Toronto's Green Future: A Decade of Trends in City-Owned Renewable Energy Installations*

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This paper investigates the trend of renewable energy installations on City-owned buildings in Toronto by analyzing an openly accessible dataset. The analysis reveals a significant increase in installations, particularly in 2017 and 2018, aligning with the city's commitment to carbon neutrality by 2040. There is also a notable diversification in installation types for different urban contexts. The findings offer an important insght into the dynamic nature of renewable energy adoption, and highlights the need for continued efforts in transitioning towards cleaner energy systems.

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*Code and data are available at: https://github.com/samielsabri/toronto-renewable-energy-analysis

1 Introduction

As the global community is increasingly faced with the challenges posed by climate change, cities worldwide are increasingly recognizing the need of transitioning towards cleaner and more sustainable energy sources (Perea-Moreno and Hernandez-Escobedo 2018). In fact, how societies use and produce energy has proven to be one of the most important drivers of climate change, and thus a major point of intervention (Sims 2004). Canada is a signatory to the Paris convention, an international treaty on climate change, and has put forward investment in renewable energy sources as a key component of the government's commitment (UNFCC 2021). In particular, it has vowed to invest $964 million in renewable energy installation projects and intends to increasingly shift towards such sources (UNFCC 2021).

As the largest city in Canada, Toronto stands at the forefront of sustainable urban development in the country. There are multiple initiatives, both at the provincial and local level, to increase the usage of renewable energy such as SolarTO which offers financial incentives (Robinson 2020), or the Conservation Authority's Renewable Energy Program (TRCA 2018). Most notably, the City of Toronto itself vowed to transform city buildings and facilities according to the Net Zero Carbon Plan, most recently in 2022. The city government plans to achieve net zero in such buildings by 2040 by installing more and more renewable energy systems (Toronto 2022), but it is unclear to what extent they have been addressing the urgency of transitioning towards renewable energy.

This paper may bridge this knowledge gap by analyzing a publically available dataset on renewable energy installations in Toronto. The findings reveal a compelling upward trajectory in the number of installations, notably peaking in 2017 and 2018. Moreover, while there is no clear trend in the kilowatt (kW) size of installations, we can observe efforts to diversify the types of installations, with both smaller and larger installations seeing an increase.

In order to investigate the trend of renewable energy installations to assess whether there is indeed an upwards trajectory in both the quantity and quality of installations by the City of Toronto, this paper has been structured as follows: First, the raw dataset of interest is introduced (Section 2.1) and then all relevant variables described, explained, and visualized (Section 2.2). The reproducible data cleaning process can be found in the appendix (Section A). Then, the results section (Section 3) highlights trends and interactions between variables. Finally, in the discussion (Section 4), the data and results are contextualized in order to draw conclusions from it, which contribute to the broader understanding of Toronto's renewable energy efforts.

2 Data

2.1 Data Source and Measurement

This report utilizes data published by the City of Toronto's Facilities Management Division on the city's Open Data Portal and is titled "Renewable Energy Installations" (opendatatoronto 2022). Specifically, the Facilities Management Division collected the locations of installed renewable energy systems on city-owned buildings such as photovoltaic, solar pool heating, and geothermal installations. The dataset was last updated Apr 22, 2022, but only contains observations from 2010 until 2019. The aforementioned increased relevance of renewable energy in Toronto's combat with climate change gave rise to this dataset. However, due to the data collection method and the Facilities Management Division as the primary data collector, a key limitation of this dataset is that it only includes city divisions, but not all city agencies or corporations. This highlights a key difficulty of measuring data related to renewable energy system installation, since there are different jurisdictions in who is responsible for which installation. No personally identifiable information is included, since the data collected is only on installed renewable energy systems, preserving the confidentiality of individuals associated with the installations.

The dataset was analyzed using R (R Core Team 2022) and downloaded using the R package opendatatoronto (Gelfand 2022). Additionally, the packages tidyverse (Wickham et al. 2019), lubridate (Wickham 2023a), stringr (Wickham 2023b), sf (Pebesma 2018), and tmap (Tennekes 2018) have been used in data cleaning and visualization.

2.2 Data Characteristics

The raw dataset contained 100 unique observations and 41 variable columns, most of which with either constant or missing values. Most columns referred to geospatial data and were deemed beyond the scope of this report. In the first basic cleaning steps, only certain variables of interest were selected: ID, type of installation, date of installation, size of installation, and the location (given by coordinates). From the date of installation, I created an additional year of installation variable. From the location, the two colummns latitude and longitude were extracted, for simpler analysis. A glimpse of the final cleaned dataset can be seen in Table 1.

Table 1: Cleaned Data of Renewable Energy Installations

ID	size	type	date	longitude	latitude	year
1	50.0	FIT	2010-03-31	-79.41722	43.63762	2010
2	30.0	FIT	2012-02-08	-79.32790	43.69098	2012
3	1.2	MicroFIT	2010-12-23	-79.47963	43.65835	2010
4	3.2	MicroFIT	2010-07-12	-79.38861	43.63769	2010

Table 1: Cleaned Data of Renewable Energy Installations

ID	size	type	date	longitude	latitude	year
5	62.0	FIT	2013-02-27	-79.49883	43.61239	2013
6	216.0	FIT	2013-03-26	-79.50348	43.60508	2013

2.2.1 Size of Installation

The size of installation represents the power capacity of each installation, measured in kilowatts (kW). All installations fall within the range of 1.2 kW to 500.0 kW. As summarized in Table 1 (Table 2), the mean size of installations is 88.1 kW, showcasing the average power capacity across the dataset. The median size, a robust measure of central tendency, is slightly lower at 68.5 kW. The difference between the mean and median suggests the presence of outliers or a skewed distribution. Indeed, the histogram (Figure 1) reveals a right-skewed distribution, indicating a higher concentration of installations at the lower end of the size spectrum and very few observations at the upper end of the spectrum. The standard deviation of 102.82 kW reinforces this variability in installation sizes.

Table 2: Size of Installation Summary Statistics

Mean	Median	SD
88.1	68.5	102.82

2.2.2 Type of Installation

Type of Installation (`type`) refers to whether the system falls under the FIT or microFIT program (with very few installations being classified as *storage*. FIT, or "Feed-In Tariff", is a program developed by the Ontario Power Authority which guarantees long-term financing and contracting for program participants, meant to incentivize the use of renewable energy sources (Canada 2022). microFIT is part of the wider FIT program, but for smaller installations (10 kW or less).

Taking a closer look at the installation types in Figure 2, we see that the majority of installations are of the FIT type, followed by microFIT, and only 2 storage installations. This is consistent with the size distribution discussed in the previous section, since microFIT only applies to installations with less than 10 kW.

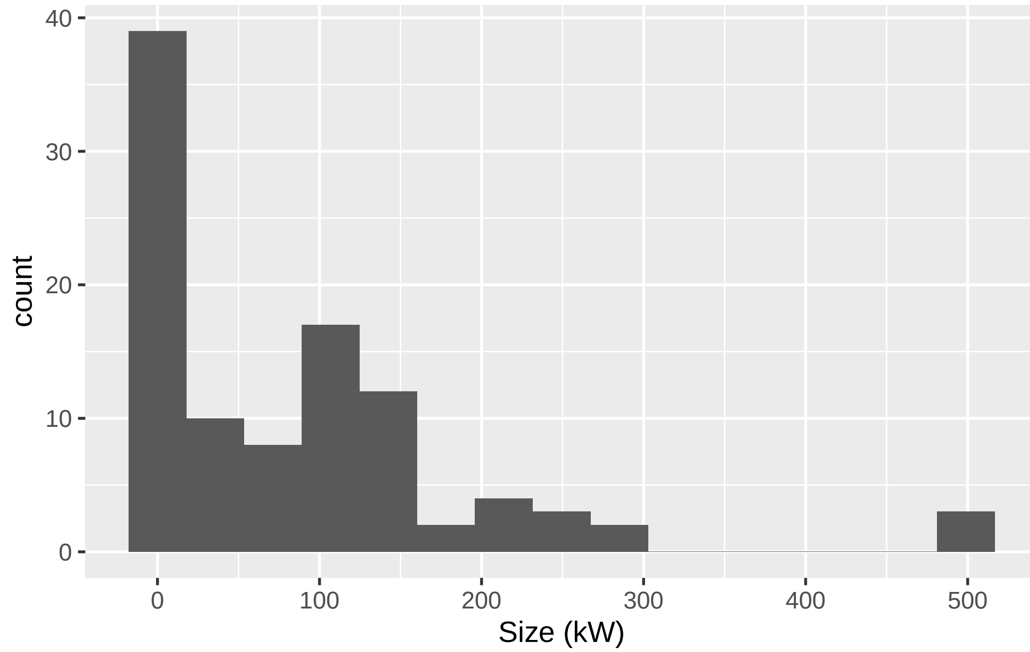

Figure 1: Distribution of size of installation

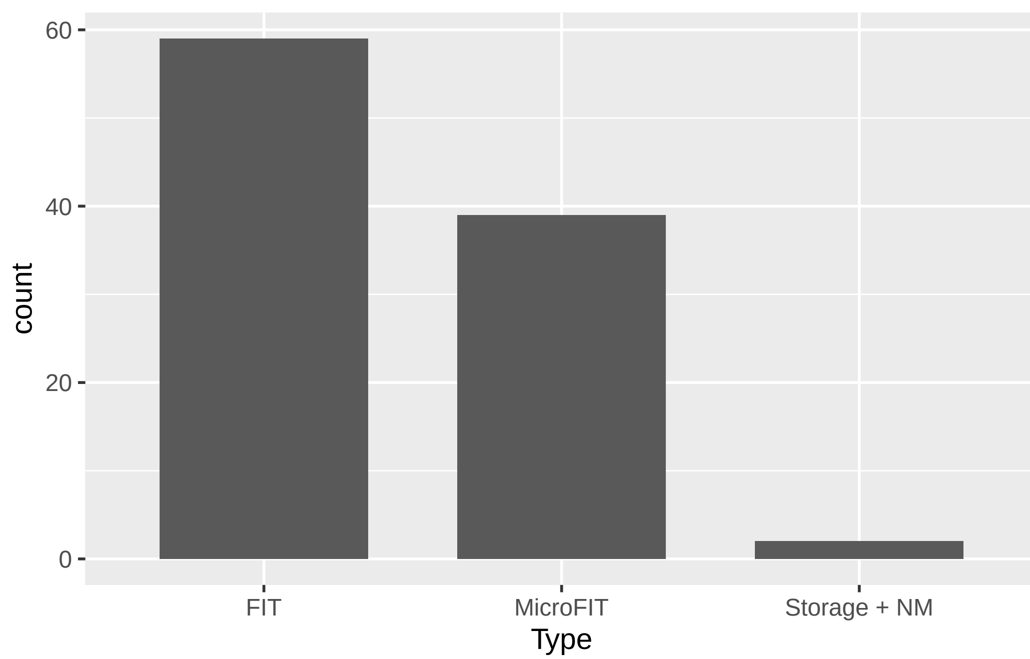

Figure 2: Types of Installations

2.2.3 Time of Installation

Date of installation, with the variable name `date`, takes dates from the 31st of March 2010, to the 1st of January 2019. As seen in Figure 3, the distribution is left-skewed with the highest number of new renewable energy systems installed was in 2018 with 31, whereas the lowest number of new systems was in 2019 with 1. While the original dataset was most recently updated in 2022, there are no entries beyond the single new installation in 2019. Since there has been no officially released statement by the government indicating the stop of installing renewable energy systems, we can make the inference that since the beginning of 2019, there has simply not been any new data collected by the City of Toronto's Facilities Management Division. Therefore, we should be careful extrapolating beyond the timeframe of 2010 to 2018.

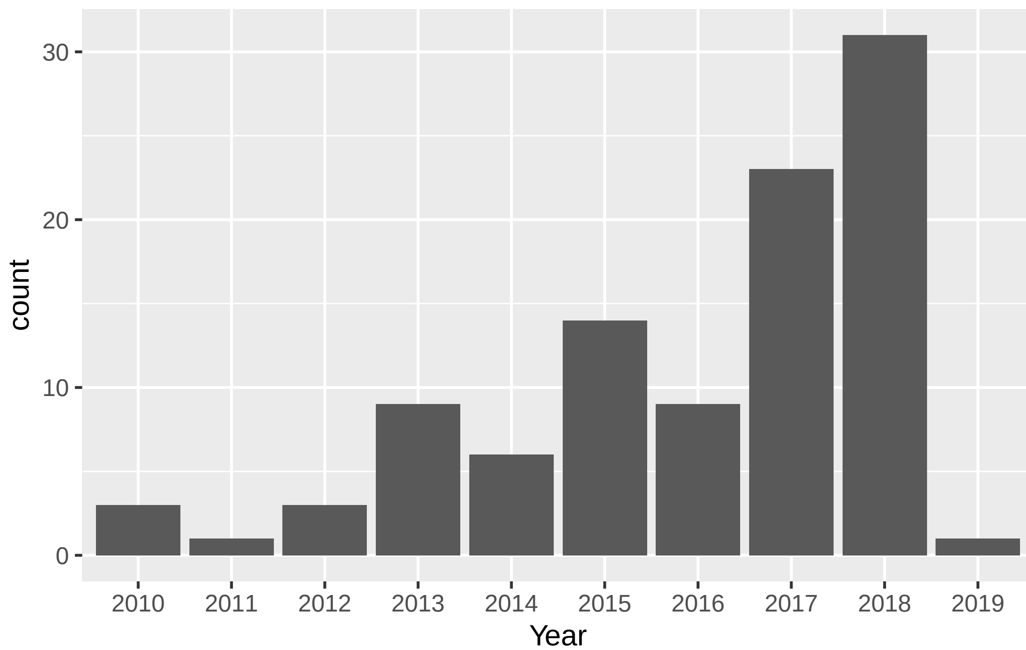

Figure 3: Count of new installations per year

Figure 3 shows a clear upwards trend in the number of newly installed renewable energy systems per year. Until 2016, the number of new systems did not exceed 10, with the exception of 2015, which saw 14 new installations. However, there is a sudden spike in 2017 with over 20 new installations - a development that was also maintained in 2018 with over 30 new installations. Thus, more than half of all systems in the designated timeframe were installed in 2017 and 2018 alone.

2.2.4 Geographical Distribution of Installations

The location of an installation is given by its coordinates, which all fall between the boundaries of Toronto. Figure 4 shows a rather even distribution of installations across the city, however with notably low densities in the Etobicoke Centre, Scarborough-Rouge Park, and Don Valley city wards.

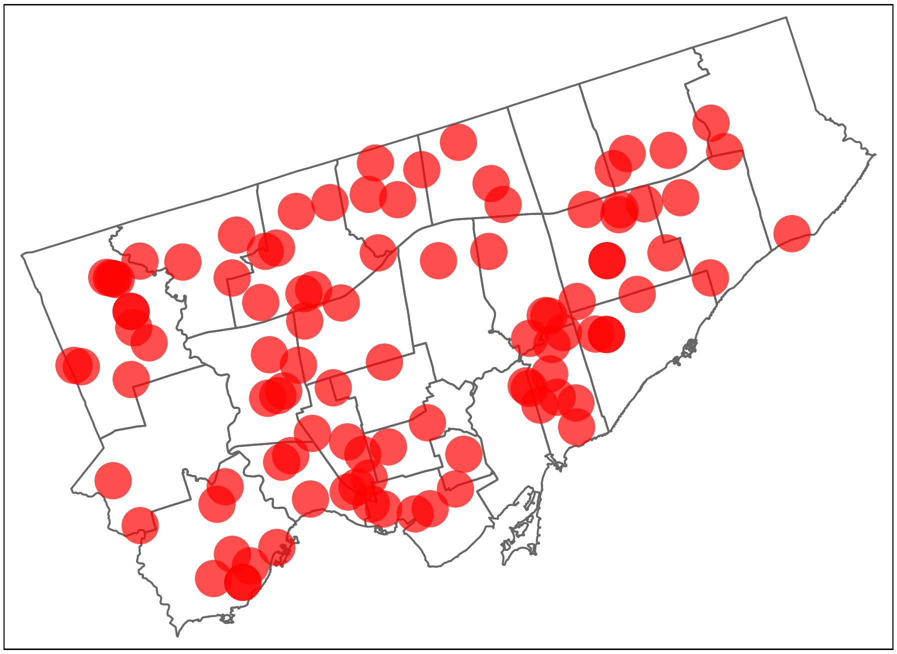

Figure 4: Locations of renewable energy installations in Toronto

3 Results

3.1 Size and type of installation over time

Figure 5 compares the sizes of new installations over time. Most strikingly, the variance of size does not seem to be constant over the years, with very large variation in 2016 and 2018. Therefore, a key assumption of linear regression is not met (Schmidt and Finan 2018), and the modest increase in size shown by the fitted regression line cannot be interpreted with certainty as an underlying increase in installation size over the years. Moreover, when taking a closer look at the dataset, it becomes also clear that the size of the installation is directly linked to the type of installation. In 2017, for example, as shown in Figure 6, the majority of new installations were "MicroFIT" instead of the larger "FIT" systems. Therefore, size values are much smaller in 2017 than they are in 2018.

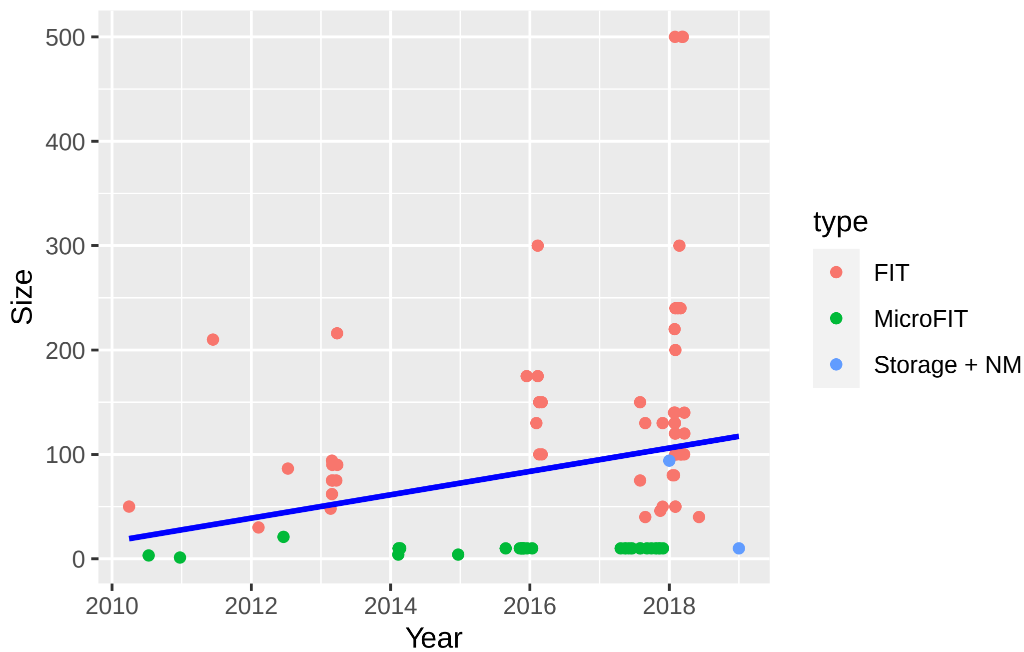

Figure 5: Size of new installations over time with fitted regression line

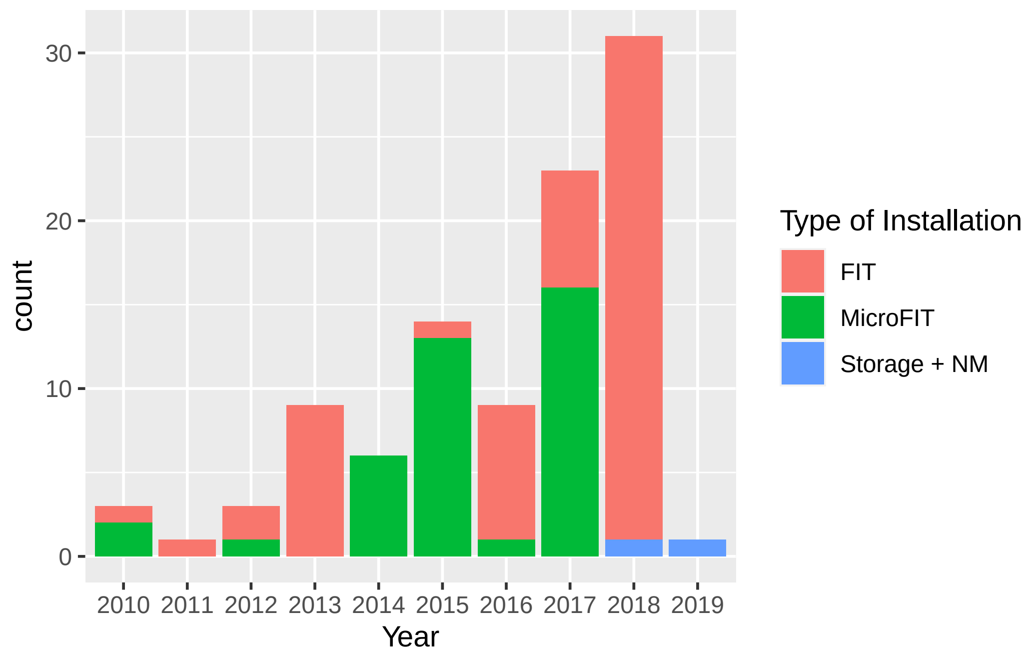

Figure 6: Count of new installations by type per year

3.2 Location of Installation over Time

Figure 7 shows that even in earlier years, before the peak, installations were distributed fairly evenly across the city. Due to the low volume in these years, however, there were of course many gaps, which were strategically filled in later years. The map also reveals that there is a notable trend of expanding more into the city's periphery in recent years rather than installing more systems in the downtown core.

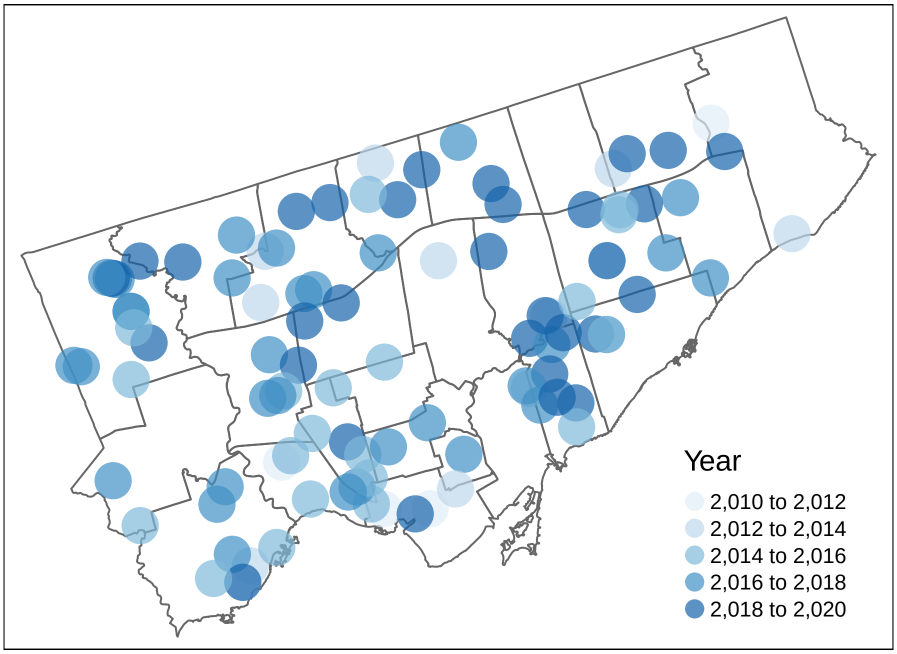

Figure 7: Geographical Distribution of installations over the years

4 Discussion

The examination of a publicly available dataset on renewable energy installations from 2010 to 2019 offers valuable insights into Toronto's renewable energy landscape. The observed upward trajectory in the number of installations, peaking notably in 2017 and 2018, indicates a concerted effort to expand and diversify the city's renewable energy infrastructure. Although the kilowatt size of installations does not exhibit a clear trend, the data reveals a strategic shift towards incorporating a variety of installation types, encompassing both smaller and larger systems.

The subsequent exploration of the relationship between installation size, type, and their distribution over time is crucial to understanding the city's commitment. The regression analysis on installation size over the years, although inconclusive due to varying variances, reinforces how installation size and type interact, and the role that different financing models may play. The concentration of smaller installations in certain years, such as 2017, further emphasizes the importance of considering installation types when interpreting size trends.

The geographical distribution map illustrates how even in earlier years, installations were spread across the city, with subsequent strategic efforts to fill gaps and extend installations into the periphery (e.g. North York and Scarborough) in recent years. This trend signifies a strategic and deliberate expansion beyond the downtown core, reflecting an equitable approach to renewable energy infrastructure.

However, it is essential to acknowledge the limitations of this analysis. The dataset primarily focuses on city divisions, excluding data from other city agencies or public-private partnerships involved in renewable energy initiatives. This limitation may impact the comprehensiveness of the dataset and potentially overlook significant installations managed by other entities.

In conclusion, the city government's commitment towards sustainable energy practices is evident in the increasing number and strategic distribution of renewable energy installations. This analysis contributes to a better understanding of Toronto's commitment to renewable energy, paving the way for informed discussions on the city's progress and future endeavors in combating climate change.

A Appendix

A.1 Data Cleaning

ID and size of installation did not require any further processing and are both of type 'double'. Type of Installation required some cleaning: Typos were fixed and similar types were merged together (e.g. "MicroFIT A" and "MicroFIT B" were combined into "MicroFIT"). The date of installation required some processing, namely the standardization into one date format and imputing missing month or day values to January or the first day of the month, respectively. For a less granular analysis of when installations occured, I also created an additional year of installation variable, based on the original date of installation.

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