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Innovations in City-Level Climate Policy: Building Energy Efficiency and Retrofitting Programs in C40 cities

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Abstract

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Worldwide buildings account for approximately a third of global energy use and a quarter of GHG emissions. In large cities these proportions can double or even triple. Combined with a slow rate of building turnover, this creates a need for policy instruments designed to address the energy efficiency of existing buildings. With a lack of national attention, cities are stepping forward to offer a solution. This paper examines policy approaches taken by six cities, all members of the C40 Climate Leadership Group. Energy efficiency policies and programs are broken down into their constituent functions, each with unique impacts, strengths, and limitations.

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1. Introduction

Over the past 20 years, cities have emerged as important actors in climate change policy. This change can be partially attributed to an increased awareness of cities being responsible for a large proportion of national and global GHG emissions (Kern, 2010). Along with this, the importance of transforming the energy efficiency of the building stock is becoming more apparent. This is particularly true of existing buildings, as in 2010 buildings accounted for 32% of total global final energy use and 19% of energy-related GHG emissions (IPCC, 2014). These numbers can be much higher in larger cities. For example, in London, buildings account for 78% of GHG emissions (C40, 2015). Invariably, emissions attributable to buildings are greater than those of other sectors such as transportation.

Across the globe, cities share similar profiles of power and organization, making them an excellent platform for mutual learning and cooperation (ARUP, 2015). Often the driving force for energy efficiency policy innovation in cities lies in the power of local government and mayoral action. Being uniquely positioned to create policies for energy efficiency and having the authority to enforce them, cities are emerging as leaders in climate governance (Corfee-Morlot, Cochran, and Teasdale, 2009). This process is aided by membership in global networks such as C40 Climate Leadership Group and ICLIE Climate Cities Program, which allow for sharing of best practices and provide resources to aid policy design. Importantly, city-level climate policies are inherently less complex than larger national-level initiatives, resulting from having a smaller and more homogeneous operating area. Additionally, cities can essentially curtail national policies, which are often conservative, in order to take rapid and ambitious action. This allows forward-thinking cities to take the approach best suited to local conditions.

Improving the energy efficiency of the existing commercial building stock is a common strategy for cities to reduce GHG emissions and energy use intensity, as a large proportion of the currently existing building stock will still exist in 2050 (IPCC, 2014). While new commercial buildings are increasingly making improvements in energy efficiency, retrofitting of existing buildings continues to present technical, financial, and social challenges (Miller and Buys, 2008). However, the attention of policy makers may be shifting towards efforts to foster retrofitting activities in existing buildings, as they represent the largest net benefit in terms of reducing energy use intensity and GHG emissions. However, multiple barriers currently exist to achieving the full potential that energy efficiency retrofits offer (Gillingham et al., 2009). Developing and promoting effective policy approaches to address these barriers is key to moving forward on energy consumption and climate governance issues.

Though a decentralized method of promoting energy efficiency through city-led action has strengths, it certainly also has weaknesses. City-level policies addressing energy efficiency vary greatly in their targets, approach and scope, with each program being bespoke to the designing city, with functions unique to specific goals. A “program” is best defined as a set of interrelated policies and incentives designed to achieve a specific purpose in a city. Thus, there has been no coherent effort to categorize and analyze the key functions of these programs. Doing so would allow for better and more holistic understanding of the various policy approaches, along with their respective strengths, limitations, and potential impacts. Also, this would serve for better and easier replication of successful programs to other cities, as well as more effective tailoring that will lead to larger impacts. To generate this knowledge, this empirical study examines flagship programs in six C40 cities: London, Mexico City, Chicago, Tokyo, Shenzhen, and Boston, designed to advance energy efficiency and retrofitting efforts for existing commercial buildings. In pursuit of this, this paper will address the following research questions:

1. What are the different functions performed by energy efficiency programs for existing commercial buildings?
2. What are the impacts or intended impacts of each function?
3. What are the strengths, limitations, and challenges encountered when implementing each function?

Data was sourced from questionnaire responses and interviews with city officials, as well as document reviews. This study took place in the context of a research project commissioned by Tokyo Metropolitan Government on behalf of the C40 Climate Leadership Group.

2. Background

2.1 Barriers

For policy makers, barriers preventing improvements to energy efficiency in existing buildings are diverse and complex. They also vary between locations, reflecting each city's geographic setting, built environment and infrastructure endowment, social environment, as well as policy and institutional framing conditions (Jollands, 2008). Compounding these challenges is the decades-long lifespan of building stocks. Not surprisingly, funding problems are regarded as one of the most serious impediments to energy efficiency (Fitzgerald, 2008). Financing for retrofitting projects is difficult to secure, and benefit-cost estimates are often uncertain, hampering interest among commercial property owners. Additionally, policies are often unable to effectively target all building types, as special interests have the ability to exempt some sectors or industries (Compston, 2009). Other market barriers include split-incentive issues, resulting from a misalignment of tenant and building owner interests, and inadequate understanding of building technologies among industry members, leading to uncertainties related to project payback. Policies and programs are often implemented to directly address barriers or market failures related to implementation of energy efficiency technology. Also significant are the cultural and procedural barriers. These include risk adversity in the real estate sector, poor enforcement practices of regulatory agencies, behavioral patterns of building owners, managers, and tenants, ineffective institutional structures, and principal-agent issues. These barriers exist not only to impede energy efficiency, but also to slow the uptake of policies seeking to address energy efficiency, and have a particularly negative impact on retrofitting activities for existing buildings (IPCC, 2014).

2.2 City climate targets and policy innovations

As efforts to improve energy efficiency in existing buildings are often tied to climate change goals, it is important to examine them within this context. Compared to efforts on a national level, the characteristics and actions of city governments can have a more direct influence over many important factors necessary to create climate solutions (Kamal-Chaoui, 2008). These include having substantial influence over public transport, energy production technology, creation and enforcement of building codes and standards, water and waste management, and land use measures that promote sustainable urban development. These abilities have helped allow a sub-national climate action movement to develop (Lutsey, 2008). In some cases sub-national jurisdictions are acting to compensate for a lack of national political momentum (IPCC, 2014). In the United States alone, over 1000 cities and municipalities have committed to what would have been Kyoto Protocol emissions reductions goals (Mehling and Frenkil, 2013). Importantly, within this category of sub-national climate movements, there is a diversity of approaches, all of which are tailored to cater to local conditions. In cities, these initiatives are strongly driven by local institutional and political context, but are often operating within the constraints of national climate action frameworks (IPCC, 2014). A prime example of this is the Better Buildings Initiative created by the US Department of Energy (US DOE). This initiative represents a national level energy use reduction goal of 20% by the year 2025. US cities can voluntarily agree to enroll in this initiative, but are allowed complete autonomy with regard to program design.

Additionally, cities have the ability to be innovative in their approach to reducing energy use. This is true for program scope and design, as city governments have a more intimate knowledge of local conditions, and can tailor programs effectively. This lends to the ability of cities, and city-level climate policy to act as “laboratories”, with the ability to host experiments and generate innovations (Evans, 2015). These policy innovations are being driven by cities’ desire to reap the economic and reputational benefits of being “first movers” (Jänicke and Jacob, 2004). These actions are in turn driven by the ability of cities to create, implement, and adjust policies more quickly and with greater flexibility (Galarraga et al., 2011). Many cities treat energy demand reduction with major initiatives, as any net reduction in energy use will be directly correlated with a decrease in emissions (Rozenzweig, 2011). To this end, cities are creating policies that directly target energy efficiency improvements in existing buildings (Doremus and Hanemann, 2008).

2.3 C40 Climate Leadership Network

As city governments have increasingly become the unit at which climate polices can innovate, the need for sharing of ideas has also grown. The C40 Climate Leadership Network (C40) was created in 2005, when leaders from 18 cities were convened by the Mayor of London to formulate coordinated action on reducing GHG emissions and facilitate progress on climate change mitigation and adaptation. Since then, C40 has grown to include over 80 cities spanning every continent. The mission of C40 is to provide cities a platform for collaboration, sharing of best practices, and to serve as a research bed and database for climate action programs and strategies. In pursuit of these goals, C40 is arranged into seven different “networks”, each with a specific function and subinitiatives. These are adaptation and water, energy, finance and economic development, measurement and planning, solid waste management, sustainable communities, and transportation. Cities have the opportunity to participate to varying degrees in the different networks. Cities with particular expertise or that have experienced success with policies in a related field are asked to serve as network leads.

3. Methods

3.1 Study sample

This study draws conclusions based on data collected November 2015 – January 2016 in collaboration between the Tokyo Metropolitan Government (TMG) and the C40 Climate Leadership Group. All cities surveyed are active C40 members, and have programs designed to advance the energy efficiency and retrofitting of existing commercial buildings. Cities in the sample were chosen based on availability of key staff members and city officials, in addition to willingness to share experiences and provide program details. Although surveyed cities hold multiple programs to advance the energy efficiency and retrofitting of existing commercial buildings, cities were asked to select one flagship, innovative program. Data was collected via three methods:

1. Written questionnaires
2. Semi-structured telephone interviews
3. Document analysis

3.2 Primary data collection

Primary data was collected through written questionnaires administered to city officials electronically, from November 2015 to March 2016. Information was gathered regarding areas such as 1) program targets, scope, goals, and any unique characteristics of the building stock that influenced program design; 2) details regarding both the design and implementation phases of the program including resources allocated, collaborations or links to other programs, reasons for choosing program functions, and any incentives offered; 3) observed program impacts, strengths and weaknesses, and lessons learned for replication. In addition to the written questionnaire, semi-structured telephone and in-person interviews were held during December 2015 – March 2016 to collect additional, more detailed data. These interviews included gathering qualitative information from those with experience in program design and implementation. Each interview lasted 90 minutes and typically involved one or two program or city officials, members of the research team in Tokyo, and representatives from Tokyo Metropolitan Government and C40. Conversations were recorded and transcribed into minutes, from which information was gathered for analysis.

3.3 Secondary data collection

Secondary data was collected through document review. Documents included official city webpages, program reports, press releases, and policy documents. Third party materials not published directly by city programs were also used, such as scholarly publications, conference presentations and reports, and press materials. Lastly, city officials were contacted via email for the purpose of clarifying information and ensuring the accuracy of interpretations and to gather further information as necessary.

3.4 Overview of programs

The following programs were examined. Key attributes of each program are summarized in **figure 1**.

Figure 1: Characteristics of sample cities and program goals

City	Program name	Population	Year Implemented	City Climate Goal(s)	Program Goal(s)
Chicago	Retrofit Chicago Commercial Initiative	2,722,000	2013	25% reduction in CO2 emissions by 2025, 80% reduction before 2050 compared to 1990 levels	Participating buildings must reduce energy use 20% within 5 years of enrolment
Boston	Renew Boston Trust - Commercial	655,000	2017	25% reduction in GHG emissions by 2020, 80% reduction by 2050 compared to 2005 levels	Increased levels of investment in energy efficiency retrofit projects
Mexico City	Sustainable Buildings Certification Program	8,918,000	2008	50% reduction in GHG emissions by 2050 compared to 2000 levels	Advancement of energy efficiency and renewable energy technology
London	Business Energy Challenge	8,539,000	2014	60% reduction in CO_2 emissions by 2025 compared to 1990 levels	Reduce the carbon intensity of London's commercial buildings
Tokyo	Carbon Reduction Reporting Program	13,506,000	2010	25% reduction in CO_2 emissions by 2020 from 2000 levels	Foster climate change action and increase energy efficiency
Shenzhen	Emissions Trading Scheme (ETS)	10,630,000	2013	40 - 45% reduction in CO2 emissions per unit GDP by 2020 compared to 2005 levels	21% reduction in carbon intensity per unit GDP by 2015 compared to 2010 levels

3.4.1 London – London Business Energy Challenge

This program awards businesses for improving energy efficiency in their London locations. Taking advantage of mayoral exposure and natural competitiveness between businesses, this program fosters a decrease in the energy demands associated with office spaces, retail locations, as well as service and hospitality industry locations through voluntary action.

3.4.2 Chicago – Retrofit Chicago Commercial Initiative

Retrofit Chicago Commercial Initiative is a voluntary program that requires participating buildings to make a commitment to reducing energy use by 20% within five years of joining, to begin work within six months of joining, and to share best practices with peers. The program is specifically targeted at existing commercial buildings. Chicago's commercial buildings initiative is part of a cross sector effort to improve energy efficiency in the city, with separate initiatives also targeting municipal and residential properties.

3.4.3 Mexico City – Sustainable Buildings Certification Program

Mexico City has created a bespoke building certification program similar to LEED. This certification requires buildings demonstrate a holistic commitment to sustainability, of which energy efficiency is only part. Key incentives for participating buildings include substantial tax breaks, increased competitiveness in a market increasingly concerned with sustainability, and the potential for the addition of green premiums for office and retail locations.

3.4.4 Boston – Renew Boston Trust - Commercial

Building on the experience and expertise of C40's Sustainable Infrastructure Finance network, the City of Boston is developing a market based solution that will help building owners secure financing for energy efficiency projects. The program will target projects in "mid-cycle", meaning between original construction and refinancing. During refinancing owners will typically make dramatic improvements to energy efficiency, but almost never in mid-cycle, causing many buildings with low performance to endure for years before improvements are made. Though not yet in implementation, this program provides valuable insight into the financial challenges associated with retrofitting existing buildings, and how they can be overcome.

3.4.5 Shenzhen – Emissions Trading Scheme

Covering 635 industrial companies from 26 sectors and spanning 197 public buildings, Shenzhen's newly implemented Emissions Trading Scheme aimed to reduce carbon intensity 21% by the end of 2015 (Shenzhen Research Center for Urban Development, 2015). Showing promising results as a pilot program, this ETS design will eventually be implemented in other cities across China.

3.4.6 Tokyo – Carbon Reduction Reporting Program

In 2014, Tokyo Metropolitan Government (TMG) began a part mandatory, part voluntary carbon reporting program for small and medium-sized buildings in Tokyo. If a business owns or operates a portfolio of buildings with energy consumption greater than 3,000 kL of crude oil equivalent, providing TMG with a report on CO_2 emissions and energy saving progress is mandatory. Businesses with portfolios that consume less than 3,000 kL of crude oil equivalent can submit reports voluntarily by the same procedure. This program typically targets businesses that have many buildings that are not large enough to qualify for coverage under Tokyo's mandatory cap and trade program.

4. Findings

4.1 Program functions

As program functions are tailored to a specific location, the design of city level energy efficiency programs and policies varies to a large extent. They can however, be broken down into constituent parts, or functions, that are common. This section will define these functions and provide examples of their use by cities in the study sample. A summary of all program functions and associated impacts can be found below in **Figure 2**.

Figure 2: Impacts, strengths, and limitations of functions identified in study sample

Function	Example city program(s)	Associated Impacts	Strengths	Limitations
Financial capacity building	Renew Boston Trust - Commercial	• Increased investment in energy efficiency retrofits	• Does not require legislative action • Easily replicated	• Relies on market tendencies
Knowledge capacity building	Retrofit Chicago Commercial Initiative	• Increased awareness • Increased retrofitting activity	• Educates building owners and managers • Fosters action in energy efficiency	• Relies on budgets of businesses
Monitoring and reporting	Tokyo Carbon Reduction Reporting Program	• Increased awareness • Increased retrofitting activity	• Allows buyers/tenants to scrutinize energy efficiency	• Data accuracy issues
Friendly competition	London Business Energy Challenge	• Decreased energy use intensity • Increased awareness of energy efficiency	• Takes advantage of publicity • Large reductions over short time	• Data accuracy issues • Lack of appeal for high/low performers
Sustainability certification	Mexico City Sustainable Buildings Certification Program	• Increased awareness • Increased use of renewable energy	• Holistic • Encourages increased performance	• Lack of appeal for high/low performers
Cap and trade	Shenzhen ETS	• Reduced GHG emissions • Increased air quality	• Mandatory • Predictable GHG reductions • Enforceable	• High costs for compliance

4.1.1 Financial capacity building

This function aims to use market mechanisms to promote energy efficiency improvements in the existing commercial building stock. As access to capital is consistently named as a barrier by energy efficiency projects in cities all over the world, this approach has large impact potential on this and other market barriers. In addition to a lack of project funding, many energy efficiency retrofitting projects do not meet the short-term financial return criteria of businesses and investors (IPCC, 2014). However, creative business and financial models from energy utilities, financial institutions, and businesses can overcome this barrier (Veeraboina and Yesuratnam, 2013). There are a number of different schemes that can be used for financial capacity buildings. Renew Boston Trust - Commercial initiative plans for the formation of a special purpose financial entity that will be used to fund energy efficiency retrofits. This special entity is created as the centerpiece to an innovative financial capacity building program. Taking advantage of current trends and existing conventions in real estate finance, Renew Boston Trust – Commercial will use a number of small initial projects to build a credit history for energy efficiency retrofits. Once a robust credit history has been established, traditional lending will be much more readily available for retrofits in existing buildings.

Renew Boston Trust - Commercial is only the latest in a series of innovative financial capacity building models. Programs often use a socially responsible investment funds as lending institutions for energy efficiency retrofits (Veeraboina and Yesuratnam, 2013). These funds are often used to fund programs using an ESCO, or energy service company. These ESCOs specialize in energy efficiency projects and will provide a guarantee that savings generated from energy efficiency will repay investments. This model has been effective in both the developing world, and in developed countries such as Germany (Marino et al., 2011).

4.1.2 Cap and trade

Cap and trade, also known as emissions trading, is being employed to limit carbon emissions in a growing number of cities around the world (IPCC, 2014). Being a market-based instrument, cap and trade should increase the prospective cost of using energy intensive technologies and practices (Van Renssen, 2015). This will drive uptake of low-carbon alternatives within regulated industries and businesses. To this end, programs utilizing the cap and trade function have the option of directly regulating carbon emissions or energy use itself. Typically a cap is placed on the chosen metric, and specific industries or businesses are chosen for regulation. Facing compliance based on amount of energy used or emissions produced, regulated entities have two options. They can either take internal measures to reduce emissions from energy use, or purchase emissions credits from another entity.

An innovative and novel feature of Shenzhen's application of the cap and trade function is the creation of a dual emissions reduction target. One goal is aimed at reducing overall carbon intensity across all regulated entities by 21% (representing 32 MMT CO_2) compared to 2005 levels, and an adjustable carbon intensity goal that is tailored for each regulated entity as appropriate. This unique approach is critical to the success of the program. It allows each company a fair chance to comply even while economic growth, and therefore energy consumption, is expected to continue increasing in Shenzhen for the foreseeable future (Shenzhen Center for Urban Development, 2015). Also innovative is the inclusion of public buildings and transport in addition to industry and large buildings.

4.1.3 Knowledge capacity building

Another critical program function, knowledge capacity building, requires that participants engage with each other to share information and resources. This function can also be used to encourage communication between building owners and managers and other program stakeholders, such as third-party technical advisors and utilities. With energy efficiency retrofits, lack of information about opportunities and costs lead to poor decision making and misallocation of financial resources (IPCC, 2014). Knowledge capacity building can be used to address this barrier, by fostering opportunities for building owners and managers to learn from others' successes, and access additional resources. This function is exemplified by Retrofit Chicago Commercial Initiative. Participation in this program promotes sharing of best practices, as building owners and managers convene four times a year to share information and experiences. This formal approach to knowledge capacity building is highly novel. This function can also be observed in the efforts of London Business Energy Challenge, where businesses are encouraged to publish case studies of successfully implemented energy efficiency projects. These case studies are distributed at an annual awards ceremony to other participating building teams, and will eventually be used to inform city policies related to energy efficiency in commercial buildings.

In addition to capacity building between participants, the sharing of information with other stakeholders is also considered part of this function. In partnership with regional utilities, Retrofit Chicago Commercial Initiative arranges for building engineers to provide energy reduction strategies for participating buildings. Additionally, by incorporating members of the building industry and real estate investment community into the design process, Retrofit Chicago Commercial Initiative was able to identify knowledge gaps early on. Program staff are also well versed in the availability of incentives from utilities, as well as local, state, and federal government, and can assist buildings in the application process. These are tasks that building owners and managers often have no ability or incentive to carry out. This sharing of information works both ways. Participants are encouraged to pass along information to program organizers and utilities in an effort to fine tune and improve this function of the program.

4.1.4 Monitoring and reporting

Monitoring and reporting of energy use, along with data verification is a necessary condition for the success of any compliance program (IPCC). This is true of both voluntary and mandatory programs. This function can be used to hold relevant parties accountable for violating emissions commitments, promote the success of high performers, or be used to inform the design of regulations. Programs such as Tokyo Carbon Reduction Reporting program are built around the ability to gather and analyze meaningful data about a building’s energy use. Using monitoring and reporting, this program aims to encourage improvements in energy efficiency in Tokyo’s small and medium-sized buildings. This program is unique in being both mandatory and voluntary, as reporting is required for facilities with annual energy consumption greater than 3,000 kiloliters of crude oil equivalent (~30,000 MWh). Reports are submitted online to city officials within the Tokyo Metropolitan Government and are then checked for discrepancies. Building owners and managers are required to provide comprehensive information on energy consumption and associated emissions. Reports are published publicly, providing businesses the opportunity to highlight energy efficiency efforts and encourage the implementation of necessary countermeasures.

Programs that require buildings to demonstrate improvements in energy efficiency similarly rely on this function. Shenzhen's ETS, for example could not work properly without making use of this function. Thus, in a sense, this function is critical to the operations of other functions. This is particularly true of mandatory programs. However, reporting is used to great effect by both Retrofit Chicago Commercial Initiative and London Business Energy Challenge. In Chicago, buildings are required to track energy use with Energy Star Portfolio Manager, created by the US EPA. In London, program staff have created a custom reporting spreadsheet. These programs use reporting of energy use to award high performers as well as to help and encourage other buildings make similar progress.

4.1.5 Benchmarking

Benchmarking has the ability to serve two purposes. One, it can be used to create a baseline from which individual buildings can measure progress on energy use and emissions reductions, and two, it can be used to directly compare performance between buildings, businesses, or whole industries. Often benchmarking energy use is difficult for building owners and managers to facilitate. City programs aim to make this process easier, or use information gathered from voluntary programs to design regulations that mandate benchmarking in existing buildings. This function is particularly important for programs to directly compare buildings, and many countries use benchmarking to compare energy use between buildings of the same sector (IPCC, 2014). Tokyo's Carbon Reduction Reporting Program used results from five years of monitoring and reporting (FY2010 - FY2014) to create a robust benchmarking index. This index divides buildings into 30 benchmarking categories based on occupancy and size, then further divides each category into 15 letter grades corresponding to relative CO_2 emissions intensity (kg-CO_2/m^2). Unique to Tokyo, this index is used to directly compare the emissions of facilities and businesses with similar operating profiles. Buildings are provided with a Carbon Report Card, consisting of their letter grade within the appropriate benchmarking category. This encourages businesses to improve performance, as a target for the desirable level of GHG emissions is made available. This is also a long term goal for the London Business Energy Challenge, as data contributed by participating buildings will be used to create a benchmarking index for London.

Importantly, many programs and regulatory schemes require benchmarking of energy to be used for tracking progress of individual buildings and businesses. This is a critical element of both Retrofit Chicago Commercial Initiative and London Business Energy Challenge. Though neither program provides financial resources for benchmarking energy use, both programs make it a requirement. This is the first step in raising awareness on energy use in buildings. Additionally, data gathered through Retrofit Chicago Commercial Initiative were used in the design of Chicago's Building Energy Benchmarking Ordinance. This clearly demonstrates the dual purpose of benchmarking as a program function.

4.1.6 Friendly competition

Offering awards and recognition for high performers, this function is of particular interest to programs that target office spaces and other businesses, as it provides them with an opportunity to stand out as leaders in energy efficiency. Tapping into the competitive disposition of the building sector, London Business Energy Challenge has used a 'friendly competition' model to drive improvements in energy efficiency in commercial properties. Each year, energy use of participating businesses is converted into a carbon intensity figure, with the top performing 45% being given awards. This approach is gaining attention for its effectiveness and also for the unique way in which government serves in a coordinating role, rather than designers and implementers (IPCC, 2014). These programs are commonly tied to mayoral exposure, with an endorsement offering potential to gain a competitive edge, thus enticing businesses to participate. This function shows promise to be effective in the commercial building sector, where competition is a constant driver for businesses and real estate.

4.1.7 Sustainability certification

Similar to larger, internationally recognized programs such as LEED, this function provides buildings in Mexico City an opportunity to earn a certification that demonstrates a commitment to sustainability. This function is notable also for being a holistic measure of sustainability, with certification criteria focused on water consumption, social responsibility, and installation of green roofs. Additionally, for existing buildings this certification means energy efficiency must be aligned with newly designed national standards. In the process of being certified, existing buildings will need to become competitive with new buildings in terms of energy efficiency. This certification program is unique in its ability to incorporate existing buildings as easily as new buildings.

4.2 Impacts of functions

As each function has unique targets and intended outcomes, analysis of impacts has been conducted from three perspectives: environmental, social, and economic. It is important to mention that all functions will have some degree of environmental impact, as they are efforts to decrease energy consumption and emissions. That said, only those functions that provide an additional environmental impact resulting from innovative features of a program or function will be considered.

4.2.1 Financial capacity building

Though varied in exact design, financial capacity building results in increased levels of investment in the commercial retrofit market by overcoming a number of key market barriers. Most importantly, this function helps building owners secure financing for energy efficiency upgrades. As demonstrated in the design of Renew Boston Trust - Commercial, this function can be used to finance projects in low performing buildings during the middle of their real estate cycle, or mid-cycle. Additionally the increased availability of financing will allow for deeper projects offering more energy use reductions, allowing for a larger net impact on emissions from commercial buildings.

4.2.2 Cap and trade

Cap and trade provides substantial environmental impacts in the form of decreased GHG emissions and the impact that will have on air quality. In Shenzhen, a newly formed ETS resulted in a 33.2% citywide reduction in carbon intensity per unit GDP compared to a 2010 baseline, with a 99.7% compliance rate (Shenzhen Research Center for Urban

Development, 2015). Additionally, these emissions reductions will be highly predictable and controllable, as they are mandatory and created by city officials in accordance with citywide climate targets and ambitions. Other market impacts will result from regulated industries and organizations innovating as they find methods for reducing energy consumption. Increased uptake of low carbon technologies and energy efficiency measures are two important examples. Similarly, changing practices to promote lower energy use will be a valuable social impact.

4.2.3 Knowledge capacity building

This function creates a system for participating buildings to gather informational resources from which to plan their approach to reducing energy use. Armed with more complete information about the cost and payback profiles of different energy efficiency measures, building owners and managers can make more informed decisions and make more effective use of limited resources. This has helped buildings participating in Retrofit Chicago Commercial Initiative make greater improvements to energy efficiency. Across all buildings participating in Retrofit Chicago Commercial Initiative, energy consumption has been reduced 7% compared to 2010 levels. This represents substantial progress towards a 20% goal. As intended, this function has also achieved notable social impacts. Sharing of best practices for the reduction of energy use and providing resources for the same has led to greater improvements. Recognition of high performers at program-sponsored events and in program literature has resulted in increased enrollment, which will also lead to greater reductions. Other programs utilizing this function, such as London Business

Energy Challenge have cited information sharing as an important driver for energy use reductions and retrofitting activity.

4.2.4 Monitoring and reporting

The main impact of monitoring and reporting data on building energy use is the information gathered on relative performance. With this knowledge, city officials are better able to create programs and policies aimed at improving performance. The impacts associated with this function also depend on whether information gathered is disclosed publicly. If not, the data from regulated entities will likely only serve to inform future policies or, in the case of Shenzhen ETS, verify compliance. If the information is disclosed publically, the impacts are greater and more diverse. In the case of Tokyo Carbon Reduction Reporting Program, the availability of energy use and emissions information allows consumers and potential tenants the opportunity to scrutinize properties based on their relative energy efficiency or emissions performance. This is both a social and economic impact, as lower cost of living will potentially improve the quality of life of tenants and the attractiveness of a property in a competitive real estate and rental market. Additionally, it may drive consumers towards businesses that are perceived to be more environmentally conscious.

4.2.5 Benchmarking

Benchmarking of building energy use serves as an informational tool, which is a social impact. This information allows a building to compare itself to others, thus incentivizing poor performers to make improvements. This can be seen in Tokyo, where the creation of a Low Carbon Benchmark and Carbon Report Cards has been used to incentivize businesses to pursue energy efficiency measures. Reductions in energy use associated with benchmarking will also create environmental impacts, resulting from decreased emissions.

4.2.6 Friendly competition

The primary impacts here are social in nature, with competitions raising awareness about building energy use and associated climate impacts. This can be said for building owners and managers, as well as employees and the general public. Often commercial building energy use, particularly in offices can be esoteric. Friendly competition will serve to bring energy efficiency and, more generally, energy use into popular consciousness. There is also potential for market impacts, with winners and high performing businesses being able to tout their achievements and attract more consumers.

4.2.7 Sustainability certifications

Certification of buildings in Mexico City has raised awareness about sustainability issues in a holistic manner across a diverse array of metrics and increased the uptake of renewable energy technologies. Criteria for sustainable mobility, building materials, and water use will contribute towards a greater understanding of sustainability in the building industry, and among building owners and tenants. This will also foster more initiatives for increasing the sustainability of buildings, as tenants and real estate investors are better able to compare the relative sustainability of buildings. Additionally, certifications have resulted in 20.1 kWh of electric power savings since 2008. This is an important environmental impact; however, there are also notable market impacts. Building owners will receive a 20% property tax reduction when certified, and tenant participants a 40% payroll tax reduction.

4.3 Strengths, limitations, and challenges

4.3.1 Financial capacity building

As securing financing for retrofitting projects is the largest impediment for improving energy efficiency in existing buildings, the ability of this function to provide the necessary funds for building owners is key. Additionally, as demonstrated in the design of Renew Boston Trust - Commercial, this function can be carried out without creating any accompanying legislation. This, in theory, will allow for rapid and easy replication in other locations and is a main strength of this approach. However, it relies on actions from the real estate finance sector. As these are not certain to occur, this is a main challenge to implementing this function. Also a strength is the relative ease with which commercial building owners will be able to secure financing. This will incentivize them to make building improvements that are otherwise not required. Additionally, as more projects are carried out via this function, the financial industry itself will become more interested in financing these projects.

4.3.2 Cap and trade

The main strength of cap and trade is an ability to produce predictable and controllable GHG emissions reductions in short periods of time. This is demonstrated by Shenzhen ETS, having produced the projected amount of emissions reductions with very few entities being noncompliant. Also, cap and trade has the ability to directly target buildings and industries that are large emitters. This will create larger net reductions in citywide energy use and GHG emissions.

Though putting an energy use or emissions cap on certain industries has the potential to cause financial hardship, this is alleviated by the trading of emissions credits. Trading of credits between regulated entities is another strength of the program. Shenzhen ETS is also innovative in designing the goals of the function, choosing to create an energy intensity goal relative to GDP in order to account for a still rapidly growing local economy. As a notable limitation, it is difficult to target small and residential buildings, as they will typically not meet minimum energy use intensity or emissions requirements necessary to force compliance.

4.3.3 Knowledge capacity building

This function creates the prospect of building owners and managers gaining new knowledge in a voluntary environment. This is a strength of the function, as it addresses what is currently a significant barrier to furthering energy efficiency efforts in commercial buildings, while also allowing buildings to reduce energy use in whatever manner they see fit. This drives innovation and fosters improvements in energy efficiency among commercial properties, and incentivizes key buildings to work with city officials to reduce energy consumption. However, even large voluntary programs, such as Retrofit Chicago Commercial Initiative, don't produce the city wide emissions reductions that will be necessary to impact climate issues. This is because voluntary programs will only ever attract those buildings that are already interested in improving energy efficiency. This function also relies mainly on building owners' and managers' own financial resources, which are typically limited.

4.3.4 Monitoring and reporting

An important strength of this function is that it presents a great opportunity for creating information about energy efficiency at low cost. Compliance can be achieved with virtually no additional resources from a business. When the results of this function are made available publicly, this will allow consumers and commercial tenants to scrutinize a property in terms of energy efficiency. This is the primary strength of this function and will drive improvements necessary for buildings to stay competitive. However, monitoring and reporting is limited by reliance on self-reporting, often with little oversight. This can lead to accuracy problems. Overcoming this issue can be challenging, though programs such as Tokyo Carbon Reduction Reporting Program have a series of data verification measures and resources for guidance on report filing that are designed to catch discrepancies. City officials check the accuracy of reports by comparing them to data from previous years. Rapid changes in energy use will elicit an onsite inspection and each year, 33% of participants are required to host city officials.

4.3.5 Benchmarking

Also exemplified by the program in Tokyo, benchmarking raises awareness about energy use and emissions intensity among building owners and managers, and may encourage efforts to elevate performance. The main limitation of benchmarking is the uncertainty of its impact on the behavior of building owners and managers. It remains unclear as to whether the information gathered motivates improvements. Additionally, this function will have no ability to foster energy efficiency improvements unless results are publicly disclosed, as tenants and consumers will be needed to create demand. Another important limitation of this function is its reliance on self-reporting. Without proper oversight, there will inevitably be problems with reported data. This is a major limitation of benchmarking. In addition to the measures described in the section above, London Business Energy Challenge contracts a firm specializing in building energy efficiency projects to analyze data for accuracy.

4.3.6 Friendly competition

Friendly competition takes advantage of publicity and city-sponsored recognition of high performers as a primary strength, potentially creating relatively large reductions over short periods. However, as with all functions that rely on self-reporting of energy use or emissions, data accuracy issues often obscure the meaning of results. To overcome this challenge, London Business Energy Challenge contracts a firm that specializes in building energy efficiency projects to analyze data for accuracy. This function also has the potential to have challenges being inclusive of a large range of building types. The function may dissuade some participants based on building characteristics such as age, size, and sector, which may affect their competitiveness. Essentially, if they don't have a chance of winning, they will likely not participate. Also, these programs likely attract those who are already interested in energy efficiency, meaning extremely low performers will not be inclined to participate. Additionally, buildings that are already high performers may not see reason to participate.

4.3.7 Sustainability certifications

The main strength of this function is the ability to foster a holistic sustainability effort on the part of building owners and tenants. This is demonstrated by the Mexico City Sustainable Buildings Certification Program, which is not only driving improvements in energy efficiency, but also promoting diffusion of renewable energy technologies, green roofs, and options for sustainable transport. Another important strength is the ability to convert environmental commitment on the part of tenants and building owners into a financial benefit, in the form of increased competitiveness. To promote these changes in the existing building stock of Mexico City, the function also offers certified buildings substantial tax incentives. A 40% payroll tax is offered to tenant participants and a 20% property tax is offered to building owners. However, these incentives do not completely address the challenge that owners and tenants face in covering the costs of performing the necessary audits. This is a critical limitation of the function in that it offers no direct financial assistance.

5. Discussion

In this paper, city-level policies for promotion of energy efficiency and emissions reductions have been broken down into their constituent functions. Each function is designed and undertaken with specific goals in mind, and often to combat a particular barrier. As such it is important to analyze them for commonalities both in design and impact, and assess the relationships, or potential relationships between functions.

5.1 Voluntary action

Firstly, among defined functions the majority operate on a voluntary basis. This is true for five out of six programs surveyed, if also considering that Tokyo Carbon Reduction Reporting Program has a voluntary component. This preponderance of voluntary programs is likely the result of an uncertain regulatory climate, where both national and sub-national governments are struggling to find non-invasive solutions to climate governance. This effect is compounded by the costs associated with making improvements to energy efficiency. Regulators are not eager to risk economic security, as heavy-handed legislation will drive businesses to other locations (Lee, 2004).

For voluntary functions as a whole, a common strength is their ability to foster action through the production and sharing of information. As a result, functions based on voluntary action frequently have the goal of creating or better distributing information. Information instruments used include energy audits, building labels and certifications, energy labels, and organized sharing of best practices. Depending on their scope and design, these approaches can be relatively effective on their own, but also have high potential in a support role for other instruments (Boza-Kiss, 2013). This rings true within the study sample, as all voluntary programs surveyed, with the exception of Renew Boston Trust - Commercial, are contributing to or benefitting from other policies. This is a strength of voluntary functions as a whole, to provide data for the design of more comprehensive and perhaps mandatory initiatives. It is notable that voluntary functions, particularly knowledge capacity building and friendly competitions, are well suited to raising awareness about energy efficiency in existing buildings. This is incredibly important, as lack of knowledge on the part of building industry professionals, as well as end-users of energy is arguably the largest barrier where efficiency measures are concerned (Boza-Kiss, 2013). This is confirmed by observing Tokyo Carbon Reduction Reporting Program, having seen a large increase in the number of enterprises and businesses in voluntary compliance. This demonstrates the growing realization that the commercial sector should make greater efforts to increase building energy efficiency.

Other voluntary functions such as financial capacity building, demonstrate that programs often benefit from having no need for legislative action. While the effectiveness of voluntary measures depends on the context and enforcement of some accompanying regulatory measures (Bertoldi, 2011), virtually any of these functions can be effective if implemented and enforced well (Boza-Kiss, 2013). As many of these functions are bespoke to the cities that house them, this is a very important realization. Moving forward, it will be necessary for cities to design holistic approaches to energy efficiency in existing buildings, combining the strengths and limitations of the functions described in this paper. It is clear that while they can be effective for those who participate, voluntary functions are somewhat lacking in their ability to produce large-scale change in existing building stocks. However, their ability to gather information could be useful as a first step. This is particularly with regard to the need to induce changes in private and professional practices (Urge-Vorsatz, 2013). That is, addressing the information gap that exists about energy efficiency and energy use generally is an area in which voluntary functions are particularly well suited.

Importantly, functions use economic instruments that have the ability, theoretically in the case of Renew Boston Trust - Commercial, to produce the large-scale effects that are typically out of reach for other voluntary approaches. As a result, market-based solutions are becoming an increasingly popular method of accelerating energy efficiency. This is demonstrated in the ambitious goal of Renew Boston Trust - Commercial to turn deep energy retrofits into an investible class asset that will be utilized by large lending institutions. This is the only voluntary approach that shows promise to bring about large-scale emissions reductions.

Mandatory approaches

Contrasting with voluntary measures, mandatory measures, represented in this study by Shenzhen ETS and the mandatory component of Tokyo Carbon Reduction Reporting Program, have the potential to facilitate large emissions reductions. Relative to voluntary measures, regulatory approaches such as cap and trade are typically the most effective policy instruments (Boza-Kiss, 2013). Importantly, these measures can directly target existing buildings, being different in this sense from most mandatory approaches that focus on the creation of new building codes for new construction. This is an important consideration, as existing buildings are the problem at hand. It is critical that cap and trade programs be designed and implemented well, with care taken to create appropriate caps and well-functioning markets for trading of credits. Additionally, as Shenzhen ETS has set an emissions cap relative to unit of GDP, rebound effects must be taken into account. In this context rebound effects may occur due to increased economic growth, resulting from lower energy services costs (Gillingham, 2013). Barring this potentiality, cap and trade in Shenzhen has been quite successful in meeting and even exceeding the original emissions reduction goal of 21% per unit GDP.

Though such definitive conclusions regarding emissions reductions cannot be drawn from the mandatory component of Tokyo Carbon Reduction Reporting Program, the creation of a comprehensive energy benchmarking index is also an important impact. Without this mandatory measure, it is likely that buildings simply would not have voluntarily provided their carbon emissions information to the public. Additionally, the presence of this mandatory function has driven similar voluntary action as well.

6. Conclusion

Using evidence from the six C40 cities that participated in the study, this paper has identified seven key functions that are carried out by energy efficiency programs around the world. Defining these functions in this way allows for a more in-depth analysis of the goals, strengths, and limitations of energy efficiency efforts than would be possible analyzing them as whole programs. Additionally, removing functions from their programmatic context allows them to be viewed as individual parts that can form one of many options in the 'toolkit' of policy instruments available to policy makers. This provides an opportunity to examine their unique features, effective as well as ineffective components, and to identify any combination of functions that may provide additional benefits in terms of energy use and emissions reductions.

As is demonstrated in the study sample, cities are mainly utilizing voluntary functions to further energy efficiency efforts in the existing building stock. This is somewhat surprising, as mandatory programs produce greater energy use and emissions reductions, as demonstrated by the success of Shenzhen ETS. Additionally, Tokyo Carbon Reduction Reporting Program has also succeeded in gathering submissions from over 30,000 facilities, which has provided enough information to create a very comprehensive carbon emissions benchmarking index for small and medium-sized enterprises in Tokyo. Use of the monitoring and reporting function as a mandatory measure has resulted in far more data collection than voluntary programs. However, it is important to note that slightly more than 10,000 facilities submitting data did so in a voluntary capacity. This more likely speaks to the effectiveness of mandatory functions to drive innovation. To stay competitive, buildings are making energy efficiency and carbon reporting a priority. This would likely not have happened without the mandatory measure in place.

Voluntary functions have their place in promoting energy efficiency as well. Though they typically do not result in significant reductions relative to a city's total emissions, they are very effective at gathering information and using that information to raise awareness. Depending on the target, knowledge capacity building can target building owners, tenants, or consumers, though all three are critical in moving forward on energy issues as they relate to climate. Retrofit Chicago Commercial Initiative is a prime example of building owner education. This program is particularly effective at raising awareness and using education to foster retrofitting activity among owners of large buildings. Though the program has produced relatively modest reductions in energy use, it is certain to have laid a foundation for a future where energy efficiency in commercial buildings is much more visible and better integrated into plans for building operation. Mexico City Sustainable Buildings Certification Program is also notable in this regard, though in a slightly different manner. While energy efficiency is a component of the certification, properties are able to raise awareness about a wider range of sustainability issues associated with the built environment.

As seen in **section 4** of this paper, each function has a unique set of environmental, social, and market impacts, as well as strengths and limitations, some being observed and others expected. These are important to identify in the context of improving energy efficiency. Knowing well the strengths and limitations of these functions will help identify any opportunities for them to work in concert with one another. The relationship between monitoring and reporting is a perfect example of this. Five years of robust monitoring and reporting were required to produce a meaningful and informative benchmarking index in Tokyo. This is a lesson that other cities will benefit from, as simply raising awareness about what is and isn't an energy efficient building will be a challenge for many cities. Another example is the potential for friendly competitions to inform the creation of benchmarking ordinances and energy efficiency building codes.

Though operating individually, cities have also contributed to global energy efficiency policy efforts by serving as innovators. Where these functions are very difficult to implement on a national level, cities are responding to this policy vacuum by designing bespoke functions that fit local conditions (IPCC, 2014). This drive has allowed cities such as Boston to sponsor the creation of a completely novel financial capacity building program. In Shenzhen, the ETS was designed by China's central government, but was piloted in Shenzhen. This does not exactly fit the mold of a city-led innovation, but it nonetheless speaks to the unique conditions present at the city level, as this potential for experimentation was recognized and used with great success.

Moving forward, cities will continue to innovate and create both new voluntary and mandatory policies. While this study was able to identify key program functions and their short-term impacts on energy efficiency efforts, further research is required to identify the long-term impacts. In the creation of voluntary programs, cities are able to innovate, but these programs lack the ability to produce large-scale energy use and emissions reductions necessary to reach citywide climate targets. Additionally, more information is needed on the potential interactions between functions, particularly between mandatory and voluntary approaches. Pairing these approaches will be critical in addressing citywide climate goals, as they have great potential to be complementary.

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