Chapter 2:

Key findings and overall analysis

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2.1 Overview of chapter

This chapter extracts the key findings that have emerged across the seven case studies making up the bulk of this report. In particular, the following sections examine areas such as:

- Key programme characteristics including general approach, start years and scope of targeted buildings
- Basic policy functions employed
- Incentives for promoting voluntary participation
- Environmental, social and market impacts achieved
- Innovative success measures and design features
- Common barriers and successful countermeasures

2.2 Key characteristics of programmes

As shown in Table 1, the sample in our second Urban Efficiency report is characterised by a preponderance of voluntary or hybrid approaches (i.e. involving both voluntary and mandatory components). Voluntary approaches are demonstrating remarkable adaptability in regards to coverage (definable both in terms of number of buildings covered and gross floor area (GFA). They are employed by both programmes targeting small groups of buildings or enterprises (i.e. around 50-100) and those targeting several thousand. For example, programmes in Tokyo and Seoul illustrate that it is possible to engage several thousand private sector buildings with voluntary approaches. In Tokyo's Carbon Reduction Reporting Program, the majority of enterprises and buildings reporting do so voluntarily. In other programmes however like in Chicago and London, the approach is more to work with a smaller cohort of influential leaders in the building industry. Although certainly significant in terms of GFA, smaller cohorts in these programmes allow for greater intimacy and relationship building. This is achieved through one-to-one communication between city officials and building owners or managers and facilitation of peer learning amongst buildings.

This said, it should of course be emphasised that each city surveyed holds multiple programmes for advancing operational energy efficiency and retrofitting in existing buildings and that some of these are mandatory. As already mentioned, our analysis is limited to a single, flagship initiative nominated by programme officials. Yet the proliferation of voluntary or hybrid approaches in our sample suggests clearly that policy innovation and effective building governance can still occur in the absence of regulatory frameworks. Voluntary schemes can also be a precursor to mandatory programmes. As argued by Trencher et al. (2016), this is by encouraging engagement and communication between city governments and building owners or tenants around energy and carbon emissions, and by nurturing relations and trust in a non-regulatory ambience. Voluntary programmes also facilitate a gradual transition to mandatory approaches by allowing policy makers to collect data to understand the performance and challenges in key areas of the building stock. This data can then inform subsequent development of additional policies or guide fine-tuning of existing programmes.

Table 1: **Approach and nature of programmes**[1]

City	Coverage		Programme type
Tokyo	Higher	34,499 buildings	Voluntary and mandatory
Shenzhen		53 km^2 total development area (on completion)	Voluntary and mandatory
Seoul		4,200 projects (in BPR finance scheme)	Voluntary
London		1,674 buildings (9.99 million m^2)	Voluntary
Chicago		62 buildings (3.99 million m^2)	Voluntary
Mexico City		65 buildings (2.2 million m^2)	Voluntary
Boston	Lower	No data (under planning)	Voluntary

Implementation year

The first year of implementation for each programme is summarised in Table 2. Boston's Renew Boston Trust – Commercial, being still in the advanced design stages, is not yet implemented. Its first batch of projects are scheduled for 2018. For the other six programmes, four were implemented in 2012 or thereafter. Outcomes for these programmes are therefore still emerging. Two programmes however, in Mexico City and Tokyo, are approaching years of maturity. The effectiveness of both programmes has therefore become relatively clear at this point, allowing several conclusions to be drawn.

Table 2: **First year of implementation**[2]

City	2009	2010	2011	2012	2013	2014	2015	2016
Boston[3]								
Chicago				◉	◉	◉	◉	◉
London						◉	◉	◉
Mexico City	◉	◉	◉	◉	◉	◉	◉	◉
Seoul				◉	◉	◉	◉	◉
Shenzhen				◉	◉	◉	◉	◉
Tokyo		◉	◉	◉	◉	◉	◉	◉

[1] Based on most recent data. Most programmes are expanding coverage.
[2] Refers to the first year that the programme came into effect and not the year when an ordinance or law was passed.
[3] Being still in the advanced stages of programme planning, the first batch of energy efficiency projects are set for implementation during 2018.

Target and scope

Table 3 summarises the attributes of the private sector buildings and stakeholders that each programme principally targets. Beginning from the left, as can be expected, all programmes are targeting commercial buildings. Although represented largely by office buildings, some programmes are actively targeting hotels, retail, health, medical, leisure, cultural, educational and worship facilities. Overall, relatively fewer programmes are targeting industrial facilities. However these are actively targeted by programmes in Boston, Mexico City, Shenzhen and Tokyo. We found that half of surveyed programmes are also targeting residential buildings. Of these, all target multi-family (MF) residences whilst only two also target single-family (SF).

Moving on to building sizes, all programmes have a relatively "open door" policy and lack minimum thresholds for gross floor area (GFA). Presumably, this comes from their voluntary or hybrid nature and ambitions to engage a large and diverse representation of private sector buildings in that city. Bearing in mind that there is no objective measure of a large or small building since this varies significantly depending on the size of the city, overall, we found that programmes tend to concentrate recruitment and engagement efforts on larger to medium buildings. This said, many small buildings were also seen to be participating. These range, for example, from small office buildings and chains of convenience stores in Tokyo to single-family or detached dwellings in Seoul and Shenzhen.

Finally, it is interesting to note that the majority of programmes are explicitly targeting tenants as well as building owners. This contrasts to mandatory approaches such as benchmarking and auditing or retrocommissioning regulations, which tend to primarily target building owners.

Table 3: **Characteristics of principally targeted buildings and stakeholders**

City	Sector			Size			Stakeholder	
	Commercial	Industrial	Residential	Large	Medium	Small	Owner	Tenant
Boston	◉	◉	◉ MF*	◉	◉		◉	
Chicago	◉			◉	◉		◉	
London	◉			◉	◉		◉	◉
Mexico City	◉	◉	◉ MF*	◉	◉	◉	◉	◉
Seoul	◉		◉ MF/SF**	◉	◉	◉	◉	◉
Shenzhen	◉	◉	◉ MF/SF**	◉	◉	◉	◉	◉
Tokyo	◉	◉		◉	◉	◉	◉	◉

* MF = multifamily ** SF = single-family, detached dwelling

Governance instruments to advance energy efficiency and retrofitting

The surveyed programmes provided much insight into the array of basic governance instruments used by city officials as they work to advance operational energy efficiency and retrofitting in the existing, private sector building stock. As shown in Table 4, what we have termed a single city "programme" is in fact a package or mix of various governance instruments.

By integrating multiple governance measures into single programmes, and also by cross-linking multiple programmes, city policymakers are able to mandate or encourage multiple forms of action or engagement from building owners and tenants. For example, as shown in the case of Tokyo, instead of just measuring and submitting energy consumption and GHG emissions data, reporting facilities and enterprises are also encouraged to display performance ratings based on benchmarks. In addition, the Carbon Reduction Reporting Program also provides various forms of capacity raising to improve access to finance and acquire industry relevant best practices for energy reduction measures.

In this way, with each city programme consisting of various instruments, the multiple components complement each other by carrying out interrelated yet subtly unique functions. The net impact of this is a situation where the totality of the mix of governance measures can prove "greater than the sum of the parts" (Van der Heijden, 2016).

Table 4: **Governance instruments used in each programme**

	Periodical data reporting	Performance disclosure & certification	Energy reduction challenge	Financial capacity building	Knowledge capacity building	Masterplan and target setting
Boston	◉			◉	◉	
Chicago	◉		◉	◉	◉	
London	◉		◉		◉	
Mexico City		◉		◉		
Seoul				◉	◉	
Shenzhen	◉			◉		◉
Tokyo	◉	◉		◉	◉	

The following sections provide an overview of the various governance instruments observed, and also extract key messages from Table 4. Our analysis is by no means intended as exhaustive. We acknowledge that each city programme may be carrying out additional functions than those indicated. Accordingly, our goal is merely to provide a more concrete idea of the multiple, varying and common or unique approaches that policy makers are developing and combining as they pursue programme goals.

Periodical data reporting

The periodical submission (both voluntary and mandatory) of quantitative data such as energy consumption, GHG emissions and GFA—sometimes in addition to qualitative information such as energy reduction measures taken—is the central governance instrument underpinning four of the seven programmes surveyed. Integration of this instrument into programmes is driven by expectations that "what gets measured gets improved" (Hsu, 2014). Two main types of data reporting mechanisms were observed; the EPA ENERGY STAR Portfolio Manager in Chicago (widely used in U.S. benchmarking programmes) and custom-made Excel spreadsheets in London and Tokyo. Although in most cases data submission is annual, the Retrofit Chicago Energy Challenge requires bi-annual reporting. This allows more frequent monitoring of progress and also gives some indication of seasonal differences in energy consumption.

For city governments, mandating or encouraging submission of quantitative and qualitative energy related data allows programme representatives to monitor the progress of individual buildings, recognise outstanding achievement and share best practices with other buildings. In Chicago, use of Portfolio Manager allows buildings to benchmark performance relative to peers. However data submission also fulfils other purposes. Firstly, it allows policy makers to understand the performance of targeted buildings and assess programme impacts. Secondly, as illustrated in the Tokyo and London cases, it allows policy makers to create building-specific benchmarks, and then share this information back to building owners. Both city programmes carry this out through carbon report cards. Benchmark information in Tokyo is highly tailored to its diverse users, consisting of more than 30 industry specific categories. Finally, collection of data on building stock energy performance allows policy makers to use this as evidence to inform future policies or fine-tune existing ones.

Performance disclosure and rating

Initiatives to publicly disclose building performance and actively communicate this to potential tenants, buyers and the general public were observed in Mexico City, London and Tokyo. In Tokyo, firstly, carbon emissions data and ongoing energy reduction measures are disclosed online. This enables both quantitative and qualitative comparisons of carbon emissions intensity (and thereby energy intensity) and energy reduction measures across same type buildings. Annually submitted carbon emissions data is also exploited to create performance ratings through the carbon report card initiative. This is novel in that it directly targets potential tenants and building owners to offer a detailed and ranked breakdown of the carbon intensity of a building relative to its business peers. This is in addition to providing qualitative information such as implemented energy efficiency improvement measures. Mexico City's certification programme takes a more holistic classification approach. It allows buildings to demonstrate differing forms of activities or innovation in an array of sustainability categories. Aside from energy efficiency, these encompass water, mobility (use of shuttle buses and connectivity to public transport etc.), renewable energy, waste, societal and environmental responsibility and green roofs. The Mexico City certification scheme is also unique in that it is entirely run by a local government, and additionally, allows tenanted sections of individual buildings to obtain certification.

Financial capacity building

Financing related governance measures were also widely observed, present in six of the seven programmes. The significance of barriers related to accessing finance is well documented elsewhere (Van der Heijden, 2016; Becqué, 2016). Banks and lending institutions are sometimes reluctant to fund retrofitting projects out of concern that investments may not be reflected in future evaluations of properties, and because of the uncertainty related to the ability of projects to generate reliable cash flows. Even in cases when financing or capital can be accessed, "split-incentive"[4] issues between tenants and owners will very often hamper efforts from either party to invest in energy efficiency upgrades. In addition, unique, local conditions can also impact the ability of building owners and tenants to invest in retrofitting or obtain finance. As an example, Tokyo's case illustrated that seismic (i.e. earthquake) resistance tends to gain priority on the building market, dampening owner enthusiasm to invest in energy efficiency. Boston's case emphasised that the structure of investment cycles is a major impediment to the acquisition of project financing. This is because "mid-cycle investments" in longer 20 to 30-year commercial real estate investment cycles are rare—and sometimes even prohibited—in leasing language.

Various forms of financial capacity raising were observed to tackle these barriers. Some programmes such as Shenzhen or Tokyo seek to alleviate retrofitting associated financial burdens by allocating direct subsidies or offering tax credits. Other programmes such as Seoul or Mexico City act as intermediaries by processing applications and then recommending applicants to private or international lending institutions. Applicants are then provided loans at attractively discounted interest rates. Boston adopts a novel approach in its adoption of an "energy aligned" or "green" lease approach (see Janda, 2016; Feierman, 2015). Firstly, it aims to help building owners overcome split-incentive issues by reforming leasing language. This allows owners to pass through the costs of energy reduction retrofitting measures to tenants as "utility payments".

[4] Refers to a situation where on one hand a building owner lacks an economic rationale to invest in an energy efficiency upgrade as the benefits (i.e. lower energy expenditures) would be principally reaped by the tenant. On the other hand, the tenant also lacks an economic incentive to invest in energy efficiency upgrade since this benefits of the upgrade would be largely received by the owner (i.e. an increased property value).

Secondly, it integrates performance guarantees into projects, assuring the ability of a project to generate cash flow for loan repayments, even in the case of an underperforming retrofit. This consequently improves the bankability of projects, and protects lending institutions from default. A third innovative feature is the creation of a special purpose, nonprofit and self-funding entity for administering the payback process to project contractors and lender investors.

Knowledge capacity building

The second type of capacity building consists of disseminating knowledge related to operational energy efficiency and effective retrofitting measures. These were widely observed across programmes. Such measures have been called "educative" (Dowling, 2014) since policy makers use this approach to fill knowledge gaps in the market and educate key stakeholders. As emphasised by the Intergovernmental Panel on Climate Change (IPCC, 2007), a lack of knowledge about the opportunities for reducing energy consumption, technological options, effective financing approaches and best practices can hamper interest in retrofitting. City programmes can therefore play an important role in closing the information gap by collecting and disseminating differing forms of knowledge. This can come not just from technical experts in the city, but also other buildings and programme partners such as private consultants or non-profit organisations.

As a prominent example, knowledge enhancing measures were particularly central to the Retrofit Chicago Energy Challenge. In addition to providing one-to-one consultations with technical experts in the city and hosting networking events and engineer roundtables, Energy Road Maps were a noteworthy approach. Implemented through grant funding and cooperation of private sector partners, the provision of road maps assisted Challenge participants with compiling energy use data, creating energy baselines, benchmarking performance, quantifying actual and planned energy reduction measures to-date, and finally, creating business cases and then identifying sequential actions and investments to meet the 20% reduction commitment. Information diffusion and educative measures were also significant in Tokyo's Carbon Reporting Program. Programme officials hold an annual training seminar to some 300 industry stakeholders. This seminar shares annual carbon emission trends for more than 30 business types, various improvement strategies for each, and best practices from frontrunner buildings. Tokyo's programme employs other important knowledge enhancing mechanisms. Programme officials conduct on-site visits to reporting facilities to verify data and identify opportunities for further improvement. In parallel, experiences accumulated through the program are collated into industry specific manuals for 27 business types (e.g. fitness centres, convenience stores, supermarkets etc.) to showcase effective capital and non-capital intensive energy reduction measures.

Energy reduction challenges

The central idea of the energy reduction challenge is to mobilise a cohort of frontrunner or motivated buildings and incentivise efforts to monitor and

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subsequently reduce energy consumption over a specific, and typically concentrated time span. As demonstrated by London and Chicago, two key variables can distinguish different adoptions of this governance measure: 1) the presence of a competitive element and 2) the length of the challenge period. In London's Business Energy Challenge, this unfolded over 12-months. Individual businesses (typically comprising of several premises across London) compete with each other to reduce CO_2 emissions from baselines. Businesses are thereby incentivised by the prospect of "winning" and qualifying for specific award categories given at ceremonies and receiving official recognition from the Mayor. Since the Business Energy Challenge unfolds over 12-months, this encourages intensified efforts and rapid improvements over energy consumption baselines. In Chicago's case, however, the approach was more long-term (five-years), and also lacked a competitive approach. Instead, the Retrofit Chicago Energy Challenge seeks to create a sense of solidarity and cooperation. This is by setting a common target for participants (a 20% energy reduction over five-years), and by asking that participants serve as mentors to other buildings.

Masterplan and target setting

The importance of setting aspirational and ambitious building sector targets for energy efficiency is highlighted by Becqué (2016). Such an approach was observed in Shenzhen's highly ambitious International Low Carbon City Initiative in Pingdi. This is unique among the sampled programmes in many respects. Firstly, all development in the low-carbon eco-city is guided by a comprehensive masterplan, prepared by an international team of Dutch and Chinese scholars and urban planning experts. As well as outlining zoning and citywide infrastructure considerations, this document provides the vision and set of principles that are guiding efforts to transform the built and natural environment. Secondly, this vision concerns both the physical environment and the economy. As such, building usage (i.e. the type of industry housed in the building and its strategic importance to the low-carbon city) is a highly important consideration in the selection of retrofitting, new construction and low-carbon business projects.

Target setting is integral to Shenzhen's approach. As shown in the case study, a large array of indicators and explicit objectives are fixed for the year 2025. These cover environmental, economic and societal dimensions. Two overarching targets include carbon emissions intensity relative to GDP (set to 0.32 t-CO_2 per RMB 10,000) and carbon emissions per capita (set to 5 t-CO_2 per capita per year). Specific building targets are also fixed. 100% of new construction is expected to meet the national green building standard and 50% for existing buildings by 2025. Data collection and monitoring is a crucial element of the target setting and governance of the low-carbon eco-city. A goal has also been fixed that energy consumption monitoring must extend to 100% of the building stock.

Inputs during design and implementation phase

We were able to collect some information—albeit limited—to illustrate the scale of time, human and financial resources made available during the design and implementation of each programme. Tables 5 and 6 summarise these findings.

Design phase

Table 5 indicates that programmes overall have been relatively quick to set up, with the bulk of planning mainly occurring over 1-2 years. For some large-scale programmes such as the Shenzhen Low-Carbon International City, this is particularly impressive. On the whole, programme planning has taken place in spite of highly limited human resources. Another notable trend is the formal and continuous input of various external parties to programme design. As prominent examples, the Retrofit Chicago Energy Challenge was collaboratively designed by both city officials and members of energy utilities, engineering firms and various non-government and non-profits, in addition to C40 staff. Similarly, the conception and masterplan for the Shenzhen Low-Carbon International City is the fruit of intense collaboration between government officials, university researchers and engineers, both locally and from the Netherlands.

Table 5: **Inputs to design phase**

	Time (years)	Human resources
Boston	3-4	1 FTE (external advisor)
Chicago	1	Multiple (internal/external)
London	1	1 FTE (internal)
Mexico City	1-2	2 FTE (internal)
Seoul	1-2	No data
Shenzhen	2	Multiple (internal/external)
Tokyo	1-2	Multiple (internal)

Implementation phase

Information showing the scale of inputs to the implementation of programmes is compiled into Table 6. Where data is available, it shows that human resources, described in full-time equivalent (FTE) for programme implementation, range from two to six internal officials. Although specific, quantitative data is lacking, it is worth noting the diversity in funding arrangements for programmes. The Renew Boston Trust – Commercial will be entirely self-funding since it will establish a non-profit entity to run the programme. This will collect revenue to cover running costs via overheads from supported projects, whilst project funding will come directly from private institutional lenders. Implementation of Retrofit Chicago Energy Challenge (and its impressive coverage of 62 buildings spanning more than 43 million ft^2) relies entirely on grant funding and part-time pro bono support from within the city and the programme's partner network.

Table 6: **Inputs to implementation phase**

	Human resources	Financial resources
Boston	Multiple (internal/external)	Self-funding, Private lenders
Chicago	Pro bono part-time support from multiple partners (internal/external)	No devoted budget Funding from grants
London	1 FTE (internal) plus consultant support (1FTE) for 3-months year.	GBP 70,000
Mexico City	2 FTE (internal)	No devoted budget
Seoul	4 FTE (internal)	KWR 22.5 billion for loan support scheme (2012-15)
Shenzhen	No data	No data
Tokyo	6 FTE (internal), including for related programs	No devoted budget JP¥ 1.237 billion budget in 2015 for incentive programmes for small to medium entities

2.3 Incentives

Given that all programmes are either completely or partially voluntary in nature and that success depends on successful engagement of the targeted building sector, cities developed an interesting array of incentives to entice participation. Some of the most noteworthy are showcased in Table 7.

Table 7: **Examples of incentives for enticing participation**

Type of incentive	Notable case examples
Financial or economic	• **Mexico City:** Payroll and property tax reductions increasing with higher levels of certification. Participating buildings also gain access to a special retrofitting loan support scheme. • **Seoul:** Attractive loan conditions such as low-interest rates, grace-periods for commercial customers and long payback periods. In addition, insulated windows and entrances provided through suppliers at discount rates. • **Shenzhen:** Allocation of subsidies per m^2 of retrofitted floor space. Provision of loan support for retrofitting and nurturing new business ventures. • **Tokyo:** Buildings participating in programme gain eligibility for retrofitting subsidies, tax credits and loan support schemes.
Marketing tools	• **Tokyo:** Provision of low-carbon industry benchmarks, broken into more than 30 business categories and carbon report cards. When combined with carbon report cards, these provide owners with new information and tools to market the property and potentially pursue green premiums.
Knowledge and capacity building	• **Chicago:** Organisation of networking events and engineer roundtables, peer-to-peer learning through sharing best practices, and consultations with technical experts. • **Tokyo:** Organisation of industry seminars for showcasing building sector emissions trends and best practice reduction measures.
Awards and public recognition	• **London:** Recognition by Mayor of London through awards ceremony. • **Chicago:** Recognition of participants on official website and newspaper advertisements. • **Tokyo:** Official programme participation plaques for display in building lobbies. High performing buildings awarded a certification and featured on official website.

2.4 Outcomes and impacts

A wide array of results and impacts were observed from surveyed programmes. Although environmental impacts such as reductions in energy consumption and CO_2 emissions were noted in several cities, strong evidence emerged to suggest that other types of impacts—namely of a social or market nature—were just as important. In light of this broad array of impacts, our findings suggest there are significant opportunities for policy makers to look beyond the narrow scope of solely environmental outcomes when designing or evaluating programmes.

Environmental impacts

Noteworthy impacts of an environmental nature were widely observed across programmes. These are summarised into Table 8. As can been seen, reductions in CO_2 emissions and energy or electricity consumption are highly significant. Additionally, important decreases in water consumption were achieved in Mexico City as a result of the Sustainable Buildings Certification Programme. Needless to say, such outcomes are important for water scarce Mexico City. However, as a general trend, programmes tend to place most emphasis on reductions of energy and GHG emissions. A host of reasons (e.g. differing baseline years, units of measurement, total GFA of affected buildings etc.) and unique programme objectives prevent direct comparison of results across cities. Also, it should be pointed out that despite such impressive outcomes, most programmes did not fix any explicit numerical targets for GHG emissions or energy consumption reductions.

Programmes in Shenzhen and Mexico City both incorporated new construction with retrofitting. A notable impact in both these cities was an increase in green building surfaces such as green roofs/walls and surrounding spaces. Particularly in Shenzhen, building and urban greenery will play a vital role in mitigating urban heat island intensity in the International Low Carbon City to less than 1°C, and also promote air purification. Shenzhen's case study also highlighted another important environmental outcome of retrofitting projects—the ability to beautify and restore deteriorated buildings and neighbourhoods. In the case of the traditional Hakka house restoration project, not only did this increase energy efficiency, comfort and fire safety, renovation of traditional buildings also generated new opportunities for commerce and culture (e.g. tea houses and exhibition spaces).

We also observed that city programmes to advance operational energy efficiency and retrofitting can drive uptake of renewable energy installations. This was particularly evident in Mexico City, where commercial and multi-family buildings are incentivised to obtain higher certification levels by installing rooftop solar photovoltaic installations and solar hot water systems. Boston's Renew Boston Trust – Commercial also demonstrated a potential to help realise climate resiliency projects such as district energy plants and microgrids across the city.

Table 8: **Various observed environmental impacts**

Type of impact	Notable case examples
Reductions in GHG emissions, energy and water consumption	• **Chicago:** As of July 2016, participating buildings achieved 11.7% reduction in energy use (weather normalised source energy) from baselines, representing annual savings of 90 million kWh of electricity and 70,000 tonnes of GHG emissions. • **Mexico City:** By 2015, 40 certified buildings achieved total savings of 66,120 t-CO_2 and 20.1 million kWh of electricity from 2009 base year. Potable water savings of 205,690 m^3 were also made. • **London:** In 2014, savings of 80,000 t-CO_2 were made relative to 2010/11 baseline year. In 2015, savings of 188,000 t-CO_2 were realised relative to the same baseline. • **Tokyo:** From 2009 to 2014, for 21,097 facilities submitting reports for six successive years, total CO_2 emissions declined by 12.3%.
Increase of green surfaces (green roofs, wall vegetation, gardens etc.) to mitigate heat island	• **Mexico City:** Increased uptake of green roofs across certified buildings • **Shenzhen:** Innovative wall vegetation installations achieved in key projects such as Low Carbon Exhibition Center.
Onsite production of renewable energy	• **Mexico City:** Increased uptake of solar hot water systems and PV installations. • **Boston:** Renewable energy and climate resiliency projects ($50 million district energy plant, efficiency upgrades and multi-user microgrid) under planning.
Environmental beautification and restoration of deteriorated buildings	• **Shenzhen:** In traditional Hakka housing restoration project, original forms and spatial layout were preserved whilst enhancing comfort, energy efficiency, fire safety and business opportunities (tea houses etc.).

Social impacts

Outcomes of a social nature were vast and widely observed across programmes. Notable examples are collated into Table 9. In addition to building owners and tenants receiving enhanced knowledge and financial capacity to improve building environmental performance, many programmes reported success in triggering greater building industry attention on climate, energy and sustainability issues. For those buildings participating directly in programmes, periodical monitoring and reporting of energy consumption is a major driver of this. Yet awareness around climate and energy efficiency issues can also be stimulated in the building community at large. This occurs from the leadership and public communication of successful energy reduction strategies shown by frontrunner buildings.

Table 9: **Various observed social impacts**

Type of impact	Notable case examples
Greater building industry attention on climate, energy consumption and sustainability issues	• **Chicago:** Consistent growth in Challenge participants, reaching 62 buildings and 43 million ft^2 in 2016. Cohort features iconic skyscrapers, historical landmarks, multi-family housing, charities and famous attractions such as Navy Pier and John G. Shedd Aquarium. • **Tokyo:** Voluntary carbon report submissions grown from 1,217 enterprises in 2010 (representing 10,965 individual facilities) to 1,871 in 2015 (representing 11,476 individual facilities). These outnumber mandatory submissions six-fold. Industry organisations now actively recruit new enterprises for the programme.
Enhanced capacity to improve building environmental performance from exposure to knowledge and financial capacity building	• **Seoul:** Over 4,000 residential and commercial building energy efficiency improvements successfully financed and completed over 2012-2015. • **Chicago:** Participant capacity to plan, finance and carry out effective retrofits enhanced through peer-to-peer learning, road maps, technical consultations and subsidised audits.
Greater transparency of building energy efficiency for potential tenants, buyers or lenders	• **Boston:** Plans to integrate performance guarantees to assure cash flow from retrofitting projects, increasing creditworthiness. • **Mexico City:** 45 buildings certified, 20 in process of certification. Commercial buildings can opt for inclusion on list of green buildings in Mexico City for prospective international tenants. • **Tokyo:** Carbon report card initiative implemented to show performance of building relative to industry specific benchmarks. Report cards can serve as green building ratings to be marketed to potential tenants. • **Mexico City and Tokyo:** Certifications and carbon report cards allow estimation of building running costs.
Behavioural changes in building usage	• **Tokyo:** Behavioural changes to reduce energy consumption continued, even after power supplies were restored after Fukushima disaster. Widely observed measures include extinguishing lights and air-conditioning in vacant rooms or after normal business hours, and also, optimising heating and cooling temperatures.
Overcoming split-incentive issues	• **Mexico City:** Individual tenanted sections of commercial buildings can obtain certification for tenant occupied space. For existing multi-family properties, certifications can be obtained for tenanted sections, common areas or whole building. Property tax reductions incentivise owner investment in tenant areas. • **Boston:** Green leases pass on amortisation costs of energy efficiency projects to tenants, allowing both owners and tenants to benefit from lower energy expenses and building upgrades.

Another important social impact is the capacity to supply missing market information and increase transparency around building energy efficiency to potential tenants, buyers or lenders. Programmes developed many unique strategies to this end. Mexico City pursued a building certification approach. Tokyo adopted a similar approach. Officials are presently experimenting with carbon report cards to render visible the performance of an individual building relative to industry benchmarks for peer buildings. In both Mexico City and Tokyo, such information allows potential tenants to estimate running costs. Boston's programme also seeks to supply missing market information, but of another kind. It uses performance guarantees to reduce uncertainty on returns and increase credit worthiness towards investor lenders by guaranteeing the ability of energy efficiency upgrades to generate cash flow. Financial and technical performance of multiple projects will be collected and supplied to financial institutions to facilitate traditional credit worthiness assessment.

Finally, noteworthy approaches were observed to tackle split-incentive issues. Chicago's programme organised workshops to assist participating buildings in forming green leases to share costs and benefits associated with energy efficiency upgrades between tenants and owners. Green lease strategies also underpinned Boston's programme. This seeks to rework lease agreements to tap into tenant utility payments to owners, reduced after energy efficiency projects, to repay costs to investor lenders. Mexico City's certification programme had a highly unique approach to enticing tenant engagement. It incentivises tenanted sections of buildings to invest in upgrade measures to obtain certification by also offering payroll and property tax reductions for tenants.

Market impacts

Outcomes of an economic nature were also widely reported across the surveyed programmes. Notable examples are summarised into Table 10. Retrofitting impacts featured highly among these. Programme influences on retrofitting activity were measured in different ways. In Seoul, officials in the Building Retrofitting Programme loan scheme are able to track retrofitting activity through financed project completion reports. Energy challenge programmes working with smaller cohorts of frontrunner buildings are more easily able to gauge programme influences on retrofitting activity due to intimate and frequent communications with participants. Tokyo uses an annual survey approach to measure changes in year to year retrofitting activity. In addition to retrofitting outcomes, programmes have also brought about other economic benefits such as reduced electricity expenditures. Tokyo's programme appears to have contributed to a 18.2% decrease in power consumption in participating buildings. Although affected in early years by electricity shortages following the Fukushima disaster, buildings have continued to conserve energy even following the restoration of power supplies. Mexico City's certification programme reported significant green premiums up to 20% for certified office buildings. Finally, both Mexico City and Seoul are contributing to green job creation. The former has created nearly 70 new jobs by training and hiring technicians to oversee building auditing and certification. By extending financing support to ESCO's, Seoul's programme is also contributing to the growth of this industry.

Table 10: **Various observed market impacts**

Type of impact	Notable case examples
Stimulation of retrofitting and installation of low-carbon technologies or onsite renewable energy	• **Seoul:** For commercial buildings, increased installation of energy efficient lighting systems, HVAC systems and insulation. For residential buildings, increased installation of insulated windows, wall insulation, heating systems and LED lighting. • **Chicago:** Commitments to energy challenge driving several buildings to invest in retrofitting of key building components such as HVAC systems. • **Shenzhen:** 100,000 m^2 of buildings retrofitted so far (mostly old factories, warehouses and residential Hakka houses).
Reduction in energy expenditures	• **Chicago:** Current financial savings from 11.7% energy use reduction in Challenge building cohort estimated at $6.4 million per year. • **Tokyo:** From FY2010 to FY2014, average electricity consumption reduction of 18.2% (from 1994 Mj/m^2 to 1646 Mj/m^2) achieved across reporting facilities, representing annual savings in 2018 of ¥838 per m2.
Growth of ESCOs, service providers and green jobs	• **Mexico City:** 68 new jobs created through training and hiring technicians to oversee auditing and certification of buildings. • **Seoul:** Expansion of ESCO business activities by providing financing.
Increased demand for green buildings, manifestation of green premiums	• **Mexico City:** Green premiums of around 20% for rental yields observed for certified office buildings.

2.5 Innovative success factors

Case studies revealed an array of strategies to increase the effectiveness and appeal of city programmes. Notable examples are compiled into Table 11. We found that these factors were often related to programme design features, as generic policy instruments (e.g. carbon reporting or building certification schemes) are appropriated from elsewhere and then tailored to local conditions and contexts. This fine-tuning and modification of generic policy instruments is an important driver of policy innovation and trailblazing in the C40 PBE network (Trencher, 2016). Newly added design features become a powerful driver of programme outcomes, also creating attractive incentives to entice building industry participation.

We also highlight how collaboration with external experts was underlined as a major success factor by programmes. For example, production of the master plan for the International Low Carbon City in Shenzhen involved extensive collaboration between city officials and Dutch and local urban planning experts (see De Jong, Wang et al. 2013; De Jong, Yu et al. 2013). There was also strong evidence of collaboration in other city programmes during both design and implementation. Chicago's programme is co-implemented by a team of experts from organisations such as C40, National Resources Defence Council and Environmental Defence Fund. Tokyo's programme collaborates tightly with industry organisations to recruit new participants, compile and then diffuse knowledge on best energy saving practices through manuals and seminars.

Table 11: **Noteworthy drivers and strengths**

City	Feature	Effect
Boston	Design of explicit economic incentives for both owners and tenants through modification of leasing language.	Owners can conduct asset improving retrofits without needing to raise capital. Tenants can benefit from reduced energy expenditures once project is paid off.
Chicago	Clear, ambitious and quantitative reduction goal (20% over 5-years).	Provides participants with a common and clear objective and timeframe to pursue from beginning. Encourages ambitious energy reduction measures and mid- to long-term planning and investment strategies.
London	Multiple award categories	Drives programme recruitment by providing diverse opportunities for businesses to receive recognition for improving energy efficiency and reducing carbon emissions.
Mexico City	Attractive financial incentives such as payroll and property tax reductions. Both owners and tenants eligible for certification.	Building owners and tenants not pursuing certification under conventional schemes like LEED etc. are incentivised to seek certification.
Seoul	Non-reliance on subsidies. Project funding is channelled from City Climate Fund to private lending institution, and then to loan recipient.	Minimises burden to City and tax payers. Creates a sustainable business model where the loan support scheme can target an increasing number of buildings and continue indefinitely as funds are repaid.
Shenzhen	Phased roll out and gradual improvement strategy, with comprehensive, quantitative targets and rigorous monitoring.	Success factors identified in pilot zone can be exported to larger, future developments. Development targets and associated monitoring of progress facilitate planning of projects in line with city goals, also offering chance to engage the public.
Tokyo	Collaboration with corporate/ industry groups to encourage participation, and produce/ disseminate information on energy efficiency measures and opportunities.	Voluntary reporting segment of programme has grown, with building numbers now outnumbering mandatory segment six-fold.
	Integration of reporting data into numerous formats such as low-carbon industry benchmarks, carbon report cards and industry specific energy conservation manuals.	Educational value and usefulness of data is enhanced, serving as a powerful incentive to drive voluntary reporting.

2.6 Key challenges and countermeasures

The case studies provide rich information on the various challenges and hampering factors encountered by officials and programme representatives during design and implementation. The most notable of these are compiled into Table 12. Overall, many of the particular challenges encountered appear to be localised, contextual and highly related to the type of programme approach taken. Others, however, were common across several programmes. The case studies also shed light on an array of innovative coping strategies taken in response to various obstacles or limitations of programmes. It is hoped other cities might learn from these experiences.

Table 12: **Notable challenges and countermeasures**

Type of challenge	Notable countermeasures
Turnover of building ownership or management challenges continuation	• **Chicago:** Monitor building market. In event of sale, re-engage new owners and managers by informing of previous owner's commitment.
Inclusion of diverse representation of building stock	• **Chicago and London:** Shift away from minimum GFA thresholds defining participation eligibility to allow inclusion of smaller, more diverse building types.
Split-incentives between tenants and owners	• **Boston:** Modify leasing language to incorporate costs of retrofitting into tenant utility payments, which are then offset by increased energy efficiency. Create opportunity for tenants to benefit from reduced energy expenditures once project costs recovered. • **Mexico City:** For commercial buildings, allow certification of tenanted building sections or common areas. In multi-family apartment complexes, also allow certification of common areas.
Limited human resources and budgets	• **Boston:** Design programme as a self-funding and self-operating public-private partnership, eliminating need for direct city budget or implementation. • **Chicago:** Secure pro bono support for programme implementation from partner network of non-profits and private sector consulting firms. Also, focus on communicating business cases for retrofits to overcome incapacity to allocate subsidy type incentives. • **London:** Secure engagement of university partner for data analysis.
Low participation of existing smaller businesses due to cost hurdles	• **Mexico City:** Allow gradual certification over several years, reducing yearly upfront costs for any necessary retrofitting.
Preference of citizens for subsidies rather than loan support	• **Seoul:** Increase economic attractiveness of loan scheme through designing highly attractive loan conditions (interest, payback and grace periods). Also, reduce upfront purchase costs of key building installations (insulated windows and entrances) through memorandums of understanding (MOUs) with equipment suppliers.
Low market demand for energy efficient commercial buildings	• **Tokyo:** Create carbon report card scheme to provide easy to understand visual representation of building energy efficiency relative to same-type buildings. Owners can use these to attract tenants. In parallel, use financial subsidy schemes and integrate estimates of improved report card performance into retrofitting plans.
Difficulties in mainstreaming low-carbon business models	• **Shenzhen:** Minimise financial burdens through retrofitting subsidies and low-interest start up loans. In parallel, promote spirit of innovation and entrepreneurship across city.

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