 2021; van der Heijden 2022). The archetypical method involves multiple steps that occur over two to four years, including a series of council motions to approve the development of a plan, approve a plan, approve funding, approve staffing, and approve programs. As a result of the latency in the municipal system, it will take another two to three years to assess whether the generation of climate action plans described in this paper will facilitate the deep GHG emissions reductions that society so desperately needs.

4.2 LOCAL GOVERNMENTS AS CHANGEMAKERS

Much of the policy and economic discourse on climate has been focused on national and provincial governments, and less so at the local level, but as mentioned above this is rapidly changing. Local governments are practical given their service mandates, are closer to the ground where climate impacts play out, and have a commitment to ensuring the safety and security of their communities. This focus on service delivery is a solid foundation for implementing concrete and practical responses to climate change, unencumbered by complex arguments about policy design and economic theory. Moving from incremental and transitional change to more transformative change, however, will be dependent upon greater alignment between the local, provincial, and federal levels (Dale *et al.* 2020) to create the enabling conditions for responding to the urgency of the crisis and critically changing current development paths.

4.3 FEASIBILITY AND THE DISCOURSE OF DELAY

A common question asked by staff, councils, and citizens when presented with a net zero pathway is its feasibility. The modelled scenarios illustrate plausible pathways that deploy existing and proven technologies with adoption curves that escalate over time using 'S'-curves (Modis 2007). In the context of conservation demand management, feasibility is assessed and narrowed according to a hierarchy of technological, social, and political feasibility. However, this approach perpetuates incrementalism when transformative change is critical (Dale *et al.* 2020) and required to address this existential crisis. Feasibility in the context of an imperative for transformation is determined by political will, multi-sectoral leadership, political incentives, innovation, and risk-taking (McHugh *et al.* 2021), and questioning the feasibility of action is a form of surrender (Lamb *et al.* 2020). The evidence that councils are no longer challenging the desirability of approving these pathways is an indication that 'seeing' these pathways may lead to greater understanding and acceptance of the need for transformational change.

4.4 EFFICIENCY AS A CORNERSTONE

A climate action plan gives both permission and direction to a city to implement climate action, guided by the mantra of reduce, improve, switch. The logic of this trifecta is that by avoiding energy consumption (reduce), increasing the efficiency of energy used (improve), the need to generate renewable energy (switch) is minimized. If, on the other hand, switch occurs first, additional and costly renewable energy capacity must be installed and major investments in the electrical grid will likely be required, which may become redundant after efficiency improvements are made, an opportunity cost. In a paradigm of the energy transition to net zero emissions, energy efficiency generates a double dividend: avoided energy consumption, and therefore costs, for the end-user, but also avoided new clean generation or storage for the electricity grid as a whole. When the city is evaluated as an energy system, land-use policy becomes an energy efficiency measure, where avoided vehicular travel translates into avoided new electricity generation, which in turn facilitates a more affordable energy transition, in addition to the host of quality-of-life benefits discussed elsewhere in the literature. Figures 6 and 7 illustrate the energy consumption Toronto in 2016 versus the net zero scenario in 2050. Despite population increases and the electrification of transportation and heating, electricity consumption is nearly flat, increasing from 94 PJ in 2016 to 107 PJ (including solar) in 2050. Overall energy consumption is also reduced by 50% from 342 PJ in 2016 to 153 PJ in 2050, due to both retrofits and increased efficiency of, in particular, heating technologies and electric vehicles.

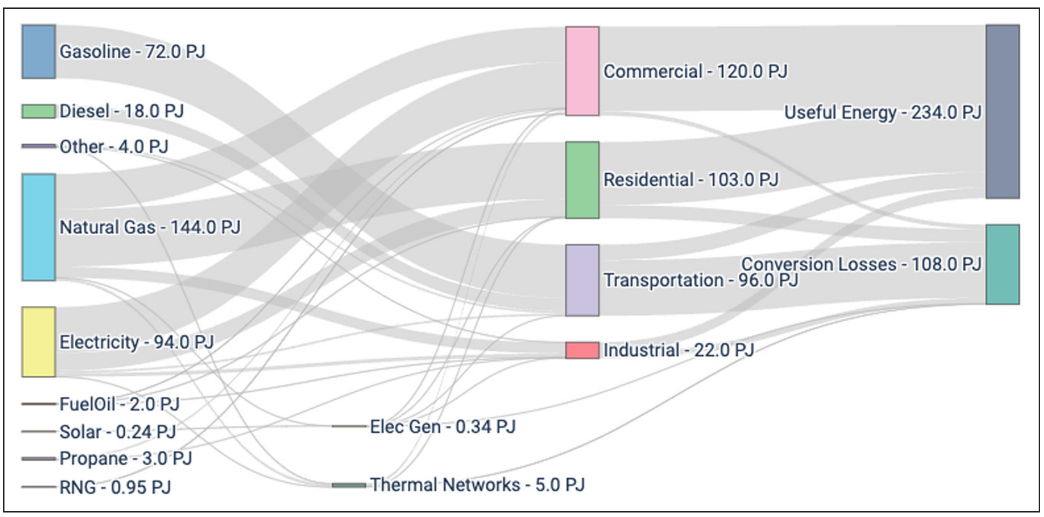

Figure 6: City of Toronto's energy consumption, 2016.

Note: **Figures 6–8** were created by the authors as part of the analysis in this paper.

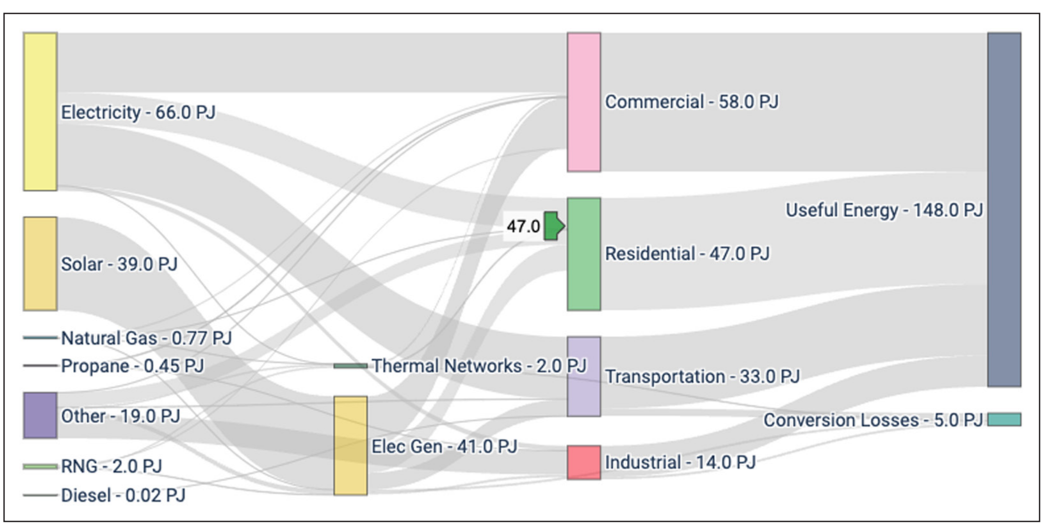

Figure 7: City of Toronto's energy consumption, net zero scenario, 2050.

4.5 THE CARBON PRICE MATTERS

The cost and savings of the decarbonization pathways are sensitive to the relative costs of natural gas and electricity. If electricity costs increase more quickly than natural gas, the savings from the decarbonization pathways decrease. Conversely, if natural gas prices increase more rapidly than electricity costs, the savings from the decarbonization pathways increase. The carbon price has the effect of increasing natural gas prices more rapidly than electricity (Figure 8). While the electricity and natural gas prices and projections vary from jurisdiction to jurisdiction, this illustration demonstrates the importance of the carbon price and the efficiency of heat pumps to the cost effectiveness of the pathways. Assuming the cost of all sources of energy are relatively flat, the carbon price results in gasoline becoming more expensive than electricity on a per unit basis by 2028. Natural gas is still cheaper than electricity on a per unit basis, but additional efficiency gains resulting from the use of heat pumps also make electricity cheaper to use for heating than natural gas by 2027.

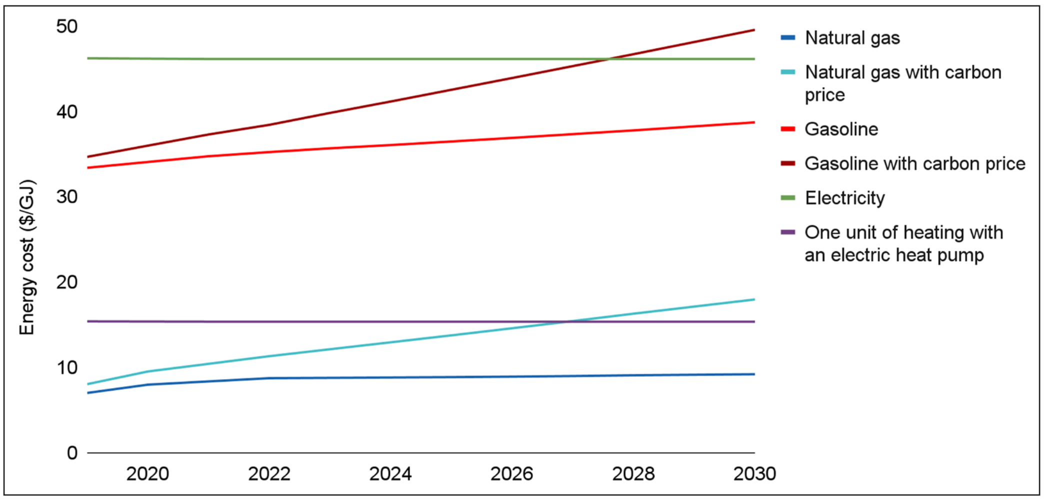

Figure 8: Projections of relative energy costs for gasoline, electricity, and natural gas.

4.6 THE CARBON BUDGET AS A MANAGEMENT TOOL

Climate action planning is evolving to adopting a whole city approach, where every aspect of the municipality's operations and policies are aligned around the common objective of emissions reductions. This means embedding consideration of climate into every policy and expenditure to achieve the city's net zero pathway.

Historically, most GHG targets have been aspirational without a management strategy to support implementation. There is no systematic linkage between projects and targets. There is also a temporal disconnect. The targets typically reference years far beyond the careers of most civil servants. And governments typically make budgetary decisions on programs and investments on short timelines, making it difficult to align these decisions with the 10–30-year emission reduction targets.

Another element of the challenge is that city administrators are generally trying to keep their communities stable. No good administrator will upend the smoothly operating elements of a community in order to embrace brand new energy sources, new industries, and new city planning approaches all at once.

A carbon budget is a management system that promises to overcome these issues. Like a financial budget, the carbon budget is a north star that guides the government in avoiding risky investments. The City of Oslo, the municipality which has pioneered this approach, described it as the 'most important management tool' for achieving its ambitious goal of net-zero emissions by 2030 (City of Oslo 2019: 3).

4.7 ARE MUNICIPALITIES SERIOUS?

It is one step to approve a transformational decarbonization pathway in a climate action plan and another to implement that pathway on the ground, particularly when cities are creatures of the

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provinces with limited legal authorities and short electoral cycles which can dramatically disrupt planned pathways. There is an interdependency between the three levels of government which is undervalued and underused in accelerating the take up of climate change innovation.

The provincial landscape of climate policy is variable, yet cities are moving forward irrespective of time lags and political will for meaningful change at the other two levels. The data reveal that cities are taking decarbonization pathways seriously in their planning processes. Examples of programs developed or in development that are being tracked are described below. In the authors' assessment, while these programs need to be accelerated and scaled up, they are aligned with the decarbonization pathways.

4.7.1 Buildings

- *New construction*

  Building codes, which determine energy performance, are established by the provinces and implemented by building inspectors employed by municipalities. In order to require increased energy and emissions performance, municipalities are using site planning authorities to require submissions that demonstrate how projects will achieve incrementally increasing levels of performance before plan approval. These programs typically require that new construction achieve net zero emissions by 2030, and projects that achieve this standard early receive an incentive. Examples include Toronto Green Standard; Halton Hills Green Development Standards; Whitby Green Standard; and Brampton, Vaughan, Markham and Richmond Hill's Sustainability Metrics. Municipalities including Mississauga, Ottawa, Caledon, and Clarington have similar programs under development. The Province of British Columbia has developed a step code that allows municipalities to mandate different levels of energy performance, and several municipalities have elected to require the highest levels of performance, equivalent to net zero buildings. Both Vancouver and Montreal have recently banned natural gas connections in new construction, drawing on unique powers assigned by City Charters (Punter 2010; Riopel 2022).

- *Existing buildings*

  Municipalities are offering commercial and residential building retrofit programs, based on the Property Assessed Clean Energy (PACE) model (Milano & Cockrell 2018). These programs range from providing interest-free loans to more turnkey solutions and are integrated with provincial and federal funding programs; most have a low-income stream. Examples include Cozy Colchester, Bridgewater's Clean Energy Financing, Toronto's Home Energy Loan Program (HELP) and Energy Retrofit Program, and Edmonton's Home and Building Energy Retrofit Accelerator. Municipalities are also aligning their asset management plans with near-term net zero plans (Orillia, Halifax, Whitby, Peel, and Edmonton), often with investment programs in the hundreds of millions of Canadian dollars.

4.7.2 Energy

- *Renewable energy*

  Edmonton has a policy of procuring renewable energy for 100% of its council operations. Halifax's Solar City and Solar Colchester are municipal programs with low interest financing and vetted contractors for homes and businesses that install solar systems. Municipalities in Nova Scotia have invested directly in wind farms and receive annual revenues.

- *District energy*

  Edmonton has developed a net zero emissions ambient temperature district energy system for a major new neighbourhood, Blatchford. Toronto is expanding a deep lake water cooling system. Toronto is also allowing access to waste heat in the septic lines for district energy serving a hospital. Markham worked with a developer and energy company on a geothermal project under roads for a new residential subdivision.

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- *Utilities*

  Toronto's council has given a mandate to Toronto Hydro, a subsidiary, to support the implementation of its Net Zero Strategy, and Toronto Hydro has subsequently prepared a climate action plan that includes investments in the grid to enable electrification of transportation and buildings, a climate advisory service, among other initiatives. Ottawa recently opposed an expansion of natural gas infrastructure, contributing to one of the first such denials issued by the regulator.

4.7.3 Land-use policy

Climate change is increasingly a consideration in land-use policy decisions in Ontario. Orillia and Hamilton voted not to expand their urban boundary, in part due to climate impacts, despite significant pressure from the development community. The City of Edmonton was the first city in North America to include a carbon budget in its city plan, ensuring alignment between legal policies and land-use policies. Markham and Toronto require that each secondary plan includes a community energy plan; and the urban form is being optimized to minimize energy consumption in the buildings.

4.7.4 Transportation

Most cities are rapidly increasing the deployment of electric buses and electrifying their vehicle fleets, including in more northern climates (Edmonton, Winnipeg, and Calgary). Several cities are evaluating low or zero emissions zones or congestion charges (Vancouver and Toronto). Expanded or lower cost transit is a key part of each municipality's efforts, and in some cases, transit is being expanded to include e-bikes (St. John's). Active transportation infrastructure is being expanded in nearly every city to facilitate walking and cycling.

4.7.5 Finance

Halifax Council approved a 10-year tax increase of 3% a year dedicated for the implementation of the city's Climate Action Plan. Edmonton and Calgary are exploring partnering with the Canada Infrastructure Bank on major investments in zero carbon retrofits of their respective municipal building portfolios. The City of Toronto has issued nearly C$800 million in green bonds to finance investments identified as part of its climate action plan, TransformTO. Bridgewater, a small municipality, has partnered with a third party to issue community bonds to finance its climate action investments.

4.7.6 Governance

Municipalities have adopted the risk framework from the Task Force on Climate-Related Financial Disclosure and embedded it in their financial reporting framework. Canadian municipalities that are developing carbon budgets include Calgary, Edmonton, Toronto, Durham, Whitby, and Halifax.

4.8 WHERE TO FROM HERE?

At this time, the focus of city climate action planning is now shifting to implementing the decarbonization pathways that have been adopted. Stepping back from any one individual city, the following areas are promising in accelerating these efforts.

- *Tracking progress*

  There is an imperative to understand if municipalities are tracking on their pathways, or not. Municipalities currently spend time and money on undertaking annual inventories, which are inconsistent over time and between cities, and therefore ineffectual. A new platform, the Municipal Energy and Emissions Database (MEED),[2] represents the first, standardized, consistent way of measuring emissions for each municipality, and provides a detailed sectoral breakdown that directly aligns with provincial and national inventories. One of the most effective ways to accelerate adoption of innovation is through establishing targets and measuring progress against those targets (Takahashi *et al.* 2020; Tomar 2022). Benchmarking is also essential as it allows practitioners to 'see' what their peers are doing and what progress can be made despite the barriers against change in large systems (references). These tools would allow the federal government to start publishing a national inventory of progress in reducing GHG emissions across the country and local municipalities to also track their success. A second tool, City Navigation, allows the user to track progress of energy per capita and emission per capita by local municipality over time, 2020–50. Previous work with the National Energy Efficiency Committee of the Association of Community Colleges in Canada (ACCC) conclusively proved the importance of benchmarking for accelerating the adoption of energy efficiency across the college sector (ACCC 1999).

- *Equity*

  Many municipalities have placed equity at the center of their climate action plans; however, the strategies to integrate equity into the programs that cities are developing are not obvious. For example, retrofit programs generally benefit homeowners rather than renters. Bridgewater is experimenting with different strategies to support renters. A focus on how to systematically embed equity into programs will ensure that no one is left behind.

- *Carbon budgets*

  Discussed above, carbon budgets are a critical management tool that ensure cities systematically embed consideration of GHG emissions into every aspect of their operations and policies, and avoid making decisions that will lock in emissions. Carbon budgets also provide accountability and transparency. C40 is currently leading an international pilot project on carbon budgets, and several municipalities in Canada are continuing to develop the approach.

- *Alignment of planning policy*

  Currently municipalities are considering the relationship between land use, the built environment, and GHG emissions in an ad hoc fashion. The provinces can embed consideration of GHG emissions into planning policy to ensure alignment.

- *Managing the car (and new forms of transit)*

  Limiting vehicular trips is an important strategy to minimize the cost of the energy transition. Avoided vehicular trips equal avoided transformers, upgrades to distribution systems, and generation in the electricity system. Investments in active transportation and transit will increase the overall efficiency of the urban energy system. Municipalities are limited in their ability to create congestion charge zones or clean air zones, which can be a key strategy in reducing vehicular transportation.

- *Scaling up retrofits*

  Retrofits are at the heart of an equitable and affordable climate action plan, but the rate of deployment is slow, as is program development. Mechanisms to industrialize building retrofits need to be proven, using approaches such as EnergieSprong. In addition to incentivizing retrofits, cities need the ability to set carbon limits for existing buildings. Vancouver, with its unique powers over the building code, is the first Canadian municipality to explore this option, but other cities such as New York and Seattle have implemented a similar approach.

- *The role of the grid*

  There is currently a disconnect between the climate action planning processes undertaken by municipalities and the regulated planning processes undertaken by utilities, which are also siloed into separate processes for natural gas and electricity. Electricity utilities need to develop strategies that align with city plans to facilitate electric vehicle charging and decentralized electricity generation, while managing an evolution of the peak demand and natural gas utilities need to limit stranded assets, as their customer base declines. New policy and regulatory frameworks are required that assess the energy system as an integrated system with a mandate to reduce GHG emissions alongside other traditional considerations on affordability and reliability.

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- *Participatory processes*

  New bottom-up, participatory approaches to the energy transition can build agency amongst citizens. Examples include the Carbon Coop model, in which citizens band together to support each other in undertaking retrofits, or renewable energy cooperatives, which can develop small- to large-scale renewable energy projects that can advance the democratization of the energy system.

- *Consumption-based emissions*

  In addition to territorial emissions, cities are major consumers of goods and services, which result in GHG emissions outside the municipal territory (Chen *et al.* 2020; Pichler *et al.* 2017). A relatively new lens on GHG emissions, a focus on consumption-based emissions will introduce new opportunities for climate action to municipalities including consideration of embodied carbon, support for food systems, and localized production of other goods.

- *Fiduciary responsibility*

  The governing board of an organization needs to consider climate change as a component of its fiduciary role. The increasing adoption of the Task Force on Climate-Related Financial Disclosure will further emphasize this trend (Griffin & Jaffe 2022). Lawsuits are successfully compelling national governments to increase their action on climate change and it is likely only a matter of time before similar lawsuits are targeted at municipalities (Dellinger 2017; Viglione 2020).

5. CONCLUSIONS

> The style is not so much of a traveller who knows the route, but more of an explorer who has a sense of direction but no clear route. Search and exploration, watching out for possibilities and inter-relationships, however unlikely they may seem, are part of the approach. There are ideas as to the way ahead, but some may prove abortive. What is required is a readiness to see and accept this, rather than to proceed regardless on a path which is found to be leading nowhere or in the wrong direction.
>
> (Clarke & Stewart 1997: 15)

Clearly, the data reveal that cities in Canada are ambitious in their recognition of the climate crisis and the political approval of climate action plans. They are also becoming more aware of the need to change their current development paths to decarbonization pathways. However, they are just beginning to determine the 'how' of implementing pathway change. Their starting point is critical for determining how quickly they can respond to the urgency of adoption on the ground. Incremental and, in some cases, transitional change in energy systems can be expected this decade. It is imperative that all levels of government need to move more urgently to transformative development path change, adopting a whole-systems approach and integrated whole-city planning.

Recall that the trajectory of emissions is a function of aiming to achieve earlier and more ambitious targets. A summary of the performance of European cities confirms that on-track cities tend to have less ambitious targets and higher baseline emissions and that cities' emissions reductions are influenced by plan-, city-, and country-level characteristics (Hsu *et al.* 2022), another argument that transformative change necessitates multilevel governance.

It has been widely argued that effective delivery of actions to promote low carbon and climate-resilient development will require new governance arrangements (Bulkeley *et al.* 2019; Castán Broto 2020; Dale *et al.* 2018, 2020). The data demonstrate the urgency of enabling place-based climate action across the country and accelerating the implementation of climate innovations locally. The authors' previous research from a seven-year climate change mitigation and adaption innovation take-up in British Columbia revealed that local enablement by provincial and federal levels of government is critical if Canada is to realize the transformative change required across macro-, meso-, and microlevels and geographically distributed climate justice (Krawchenko & Gordon 2021). This will not happen without action at multiple scales with multisectoral and level partnerships and unprecedented levels of collaboration and coordination.

NOTES

1 Discounting reflects the idea that people would rather have C$100 now than C$100 in a decade. From an ethical perspective, a higher discount rate indicates that future generations are worth less than current generations; for this reason, the Stern Review (Stern 2006) recommended a discount rate of 1.4%, well below traditional discount rates (Stern & Taylor 2007). The government of Canada recommends 3% in circumstances where environmental and human health impacts are involved (Canada & Environment and Climate Change Canada 2016).

2 For MEED, see www.meed.info/.

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YH is the principal author and main contributor to the data analysis and evaluation of the progress of Canadian cities. AD is the second author and contributor to the synthetic analysis, introduction, and conclusions. CS compiled the data for analysis.

COMPETING INTERESTS

The authors have no competing interests to declare.

DATA AVAILABILITY

As of this time, the data are proprietary, although the model itself is open source, but not its coding. Sustainability Solutions Group is working on making all the data publicly accessible as well as the model coding.

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SUPPLEMENTAL DATA

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REFERENCES

ACCC. (1999). *Benchmarking practices in the Canadian community college sector*. Association of Community Colleges in Canada (ACCC).

Albrechts, L., Barbanente, A., & **Monno, V.** (2019). From stage-managed planning towards a more imaginative and inclusive strategic spatial planning. *Environment and Planning C: Politics and Space*, 37(8), 1489–1506. DOI: https://doi.org/10.1177/2399654419825655

ARUP & C40. (n.d.). *Deadline 2020*. http://www.c40.org/researches/deadline-2020

Bansard, J. S., Pattberg, P. H., & **Widerberg, O.** (2017). Cities to the rescue? Assessing the performance of transnational municipal networks in global climate governance. *International Environmental Agreements: Politics, Law and Economics*, 17(2), 229–246. DOI: https://doi.org/10.1007/s10784-016-9318-9

Barnett, C., & **Parnell, S.** (2016). Ideas, implementation and indicators: Epistemologies of the post-2015 urban agenda. *Environment and Urbanization*, 28(1), 87–98. DOI: https://doi.org/10.1177/0956247815621473

Bataille, C., Waisman, H., Colombier, M., Segafredo, L., Williams, J., & **Jotzo, F.** (2016). The need for national deep decarbonization pathways for effective climate policy. *Climate Policy*, 16(Suppl. 1), S7–S26. DOI: https://doi.org/10.1080/14693062.2016.1173005

Brown, M. A., Chandler, J., Lapsa, M. V., & **Sovacool, B. K.** (2008). *Carbon lock-in: Barriers to deploying climate change mitigation technologies* (ORNL/TM-2007/124, 1424507). US Department of Energy, Office of Scientific and Technical Information. DOI: https://doi.org/10.2172/1424507

Bulkeley, H. (2015). Can cities realise their climate potential? Reflections on COP21 Paris and beyond. *Local Environment*, 20(11), 1405–1409. DOI: https://doi.org/10.1080/13549839.2015.1108715

Bulkeley, H., & **Betsill, M.** (2005). Rethinking sustainable cities: Multilevel governance and the 'urban' politics of climate change. *Environmental Politics*, 14(1), 42–63. DOI: https://doi.org/10.1080/0964401042000310178

Bulkeley, H., & **Betsill, M. M.** (2013). Revisiting the urban politics of climate change. *Environmental Politics*, 22(1), 136–154. DOI: https://doi.org/10.1080/09644016.2013.755797

Bulkeley, H., Marvin, S., Palgan, Y. V., McCormick, K., Breitfuss-Loidl, M., Mai, L., … & **Frantzeskaki, N.** (2019). Urban living laboratories: Conducting the experimental city? *European Urban and Regional Studies*, 26(4), 317–335. DOI: https://doi.org/10.1177/0969776418787222

Burch, S., Herbert, Y., & **Robinson, J.** (2015). Meeting the climate change challenge: A scan of greenhouse gas emissions in BC communities. *Local Environment*, 20(11), 1290–1308. DOI: https://doi.org/10.1080/13549839.2014.902370

Canada & Environment and Climate Change Canada. (2016). *Pan-Canadian framework on clean growth and climate change: Canada's plan to address climate change and grow the economy*. http://www.deslibris.ca/ID/10065393

Castán Broto, V. (2020). Climate change politics and the urban contexts of messy governmentalities. *Territory, Politics, Governance*, 8(2), 241–258. DOI: https://doi.org/10.1080/21622671.2019.1632220

Chen, S., Chen, B., Feng, K., Liu, Z., Fromer, N., Tan, X., Alsaedi, A., Hayat, T., Weisz, H., Schellnhuber, H. J., & **Hubacek, K.** (2020). Physical and virtual carbon metabolism of global cities. *Nature Communications*, 11(1), 182. DOI: https://doi.org/10.1038/s41467-019-13757-3

City of Oslo. (2019). Climate budget 2019. https://www.klimaoslo.no/wp-content/uploads/sites/88/2019/03/Climate-Budget-2019.pdf

Clarke, M., & **Stewart, J.** (1997). *Handling the wicked issues: A challenge for government*. University of Birmingham, Institute of Local Government Studies.

Dale, A. (2015). Prioritizing policy. *A\J—Canada's Environmental Voice*. https://www.alternativesjournal.ca/policy-and-politics/prioritizing-policy

Dale, A., Burch, S., Robinson, J., & **Strashok, C.** (2018). Multilevel governance of sustainability transitions in Canada: Policy alignment, innovation, and evaluation. In S. Hughes, E. K. Chu, & S. G. Mason (Eds.), *Climate change in cities: Innovations in multi-level governance* (pp. 343–358). Springer. DOI: https://doi.org/10.1007/978-3-319-65003-6_17

Dale, A., Robinson, J., King, L., Burch, S., Newell, R., Shaw, A., & **Jost, F.** (2020). Meeting the climate change challenge: Local government climate action in British Columbia, Canada. *Climate Policy*, 20(7), 866–880. DOI: https://doi.org/10.1080/14693062.2019.1651244

Damsø, T., Kjær, T., & **Christensen, T. B.** (2016). Counting carbon: Contextualization or harmonization in municipal GHG accounting? *Carbon Management*, 7(3–4), 191–203. DOI: https://doi.org/10.1080/17583004.2016.1214475

Dellinger, M. (2017). See you in court: Around the world in eight climate change lawsuits. *William & Mary Environmental Law & Policy Review*, 42, 525. https://scholarship.law.wm.edu/cgi/viewcontent.cgi?article=1703&context=wmelpr

Environment and Climate Change Canada. (2021). *National inventory report 1990–2019: Greenhouse gas sources and sinks in Canada—Part 1*. Government of Canada. https://publications.gc.ca/collections/collection_2021/eccc/En81-4-2019-1-eng.pdf

Epstein, J. M. (2008, October 31). *Why model?* JASSS. https://jasss.soc.surrey.ac.uk/11/4/12.html

Fitzgerald, J. (2022). Transitioning from urban climate action to climate equity. *Journal of the American Planning Association*, 88(4), 508–525. DOI: https://doi.org/10.1080/01944363.2021.2013301

Fong, W. K., & **Doust, M.** (2014). *Global protocol for community-scale greenhouse gas emission inventories*. World Resources Institute. https://www.wri.org/research/global-protocol-community-scale-greenhouse-gas-emission-inventories

Forrester, J. W. (1997). Industrial dynamics. *Journal of the Operational Research Society*, 48(10), 1037–1041. DOI: https://doi.org/10.1057/palgrave.jors.2600946

Garvey, A., Norman, J. B., Büchs, M., & **Barrett, J.** (2022). A 'spatially just' transition? A critical review of regional equity in decarbonisation pathways. *Energy Research & Social Science*, 88, 102630. DOI: https://doi.org/10.1016/j.erss.2022.102630

Griffin, P., & **Jaffe, A. M.** (2022). Challenges for a climate risk disclosure mandate. *Nature Energy*, 7(1), 2–4. DOI: https://doi.org/10.1038/s41560-021-00929-z

Harris, S., Weinzettel, J., Bigano, A., & **Källmén, A.** (2020). Low carbon cities in 2050? GHG emissions of European cities using production-based and consumption-based emission accounting methods. *Journal of Cleaner Production*, 248, 119206. DOI: https://doi.org/10.1016/j.jclepro.2019.119206

Heath, M., & **Foyer, A.** (2021). *The emissions gap and what countries are doing about it*. Energy minute. https://energyminute.ca/single/infographics/1470/the-emissions-gap-and-what-countries-are-doing-about-it?gclid=Cj0KCQjwhsmaBhCvARIsAIbEbH4Ed2LLVSgCTJmjTYQGu-8UUiyDwWZCcD4BYmDJ-ge3sISJN2kOVSsaAuRhEALw_wcB

Holtz, G., Alkemade, F., de Haan, F., Köhler, J., Trutnevyte, E., Luthe, T., Halbe, J., Papachristos, G., Chappin, E., Kwakkel, J., & **Ruutu, S.** (2015). Prospects of modelling societal transitions: Position paper of an emerging community. *Environmental Innovation and Societal Transitions*, 17, 41–58. DOI: https://doi.org/10.1016/j.eist.2015.05.006

Howarth, C., Lane, M., & **Slevin, A.** (Eds.) (2022). *Addressing the climate crisis: Local action in theory and practice*. Springer. DOI: https://doi.org/10.1007/978-3-030-79739-3

Hsu, A., Tan, J., Ng, Y. M., Toh, W., Vanda, R., & **Goyal, N.** (2020). Performance determinants show European cities are delivering on climate mitigation. *Nature Climate Change*, 10(11), 1015–1022. DOI: https://doi.org/10.1038/s41558-020-0879-9

Huovila, A., Siikavirta, H., Antuña Rozado, C., Rökman, J., Tuominen, P., Paiho, S., Hedman, Å., & **Ylén, P.** (2022). Carbon-neutral cities: Critical review of theory and practice. *Journal of Cleaner Production*, 341, 130912. DOI: https://doi.org/10.1016/j.jclepro.2022.130912

Jost, F., Dale, A., Newell, R., & **Robinson, J.** (2020). Climate action assessment in three small municipalities in British Columbia: Advancements vis-à-vis major neighboring cities. *Current Research in Environmental Sustainability*, 2, 100010. DOI: https://doi.org/10.1016/j.crsust.2020.100010

Kanemoto, K., Shigetomi, Y., Hoang, N. T., Okuoka, K., & **Moran, D.** (2020). Spatial variation in household consumption-based carbon emission inventories for 1200 Japanese cities. *Environmental Research Letters*, 15(11), 114053. DOI: https://doi.org/10.1088/1748-9326/abc045

Keirstead, J., Jennings, M., & **Sivakumar, A.** (2012). A review of urban energy system models: Approaches, challenges and opportunities. *Renewable and Sustainable Energy Reviews*, 16(6), 3847–3866. DOI: https://doi.org/10.1016/j.rser.2012.02.047

Krawchenko, T. A., & **Gordon, M.** (2021). How do we manage a just transition? A comparative review of national and regional just transition initiatives. *Sustainability*, 13(11), 6070. DOI: https://doi.org/10.3390/su13116070

Lamb, W. F., Mattioli, G., Levi, S., Roberts, J. T., Capstick, S., Creutzig, F., Minx, J. C., Müller-Hansen, F., Culhane, T., & **Steinberger, J. K.** (2020). Discourses of climate delay. *Global Sustainability*, 3, e17. DOI: https://doi.org/10.1017/sus.2020.13

Lund, H., Arler, F., Østergaard, P. A., Hvelplund, F., Connolly, D., Mathiesen, B. V., & **Karnøe, P.** (2017). Simulation versus optimisation: Theoretical positions in energy system modelling. *Energies*, 10(7), 840. https://www.mdpi.com/1996-1073/10/7/840. DOI: https://doi.org/10.3390/en10070840

Markolf, S. A., Matthews, H. S., Azevedo, I. L., & **Hendrickson, C.** (2017). An integrated approach for estimating greenhouse gas emissions from 100 U.S. metropolitan areas. *Environmental Research Letters*, 12(2), 024003. DOI: https://doi.org/10.1088/1748-9326/aa5731

McHugh, L. H., Lemos, M. C., & **Morrison, T. H.** (2021). Risk? Crisis? Emergency? Implications of the new climate emergency framing for governance and policy. *Wiley Interdisciplinary Reviews: Climate Change*, 12(6), e736. DOI: https://doi.org/10.1002/wcc.736

Meadows, D. H., Randers, J., & **Meadows, D. L.** (2013). The limits to growth (1972). In *The future of nature* (pp. 101–116). Yale University Press. DOI: https://doi.org/10.12987/9780300188479-012

Milano, J., & **Cockrell, P.** (2018). Recent developments in PACE financing. *Business Law*, 74, 519. https://www.americanbar.org/content/dam/aba/publications/business_lawyer/2019/74_2/survey-cfs-pace-201905.pdf

Millard-Ball, A. (2018). Pedestrians, autonomous vehicles, and cities. *Journal of Planning Education and Research*, 38(1), 6–12. DOI: https://doi.org/10.1177/0739456X16675674

Modis, T. (2007). Strengths and weaknesses of S-curves. *Technological Forecasting and Social Change*, 74(6), 866–872. DOI: https://doi.org/10.1016/j.techfore.2007.04.005

Moore, B., Verfuerth, C., Minas, A. M., Tipping, C., Mander, S., Lorenzoni, I., Hoolohan, C., Jordan, A. J., & **Whitmarsh, L.** (2021). Transformations for climate change mitigation: A systematic review of terminology, concepts, and characteristics. *WIREs Climate Change*, 12(6), e738. DOI: https://doi.org/10.1002/wcc.738

Neij, L., & **Heiskanen, E.** (2021). Municipal climate mitigation policy and policy learning—A review. *Journal of Cleaner Production*, 317, 128348. DOI: https://doi.org/10.1016/j.jclepro.2021.128348

Newell, R., & **Robinson, J.** (2018). Using decomposition methodology to gain a better understanding of progress in and challenges facing regional and local climate action. *Journal of Cleaner Production*, 197, 1423–1434. DOI: https://doi.org/10.1016/j.jclepro.2018.06.265

O'Brien, K., & **Sygna, L.** (2013). Responding to climate change: The three spheres of transformation. *Proceedings of Transformation in a Changing Climate*, 16, 23.

Papachristos, G. (2019). System dynamics modelling and simulation for sociotechnical transitions research. *Environmental Innovation and Societal Transitions*, 31, 248–261. DOI: https://doi.org/10.1016/j.eist.2018.10.001

Pichler, P.-P., Zwickel, T., Chavez, A., Kretschmer, T., Seddon, J., & **Weisz, H.** (2017). Reducing urban greenhouse gas footprints. *Scientific Reports*, 7(1), 14659. DOI: https://doi.org/10.1038/s41598-017-15303-x

Pruyt, E. (2013). *Small systems dynamic models for big issues: Triple jump towards real-world dynamic complexity*. TU Delft Library. https://repository.tudelft.nl/islandora/object/uuid:10980974-69c3-4357-962f-d923160ab638/datastream/OBJ/link.pdf

Punter, J. (2010). *The Vancouver achievement: Urban planning and design*. UBC Press.

Ravetz, J., Neuvonen, A., & **Mäntysalo, R.** (2021). The new normative: Synergistic scenario planning for carbon-neutral cities and regions. *Regional Studies*, 55(1), 150–163. DOI: https://doi.org/10.1080/00343404.2020.1813881

Riopel, A. (2022, May 2). *Un impératif «zéro émission» pour les nouvelles constructions à Montréal en 2025*. https://www.ledevoir.com/politique/montreal/706458/un-imperatif-zero-emission-pour-les-nouvelles-constructions-a-montreal-en-2025

Rittel, H. W. J., & **Webber, M. M.** (1973). Dilemmas in a general theory of planning. *Policy Sciences*, 4(2), 155–169. DOI: https://doi.org/10.1007/BF01405730

Scamman, D., Solano-Rodríguez, B., Pye, S., Chiu, L. F., Smith, A. Z. P., Gallo Cassarino, T., Barrett, M., & **Lowe, R.** (2020). Heat decarbonisation modelling approaches in the UK: An energy system architecture perspective. *Energies*, 13(8), 1869. DOI: https://doi.org/10.3390/en13081869

Science-based Targets Network. (2020). *Science-based climate targets: A guide for cities*. https://sciencebasedtargetsnetwork.org/wp-content/uploads/2021/04/SBTs-for-cities-guide.pdf

Shaw, A., Burch, S., Kristensen, F., Robinson, J., & **Dale, A.** (2014). Accelerating the sustainability transition: Exploring synergies between adaptation and mitigation in British Columbian communities. *Global Environmental Change*, 25, 41–51. DOI: https://doi.org/10.1016/j.gloenvcha.2014.01.002

Singh, S., & **Kennedy, C.** (2015). Estimating future energy use and CO_2 emissions of the world's cities. *Environmental Pollution*, 203, 271–278. DOI: https://doi.org/10.1016/j.envpol.2015.03.039

Skea, J., Shukla, P., Reisinger, A., Slade, R., & **Pathak, M.** (2022). *Climate change 2022: Mitigation of climate change—Final government draft*. Intergovernmental Panel on Climate Change (IPCC). https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_FullReport.pdf

Statistics Canada. (n.d.). *Gross domestic product, expenditure-based, provincial and territorial, annual* [Dataset]. Government of Canada. DOI: https://doi.org/10.25318/3610022201-ENG

Stern, N. (2006). *The Stern Review on the economic effects of climate change*. Cambridge University Press. https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull48-2/48205692528.pdf

Stern, N., & **Taylor, C.** (2007). Climate change: Risk, ethics, and the Stern Review. *Science*, 317(5835), 203–204. DOI: https://doi.org/10.1126/science.1142920

Stevenson, M., & **Gleeson, B.** (2019). Complex urban systems: Compact cities, transport and health. In M. Nieuwenhuijsen & H. Khreis (Eds.), *Integrating human health into urban and transport planning: A framework* (pp. 271–285). Springer. DOI: https://doi.org/10.1007/978-3-319-74983-9_14

Takahashi, K., Hopkins, A., White, D., Kwok, S., Garner, N., & **Rosenkranz, J.** (2020). *Assessment of National Grid's long-term capacity report: Natural gas capacity needs and alternatives*. Synapse Energy Economics for the Eastern Environmental Law Center. https://www.synapse-energy.com/sites/default/files/Synapse-final-report-for-EELC-%28April-15-Revision%29-20-023.pdf

Tomar, S. (2022). *Greenhouse gas disclosure and emissions benchmarking*. https://ecgi.global/sites/default/files/working_papers/documents/tomarfinal.pdf

Tozer, L., & **Klenk, N.** (2018). Discourses of carbon neutrality and imaginaries of urban futures. *Energy Research & Social Science*, 35, 174–181. DOI: https://doi.org/10.1016/j.erss.2017.10.017

van der Heijden, J. (2021). Risk as an approach to regulatory governance: An evidence synthesis and research agenda. *SAGE Open*, 11(3), 21582440211032202. DOI: https://doi.org/10.1177/21582440211032202

van der Heijden, J. (2022). Towards a science of scaling for urban climate action and governance. *European Journal of Risk Regulation*. DOI: https://doi.org/10.1017/err.2022.13

Viglione, G. (2020). Climate lawsuits are breaking new legal ground to protect the planet. *Nature*, 579(7798), 184–185. DOI: https://doi.org/10.1038/d41586-020-00175-5

Watson, R., Baste, I., Larigauderie, A., Leadley, P., Pascual, U., Baptiste, B., … & **Mooney, H.** (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. IPBES Secretariat. http://www.mari-odu.org/academics/2018su_Leadership/commons/library/Summary%20for%20Policymakers%20IPBES%20Global%20Assessment.pdf

Wheeler, S. M. (2008). State and municipal climate change plans: The first generation. *Journal of the American Planning Association*, 74(4), 481–496. DOI: https://doi.org/10.1080/01944360802377973

Whitehead, M. (2013). Neoliberal urban environmentalism and the adaptive city: Towards a critical urban theory and climate change. *Urban Studies*, 50(7), 1348–1367. DOI: https://doi.org/10.1177/0042098013480965

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