City of Toronto

2019 Buildings and Linear Infrastructure Emissions Analysis

July 2023

TORONTO

EcoDataLab

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Glossary

Activity data	Activity data refers to the data associated with an activity that leads to GHG emissions. In this report, activity data includes occupancy permits and capital budget data.
Baseline	The reference year against which annual emissions reductions/increases are measured over time.
CBEI	A consumption-based emissions inventory (CBEI) is a calculation of all GHGs associated with producing, transporting, and using products and services consumed by a particular community or entity in a given time (typically one year).
Carbon dioxide equivalent (CO_2e)	A unit that allows emissions of different greenhouse gases (such as carbon dioxide [CO_2], methane [CH_4], and nitrous oxide [N_2O]) to be expressed as a single unit of measurement.
Direct emissions	Emissions from sources that are owned or controlled by a given entity, such as fuel combustion in a furnace or vehicle.
Emissions	Refers to greenhouse gas emissions (see *GHG*)
Emission factor	An emission factor is a measure of the mass of GHG emissions (typically in CO_2e) relative to a unit of activity.
Greenhouse Gases (GHGs)	Compound gases that trap heat and emit longwave radiation in the atmosphere causing the greenhouse effect.
Global Warming Potential (GWP)	GWP measures how much a particular GHG contributes to global warming relative to carbon dioxide (CO_2). It is used to convert tonnes of a GHG to tonnes of carbon dioxide equivalent (CO_2e) to express total emissions using a common unit.
Indirect emissions	Emissions that are the result of activities from assets not owned or controlled by a given entity, but that are indirectly affected by activities of that entity, such as fuel combustion in a power plant to provide electricity to an entity.
Kilotonne (kt)	A kilotonne, abbreviated as kt, is a metric unit equivalent to one thousand (10^3) tonnes.

Lifecycle emissions	Emissions associated with the full life of a good or service, including material extraction, processing, production, transport, sale, use, and disposal.
Megatonne (Mt)	A megatonne, abbreviated as Mt, is a metric unit equivalent to one million (10^6) tonnes.
NAICS	North American Industry Classification System, a classification of business establishments used by government and businesses in Canada, the US, and Mexico.
Net Zero emissions	Net zero emissions occurs when the amount of greenhouse gases released into the atmosphere and amount removed from the atmosphere are equal.
Sector-based emissions inventory (SBEI)	Toronto's sector-based emissions inventories measure GHGs attributable to emissions-generating activities taking place within the geographic boundary of the city, as well as some indirect emissions from waste produced in the city, and transmission of electricity into the city boundary in a given time (typically one year).
Tonne (t)	One metric tonne (1,000 kilograms)
Upstream emissions	Emissions associated with the production, transport, and sale of goods or services, prior to purchase by the ultimate consumer. Equivalent to embedded or upfront emissions.
Use phase emissions	The burning of fossil fuels (such as gasoline or natural gas) for transportation or home heating energy

Executive Summary

In 2019, construction and maintenance of buildings and linear infrastructure[1] in Toronto accounted for 1,513 kilotonnes (kt) of carbon dioxide equivalent (CO_2e). Of this total, buildings comprised 1,065 $ktCO_2e$, while linear infrastructure comprised 448 $ktCO_2e$.

Within emissions associated with buildings, new construction[2] accounted for roughly 60 per cent of building emissions, at 634 $ktCO_2e$, while permitted maintenance and renovations[3] to existing buildings accounted for 431 $ktCO_2e$ (40 per cent). Within these sub-categories, emissions predominantly came from the construction of new large multi-unit residential (MUR)[4] and miscellaneous buildings[5] (322 and 159 $ktCO_2e$, respectively, for a total of 482 $ktCO_2e$), and the maintenance and renovation of non-residential structures (351 $ktCO_2e$). This is depicted in Figure 3.

Together, construction of large MUR, construction of miscellaneous buildings, and non-residential maintenance and renovation comprised roughly 78 per cent of all emissions associated with buildings. Permitted building activities in facilities owned by the City of Toronto (including both new construction and maintenance and renovations) comprised ten per cent of the total emissions from buildings (108 $ktCO_2e$).

For linear infrastructure, the City of Toronto's budgeted expenditures in 2019 comprised 448 $ktCO_2e$, or roughly 30 per cent of total buildings and linear infrastructure emissions. This was predominantly made up of budgeted expenditures on water and sewer infrastructure (202 $ktCO_2e$, or 45 per cent), and

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[1] Linear infrastructure refers to long, narrow physical assets that span significant distances and are used to deliver and support public services, such as such as roads, railways, and pipelines.
[2] New construction emissions include all emissions from occupancy permits identified by City staff as relating to new construction.
[3] Maintenance & renovation includes emissions from all occupancy permits that are not related to the construction of new buildings.
[4] Large MUR includes all occupancy permits coded as Apartment Building, Apartment Hotel, Long Term Care Facility, Mixed Comm/Res, Mixed Use/Res w Non Res, Motel/Hotel, Multiple Unit Building, Residential, Residential Decks, or Student Residence
[5] The "miscellaneous" category includes buildings such as industrial facilities, parking garages, university buildings, transit stations, libraries, laboratories, schools, hospitals, museums, and other building types not otherwise classified as commercial office / retail or any of the various residential classifications.

highways, street, and bridge construction (167 $ktCO_2e$, or 37 per cent). The remaining 18 per cent included miscellaneous heavy and civil engineering construction of linear infrastructure, such as trails and pathways (9 per cent), buildings associated with linear infrastructure, such as train stations (5 per cent), and lighting associated with linear infrastructure (4 per cent). At the Agency, Board, Commission, or Division (ABCD) level, Toronto Water, Transportation Services, and the Toronto Transit Commission were the largest ABCDs, accounting for 45, 28, and 13 per cent, respectively. Seven other programs comprised the remaining 14 per cent.

This is a supplemental and complementary analysis to the City of Toronto's Community-wide CBEI and Corporate CBEI reports, not a comprehensive inventory: it is a detailed look at specific categories of consumption-based emissions (buildings and linear infrastructure), rather than a full inventory of the emissions associated with a jurisdiction (like the Community-wide CBEI report) or an organization (like the corporate CBEI report). As a result, these findings should be taken in the context of those other reports.

With this initial analysis, the City is prepared to begin identifying and developing emission reduction strategies in the areas of buildings and linear infrastructure.

Introduction

In 2019, Toronto City Council voted to declare a climate emergency and pledged to accelerate the City's climate action strategy. In 2021, Council adopted the TransformTO Net Zero Strategy (NZS[6]) and the TransformTO Net Zero Strategy Short-Term Implementation Plan, which included the action to develop a plan to measure, monitor, and reduce consumption-based (lifecycle) greenhouse gas (GHG) emissions[7], and specifically to evaluate and limit impacts of embodied carbon in construction.

In 2023, the City prepared a Toronto Community-wide Consumption-Based Emissions Inventory (CBEI), as well as an expanded City of Toronto Corporate CBEI. However, those inventories did not provide a detailed review of the emissions associated with buildings and linear infrastructure. The Community-wide CBEI

[6] https://www.toronto.ca/services-payments/water-environment/environmentally-friendly-city-initiatives/transformto/
[7] Item 6f: https://secure.toronto.ca/council/agenda-item.do?item=2019.MM10.3

allocates all emissions to households, and does not explicitly calculate emissions associated with local construction activity in a given year. Meanwhile, the Corporate CBEI calculates emissions associated with construction and maintenance done by the City of Toronto, but does not go into detail on either buildings or infrastructure, and does not include non-City construction activity.

This report analyzes those two categories of emissions: buildings and linear infrastructure. Within the buildings category, activity data (occupancy permits) are further broken down into two sub-categories: new construction, and maintenance and renovations. This report is not a comprehensive consumption-based emissions inventory (CBEI), because of its limited scope: it is a detailed look at specific categories of consumption-based emissions (buildings and linear infrastructure), rather than a full inventory of the emissions associated with a jurisdiction (like the Community-wide CBEI report) or an organization (like the Corporate CBEI report). This report is complementary to the City of Toronto's Community-wide CBEI and Corporate CBEI reports.

This report uses data from 2019, for both public and private buildings citywide as well as corporate infrastructure budgeting, to establish a baseline for setting reduction targets and future monitoring, tracking, and reporting of building and infrastructure emissions.

Emissions associated with building construction make up roughly 21 per cent of global greenhouse gas (GHG) emissions[8]. Most of these emissions (over 90 per cent, for construction projects in the Greater Toronto-Hamilton Area) occur in the production and transport of the raw materials used in construction[9]. These "embodied emissions" may occur anywhere in the world; however, because the materials are ultimately used in Toronto, the City has an opportunity, through policies and programs, to influence builders' choices of project design and materials, with the potential to reduce the associated embodied emissions[10].

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[8] Carbon Leadership Forum (2019) "Embodied Carbon in Buildings Facts and Figures": https://carbonleadershipforum.org/wp-content/uploads/2019/11/Embodied-Carbon-Facts-and-Figures.pdf

[9] Mantle Development, "Embodied carbon benchmarks for Part 3 buildings in the Greater Toronto-Hamilton Area": https://drive.google.com/file/d/13vU61c7_0UINI_LjzODykqAE0sXgNL9S/view

[10] GHG emissions also occur after building construction in the form of operating and maintenance emissions. These emissions result from energy used in the operation of the building (such as

In addition to buildings, the City of Toronto itself directly invests in the construction of linear infrastructure: facilities designed and built in an elongated or linear shape, connecting two or more points, for the transportation of people, goods, or other resources. Linear infrastructure includes roads, highways, railways, and pipes, as well as related elements such as traffic lights, subway stations, and water pumps. In contrast, non-linear infrastructure includes facilities such as buildings, parks, and IT systems, which either serve a single location or are distributed in multiple locations across the city. Linear infrastructure is typically made of high-emission materials such as steel, asphalt, and concrete, and represents a significant fraction (19 per cent) of the City's corporate consumption-based emissions inventory (CBEI)[11].

Methodology

Building Construction

In order to estimate emissions associated with the materials used in building construction in 2019, City staff prepared a dataset of construction projects which received their occupancy permits[12] in 2019. Building occupancy permits were classified by building type (either residential, including detached, semi-detached, townhouse, small MUR, and large MUR; or non-residential, including commercial office / retail, and miscellaneous[13]), as well as either "new construction" or "maintenance"[14]. Lastly, City of Toronto building projects were identified based upon property ownership.

This building occupancy permit dataset included data on expenditures and gross floor area. Three sets of emission factors were used:

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through using natural gas for space heating), as well as embodied and direct emissions from materials replacements when building elements reach their end of life (such as replacing structural elements and finishes over time).

[11] Other entities and levels of government are also responsible for linear infrastructure construction in Toronto (such as the Province of Ontario through Metrolinx). However, this analysis focuses only on emissions attributable to municipally-budgeted linear infrastructure projects, which the City has the most influence over.

[12] Occupancy permit requirements are set out in Division C, Part 1, Article 1.3.3.1 of the Ontario Building Code.

[13] The "miscellaneous" category includes buildings such as industrial facilities, parking garages, university buildings, transit stations, libraries, laboratories, schools, hospitals, museums, and more.

[14] Maintenance includes renovation. Demolition projects were also classified, but had no associated emissions.

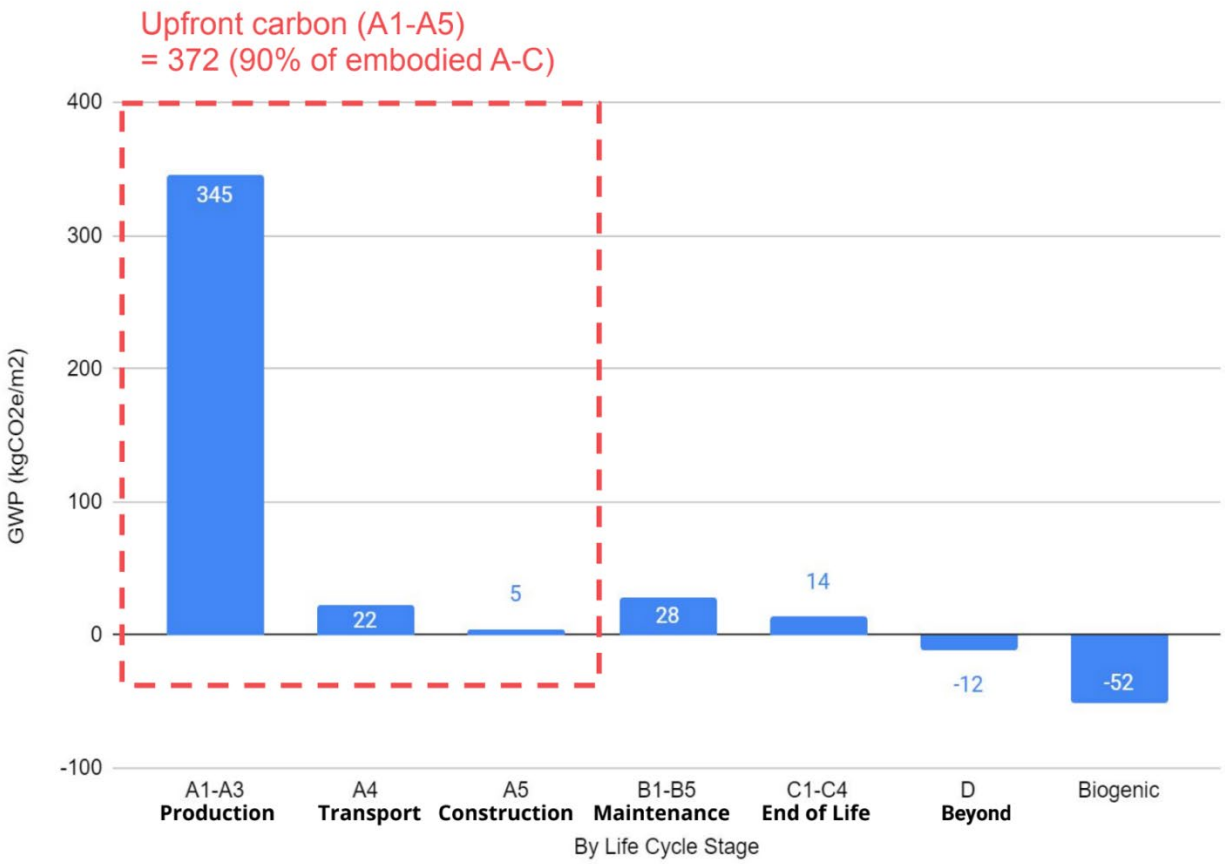
1. For detached, semi-detached, and townhome projects with gross floor area data, emission factors from the Emissions of Materials Benchmark Assessment for Residential Construction (EMBARC) Report[15] were used.
2. For all other projects with gross floor area data, adjusted emission factors from the "Embodied carbon benchmarks for Part 3 buildings in the Greater Toronto-Hamilton Area" report, prepared by Mantle Developments and Ha/f Research Studio ("Mantle / Ha/f Report"[16]) were used.
3. For all other projects, emissions were estimated based upon U.S. EPA's Environmentally-Extended Input-Output Model (USEEIO[17]) v1.2 data for residential or non-residential building repair and maintenance.

Both USEEIO and EMBARC Report emission factors are "cradle-to-gate" estimates, accounting for emissions associated in the production of materials but not including the transport or construction phases. The Mantle / Ha/f Report, in contrast, provided full lifecycle emissions. The report broke down the lifecycle into different stages from production to transportation to construction, including maintenance and end-of-life (Figure 1).

In order to align emissions from the Mantle / Ha/f Report with EMBARC and USEEIO emission factors, average emission factors from the Mantle / Ha/f Report were multiplied by 0.8343, based upon data in the Mantle / Ha/f Report (Figure 1) showing that embodied emissions from upstream sources (materials production and transport, and construction activity) account for 90 per cent of overall building emissions; and that within those sources, materials production accounted for 92.7 per cent of emissions, for a combined 83.43 per cent of total lifecycle emissions. For more details on the figure, see the Mantle / Ha/f Report.

[15] https://www.passivebuildings.ca/embarc
[16] https://drive.google.com/file/d/13vU61c7_0UINI_LjzODykqAE0sXgNL9S/view
[17] https://www.epa.gov/land-research/us-environmentally-extended-input-output-useeio-models

Figure 1. Mantle / Ha/f Report Emissions Results by Life-Cycle Assessment Phase



As a result of this adjustment, emissions from construction and maintenance are consistently calculated on the "A1-A3" basis of production emissions only.

USEEIO emission factors were adjusted using Bank of Canada data on currency conversions[18] and U.S. Bureau of Labor Statistics data on inflation[19].

Overall, this approach was developed to provide a relatively straightforward and repeatable estimate of embodied construction emissions across building projects within a given year, using readily available data. However, it has several simplifying assumptions and limitations.

Firstly, while building projects can take multiple years, all emissions from construction of a given project were allocated to a single year (2019), based upon

[18] Bank of Canada, Annual Exchange Rates. https://www.bankofcanada.ca/rates/exchange/annual-average-exchange-rates/

[19] US Bureau of Labor Statistics, CPI for All Urban Consumers: https://data.bls.gov/cgi-bin/surveymost?cu

the year in which the project received its occupancy permit. 2019 was selected as a baseline year as the most recent year for which data was available without being impacted by the Covid-19 pandemic, but it is not necessarily reflective of either pre- or post-covid building construction activity levels.

Secondly, emissions intensities of construction are roughly estimated. While these estimates are based on local studies of emissions intensities by building type, where data is available, these studies found significant ranges within and between building types. These studies were also limited and may not have sampled a fully representative range of projects.

Thirdly, for projects without floor area data, estimates were based on project expenditures (where provided), using US emissions intensities for appropriate industries. However, project expenditure estimates may be inaccurate, and these emission factors are also representative of averages, without considering the full range of possible emissions intensities.

Lastly, the occupancy permit data itself may be incomplete or inaccurate, with projects potentially completed illegally without permits, or with incorrect information provided on floor area or cost.

Despite the limitations, a more accurate approach would require project-level life-cycle assessments for a much broader range of construction projects – a very significant commitment of time and resources. As such, the approach selected is the most effective approach for estimating emissions associated with construction.

Linear Infrastructure

For the City's construction of linear infrastructure, line items from the 2019 capital budget were individually reviewed and identified as linear infrastructure projects. Emission factors were previously assigned from the Corporate CBEI, using USEEIO v1.2 emission factors based upon the corresponding North American Industry Classification System (NAICS) codes for each line item. Adjustments were made to correct for Canadian dollars (using Bank of Canada exchange rates for 2019) and inflation (using Bureau of Labor Statistics Consumer Price Index data).

2019 Building Construction Emissions Results

A total of 29,629 projects across seven building type categories were analyzed from the occupancy permit dataset, as shown in Table 1.

Table 1. Number of Occupancy Permits by Building and Project Type (2019)

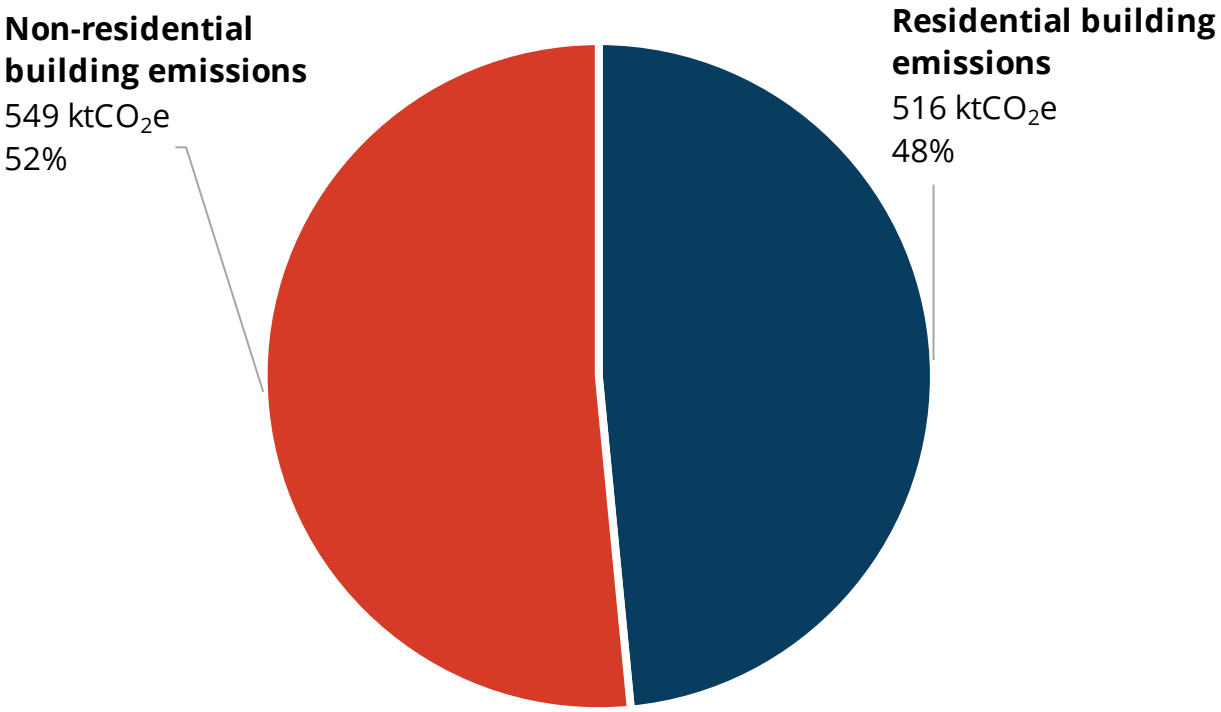
Building Type	New Construction	Maintenance	*Total*
Detached	3,036	9,009	*12,045*
Semi-Detached	580	2,122	*2,702*
Townhouse	1,004	2,054	*3,058*
Small MUR	38	217	*255*
Large MUR	120	2,484	*2,604*
Commercial Office / Retail	508	6,906	*7,414*
Misc.[20]	182	1,369	*1,551*
Total	*5,468*	*24,161*	*29,629*

Based upon the City's occupancy permit data, embodied emissions associated with building construction in city limits for projects completed in 2019 were an estimated 1,065 $ktCO_2e$[21]. This is equivalent to roughly three per cent of the community-wide CBEI (39 $MtCO_2e$), which accounts for the consumption-based emissions associated with Toronto residents' activities, or seven per cent of the community-wide sector-based inventory (15.6 $MtCO_2e$, which accounts for emissions occurring locally within City borders, as well as some indirect emissions from waste and electricity)[22]. These embodied emissions associated with building construction are partially overlapping with the emissions already counted in the community-wide CBEI.

[20] The "miscellaneous" category includes buildings such as industrial facilities, parking garages, university buildings, transit stations, libraries, laboratories, schools, hospitals, museums, and more.
[21] While this is the best available estimate, there are identified shortcomings and limitations which could mean that this analysis underestimates (or overestimates) embodied and direct emissions from construction, as noted in the Methodology section.
[22] City of Toronto Greenhouse Gas Emissions Inventory 2019: https://www.toronto.ca/wp-content/uploads/2021/10/8f2e-2019-Inventory.pdf

Of this 1,065 $ktCO_2e$, roughly 516 $ktCO_2e$, or 48 per cent, is the results of residential projects (including MUR buildings), and 549 $ktCO_2e$, or 52 per cent, is from non-residential projects (Figure 2). Despite there being many more permits issued for residential projects, emissions are largely the same across the two categories due to the size of projects permitted (commercial office / retail and miscellaneous building categories tend to be much larger than residential projects).

Figure 2. Toronto Residential vs Non-Residential Building Emissions (2019)



When looking at the breakdown of new construction versus maintenance and renovation across both residential and non-residential permits, new construction made up the bulk of building emissions. As shown in Figure 3, residential new construction comprised 439 $ktCO_2e$, or 41 per cent, while non-residential new construction comprised 195 $ktCO_2e$, or 18 per cent, for a total of 634 $ktCO_2e$, or 59 per cent of building emissions. The remaining 41 per cent came from residential maintenance & renovation (79 $ktCO_2e$, or 8 per cent), and non-residential maintenance & renovation (351 $ktCO_2e$, or 33 per cent).

Figure 3. New Construction vs. Maintenance & Renovation Emissions (All Permits) (2019)

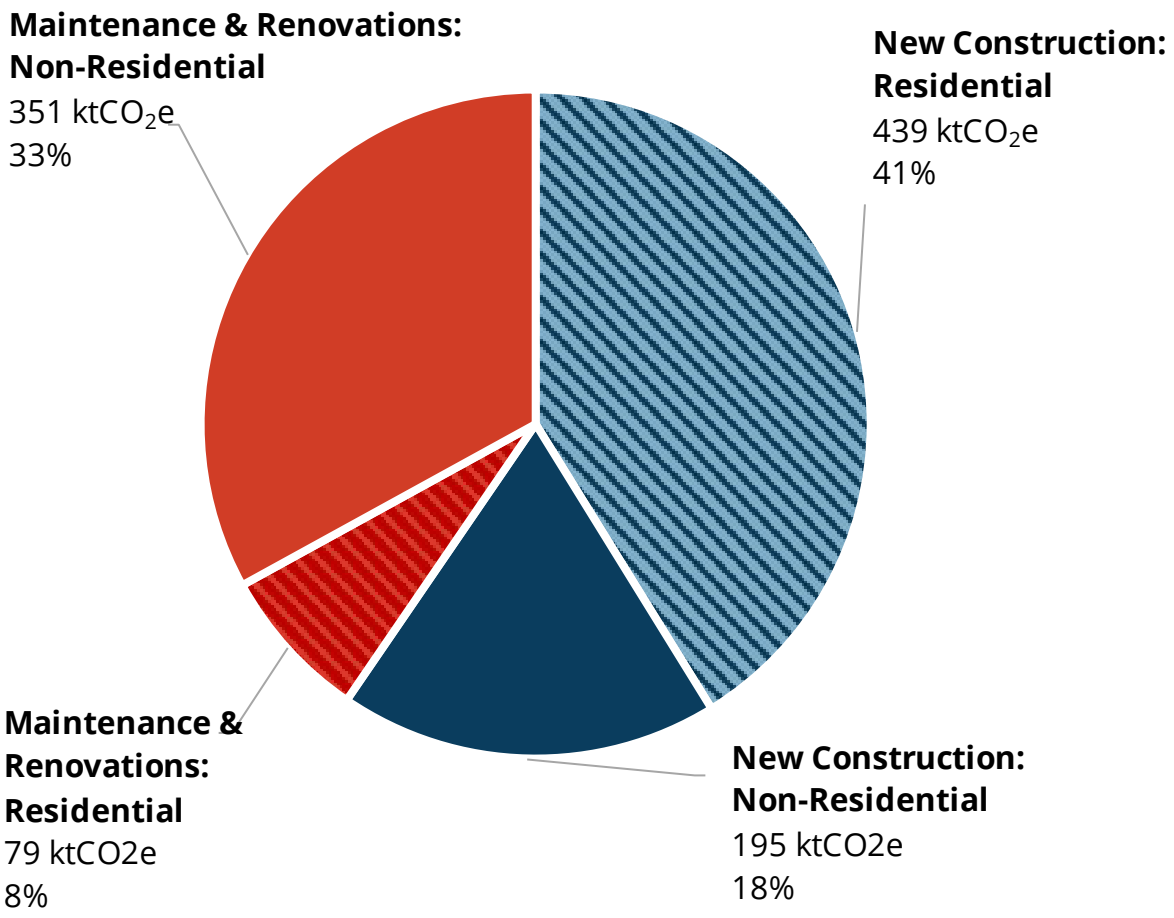


Figure 4 shows that of the 634 $ktCO_2e$ of emissions from new construction projects, residential projects comprised roughly 69 per cent (51 per cent from large MUR buildings, and 18 per cent from small residential, including 14 per cent from detached single-family buildings, three per cent from townhouses, one per cent from semi-detached residential buildings, and one per cent from small MUR buildings).

Figure 4. New Construction Emissions by Sector (2019)

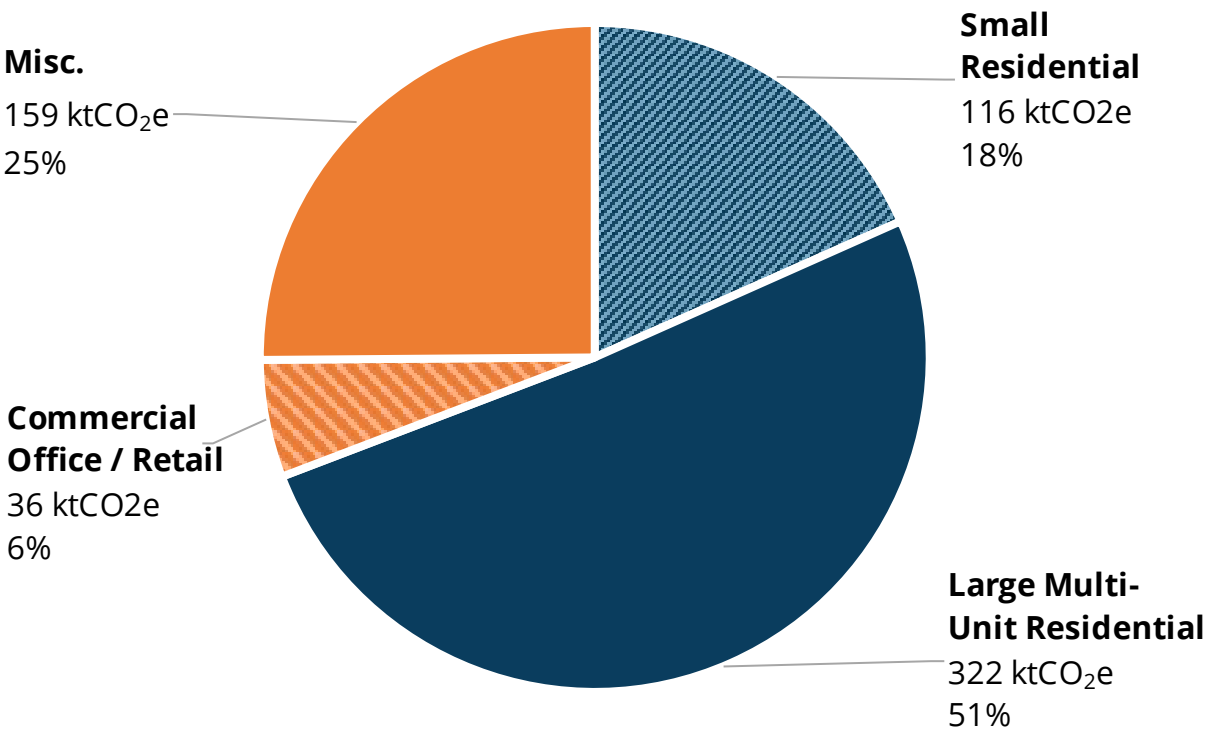


Figure 5 shows that for maintenance and renovation, 82 per cent of the 525 $ktCO_2e$ of emissions were associated with non-residential properties (57 per cent from commercial and 25 per cent from miscellaneous non-residential).

Figure 5. Maintenance & Renovation Emissions by Sector (2019)

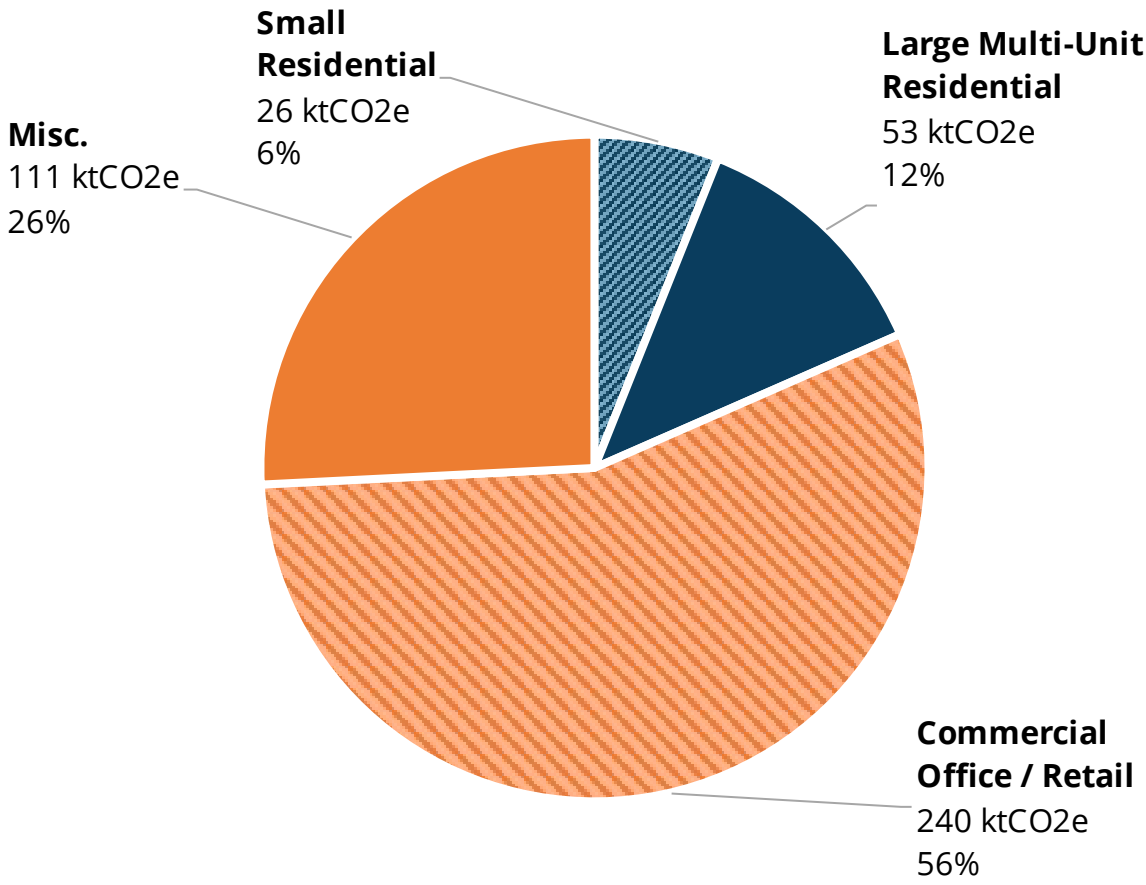


Table 2 shows the breakdown of emissions by sector across new construction.

Table 2. Emissions from New Construction by Sector (2019)

Building Sector	$ktCO_2e$	Per Cent of New Construction Emissions	Residential?
Detached	86	14%	Yes, small
Semi-Detached	6	1%	Yes, small
Townhouse	21	3%	Yes, small
Small MUR	3	<1%	Yes, small
Large MUR	322	51%	Yes, large
Commercial Office / Retail	36	6%	No

Building Sector	$ktCO_2e$	Per Cent of New Construction Emissions	Residential?
Misc.[23]	159	25%	No
Total	*634*	*100%*	

Table 3 shows the breakdown of emissions by sector across maintenance and renovation projects.

Table 3. Emissions from Maintenance and Renovations by Building Sector (2019)

Building Sector	$ktCO_2e$	Per Cent of Maintenance and Renovations Emissions	Residential?
Detached	16	4%	Yes, small
Semi-Detached	7	2%	Yes, small
Townhouse	1	<1%	Yes, small
Small MUR	2	<1%	Yes, small
Large MUR	53	12%	Yes, large
Commercial Office / Retail	240	56%	No
Misc.[23]	111	26%	No
Total	*431*	*100%*	

Per-Unit Emissions for Residential Building Construction

As shown in Table 2 above, within new construction, Large MUR buildings are the single largest source of emissions, making up 49 per cent of new construction emissions. Large MUR is generally comprised of taller buildings made of more carbon-intensive materials (such as steel and concrete). The Mantle / Ha/f Report, found that these larger buildings typically have higher emissions per floor area (an average of 435 kg CO_2e per square metre (m^2) for large residential versus an average of 191 kg CO_2e/m^2 for small residential/single-family dwellings).

Critically, though, based on the occupancy permit data for 2019, large MUR buildings typically have smaller emissions than single-family dwellings on a per-unit basis. The average floor area per unit among all new large MUR buildings in the

[23] The "miscellaneous" category includes buildings such as industrial facilities, parking garages, university buildings, transit stations, libraries, laboratories, schools, hospitals, museums, and more.

2019 occupancy permit data was 125 m^2, whereas the average floor area per unit of a new single-family dwelling was 348 m^2. Overall, apartment and condominium units were estimated to have embodied emissions of roughly 49 tCO2e, while single-family dwellings had embodied emissions of about 65 tCO2e. Table 4 shows the breakdown of emissions per unit, by housing type. Based on the data available small multi-unit residential and townhouses are the most efficient development option from an embodied carbon standpoint, at only 22-24 tCO2e.

Table 4. Embodied Emissions per New Housing Unit (2019)

Building Sector	tCO_2e	$kgCO_2e$ per m^{2*}
Detached	65	172
Semi-Detached	31	173
Large MUR	49	389
Small MUR	22	199
Townhouse	24	193

**emissions per m^2 based upon data from EMBARC and Mantle studies, including adjustments to Mantle emissions factors*

Comparison with Community-Wide CBEI "Shelter" Sub-category

This analysis of emissions associated with residential construction is a parallel but different approach to the estimates developed for the community-wide CBEI "Shelter" sub-category.

In the community-wide CBEI, the "Shelter" sub-category is developed based upon modeled estimates of average household spending on shelter in 2019. These "Shelter" expenditures include mortgage, property taxes, maintenance, insurance, property management, parking, and rent. The overwhelming majority of these costs are direct housing expenses, namely mortgage and rent. This average spending is then multiplied by an economy-wide estimated emissions intensity (gCO_2e per dollar) of residential construction and maintenance. Overall, this results in estimated "Shelter" sub-category emissions that are reflective of the long-term average housing construction rate and emissions intensity.

In Canada, the average expected lifetime of a single detached house is 65 years[24]. The community-wide CBEI estimates "Shelter" sub-category emissions at 0.8 tCO_2e per household per year, or 52 tCO_2e per home over a 65-year lifetime. While this is lower than the emissions associated with new detached homes built in Toronto in 2019, new detached homes are typically larger than older homes, and modern energy efficiency codes typically result in more emissions associated with construction than older, less efficient codes did. As a result, 52 tCO_2e per home from the community-wide CBEI is a reasonable estimate for the average existing home – particularly detached or small attached buildings, which are more common in the U.S. (the emissions factors used in the community-wide CBEI are based upon U.S. data).

However, these emissions from the community-wide CBEI are not based upon the actual construction activity occurring in any given year, nor are they based upon the emissions intensity data available for Toronto. In contrast, the occupancy permit data used in this Buildings and Linear Infrastructure Analysis are specific to construction activity completed in 2019, while the square footage emissions factors are developed using regional studies. As a result, the analysis in this report is more accurate to the actual emissions associated with construction occurring in 2019 in Toronto, while the community-wide CBEI is more reflective of long-term averages.

Maintenance & Renovations

Non-residential projects – predominantly in commercial office and retail buildings – make up the overwhelming majority of emissions associated with permitted maintenance and renovation projects (56 and 26 per cent, respectively). Large MUR comprises 12 per cent of emissions associated with maintenance and renovation projects, while small residential (small MUR, townhouses, semi-detached, and detached) together are a mere six per cent.

However, these data are limited to those projects for which permit data is available. Smaller renovation or maintenance projects (such as many of those that might occur in a typical single-family home) do not always require an occupancy permit

[24] StatCan, Average expected useful life of new municipally owned social and affordable housing assets, by urban and rural, and population size, Infrastructure Canada https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=4610000801

upon completion, or may be done without the proper authorization required by the Ontario Building Code.

Spotlight on the City of Toronto's Corporate Building Construction Emissions

Within the occupancy permit data, there were 376 projects associated with City-owned buildings for which project cost and/or gross floor area data were available. Overall, embodied emissions from construction associated with City projects made up about seven per cent of overall city-wide construction-related emissions.

These building construction and maintenance projects resulted in 69 ktCO_2e of emissions. Of this, 39 ktCO_2e (57 per cent) was associated with maintenance and renovations, while the remaining 30 ktCO_2e (43 per cent) was associated with new construction.

Some of these emissions are likely also reflected in the 2019 Corporate CBEI. However, most new construction projects took multiple years to develop and build, and may have had emissions – and spending – occurring in prior years.

2019 City of Toronto Linear Infrastructure Construction Emissions Results

City of Toronto's linear infrastructure emissions in 2019 totaled 448 $ktCO_2e$. Water and sewer line construction and highways, streets, and bridges were the top two categories of linear infrastructure emissions, comprising 202 $ktCO_2e$ (45 per cent) and 167 $ktCO_2e$ (37 per cent), respectively, as shown in Figure 6 and Table 5.

Figure 6. City of Toronto Linear Infrastructure Emissions by Category (2019)

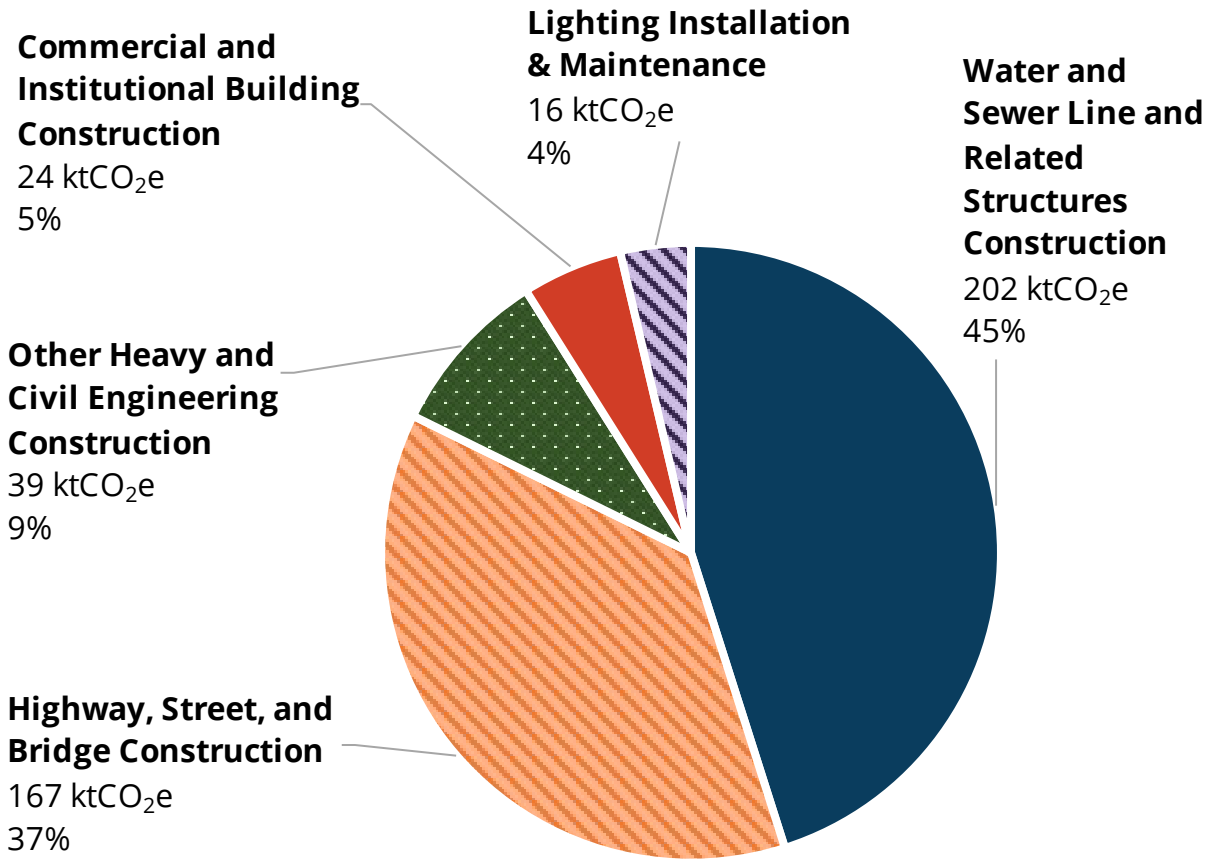


Table 5. City of Toronto Linear Infrastructure Emissions by Category (2019)

Category	$ktCO_2e$	Per Cent
Water and Sewer Line and Related Structures Construction	202	45%
Highway, Street, and Bridge Construction	167	37%
Other Heavy and Civil Engineering Construction	39	9%
Commercial and Institutional Building Construction	24	5%

Lighting Installation & Maintenance	16	4%
Total	*477*	

Most emissions from linear infrastructure are associated with either water infrastructure or highways, streets, and bridges. Water infrastructure includes improvements to sewage lines, stormwater management, and drinking water infrastructure[25]; while the highways, streets, and bridges category includes budgeted expenditures for roadway improvements, subway tracks, bridge lanes, bike lanes, pedestrian improvements, and more.

Meanwhile, a handful of emissions are assigned to other categories. The "Other Heavy and Civil Engineering Construction" category includes a variety of projects, such as trail & pathway improvements, waterfront and stream restoration, and electrical infrastructure for streetcars. Commercial and institutional building construction includes train station improvements, while the lighting installation and maintenance includes all lighting-related projects associated with linear infrastructure, including path and street lighting and traffic lights.

At the Agency, Board, Commission, and Division (ABCD) level, the single City ABCD with the greatest consumption-based emissions associated with its budget was Toronto Water, with 204 $ktCO_2e$ (45 per cent) associated with improvements to water and wastewater infrastructure, followed by Transportation Services (126 $ktCO_2e$, or 28 per cent) and the Toronto Transit Commission (57 $ktCO_2e$, or 13 per cent), both with significant investments in transportation infrastructure throughout the city. While other ABCDs had linear infrastructure emissions associated with their activities, Table 6 shows that no other ABCD had more than 10 per cent of the City's total linear infrastructure emissions. These top three ABCDs accounted for 86 per cent (386 $ktCO_2e$) of the City's 448 $ktCO_2e$ in linear infrastructure emissions.

Table 6. City of Toronto Linear Infrastructure Emissions by ABCD (2019)

ABCD	**$ktCO_2e$**	Per Cent
Toronto Water	204	45%
Transportation Services	126	28%
Toronto Transit Commission	57	13%

[25] Wastewater treatment plants are not considered linear infrastructure and are excluded from this analysis.

ABCD	$ktCO_2e$	Per Cent
Waterfront Revitalization Initiative	36	8%
Scarborough Subway Extension	20	4%
Corporate Initiatives	2	1%
Parks, Forestry & Recreation	2	<1%
Facilities, Real Estate, Environment & Energy	1	<1%
Exhibition Place	1	<1%
Total	*448*	

Note: Values may appear to be 0 or not add to 100% due to rounding.

Further Analysis & Progress Monitoring

This Buildings and Linear Infrastructure Emissions Analysis is limited by the available data and methodologies.

The EMBARC and Mantle / Ha/f Reports provide good foundations for estimating average emissions from new construction for local building types based upon floor area, but floor area data is absent for many projects (roughly 20 per cent of new construction permits did not include floor area data). For those remaining projects, and for all maintenance & renovations and linear infrastructure, emissions are estimated based upon available expenditure data (which is subject to significant uncertainty in the occupancy permit dataset), as well as US national averages for emissions intensity of different industries / building sectors.

Unfortunately, better data is challenging to come by. As noted in the Corporate CBEI, the City could explore options for life-cycle assessment (LCA) of corporate projects, and potentially require them for larger construction or maintenance & renovation work as well. The City can also work to improve the availability of more local emission factors.

While the methodology used for this analysis provides a benchmark, it does not allow the City to readily track progress in reducing emissions – only in reducing floor area or expenditures on buildings and infrastructure. When developing emission reduction strategies in the future, the City will need to incorporate additional data collection to be able to calculate the effects and avoided emissions of these strategies.

Conclusion: Buildings & Infrastructure Construction

In 2019, construction of buildings and linear infrastructure in Toronto accounted for roughly 1,514 $ktCO_2e$, equivalent to roughly four per cent of the Community-wide CBEI. Of this total, building construction & maintenance comprised roughly 1,065 $ktCO_2e$, while linear infrastructure comprised roughly 448 $ktCO_2e$.

Across buildings and infrastructure, the largest sources of emissions are:

- New residential construction (439 $ktCO_2e$)
- Non-residential maintenance & renovations (351 $ktCO_2e$)
- Water & sewer infrastructure (202 $ktCO_2e$)
- Highway, street, and bridge construction (167 $ktCO_2e$)

Together, these four areas made up 1,159 $ktCO_2e$, or 77 per cent of total buildings and infrastructure emissions. Permitted buildings construction and maintenance activities in buildings owned by the City of Toronto comprised about five per cent of the total (69 $ktCO_2e$).

This study provides a baseline for the City of Toronto to begin exploring opportunities to address emissions from buildings and linear infrastructure. Further research is needed to determine strategies for reducing these emissions and identifying and tracking necessary data to measure progress.