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Building energy efficiency progress in world-leading cities: what do the data show?

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Abstract

Cities are often described as the policy laboratories where new policies can be tested, and cities are often cited as leading the world in new climate policies, including building energy efficiency policy activity. Many of the policies are adopted based on expected effectiveness in driving energy use reduction, though there has not been a lot of formal evaluation on the progress that cities have in reducing building energy use across a large economy. Some world-leading cities have in the past decade launched policy initiatives linked to close tracking of both energy and GHG performance from an established baseline, which provides an opportunity to review the real progress from the policies.

This paper reviews the progress on building energy reduction, normalized to economic activity, population, and GHG emissions, in two globally recognized policy leading large cities: Tokyo and New York City. The paper focuses on these two cities that have committed to ambitious building energy and GHG reduction policies (e.g. building energy benchmarking and cap-and-trade) and have done comprehensive annual progress reporting of both energy and GHG emissions down to building sector (e.g. residential, services, etc.) level. It discusses data challenges with comparability of progress, and recommendations to make future comparisons of relative progress more robust.

Introduction

The world's economic activity and population is increasingly concentrated in major urban areas; it is forecast that by 2050 85 % of global GDP will be generated by urban areas. In 2013, the world's urban areas accounted for 64 % of global primary energy use, and 70 % of global CO_2 emissions (IEA 2016). In recent years, in many countries, local governments have picked up the leadership baton from national governments on sustainability and climate change. Instead of waiting for federal action, cities have recognized that they have the ability to develop and implement impactful policies at the local level.

While the world's largest cities are increasingly becoming important players for global climate sustainability, they are already well established as major drivers of the world's economy. They are home to major blocks of population and are generally magnets for creativity and innovation. Because of this, climate risks to cities will not only harm people, certainly enough to warrant concrete action, but will also impact the reliability and durability of the global economy.

The greatest source of greenhouse gas (GHG) emissions in large cities is usually from either energy use in buildings or transportation. Many cities in well-developed parts of the world often have advanced mass transit systems. These systems minimize both total and per capita energy use and emissions from transport and leave buildings with a larger portion of the cities' energy and carbon footprint. In the two cities analysed in this paper New York City and Tokyo – building sector emissions account for approximately 66 % and 77 % of total city emissions, respectively.

Buildings provide cities with significant opportunities for GHG emissions reductions; however, this sector has challenges. Numerous barriers exist for achieving substantial GHG emissions reductions in the building sector; examples include having multiple stakeholders with varied interests and the conflict between building occupiers who use energy and buildings owners who may be expected to pay for energy efficiency measures (the "split incentive"). Additionally, complex legal systems affect each city government's capacity to act, especially on private sector buildings. Cities' capacities to act are generally determined by the power delegated to them by national and/or state governments.

Fortunately, mayoral leadership on urban sustainability has been steadily increasing over the past fifteen years. Cities have demonstrated a willingness to not only lead, but also to collaborate with each other and share the lessons of their success. For example, mayors in over ninety megacities have joined the C40 Cities Climate Leadership Group to achieve meaningful GHG emissions reductions across their citywide emissions portfolios.

For this paper, we have focused on two "world leading cities" that generally appear at or near the top of any ranking of the world's most influential metropolises: New York City (NYC) and Tokyo. The climate change challenge has been an important priority for the mayors of each of these cities over the past one to two decades. Recent "extreme weather" events in cities like New York, and the electricity shortages in Tokyo following the Fukushima disaster have only reinforced this imperative.

This paper focuses on building energy efficiency and emissions reductions policies, and available data to document progress, in NYC and Tokyo. These two cities are good candidates for analysis as they are widely recognized as global leaders, both with policies, and transparency of publicly reported, longitudinal data on building energy consumption and resulting emissions. Our analysis begins to address several questions, including what has each of these leading cities accomplished, given the drive to reduce GHGs; what are the results of their building policies; and how are their buildings performing, given each's targeted efforts to reduce emissions from the built environment?

Tokyo established a greenhouse gas (GHG) reduction goal of 25 % below the 2000 emissions level by 2020, while the initial NYC goal established in 2007 was 30 % reduction from 2005 baseline by 2030. In 2016, NYC strengthened its goal to a 40 % reduction by 2030, and 80 % reduction by 2050. Additionally, in 2018, as part of the Net Zero Carbon Building Declaration announced by a range of cities in September 2018, both cities committed to enacting regulations and/or planning policy to ensure that new buildings operate at net zero carbon by 2030, and that all buildings operate at net-zero carbon by 2050 (C40 2018).

While other smaller cities have established more ambitious goals, and may have more detailed data available, the world watches when the global leaders make announcements about climate and energy policy leadership. The ambitious targets set in the two cities have led to a variety of building energy policies, with documented impacts, that are described more in this paper.

Review of New York City and Tokyo building EE policy activity

Tokyo and New York City are obviously not the only leading cities doing ground breaking and world leading policies in building energy efficiency, but they have been widely recognized as global policy leaders. We discuss their policy achievements below.

For both of these cities (and nearly all others except a small number of national "city-states" such as Singapore), the impacts and overall building energy efficiency and GHG reduction progress are not only driven by city policies, but generally also a mix of policies and support initiatives developed and implemented by other layers of government, including state or provincial activities, regional energy provider/utility mandates or obligations, and national level policies that impact building energy performance.

TOKYO

In June 2007, the Tokyo Metropolitan Government (TMG) built on prior clean energy initiatives and formalized its climate change mitigation vision in the Tokyo Climate Strategy (TMG 2007). The Strategy was a 10-Year Plan establishing goals to reduce carbon emissions by 25 % by 2020, from a 2000 baseline. It set the stage for TMG's two major policies to address energy consumption in existing buildings, namely the Tokyo Cap-and-Trade Program (TCTP) and Carbon Reduction Reporting (CRR) for Small and Medium Entities.

Collectively, the TCTP and CRR address the most significant source of GHG emissions in Tokyo, commercial and industrial buildings. In the 2016 Fiscal Year (FY), the sector was responsible for 52.3 % of Tokyo's total GHG emissions (TMG 2018a). TCTP targeted the most-energy intensive buildings in the sector. The approximately 1,400 buildings required to comply with TCTP – made up of large industrial and commercial buildings – were responsible for 20 % of Tokyo's emissions (C40 2014). TMG required that buildings whose annual energy consumption exceeded 1,500 kL (in crude oil equivalent) be in TCTP. The balance of the sector's GHG emissions are attributed to 660,000 small and medium-sized buildings (C40 2017). TMG created the CRR to target these smaller buildings. As discussed more below, buildings whose annual energy consumption was less than 1,500 kL were eligible or required to participate in CRR.

TMG enacted TCTP in 2008 and began administering it in 2010. Through TCTP, each covered building is required to meet emissions reduction goals during two back-to-back compliance periods. The first period ran from April 2010 to March 2015 and the second runs from April 2015 to March 2020. Depending on the building type, facilities were required to reduce their emissions by 6 % or 8 % from baseline emissions in the first compliance period and 15 % to 17 % in the second compliance period (C40 2014). Facilities reduce emissions levels by installing energy efficiency measures, generating renewable energy, purchasing credits from other participants, or any combination thereof.

Initial results indicate that buildings participating in TCTP have seen significant reductions in their emissions. In the final year of the first compliance period, emissions in the covered buildings decreased by 25 % from emissions in the baseline year (Trencher et al. 2016).

CRR is a reporting program targeting those buildings not participating in TCTP. Program participants have their emissions levels published in annual reports and gain access to feedback and guidance from TMG. The program is mandatory for some building owners and voluntary for others. Those facilities with annual energy consumption of between 30 kL and 1500 kL must participate. Businesses owning multiple facilities must participate if energy consumption across their portfolio

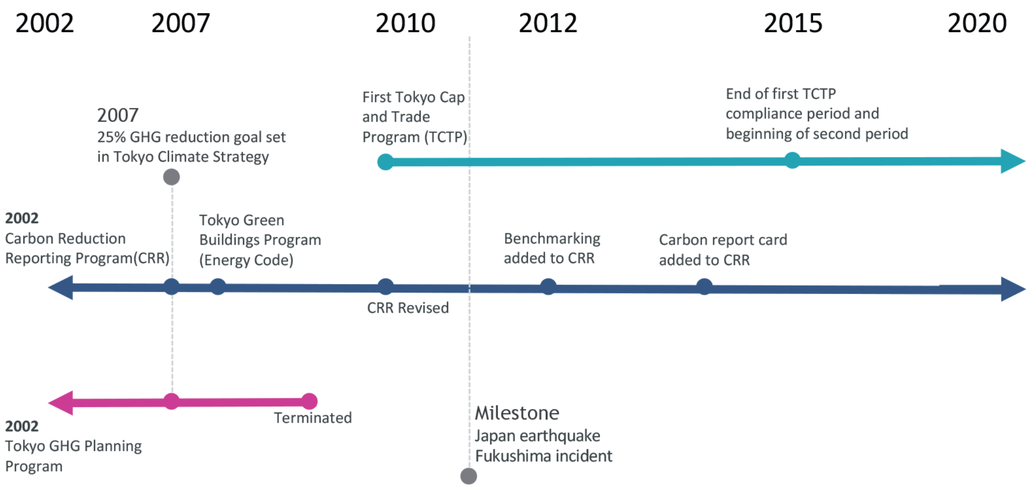

Figure 1. Recent policy timeline for Tokyo Municipal Government.

is greater than or equal to 3,000 kL. However, the number of voluntary program participants is larger than mandatory participants. In FY2015, TMG required 291 entities to participate but 1,871 entities, representing 11,746 individual facilities, participated voluntarily the same year (C40 2017).

While CRR originally started solely as a reporting program, it has evolved over the years. In 2012, TMG added building benchmarks to reporting forms, allowing participants to see how their buildings compared to buildings of similar size and use. In 2014, TMG introduced a Carbon Report Card that could serve as the beginnings of a building labelling initiative. It contains both quantitative information on GHG performance as well as qualitative information on ongoing or planned energy efficiency measures (C40 2017).

Data shows that buildings covered by the program have experienced reductions in GHG emissions levels. Nearly 24,000 buildings submitting reports for five consecutive years beginning in 2010 saw CO_2 emissions reductions of 13.3 % (C40 2017). However, it is important to note that other exogenous factors effected emissions reductions, most notably the Fukushima Daiichi Nuclear Power Plant meltdown.

Unlike in the United States, state or provincial government policy does not affect energy use in Tokyo. Japan is divided into 47 prefectures; within this system, Tokyo is a prefecture unto itself. No layer of government exists in between TMG and the national government.

Nationally, Japan has had some world leading energy efficiency policies that have significant impact on Tokyo building energy consumption. There are a variety of different product efficiency standards in place, and Japan has a world-leading "Top-Runner" program that recognizes highest efficiency equipment, and moves that highest efficiency level toward broader market adoption. Additionally, there are requirements for building owners and developers to submit energy savings plans when undergoing large renovations.

NEW YORK CITY

New York City has a long history of using local policy and regulatory action to target energy savings in its buildings. In 2007, New York City launched PlaNYC, one of the world's first major city sustainability plans, with a target of reducing gross CO_2 emissions 30 % by 2030, despite the expected addition of over 1 million new residents and strong economic growth during that period. Further, the City would lead by example, with a target to meet the same 30 % CO_2 reduction within its own operations within ten years (by 2017). Recognizing that buildings represented over 70 % of the City's GHG footprint, New York City adopted the Greener, Greater Buildings Plan (GGBP) in 2009 as part of its PlaNYC sustainability initiative. GGBP's goal was to target energy use in its large existing buildings and ramp up energy savings. It did so through the passage and implementation of several local laws, namely local laws 84, 85, 87, and 88.

Local Law 84 of 2009 (LL84) has been one of the calling cards of the GGBP. It required the benchmarking of individual buildings larger than 50,000 square feet and the benchmarking of groups of buildings on a lot if the square footage of the buildings on that lot exceeded 100,000 square feet. Altogether, the policy covered 47 % of building floor space in New York City (NYC 2017a).

Results from the first six years of the program (2010 through 2015) show compliance rates going up while energy use and GHG emissions go down. The compliance rates among all buildings have improved dramatically throughout the six years with available data. As of 2015, more than 90 % of the private buildings that were required to comply with the ordinance had done so (NYC 2017a).

Results also show that New York City has seen energy savings of 6 % to 14 % within the first three to four years of the program and GHG emissions avoidance of up to 14 % (Meng et al. 2017; NYC 2017a). The energy saving and GHG avoidance may have been boosted by other local government efforts, including other aspects of the GGBP. Local Law 88 requires lighting upgrades in select buildings and Local Law 87 requires energy audits and retro-commissioning once every ten years for large buildings. New York City also has oil heating system requirements – eliminating the use of residual fuel oils (#4 and #6) – that have led many building owners to convert to newer more-efficient heating systems.

In 2016, New York City took steps to further strengthen its energy efficiency programs. Local Law 133 of 2016 expanded the benchmarking requirement by amending LL84 to include

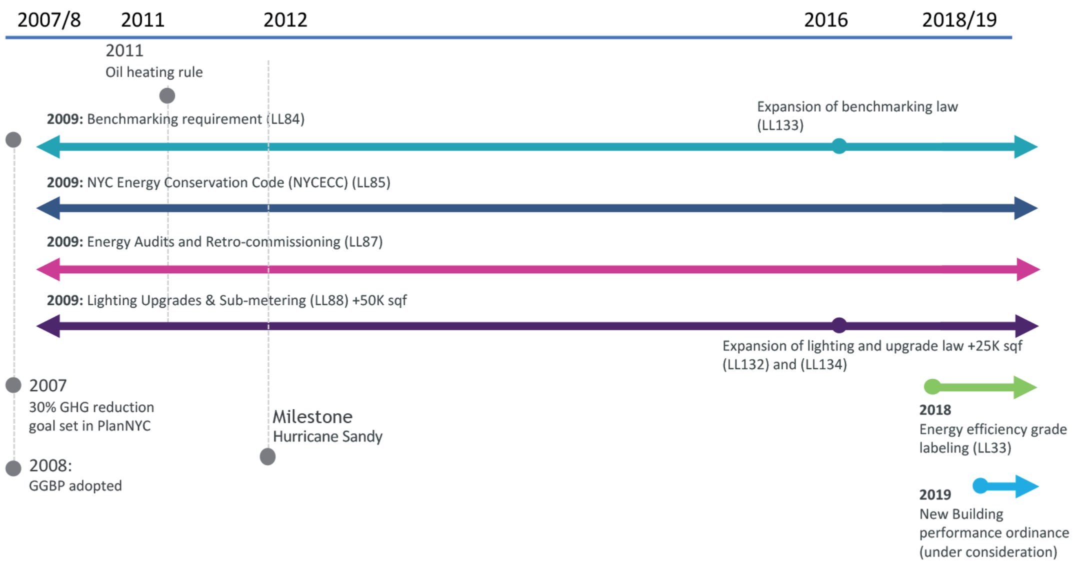

Figure 2. Recent policy timeline for NYC.

properties 25,000 square feet and up, approximately 57 % of floor area in NYC. Furthermore, Local Law 33 of 2018 takes innovative steps to make buildings' energy performance more transparent. It requires large buildings to display energy efficiency grades by 2020 based on their ENERGY STAR scores. Labelling buildings using scores or grades can raise customers' and tenants' awareness of energy consumption even more. The City is also using benchmarking data to inform its policy decisions, leveraging the data to inform the development and targeting of retrofit requirements. Legislation is currently pending that would mandate significant energy retrofits, requiring large buildings to meet prescribed GHG intensity targets, expressed as CO^2e per unit of floor area.

We must acknowledge that New York City benefits from energy efficiency initiatives driven by state and federal policy. In each edition of ACEEE's State Energy Efficiency Scorecard – an annual report dating back to 2007 – New York State has ranked in the top-ten of all US-states for energy efficiency. Utilities operating in the state continue to treat energy efficiency as a supply side resource through their energy efficiency portfolios and programs through New York State Energy Research and Development Authority and its Clean Energy Fund allocate funding for energy efficiency. The State has also adopted new, stringent building codes and was one of the first states – after California – to set appliance standards in the 1980s.

On the federal level, appliance standards have been valuable in driving savings. Standards began taking effect in 1990, and now over 50 appliances are covered. The total savings from all these standards amount to 12 % of US electricity consumption and 4 % of US end-use natural gas demand (Nadel et al. 2015).

Available data

As noted above, Tokyo and NYC were chosen for analysis in this paper – both cities have been recognized as leaders in building policies through C40 and other global city rankings. Both cities are also leaders in the transparency of energy and GHG data, and the level of data publicly available that makes longitudinal comparison of policy performance and progress possible. In fact, the two cities' regular reporting of granular energy consumption and resulting GHG emissions data by sector, fuel, and a variety of other factors allows for more detailed analysis than any other major cities.

However, some challenges exist in comparing the building energy and GHG performance in these two leading cities. The Tokyo energy data are reported in "final energy" (often referred to as "site" energy use in North America), while "source" or "primary" energy is more widely used in NYC and other US city reporting.[1]

Another challenge is that since both cities began reporting detailed energy and GHG data around 10–12 years ago, reporting protocols have evolved significantly (some of this evolution led by one or both cities) in order to have more comparability among cities internationally. While important, the evolution means that realistically there is not a static baseline year of data, making longitudinal review more challenging.

TOKYO

Tokyo has probably the most detailed regular, public energy consumption and GHG emissions data reporting of any major city in the world. Since 2012, Tokyo has released a very comprehensive annual "Final Energy Consumption and Greenhouse Gas Emissions in Tokyo" report (most recent version TMG 2018b). The reports contain a wealth of very detailed data on how energy is consumed in Tokyo, by sector, fuel, and many other characteristics, even including data on saturation of air-conditioners and other residential appliances, as well as trends in refrigerator efficiency among units sold in Tokyo.

A high-level view of Tokyo citywide building sector energy use and GHG emissions is shown in Figure 3, drawn from TMG 2018b. While building energy consumption grew from 1990 through 2005, it has been steadily decreasing since 2007; the largest reductions have come from the commercial sector

1. Final or site energy refers to energy used onsite by end users. Primary or source energy refers to energy use onsite plus energy used to generate and transmit energy (i.e. transmission, delivery, and production losses in the electricity system).

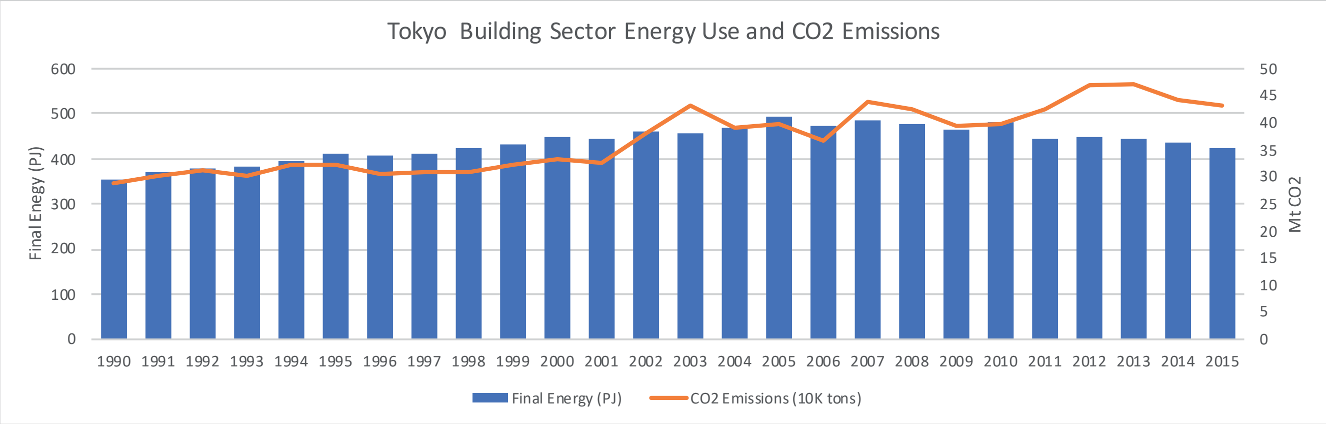

Figure 3. Tokyo Building Sector Energy Use & CO_2 Emissions (1990–2015).

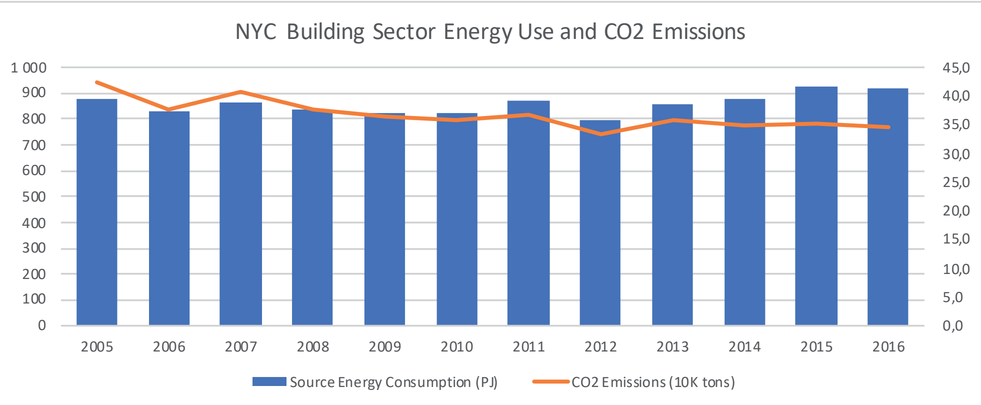

Figure 4. New York City Building Sector Energy Use & CO_2 Emissions (2005–2016).

while residential consumption has stayed relatively flat from 2001 to 2015. The GHG emissions, though, rose through 2013, largely due to the loss of most of Tokyo (and Japan's) low emissions nuclear electricity generation. There is a marked decrease in the GHG emissions from 2013 to 2015, likely due to the TCTP first compliance period deadlines, and intensive conservation efforts following the Fukushima incident.

Beyond the detailed, macro level data on energy and GHG emissions from buildings (and other sectors), the specific Tokyo buildings covered by the Cap-and-Trade policy also have individual building emissions levels and progress toward their emissions allowance, reported annually, as we discussed earlier.

NEW YORK CITY

Since releasing its first GHG emissions inventory in 2007 (reporting 2005 energy consumption and emissions data), NYC has prepared and publicly released an annual GHG emissions inventory report that includes detailed information on energy consumption by fuel, and by sector, breaking out buildings by residential, commercial and institutional. In addition to the citywide detailed energy consumption and GHG data, the annual inventory reports also have details on energy consumption by fuel for all City Government facilities.

When compared with Tokyo, NYC building sector wide source energy consumption has stayed more level, though sectoral GHG emissions have been reduced more significantly, particularly since 2011.

TRENDS IN CITY BUILDING ENERGY DATA AND RELATED FACTORS

Exogenous factors as well as endogenous policy-related actions affect energy consumption levels and GHG emissions from cities. For example, GHG emissions reductions may be driven by local government programs to encourage more energy-efficient buildings (endogenous), a decline in population or economic activity (exogenous), or a combination of both.

In our analysis of trends in city building energy consumption, we sought to better understand the role that exogenous and endogenous factors had in energy consumption trends in New York City and Tokyo. The figures that follow display percent changes in energy consumption, GHG emissions, gross city product (GCP), and population in each city.

We cannot make causal linkages between exogenous and endogenous factors using these charts, but they inform lines in inquiry to explore.

Figure 5[2] displays exogenous and endogenous factors related to energy consumption in New York City. Changes in energy consumption, GHG emissions, and gross city product (GCP) are somewhat correlated until 2010, with 2006 as an outlier (perhaps due to weather, with an extremely mild heating and cooling year in 2006). From 2011 on, the three diverge. GCP steadily rises; energy consumption stays relatively flat, and

2.New York City GCP and Population data from https://nyc-ghg-inventory.cusp.nyu.edu/.

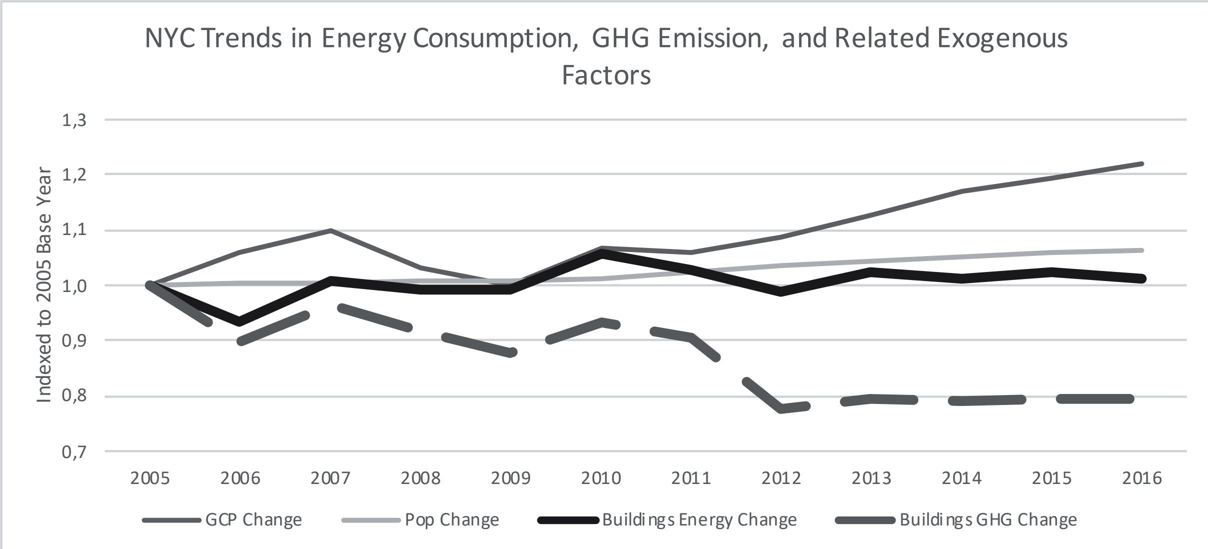

Figure 5. New York City trends in energy consumption, GHG emissions, and related exogenous factors.

GHG emissions initially fall but then level out. Some policies were entering implementation phases by this time, including the benchmarking, audit, and retro commissioning requirements adopted in 2009. However, there are items not displayed that may have affected energy levels and GHG emissions as well. Hurricane Sandy hit the New York City area in 2012. Its impacts likely affected energy consumption levels and GHG emissions. In addition, changes to the electric generating fuel mix in New York City significantly reduced GHG emissions, as well as substantial efficiency improvements in the City's district heating system, explaining some of the drop in GHG emissions decoupled from energy consumption.

Similarly, Figure 6[3] shows exogenous and endogenous factors related to energy consumption in Tokyo. The correlation between energy consumption and GHG emissions was similarly correlated from 2005 through 2011, though diverged sharply in 2012 and 2013, largely due to major changes in the GHG intensity of electricity following the Fukushima incident that closed nuclear power plants throughout Japan.

Discussion

Beyond the policies highlighted earlier in this paper, both cities have a wide range of support initiatives and market development activities through energy providers/utilities, financing support, and major information programs and campaigns. The comprehensive approach taken in both cities (two of the world's largest, and wealthiest cities) has meant that nearly any potential support activity and policy initiative is considered for implementation, and the result is two of the most comprehensive policy packages of large cities in the world. The approach to "comprehensive policy packages" has been shown to be the most effective approach to building energy efficiency improvement (see Levine et al 2012). While NYC is highlighted as the global leader in that cited research, Tokyo's approach has been more recently highlighted as extremely comprehensive and driving success in reducing building sector energy consumption (C40 2014 and 2017).

FINDINGS

Progress made but more to do to reach goals

In both cities, building sector energy consumption has been somewhat flat over the past ten to fifteen years despite substantial economic and population growth, a very healthy demonstration that energy consumption can be decoupled from economic activity. The GHG emissions picture has been quite different between the two cities, largely driven by very different changes to fuel mix and relative GHG intensity of electricity over the period analysed.

Looking at the results with building sector energy and GHG reductions over the period could be viewed as less successful than expected, given the ambitious goals established by each city. That said, the policy activities in these two cities have been copied and adopted in many other cities in their regions, with results that have shown dramatic impacts relative to cities without the same types of policies.

Drivers for changes in GHG emissions

In NYC, building energy consumption for the overall buildings sector has been relatively flat from 2005 to 2016. However, the largest buildings (those covered by GGBP) have shown approximately 10 % source (primary) energy, and 14 % GHG, reduction from 2010 through 2015. According to the most recent NYC GHG Emissions inventory,[4] the GHG emissions from NYC citywide buildings, though, has dropped by 20.5 % from the 2005 baseline.

Tokyo saw steady growth in energy consumption through 2007, but from 2010 to 2015, buildings sector energy consump-

3. Tokyo population history from http://www.metro.tokyo.jp/ENGLISH/ABOUT/HISTORY/history03.htm; Tokyo GCP data (in Japanese Yen) from http://www.toukei.metro.tokyo.jp/keizaik/kk16qa0310.xls.

4. Inventory of New York City Greenhouse Gas Emissions in 2016, published by the City of New York, December 2017. https://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/GHG%20Inventory%20Report%20Emission%20Year%202016.pdf

tion dropped by over 12 %, a very impressive more than 2 % per year reduction. However, GHG emissions (the metric for the goals established in the city) have risen fairly dramatically, partially driven by a very different electric generating fuel mix in the city.

Both cities have seen significant shifts in the fuel mix serving buildings, particularly for electricity in Tokyo. Prior to the Fukushima tsunami in 2011, the vast majority of Tokyo's electricity came from carbon free nuclear power generation, but with the shutdown of most nuclear plants following the Fukushima disaster, by 2015 a very small portion of electricity came from nuclear, with much of the difference made up by fossil fuel fired electricity generation. In NYC, the CO2e/MWh dropped from 429 in 2005 down to 260 in 2016, a drop of more than 39 %, by far the biggest driver of citywide GHG emissions reduction. These big changes in relative carbon intensity of electric generation in the two cities are highlighted in Figure 7. The fossil fuel mix serving NYC buildings also shifted quite significantly during that period due to some city laws that phased out the burning of higher carbon intensity residual fuel oil, much of it replaced with cleaner natural gas or distillate fuel oil (which has also dramatically lowered local air pollution, resulting in measurable public health benefits).

It is unclear if Tokyo and NYC are fully taking advantage of EE opportunities throughout the whole of their building stocks as non-efficiency factors seem to be the most significant drivers of GHG emissions. As the next section discusses, portions of the cities' buildings stocks are achieving energy savings but these savings appear uneven throughout communities. However, it is impossible to know for sure as no business as usual scenarios exist to our knowledge.

Differing Energy Trends Within Cities

Because the largest buildings/emitters in each city publicly report their GHG emissions data each year, it is possible to compare the progress among the largest facilities to understand how buildings have improved over time.

In NYC, there seems to be a significantly different trend line for the largest buildings, those covered by the 2009 Greener, Greater Buildings laws. For the over 4,000 buildings that consistently benchmarked and reported their performance for all years from 2010 through 2015, those buildings reduced energy

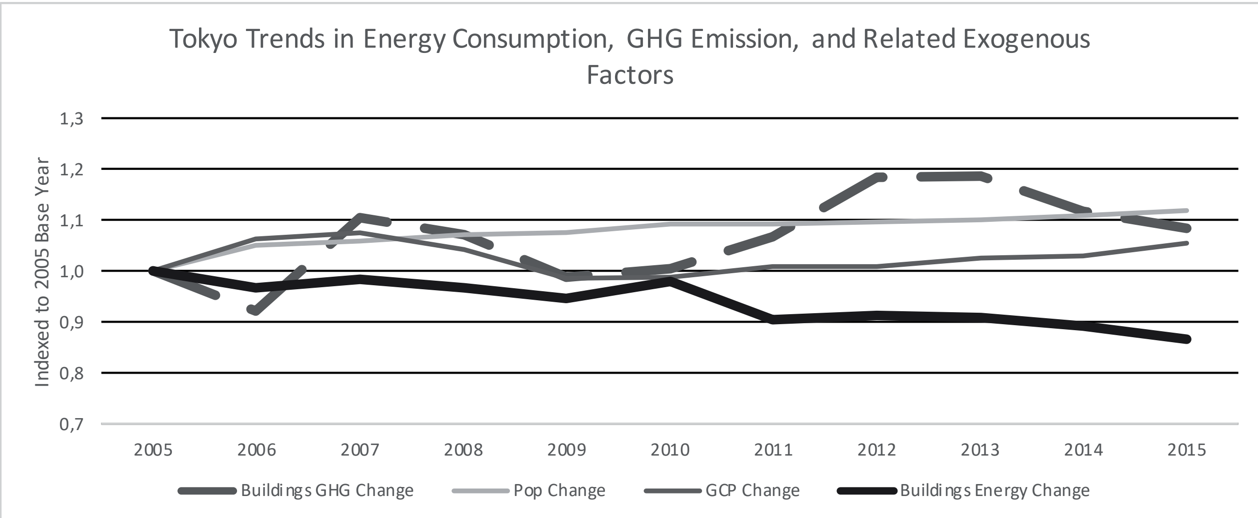

Figure 6. Tokyo trends in energy consumption, GHG emissions, and related exogenous factors.

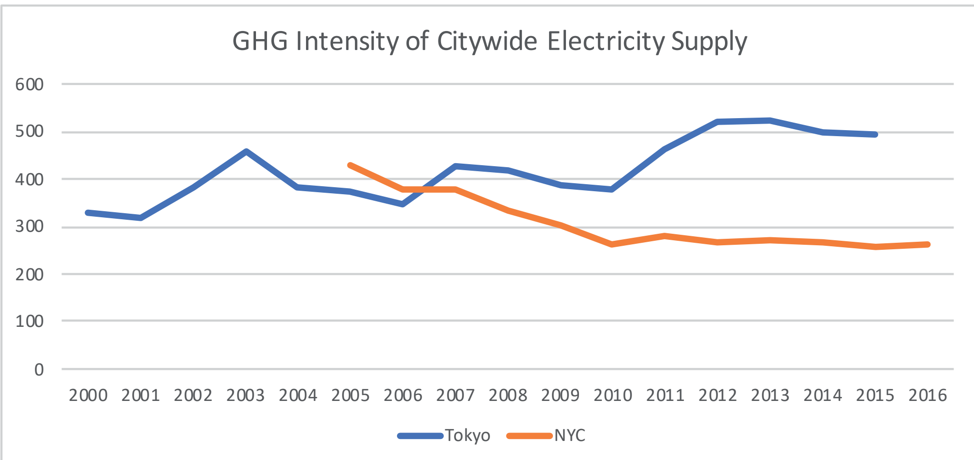

Figure 7. GHG Intensity of Citywide Electricity Supply (NYC and Tokyo).

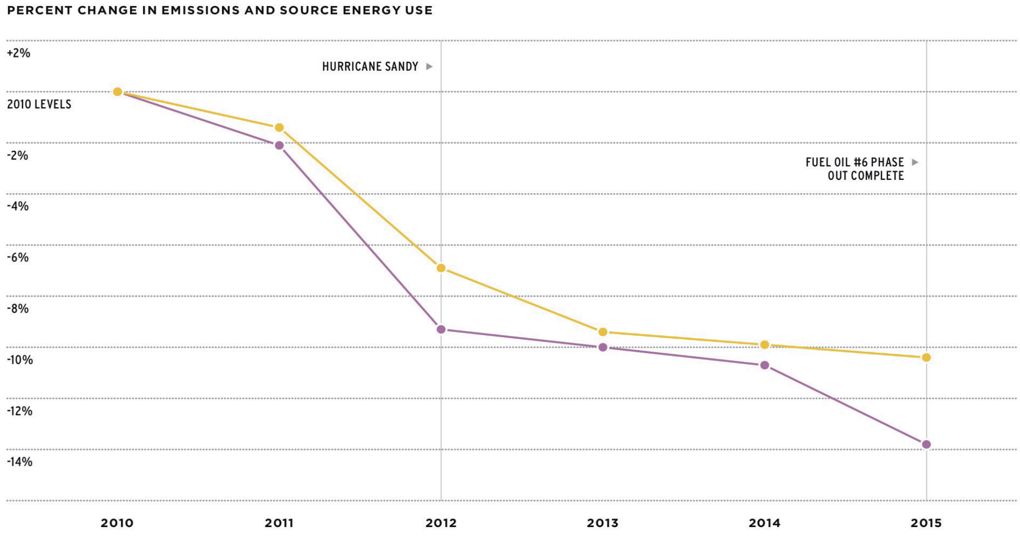

Figure 8. NYC Large Building Energy & Emissions Progress 2010 to 2015. Source: New York City's Energy and Water Use 2014 and 2015 Report (NYC 2017a).

Table 1. Percent change in energy levels, GHG emissions, and related factors between 2005 and 2016.

% Change 2005 to 2015				
	Citywide		Buildings Sector	
	Population	GCP	Energy	GHG
Tokyo	+11.9 %	+5.3 %	-13.4 %	+8.3 %
NYC	+6.3 %	+22.0 %	+1.1 %	-20.5 %

consumption during that six-year period by more than 10 %, and total GHG emissions by almost 14 % as shown in Figure 8 below (NYC 2017a). This trend of 10 % energy reduction from 2010 through 2015 is significantly different from the 3.5 % reduction during that same period for citywide building sector energy consumption. It is not clear whether this is due to faster growth in consumption in the smaller buildings not covered by the same laws, or if it is more of a data anomaly that needs more exploration.

While policy evaluations exist for signature policy efforts like benchmarking in NYC and TCTP in Tokyo, most city-level energy efficiency policies are not formally evaluated. The lack of evaluations makes it challenging to bridge the gap between the results of individual programs and wider community-wide trends in energy consumption and GHG emissions.

IMPLICATIONS FOR FURTHER RESEARCH

Linking of energy consumption, GHG emissions, and economic activity

Historically speaking, it is acknowledged that accelerating population and economic growth has led to increased energy consumption and GHG emissions. Figures 5 and 6 displayed above illustrate that this pattern has not been the case recently in either New York City or Tokyo.

As mentioned earlier, GHG emissions and GCP are somewhat correlated in New York City between 2007 and 2010, but GCP, energy consumption, and GHG emissions diverge beginning in 2011. In Tokyo, it is difficult to ascertain any linkages among these factors in the years assessed. The data in Table 1[5] also shows the lack of a relationship among these factors. For example, one might have expected energy consumption and GHG emissions to rise considerably in New York City due to large percent increase in population and GCP, but that did not occur.

It is not clear if a decoupling of these factors occurred at a specific point in time due to a specific event or intervention. Similarly, though, especially for Tokyo, it is not clear if these factors have been at all coupled or linked in recent history. It is unclear if the experiences of New York City and Tokyo are unique or if other global cities are having similar experiences.

Base year selection

Another point in analysing the trends, particularly when comparing buildings sector energy and GHG emissions with the exogenous factors of population and GDP, is the key importance of the base year chosen. The figure presented earlier on Tokyo trends has a quite different shape if the base year for compari-

5. Tokyo population history from http://www.metro.tokyo.jp/ENGLISH/ABOUT/HISTORY/history03.htm; Tokyo GCP data (in Japanese Yen) from http://www.toukei.metro.tokyo.jp/keizaik/kk16qa0310.xls; New York City Population and GCP data from https://nyc-ghg-inventory.cusp.nyu.edu/; City energy and GHG data from TMG 2018b, and NYC 2017b.

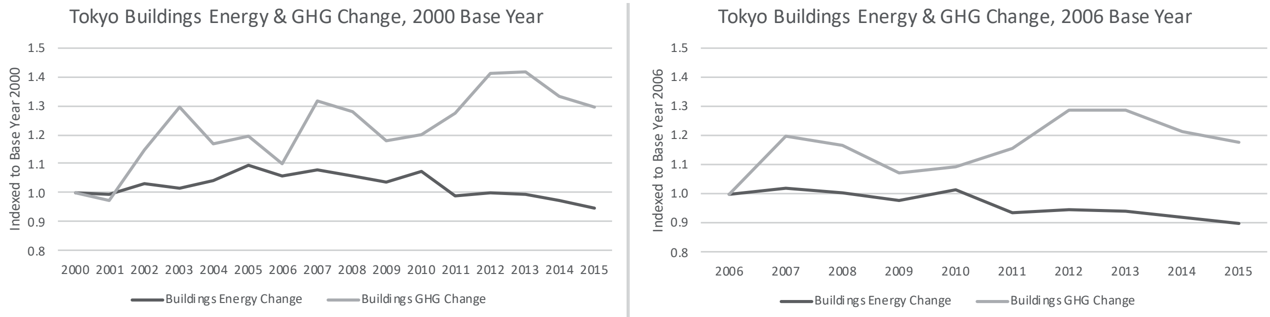

Figure 9. Impact of base year on trend figure and progress.

son was 2000 instead of 2005 as presented earlier; the energy and GHG trend figures for two different base years (2000 and 2006) are shown in Figure 9. With 2000 as the base year, by 2015 GHG has risen by 29.2 %, and energy use dropped by 5.1 %, though with 2006 as the base year (after both energy and emissions had risen), the same changes would be +17.6 % and -10.3 %, respectively.

Conclusions

Tokyo and NYC have been widely credited as developing and leading building energy efficiency policies that are being emulated around the world. While more evidence will be needed to continue to validate the impacts, this early review shows that the policies are world leading, and the level of data transparency sets an example for other cities (and nations) around the world.

The experiences of both cities, but in particular the experience of Tokyo, show the importance and promise of local action as well as the limitations of local action. In Tokyo, the national decision to phase out nuclear energy in the wake of the Fukushima Daiichi Disaster resulted in much higher GHG emissions for Tokyo. This national decision meant that the TCTP was not as impactful as desired in terms of Tokyo's progress toward its GHG goals. However, importantly, without the local action of the TCTP, the national decision would have had an even more profound impact on GHG emissions from Tokyo.

Our analysis demonstrates that it is challenging to map reductions in energy use and GHG emissions to specific policy initiatives. A combination of endogenous policy-related factors and exogenous factors converge to shape actual energy consumption and GHG emissions in cities. Disaggregating these factors is difficult to do. Furthermore, the lack of formal policy evaluations for most city-level clean energy policy – with the exception of some signature policies – makes it difficult to decipher the effects of most cities' energy efficiency portfolios as a whole. In many cases where analysts work to understand policy effectiveness, it is done with a minimal amount of data, and the evaluations are done solely on "have policies been established?", and if so, levels of assumption that the policies are delivering as hoped. Too often, the evidence-based review is lacking, and evaluations are more on "box-ticking" instead of what can be proven.

Our analysis yields several recommendations for other cities looking to learn from NYC and Tokyo. For one, local context matters and should drive decision-making. Both NYC and Tokyo took targeted, data-driven approaches to reduce energy use in their largest and most energy-intensive buildings through the GGBP and TCTP respectively. While it is difficult to fully unpack the drivers affecting changes in community-wide energy use and GHG emissions, evaluations have shown GGBP and TCTP to have been effective. Other communities would be wise to take similar data-driven approaches to target their biggest needs.

Another recommendation is to track the level and granularity of data that permits such data-driven decision-making. Leadership in both NYC and Tokyo have embraced the well-worn business axiom: if you can't measure it, you can't manage it. To allow for informed decision-making, data must be available on regular intervals for energy consumption, GHG emissions, and other complementary information like gross city product (GCP). Even if all this data is not presented in uniform formats across cities or even from year to year within cities, some imperfect data is better than no data at all. Furthermore, while it may be tempting to focus solely on GHG emissions, do not overlook data that can provide a fuller picture of changes in energy consumption and GHG emissions. For example, good GCP data can provide a fuller understanding of how economic drivers affect energy consumption.

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