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.

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).

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

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 and relevant variables explained (Section 2). The reproducible data cleaning process can be found in the appendix (Section A). Then, the cleaned dataset is explained and important summary statistics outlined. Finally, the data is visualized and contextualized in order to draw conclusions from it, which contribute to the broader understanding of Toronto's renewable energy efforts.

2 Data

The dataset that is analyzed in this paper using R (R Core Team 2022) was obtained on the City of Toronto's Open Data Portal and is titled "Renewable Energy Installations" (opendatatoronto 2022). Specifically, they collected the locations of installed renewable energy systems on city-owned buildings such as photovoltaic, solar pool heating, and geothermal installations. The aforementioned increased relevance of renewable energy in Toronto's combat with climate change gave rise to this dataset. However, one 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 raw dataset has been downloaded using the opendatatoronto package (Gelfand 2022) and contained 100 unique observations and 41 variable columns. This dataset has then been cleaned using the packages tidyverse (Wickham et al. 2019), lubridate (Wickham 2023a), and stringr (Wickham 2023b). First, only the variables of interest were selected: ID, type of installation, date of installation, and size of installation. An additional year of installation variable was created to simplify certain aspects of the analysis. The ID and date of installation variables are self-explanatory. Size of installation refers to the kilowatts (kW) that are measured at each of the installations. Type of Installation refers to whether the system falls under the FIT or

microFIT program. 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).

In the final cleaned dataset, shown in Table 1, IDs are between 1 and 100, with no duplicates. Size of Installation, with the variable name `SIZE_INSTALL`, takes values between 1.2 and 500.0 kW. The distribution is right-skewed, as shown in Figure 1. As can be seen in Table 2, the mean and median sizes are 88.1 and 68.5 kW, respectively, with a standard deviation of 102.82 kW. Taking a closer look at `TYPE_INSTALL` in Figure 3, 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, since microFIT only applies to installations with less than 10 kW.

Date of installation, with the variable name `DATE_INSTALL`, takes dates from the 31st of March 2010, to the 1st of January 2019. As seen in Figure 2, 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. We can make the inference that since the beginning of 2019, there has not been any new data collected. Therefore, we should not extrapolate too much beyond the timeframe of 2010 to 2018.

Table 1: Cleaned Data of Renewable Energy Installations

ID	TYPE_INSTALL	DATE_INSTALL	SIZE_INSTALL	YEAR_INSTALL
1	FIT	2010-03-31	50.0	2010
2	FIT	2012-02-08	30.0	2012
3	MicroFIT	2010-12-23	1.2	2010
4	MicroFIT	2010-07-12	3.2	2010
5	FIT	2013-02-27	62.0	2013
6	FIT	2013-03-26	216.0	2013

Table 2: Size of Installation Summary Statistics

Mean	Median	SD
88.1	68.5	102.82

Figure 2 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.
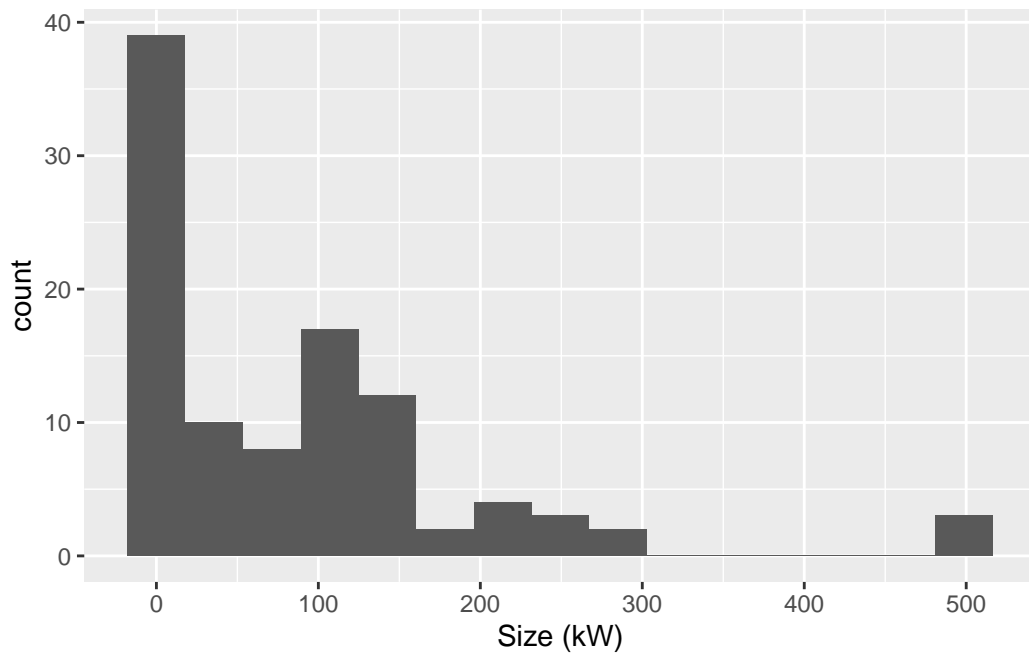
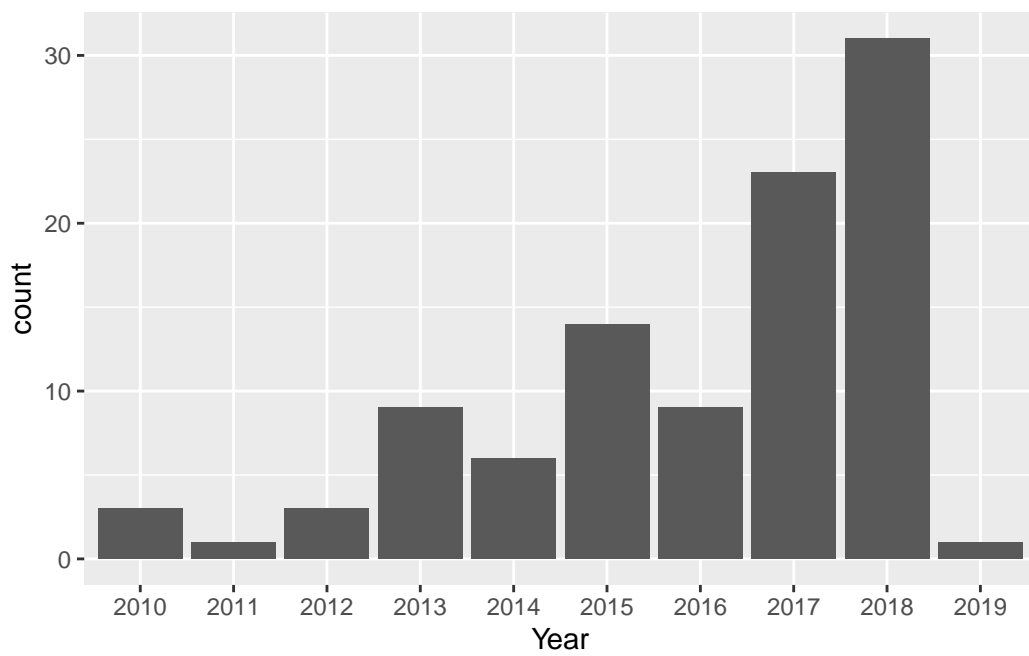Figure 1: Distribution of size of installation
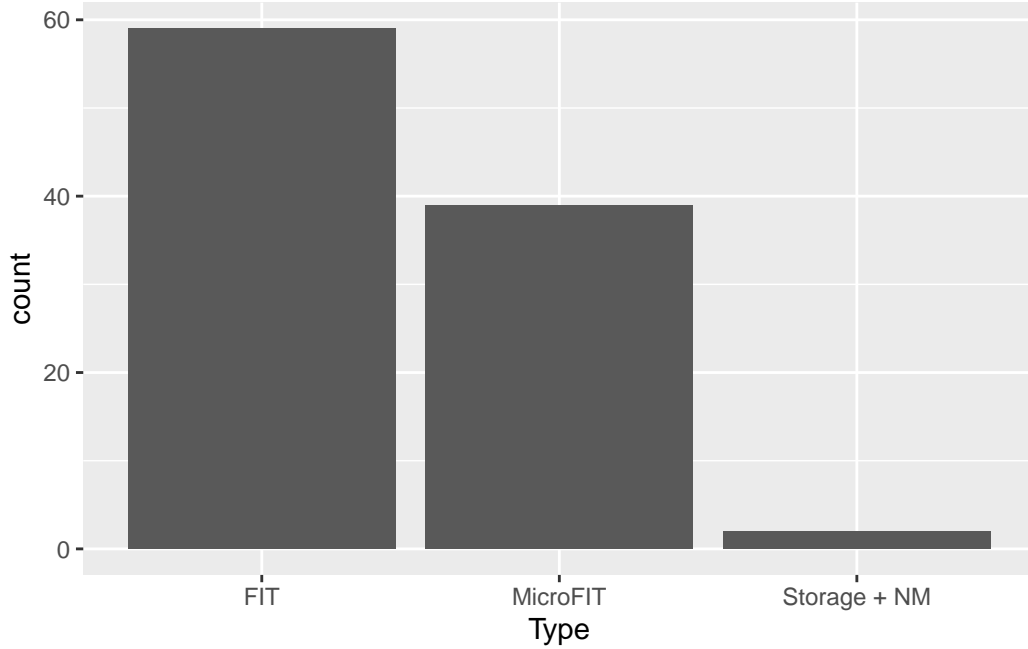

Figure 2: Count of new installations per year

Figure 3: Types of Installations

Figure 4 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 5, 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.
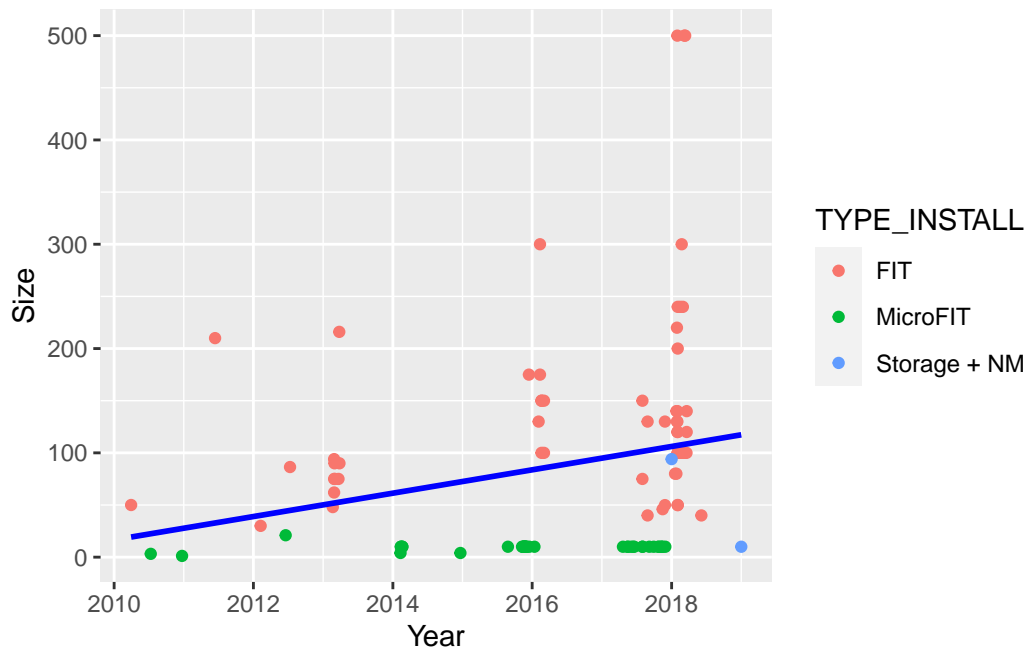
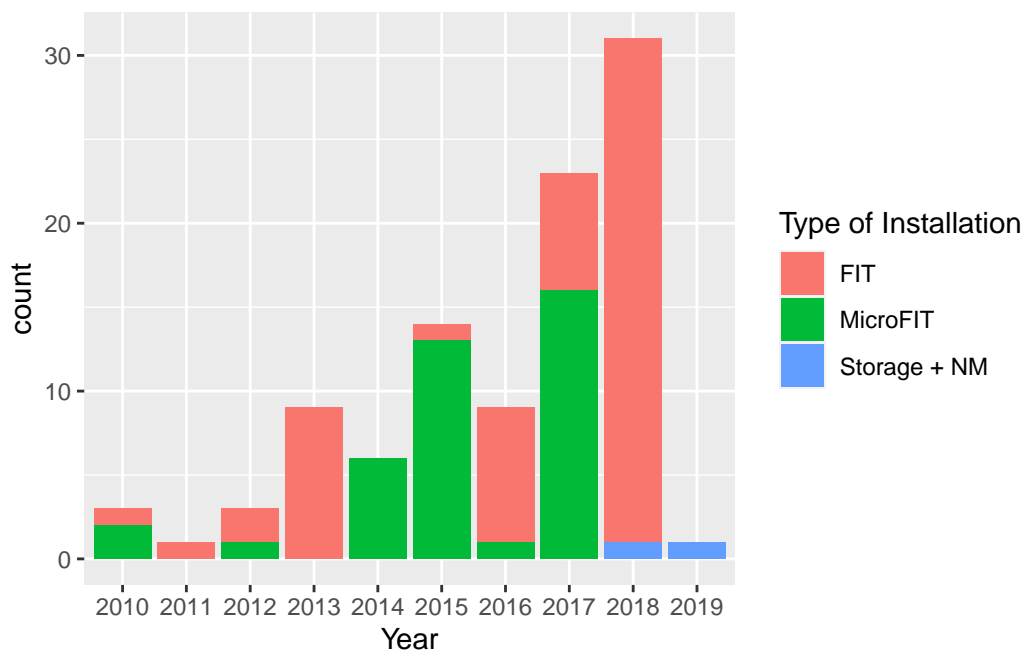Figure 4: Size of new installations over time with fitted regression line

Figure 5: Count of new installations by type per year

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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