Designing policy mixes for complementariness

Lessons from building energy efficiency programmes in New York, Tokyo, Seoul and Sydney

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Abstract

Cities are crucial sites for achieving socio-technical transitions in key infrastructure systems. Raising building energy efficiency through new construction or retrofitting holds particular relevance to sustainability transitions since this requires diffusion of new technologies and energy management practices. In pursuit of this, city policymakers around the world are increasingly utilising mixes of multiple policy instruments. The idea that interactions occur across instruments is integral to understanding policy mixes. Positive interactions that enhance the outcomes of other instruments or even the entire mix can be conceived as complementarities. Whilst previous research has focused on how policy mixes can be assembled, knowledge on how exactly complementarities may arise, and what different types are possible, has been limited.

Addressing this gap, we set out to understand how complementariness between different instruments in a policy mix can be achieved. In studying policy mixes designed to promoted building energy efficiency and retrofitting in New York, Seoul, Sydney and Tokyo, our analysis unearthed five distinct kinds of complementarities: *coverage*, *temporal*, *facilitation*, *functional* and *synergistic*. Our multi-case analysis illustrates how these arise in practice, also examining conditions that affect the ability of policymakers to successfully design complementarities and achieve enhanced results in mixes.

Key words: policy mixes, instrument interactions, complementarities, synergies, sustainability transitions, energy efficiency

1. Introduction

Cities are crucial sites for achieving socio-technical transitions in key infrastructure systems such as the built environment, energy and transport (Hodson and Marvin 2010, Rutherford and Coutard 2014). The challenge of raising the energy efficiency of the built environment is of particular relevance to sustainability transitions since spurring new construction and retrofitting of existing buildings to raise energy efficiency requires technological innovation and diffusion of new or emerging technologies (Van der Heijden 2014, Van der Heijden 2017a). Policies are crucial tools to spur this process. Given the wide array of environmental, social and economic performance expectations attached to environmental policies (Schmidt and Sewerin this issue), there is no single 'silver bullet' policy instrument for addressing complex sustainability and energy challenges. As such, expectations are high for policy mixes that bring together a variety of instruments (Rogge and Reichardt 2016, Kivimaa and Kern 2016, Flanagan, Uyarra, and Laranja 2011, Sorrell et al. 2003, Gunningham and Grabosky 1998). Integral to understanding policy mixes are the interactions between different instruments (Viguié and Hallegatte 2012, Nilsson et al. 2012, Oikonomou and Jepma 2008, Lieu et al., this issue). Yet, despite important theoretical insights, empirical understanding of how exactly interactions can occur across multiple policies is noticeably thin (Rogge and Reichardt 2016).

Seeking to address this knowledge gap, this article focuses on the positive interactions—what we term 'complementarities' following Flanagan, Uyarra, and Laranja (2011)—that might arise between different instruments in a policy mix. Although unpacked in more detail in our background section, for now our conception of complementariness depicts a situation where outcomes of multiple instruments on socio-technical systems combine to reinforce rather than conflict with respective policy objectives (Howlett and Rayner 2013, Boonekamp 2006). This said, our view is that merely combining a range of instruments does not guarantee positive interaction—or 'complementariness'. If not carefully designed, policymakers risk designing mixes where complementariness is compromised by poorly aligned or even conflicting instruments (Boonekamp 2006, Lieu et al., this issue). Consequently, in practice, outcomes of policy mixes as a whole may not surpass the sum of individual instruments, and in some situations, may fall short of this (Taeihagh, Givoni, and Bañares-Alcántara 2013). Using an illustrative case of energy efficiency and retrofitting in existing buildings, this article contributes to the emerging scholarship on policy mixes for triggering sustainability and socio-technical transitions. We do so by empirically demonstrating the precise mechanisms by which complementarities can arise across differing policy instruments, and additionally, considering various strategies taken in large cities to increase potential complementariness when designing mixes.

For this task, we examine building energy efficiency policy mixes in four large cities (New York, Seoul, Sydney and Tokyo). Highly concentrated building stocks in such locations contribute up to 70% of citywide greenhouse gas (GHG) emissions, far outweighing other sectors such as transport or industry. Building energy efficiency (BEE) therefore forms a key focus of climate change and energy strategies for cities (Castán Broto and Bulkeley 2013). When tackling BEE, cities actively employ policy mixes (Kern, Kivimaa, and Martiskainen 2017, Boonekamp 2006, Rosenow et al. 2016). This need arises from the heterogeneity of the building stock in terms of building size and usage (commercial, residential etc.), ownership configuration, year built, technological complexity and financial capacity of owners and tenants (Van der Heijden 2014). Unique local markets, cultures and contexts (Trencher et al. 2016) further increase the need for implementing policy mixes. In sum, heterogeneity and unique city environments thereby demand multiple, diverse policy instruments (voluntary, mandatory, hybrids, top-down, bottom-up etc.) that each carry out numerous functions to spur greater energy efficiency of current and future buildings.

To empirically explore how complementarities may arise in BEE policy mixes at the city-level, we examine policy making and implementation experiences in four city members of the C40 Cities Climate Leadership Group (henceforth C40 network). This city network is widely acknowledged to be at the forefront of energy, climate and sustainable urban development policies (Acuto and Rayner 2016, Acuto 2016). The C40 network has been active for over 10 years and now covers 90 of the planet's major cities. It has a proven track record of climate impact. Recent research shows that 9,831 'actions' undertaken in member cities since COP15 in Copenhagen in 2011 will generate by 2020 an approximate annual savings over 645 Mt-CO_2 (C40 Cities Climate Leadership Group and ARUP 2015).
Key to the C40 network is the creation of opportunities for peer learning and emphasis on encouraging experimentation with new and emerging forms of policy instruments (Trencher et al. 2016, Trencher et al. 2017). Building energy efficiency has been a pivotal part of C40 action, and in particular, policies and policy mixes targeting private sector and municipality buildings. The C40 network therefore offers much insight into innovative policies and best practices in this area.

Seizing this learning opportunity, this paper specifically focuses on the design and implementation of policy mixes in city-level programmes for advancing energy efficiency and retrofitting of existing, private sector buildings. With ambitions of extracting lessons for policymakers and scholars tackling other environmental and social challenges, our data comes from document analysis and interviews with policymakers and industry practitioners.

The remainder of this paper unfolds as follows. Section 2 summarises current theoretical understanding into policy mixes and complementarities. Section 3 then presents our analytical framework and methodology, whilst Section 4 applies this and presents the findings of our case studies. Our combined discussion and conclusion, finally, extracts key lessons and suggests a typology of important types of complementarities in policy mixes.

2. Theoretical perspectives: knowledge on policy mixes and complementarities

Particularly in the area of climate policy, scholars point out that effective governance requires a mix of instruments due to the "wickedness" of climate change's multiple causes, limited time available to reduce emissions, and the wide range of government and societal actors needed to mobilise action (Gunningham and Sinclair 1999, Lehmann 2010, Sijm 2003, Adelle and Russel 2013). Also behind calls for policy mixes is the view that no single, perfect policy solution exists for complex environmental and sustainability challenges since all individual policy instruments inevitably have both strengths and weaknesses, whilst in addition, causes of problems are numerous. Effective governance can therefore involve compensating for the weaknesses or limitations of one instrument by introducing another (Gunningham and Grabosky 1998, Van der Heijden 2016).

Central to the promise of policy mixes is that interaction occurs when multiple policy instruments are linked together to a common objective (Uyarra, Shapira, and Harding 2016, Gawel, Strunz, and Lehmann 2014, Rio 2009, Rogge and Reichardt 2016, Lieu et al., this issue). Scholars have conceptualised potential interactions across instruments—whether coincidental or designed—in various ways. Notable work has demonstrated that policy interaction pathways in a mix can occur vertically/horizontally, internally/externally (Nilsson et al. 2012, Oikonomou and Jepma 2008, Sorrell et al. 2003). Vertical interactions refer to those taking place across policies from different governance levels (i.e. national, state, city, etc.) targeting the same environmental problem or group of actors (Schmidt and Sewerin this issue). Similarly, interactions can be horizontal and occur across the same governance level. Internal interaction refers to those taking place in the same type of instruments (i.e. climate policies) whilst external reflects potential for a climate policy to interact with, for example, a transport policy. Additionally, in analysing differing energy instruments targeting households in Europe, Boonekamp (2006) argued that the net result of interactions from multiple instruments can achieve differing intensities, ranging from strong to weak. The author classified instrument interactions as either *mitigating* (i.e. a negative, non-desirable state where effects of instruments cancel each other out), *reinforcing* (i.e. a positive, desirable state where instruments achieve an outcome greater than the sum of instruments) or *neutral* (i.e. no interaction is achieved).

These insights lead nicely to notions of 'complementariness' and 'synergy'. Our conception of complementariness follows those from literature (Flanagan, Uyarra, and Laranja 2011, Borras and Edquist 2013, Oikonomou and Jepma 2008) where a level of consistency is achieved across instruments in a policy landscape, by both design or chance. In using the term 'consistency', we refer to a definition supported by scholars (Lieu et al., this issue, Kern, Kivimaa, and Martiskainen 2017) and laid out by Howlett and Rayner (2013: 174): "the ability of multiple policy tools to reinforce rather than undermine each other in the pursuit of policy goals". Our conception of complementariness is thus compatible with the Boonekamp (2006) notion of multiple instruments 'reinforcing' each other. It also mirrors arguments from Howlett and Rayner (2013: 175) that multiple policies can achieve 'complementary effects' and a "mutually reinforcing or supplementing arrangement". To illustrate complementariness hypothetically, targeting the same group of actors (e.g. passenger vehicle manufacturers) with the same overall goal (e.g. to raise fuel efficiency), policy A might carry out one function (e.g. provide information to the market such as a fuel efficiency rating) whilst policy B assumes another (e.g. dictate a minimum fuel efficiency standard).

Synergy, arguably, is the ultimate goal of the policy mix. Scholars frame synergy as a situation where various instruments generate a combined result surpassing the sum of the policy mix's individual components (Freeman and Farber 2005, Duguma, Minang, and van Noordwijk 2014, Boonekamp 2006, Viguié and Hallegatte 2012, Adelle and Russel 2013). More concretely, Matt et al. (2013) argue that synergies arise from a two-way interaction across instruments as the presence of one instrument enhances another, creating a ‘symbiotic effect’. These conceptions suggest the presence of potential feedback loops across instruments (Edmondson, Kern, and Rogge, this issue). To hypothetically illustrate this situation again in the context of transport, policy A might target consumers to partially subsidise the purchase cost of an electric vehicle (EV) whilst policy B might offer subsidies for industry to install no-cost charging stations. The combination of the two could cross a threshold where EV ownership becomes cheaper than owning a gasoline vehicle, further spurring consumer purchases of EVs, which in turn, spurs retailers to install charging stations, further driving diffusion by lowering charging inconveniences. Scholars (Matt et al. 2013, Taeihagh, Givoni, and Bañares-Alcántara 2013) emphasise that the two-way interactions described here contrast to the one-way interactions that occur in the above situation of instrument complementarity (i.e. where policy A complements policy B with no reciprocal effect). Such synergistic expectations have been recently raised in applied work by the C40 network in the context of ‘co-benefits’ of climate action across sectors (Floater et al. 2016). This has emphasised the idea of mixing different sectorial policies for positive externalities. Although mostly concentrated on health, land use and transport policymaking, the potential of BEE policy mixes might be large and yet under-appreciated in C40 research or in academia.

Whilst these slightly ‘mechanical’ conceptions of instrument interaction sound simple to design, there remains a gap between normative expectations of what policy mixes can achieve and the empirical reality of what policy mixes attain in practice (Wurzel, Zito, and Jordan 2013, Van der Heijden 2014). This appears largely a result of how policy mixes come about. More likely than not, a mix of policy instruments is achieved over time rather than being designed and implemented as a whole during a specific period (Oikonomou and Jepma 2008, Kern, Kivimaa, and Martiskainen 2017). This occurs as new policy instruments are introduced or major amendments made at various locations in the policy landscape; a process which creates avenues of interaction across various components. This sequential emergence of policy mixes affects the extent to which those involved in developing the policy mix can design or anticipate interactions and complementarities between the various pieces of the mix (Mahoney and Thelen 2010, Van der Heijden and Kuhlmann 2017, Baumgartner and Jones 2009). The existence of older policies in the landscape may also render it difficult for policymakers to create new packages of instruments from scratch (Schmidt and Sewerin this issue) that might otherwise be designed to achieve optimal levels of interaction. Also, due to resource and knowledge limitations, many policy makers are unable to consider interactions with other instruments located horizontally or vertically in the landscape (Taeihagh, Givoni, and Bañares-Alcántara 2013). Additionally, the nature of interactions across instruments hinges significantly on context and how targeted stakeholders respond to policies (Lieu et al., this issue).

The question arising at this point is: How do complementarities and synergies actually arise in policy mixes? Is it enough to just introduce one instrument after another into a policy landscape? Are there particular strategies that policymakers can use to enhance complementariness across instruments? In the policy mix literature, studies on this subject are highly limited. In addition to the above examined literature explaining the pathways (i.e. horizontal/vertical and internal/external) by which complementarities might arise, to date, much scholarship has focused on the mechanisms and triggers by which policy mixes can be assembled. These include, non-exhaustively, the 'layering' of a somewhat exogenous instrument to a mix to ultimately change its direction (Thelen 2009); the 'patching' of a malfunctioning policy or mix with a new instrument to improve the performance of the mix as a whole (Howlett and Rayner 2013, Kern, Kivimaa, and Martiskainen 2017); and the strategic 'packaging' of various instruments into a larger policy programme in the goal of attaining a higher level of acceptance than could be attained individually (Givoni 2014, Howlett and Mukherjee 2014).

As illustrated in our empirical section, these conceptions are highly useful in explaining various triggers and processes behind the formation of policy mixes and any complementarities that subsequently arise. However literature on the precise mechanisms that lead to positive complementariness or synergies is noticeably lacking, particularly empirical studies on realworld policymaker experiences (Rogge and Reichardt 2016). Some limited studies (Taeihagh, Givoni, and Bañares-Alcántara 2013, Taeihagh 2017) have laid down useful foundations for understanding differing types of complementarities by pointing out that interactions across instruments might be one-way or two-way (i.e. synergistic). Yet it could be that there are other important forms of instrument interaction not yet identified by literature. Filling this gap will help scholars to better understand the different types of complementarities that might arise in policy mixes, and by extension, various strategies to increase interactions, complementarities and synergistic potential when designing mixes. For policymakers, and practically-applicable insights grounded in systematic scholarly work could help C40 cities in deploying more strategically a policy mix approach to climate action.

3. Analytical framework and methodology

3.1 Analytical framework

Understanding that policies operate within a landscape or policy space (Flanagan, Uyarra, and Laranja 2011), Figure 1 illustrates the analytical framework developed to understand typical components of policy mixes for advancing building energy efficiency at the city level, and potential pathways by which interactions and complementarities can occur. This framework was created deductively from insights in both policy mix and urban climate policy scholarship (Bulkeley and Betsil 2003, Evans et al. 2005, Johnson, Toly, and Schroeder 2015, Knieling 2016), with the schematic tailored inductively to fit our empirical observations.

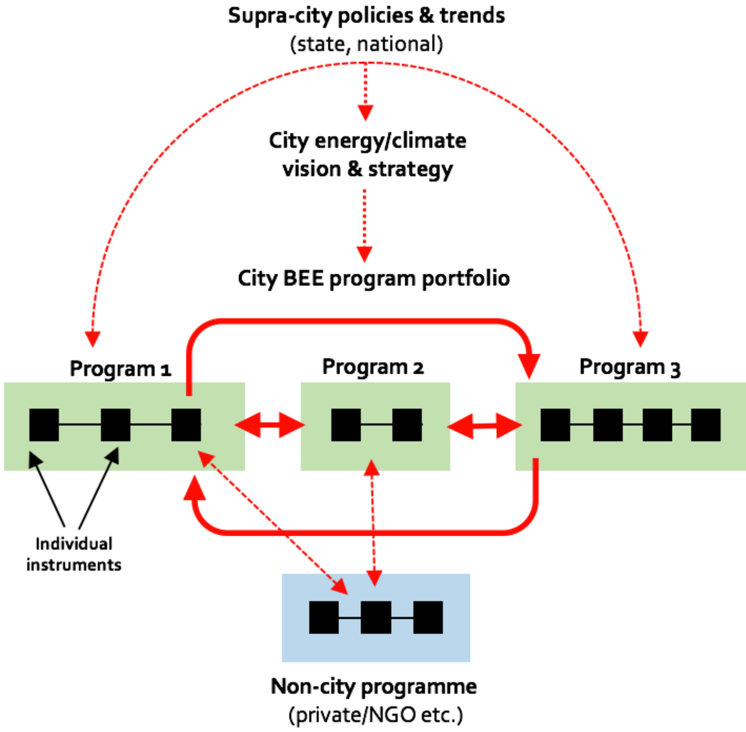

Figure 1 Analytical framework for understanding policy mixes and complementariness pathways (source: authors).

Through this framework, the BEE policy mix in many cities may be understood as an amalgamation of city visions and strategies (which are influenced by supra-city level policies and trends at the state or national level) that shape a portfolio of various programmes, each tailored to specific target buildings and stakeholder types. Each programme in turn consists of multiple instruments such as, for example, carbon reporting and disclosure requirements, building certification schemes and financial incentives. Further interactions occur across policy instruments and programmes through non-city government initiatives, such as those in the private or non-profit sector (either in the same city or nationally). Observing scholarship previously outlined in Section 2 (Sorrell et al. 2003, Oikonomou and Jepma 2008, Nilsson et al. 2012), our conception illustrates that interactions may occur horizontally (i.e. internally in the city, both across multiple policy instruments in one programme or across multiple city programmes) and vertically (i.e. from differing levels of governance, and externally, from policies or initiatives outside the city). In addition to this two dimensions of differing geographical spaces and governance levels/actors, we also follow Flanagan, Uyarra, and Laranja (2011) to emphasise a third temporal dimension. That is, mixes are typically assembled over time, and therefore, interactions and complementarities occur at different temporal periods (Kern, Kivimaa, and Martiskainen 2017).

3.2 Case selection and sample overview

The four cities examined herein (New York, Tokyo, Seoul, Sydney) were chosen from the wider sample of our ongoing research on BEE and sustainability policies and actions in C40 cities (e.g. Trencher et al. 2016, Trencher et al. 2017, Van der Heijden 2016, 2017b, Acuto

2013, Watts et al. 2015). Owing to our study's exploratory nature, several case studies were deemed necessary to build understanding into differing potential types of complementarities. To illustrate variances of how complementarities have developed in respective BEE policy mixes, our sample selection follows an 'information oriented selection' (Flyvbjerg 2015, 79). All cities have a long history of BEE policies and mixing instruments, allowing for collection of high quality and relatively longitudinal data. The examined mixes indicate sufficient similarities and differences in instruments and intent to enrich understanding on how promising policy portfolios can be designed. Equally, this sample demonstrates how small differences in design and context can significantly impact the achievement of overall BEE policy goals. Pragmatically speaking, the authors have established and ongoing working relationships with officials in these cities. This facilitated access to relevant documents and key stakeholders and allowed an enrichened understanding of how policy mixes are conceived and implemented. As further reasons behind case selection, these cities were among C40's first members and all are particularly active in BEE policy innovation through the Private Building Energy network (a smaller BEE focused working group of C40). For instance, Sydney and Tokyo lead this sub-network whilst New York received public recognition at the 2015 C40 Cities Awards for its Greener Greater Buildings Plan (examined later).

3.3 Data collection and analysis

In addition to data integrated from ongoing, aforementioned research into C40 cities, we collected data specifically for this study between June and December, 2016. Secondary data was collected from documentation such as policy reports, official government websites and academic literature etc. This was complemented with primary data from semi-structured interviews with experts include city policymakers, industry practitioners and representatives from non-profit organisations. Interviews sought to fill data gaps from the document analysis and gain knowledge about interactions between instruments, complementarities achieved (either designed or coincidental), and challenges or factors affecting these. A total of 35 experts (seven in New York, ten each for Tokyo and Seoul and eight in Sydney) were interviewed specifically for this study in person or via telephone or Skype. Findings, however, integrate insights into the four cities from historical interviews with some 100 experts, and document analysis, from mid-2013 onwards.

Three sets of research questions guided our data collection and analysis:

1. What are the key components of BEE policy mixes? What factors have influenced formation of these mixes?
2. How in practice do complementarities (both designed or non-designed) actually arise across multiple policies and instruments? What different types of complementarities may be observed?
3. What factors hamper or increase the ability to achieve complementarities or synergies in a mix?

Data from interviews and document analysis was compiled into an electronic spreadsheet mirroring the structure of Figure 1 and Table 1. Qualitative information for the principle elements identified in each city's mix was entered, and columns created to articulate key interactions identified across instruments. This was repeated for each city, with findings verified and modified across the author team. Following Layder (2006) we employed an 'adaptive theory' approach. We turned frequently to literature on policy instrument interactions to aid our conceptions of differing complementarities, and also allowed empirical observations to shape these.

4. Case studies: Designing and implementing policy mixes for complementariness.

Table 1 applies our analytical framework to provide a snapshot of the most relevant components comprising the BEE policy mix in each of the four cities. The following cases examine the most significant relationships and complementarities occurring in these mixes. Admittedly, in reality each mix is more complicated since there are more relevant components than represented. However instead of trying to capture the entire mix, our purpose is rather to examine in detail the principle areas of policy interaction and complementariness. Each case analysis is conducted mainly from the perspective of the various BEE programmes and instruments in that city. For the purposes of consistency, cases adhere roughly to the same analytical structure. After 'vertically situating' the BEE mix from the perspective of other city visions and national/state policies, we proceed to identify and articulate differing types of complementarities. We also examine triggers influencing the formation of policy mixes and complementarities, challenges encountered during policy implementation, and lost opportunities for greater complementarity across policy mix components.

Table 1 Summary of key BEE policy mix components in each city

	New York City	Seoul Metropolitan	City of Sydney	Tokyo Metropolitan
STATE/NATIONAL GOV'T (SUPRA-CITY) **Ministry/department** *Most relevant BEE policy name* • Instrument(s)	**Department of State** *Energy Conservation Construction Code of New York State* • New construction and retrofitting code	**Ministry of Land, Infrastructure and Transport** *G-SEED* • Voluntary Certification • Growing national energy consumption and reliance on nuclear	**Australian Government Department of the Environment and Energy** *Building Energy Efficiency Disclosure Act 2010* • Mandatory certification for offices ≥ 2,000m2 (NABERS)	**Ministry of Land, Infrastructure and Transport** *Energy Saving Law* • Voluntary standards
CITY GUIDING VISIONS **Department** *Name (year)*	**New York City Mayor's Office of Sustainability** *PlaNYC (2007)* *80 x 50 (2014)*	**Climate and Environment Headquarters** *One Less Nuclear Power Plant (2012)*	**City of Sydney Government** *Sustainable Sydney 2030 (2008)*	**Bureau of Environment** *Tokyo Climate Change Strategy (2007)* *Environmental Master Plan (2008)*
INTERNAL BEE PROGRAMME **Programme name (year)** • *Instrument(s)*	**Greater Green Buildings Plan (2010)** • Reporting and disclosure • Mandatory auditing & retrocomissioning	**Building Retrofit Program (2012)** • Mandatory regulation • Low interest loans • Energy disclosure	**Better Buildings Partnership (2011)** • Action network **Environmental Upgrade Agreements (2012)**	***Carbon Reduction Reporting Program (CRRP)*** • Emissions disclosure • Credits for reductions • Financial incentives

	• Lighting & sub-meter installation • Retrofitting codes **Retrofit Accelerator** • Capacity building **Energy aligned clause** • Capacity building	**LED distribution (2012)** • Lead by example • Information • Financial support **Eco-mileage (2012)** • Behavioural change • Financial incentive	• Financing support	• Benchmarking • Certification **Cap and Trade Program (C&T)** • Mandatory reductions • Credit trading • Carbon offsetting **Green Building Program** • Mandatory certification • Mandatory requirements
EXTERNAL (NON-CITY) BEE INITIATIVE **Organisation** ***Programme name*** • *Instrument(s)*	**EPA** *Energy Star* • Voluntary certification **Con Edison (utility)** *Commercial Industrial Energy Efficiency Program* • Financial incentives **NYSERDA** *Commercial Implementation Assistance Program* • Financial incentives	N/A	**CitySwitch** *CitySwitch* • Behavioural change **Green Building Council of Australia** *Green Star* • Voluntary certification	**GRESB B.V.** **Global Real Estate Sustainability Benchmark (GRESB)** • Emissions disclosure and sustainability reporting **Institute for Building Environment and Energy Conservation** *CASBEE* • Voluntary certification

4.1 City of New York's Greater, Green Buildings Plan

The BEE mix in New York City (NYC) is ambitious and pioneering. For instance, NYC policymakers were the first in the U.S. to implement benchmarking (i.e. annual submission and disclosure of energy/water consumption data, which generates a performance profile to compare to same-type buildings across the U.S.). NYC's portfolio of BEE programmes consists of strict mandatory approaches balanced with voluntary initiatives and various financial incentives implemented by State agencies or foundations. This case focuses on the flagship BEE policy mix, the *Greater Green Buildings Plan* (GGBP) implemented in 2010, and interlinkages to other policies and programmes.

The GGBP policy mix consists of four interlinked instruments. Each is enshrined into local laws (LL) and shares the common objective of seeking to raise building energy efficiency. The first three apply to commercial and multi-family residential buildings over 50,000 m^2 whilst the last covers all buildings.

- *LL84 Benchmarking and disclosure:* Annual submission, with public disclosure, of energy and water consumption data.
- *LL87 Auditing and retrocomissioning:* Both required once each ten-years, with submission of audit results to NYC.
- *LL85 Local energy code:* Energy efficiency requirements in retrofitting stretched tighter than state counterpart.
- *LL88 Lighting and sub-meters*: By 2025, installation of 1) sub-meters in tenant spaces over 10,000 ft^2 and 2) new lighting meeting local energy code.

Two factors significantly influenced GBBP's formation. The first was the gap in the BEE policy landscape for existing buildings at the national and state-level (Van der Heijden 2017b) . This lack of precedence required trailblazing and experimentation at city level. The most relevant law at the time was the *Energy Conservation Construction Code* of New York State, which lays out energy efficiency requirements for retrofits. It harboured a major loophole, however, by only applying to major retrofits. Since most buildings carry out retrofit works in stages, in practice the law affected very few retrofitting projects. GGBP therefore set out to patch this problem. A second factor shaping GGBP was the citywide sustainability vision *PlaNYC* (City of New York 2007). In pursuit of a citywide GHG reduction of 30% by 2030, energy actions in this vision focused on large commercial and residential buildings, introducing several ideas for mandatory measures such as benchmarking, auditing/retrocomissioning and lighting upgrades. The more recent city vision *80 x 50* (City of New York 2014), involving a legally binding commitment to reduce GHG emissions by 80% by 2050 and 40% by 2030, further increases the expected contribution of buildings to these targets. Accordingly, GGBP regulations are being extended to smaller buildings whilst a future mix of increasingly stricter mandatory instruments is under planning, to complement GGBP (City of New York 2016b).

Complementarities

Complementarities across GBPP and other instruments have occurred through design, patching and chance. As in other cities examined, coverage complementarities are evident and consciously designed. That is, individual instruments individually target differing areas (building types, sizes and stakeholders) of the building sector, thus allowing the mix to collectively achieve wide sectorial coverage. First, GBPP covers both commercial and multi-family residential buildings. Second, although all four laws target primarily building owners, sub-meter requirements explicitly target tenants. Third, iterative lowering of the target flooring threshold for benchmarking (to 25,000 m^2) with recently added local law (LL163) has allowed a phased-in, increased coverage of the building stock.

GGBP is a long-term strategy, meticulously designed to create various temporal complementarities. Benchmarking actions (data collection, reporting and analysis of results) occur annually whilst auditing and retrocomissioning is required once-per-decade. Yet temporal overlap is assured by mandating that one tenth of affected buildings (decided by building lot numbers) fulfil this obligation each year. For the other two laws, temporal complementarities are thinner. Lighting upgrades and sub-meter installation is envisioned as a once-off action before 2025, whilst energy efficiency codes kick-in only during a retrofit. Complementariness across instruments will increase in the future as more buildings install sub-meters and lighting (which will improve benchmarking performance), or alternatively, carry out building modifications or extensions, which would trigger compliance with the energy code.

We also observed strategies to create a functional complementariness whereby multiple instruments serve a common objective by performing a similar function. Interviewed policymakers emphasised how benchmarking, auditing and sub-meter requirements perform a common function of supplying information to the market. Benchmarking annually provides building-level operational data to building owners and the market (individual building energy/water consumption is publically disclosed on NYC's website). Expectations are that higher transparency around BEE performance might spur investments in retrofitting and stimulate demand for efficient buildings. Auditing (conducted once per decade) provides detailed asset-level information and recommends capital intensive energy efficiency upgrade measures, with payback periods. Benchmarking and audits both increase policymaker understanding of building stock energy consumption and installed equipment, and subsequently, inform future policies. Finally, sub-meters supply monthly electricity consumption information to tenants in hopes of fostering conservation measures and joint tenant-owner investments in retrofits. As one policymaker expressed, this ensemble of this information is intended to "increase energy efficiency literacy and awareness" in the building community and thereby drive retrofitting and building management improvement measures. For policymakers, information from benchmarking and auditing aids to monitor outcomes of the policy mix and build evidence to guide design of future policies.

Of particular interest are the unanticipated functional complementarities that have occurred where implementation of a local instrument facilitates the implementation of a national initiative. This is most evident with the *Energy Star* building certification, a voluntary national BEE programme managed by the Environmental Protection Agency (EPA). Benchmarking data is submitted to NYC through the EPA's Energy Star Portfolio Manager online platform. Buildings finishing in the top quartile of nationally ranked peer buildings qualify automatically for *Energy Star* certification provided a follow-up audit verification is conducted. Annual benchmarking through Portfolio Manager thereby creates new opportunities for buildings to apply for *Energy Star* certification. Evidence suggests that NYC's mandatory benchmarking has contributed to an increase in *Energy Star* certification in the city since 2007 (Seiden et al. 2015). These certifications now complement benchmarking data on the market to increase transparency around BEE and facilitate comparison across buildings during a market transaction (City of New York 2016a).

Interviews also revealed that some policies were designed to achieve a facilitation type of complementarity where one instrument improves or accelerates the implementation or outcomes of another. This strategy was used in NYC to form new policies intended to patch unanticipated problems or weaknesses in other policies. For example, NYC launched the *Retrofit Accelerator* to enhance the effectiveness of the energy audit regulation (LL87). This was after observations that the energy conservations measures (usually requiring capital) identified in audits were "gathering dust on shelves" and not being implemented. As the name suggests, by offering knowledge and financial capacity support, this programme aims to literally 'accelerate' the speed by which energy audit recommendations are translated to retrofitting projects and energy savings subsequently achieved.

Lost complementarities and challenges

Interviews with building industry representatives revealed discontentment regarding reduced subsidies for auditing and retrocomissioning. If still available, they argued, these would assist implementation of GGBP and thus create facilitation complementarities by increasing the effectiveness of auditing regulation outcomes. Building owners now face increased financial burden in complying with auditing requirements. This reduces available capital for implementation of identified energy saving measures, reducing the effectiveness of the auditing law. Interviews revealed this misalignment between "sticks and carrots" occurred due to the state-level New York State Energy Research and Development Authority's (NYSERDA) concerns about providing financial support for actions required by law. Following introduction of GBBP, NYSERDA's policy is to allocate subsidies only for actions going beyond GBBP requirements. For example, subsidies are made available for deeper audits than those mandated by GGBP, or for installation of high-end technologies with market transformation promise.

4.2 Seoul's One Less Nuclear Power Plant policy

Since the early 2000s, Seoul Metropolitan Government (SMG) has made low-carbon city development and urban transformation the core of its masterplans (SMG 2009). In 2012, it brought together a range of policies, including BEE instruments, under the *One Less Nuclear Power Plant* policy (ONLPP). This overarching climate change policy set ambitions to replace the capacity of a nuclear power plant (2 million TOE) by 2014 through energy efficiency measures, combined with new and renewable energy production (SMG 2012). The policy counters a national trend towards higher energy consumption, a growing reliance on nuclear power, and a continuing need for more power stations. As in the other cases, a gap in the national policy landscape for existing buildings drove SMG officials to trail-blaze and design new BEE instruments. Yet other important triggers too are behind ONLPP; most particularly the Fukushima nuclear power accident, which coincided with the election of a former social justice and environmental activist Park Won-Soon as the Mayor of Seoul in 2011. Mayor Park won office on promises to address Seoul's environmental and social problems, promising a city with higher energy efficiency and energy self-reliance.

OLNPP is of particular interest as a policy mix as it is explicitly designed to bundle all SMG urban climate governance measures in the areas of buildings, transport and urban greenery. Each area wields its own mix of policy instruments, with complementarities and synergies pre-designed. These mixes comprise of voluntary and mandatory instruments developed and implemented by SMG, and instruments developed by the National Government of South Korea. Following traditions of state-led development in South Korea, there is little activity in these areas by private sector organisations (SMG 2014, 2012, Lee, Lee, and Lee 2014).

Three complementary, voluntary BEE instruments are central to OLNPP:

- *Building Retrofit Program (BRP):* Provides incentives to owners of public, commercial and residential buildings for retrofitting or new construction with considerably higher performance than mandatory building energy standards. Low-interest loans are provided, in addition to discounted high insulation windows and entrances through cooperation with suppliers.
- *LED Lights Initiative*: Seeks to replace all lights in the public sector (2.2 million) and 65% of commercial and residential sector lights (29 million) with LED by 2018. Whilst leading by example through a focus on its own buildings, SMG also incentives LED installation by providing financial incentives to private building owners and collaborating with small and medium suppliers to deliver reduced price bulbs to the

market.

- *Eco-Mileage System:* Rewards households and businesses reducing annual energy consumption by 10% compared to the previous two years with 'eco-miles'. These may be redeemed for, for example, LED lamps or public transport vouchers. Besides these financial incentives, this programme provides information through a website (for households to share experiences) and energy audits (to inform households on energy reduction opportunities) (SMG 2014, 2012, Lee, Lee, and Lee 2014).

These three ONLPP instruments complement a wider suite of mandatory BEE instruments and aspirational targets in Seoul. Asides mandatory disclosure of energy efficiency when an existing building comes to the market for sale or lease, most policies target new construction. For example, *Green Standard for Energy and Environmental Design (G-SEED)* requires new construction work of a certain size to obtain certification, *Green Building Design Guidelines of Seoul* (MLTMA 2013) set strict energy efficiency standards for new commercial buildings; and mandatory requirements for new residential construction aim for net-zero emission housing development by 2023. Despite their mandatory nature, these instruments have achieved a limited impact on the energy performance of existing buildings (Van der Heijden 2014). SMG has therefore used ONLPP as platform for developing complementary voluntary instruments to target this sector.

Complementarities

Comparably to the NYC case, the BEE mix introduced under OLNPP seeks coverage complementarities. Each policy instrument is tailored to specific types of buildings (residential/public/commercial and large/small) and ownership (owner/tenant), thus allowing the entire mix to target relatively wider sectorial coverage. Also, unlike NYC's case where the mix was designed from scratch, SMG has mainly packaged and updated existing programmes and actively designed complementarities and synergies across the various instruments.

Facilitation complementarities are also consciously designed into the mix. **By** actively promoting installation of LED lights, BRP serves to accelerate achievement of the installation targets underlying the LED Lights Initiative. Facilitation complementarities are also pursued through subsidy alignment, by providing financial support for households and businesses purchasing LED lights through BRP. Additionally, another strategy involves linking energy and transport programs through the Eco-Mileage initiative. Whilst participants can redeem miles through public transport vouchers, they are also given the option to redeem credits for LEDs, which further accelerates the LED Lights Initiative.

To ensure compatibility across instruments, SMG has established a dedicated agency for the development and implementation of OLNPP. This agency cuts across earlier horizontal departmental boundaries in SMG (SMG 2014, 2012, Lee, Lee, and Lee 2014). It is responsible for the ongoing development and evaluation of OLNPP and its underlying instruments. Interviewees unequivocally pointed to the role of the OLNPP agency as the major factor behind the ability to design complementariness and synergies across instruments.

Lost complementarities and challenges

Interviewees emphasised that low interest rates and generous repayment conditions offered in BRP loans are generally not considered attractive enough by building owners. Currently only a small number of Seoul's existing buildings (3%) have been retrofitted under the programme. Interviewees argued that rather than seeking to accelerate BRP through these loans, traditional subsidies for building retrofits would be more promising and attractive to citizens. Indeed, also Eco-Mileage indicates marginal performance. Whilst it has attracted 1.8 million participants, only 10% of these (approximately 2% of Seoul's citizens) have achieved the modest requirement of reducing energy performance over a two-year period. Lastly, one core factor limits the various voluntary instruments implemented under OLNPP. South Korea has one of the lowest, if not lowest, energy prices in OECD countries due to generous national government subsidies (OECD 2015). Cheap energy prices from national policy thereby significantly reduce economic rationale for energy conservation and retrofitting in Seoul.

4.3 Tokyo's portfolio of BEE programs

Tokyo Metropolitan Government (TMG) has a history of ambition and active environmental governance relative to the national government (Sorensen 2002). It has developed a sophisticated policy mix of mandatory requirements, voluntary programmes, and attractive incentives to address GHG emissions in buildings. As in other cases, gaps in the national climate policy landscape drove TMG to implement its own BEE measures at the city level. Frustration at a lack of national government leadership is explicit in the first Climate

Change Strategy (Tokyo Metropolitan Government 2007) and repeated in its Environmental Master Plan (TMG 2008). These documents advocate for a mix comprising of stringent mandatory instruments for large emitters, carbon reporting for small to medium entities, and importantly, complementarities across financial incentives and various BEE instruments.

Three flagship programmes thus emerged as foundations of Tokyo's BEE portfolio:

- *Tokyo Cap and Trade Program* (TCTP) for large, existing commercial 'facilities'[1]. Involves mandatory emissions reductions and voluntary credit trading and covers 20% of CO_2 emissions in the Tokyo Metropolitan.
- *Carbon Reduction Reporting Program (*CRRP*)* for small to medium, existing commercial facilities. Involves mandatory/voluntary reporting and disclosure.
- *Green Building Program* (GBP) for medium to large, newly constructed commercial and multi-family buildings. Mandates adherence to construction codes/guidelines and building certification (all stretched beyond national government requirements).

Complementarities

Documents and officials from TMG emphasise the strategically designed coverage complementarities achieved by these three programmes. These concern facility size, type and lifecycle and result from the instruments collectively achieving a larger degree of

[1] A "facility" refers to either an individual building or a single property comprised of several buildings (e.g. a university campus).

coverage in the building sector than a single instrument could attain. Regarding lifecycles for example, GBP targets new construction during the planning stage whilst the others target operation of existing buildings. This creates complementarities that unfold over time, since once constructed, new buildings roll from GBP into the two other programmes. Coverage complementarities also concern differing building types—both commercial and multi-family are covered by GBP whilst the first two cover existing, commercial facilities. Finally, for building sizes, explicit target thresholds concerning annual energy consumption were developed to ensure tight coverage across instruments and minimal gaps in between. TCTP focuses on large facilities consuming above 1,500 kL COE/year whilst CRRP targets small to medium buildings below this. In this way, CRRP also acts as a 'safety net' to catch buildings that might reduce their emissions to the point of falling below the TCTP threshold. CRRP allows such facilities to continue monitoring and reporting emissions, and receive recognition for energy reduction measures. Coverage complementarities are enhanced since both TCTP and CRRP focus principally upon carbon emissions. Reporting protocols in both programmes are therefore entirely compatible.

As measures to achieve facilitation complementarities, TMG policymakers have introduced targeted financial incentives to improve the carbon reduction outcomes of other programmes—most particularly CRRP. Small to medium businesses are offered under several schemes subsidies or tax credits for retrofitting (covering up to 50% of purchase/installation costs of specified technologies) or moving in-house data management to energy efficient cloud servers. These measures lead to lower energy consumption, thereby improving carbon emission reduction outcomes of CRRP. Alignment with subsidies is assured by setting CRRP participation as a condition of eligibility, or additionally, by requiring use of CRRP carbon report cards (for showing rated carbon intensity on a lettered scale) in planning outcomes of subsidised retrofitting projects.

Also signatory in Tokyo's BEE mix is a focus on long-term, temporal complementarities in design and implementation of instruments. This is formalised in TMG's iterative "hop, step and jump" approach (Tokyo Metropolitan Government 2015). As a preliminary 'hop', a now discontinued programme was implemented from 2002-2009 to mandate for large commercial and industrial facilities submission of annual carbon emissions and a three-year reduction plan. This lay the basic framework for bringing large emitters to monitor carbon emissions, although implementation of reduction measures was voluntary. A 'step' was taken in 2005, by adding an evaluative dimension (a five-grade scale) for reduction plans, and strongly encouraging facilities to voluntarily implement 12 retrofitting measures. A 'jump' to TCTP, mandating emissions reductions, was launched in 2010. This was after it became apparent that voluntary measures were insufficient for bringing facility owners to retrofit (Nishida, Hua, and Okamoto 2016). Trust and relationships built up during the former reporting programme, combined with data on energy consumption and installed building equipment, proved crucial in overcoming industry resistance to a transition to a mandatory cap-and-trade (Nishida and Hua 2011).

Policymakers made explicit attempts to design synergies in the mix, most notably across TCTP and CRRP. Small to medium facilities in the latter can register GHG emissions reduction projects as credits and sell these to large entities in cap-and-trade. This creates a financial incentive for building owners in CRRP to retrofit their assets. As well as improving carbon reduction outcomes of the programme, this could potentially create a two-way, symbiotic relationship with TCTP. This would emerge as demand for carbon credits increased in response to the sequential tightening of the cap in each commitment period, which would potentially spur further retrofitting in the CRRP. Interestingly, in addition to this strategy to achieve horizontal and internal synergies across instruments, policymakers also sought to create potential for external and vertical synergies by linking the TCTP with the national renewable energy credit market and a cap-and-trade in neighbouring Saitama.

Tokyo's BEE instruments have been highly successful. TCTP has achieved a 25% reduction from baseline emissions between 2010 and 2014 (TMG 2016) and CRRP has achieved a remarkable engagement of voluntary reporters, which outnumber mandatory submitted reports by a factor of six (Trencher et al. 2017). Significant retrofitting activity has also occurred through both programmes. Success in both programmes was, in part, driven by unanticipated complementarities with multiple policies triggered by the 2011 Fukushima nuclear power accident. Ensuing this, both TMG and the Japanese government issued power rations and energy reduction policies to industry to cope with electricity supply shortfalls as nuclear reactors went offline. These measures fostered a culture of energy conservation in commercial and industrial buildings through both operational and simple retrofitting measures like lighting upgrades. Interviewees emphasised this wider cultural shift towards greater energy efficiency was particularly pronounced in firms participating in TCTP and CRRP. Interestingly, although power saving measures have discontinued, retrofitting and operational energy saving measures continue to be implemented in buildings in both programmes.

Lost complementarities and challenges

Whilst the BEE mix has achieved considerable coverage complementarities, it barely covers a key area: retrofits for existing residential buildings. Tokyo is characterized by highly dispersed ownership of property and high numbers of buildings on small plots (Okata and Murayama 2011). Particularly in addressing the market of owner-occupied houses and smaller apartment buildings, TMG faces exceptional horizontal coordination problems with limited interaction, for example, between the teams that develop and implement TCTP and those responsible for CRRP. It has not found a way to address this coordination challenge, so explained interviewed TMG representatives.

Another challenge concerns marginal use of credit trading under TCTP. As well as potentially raising the short-term costs of compliance in some affected facilities, this is undermining manifestation of the aforementioned potential synergies between TCTP, CRRP and other programmes outside Tokyo (Nishida, Hua, and Okamoto 2016). As explained by interviews and studies (Nishida and Hua 2011, Rudolph and Kawakatsu 2013), reasons behind this lost synergy include the high cost of credits from retrofitting projects in the CRRP relative to other carbon credits, a cultural preference in the building community for long-term retrofitting strategies over short-term trading reliance, and the possibility for TCTP facilities to bank credits for use under future compliance periods.

Finally, and conversely to complementary opportunities offered by the Fukushima incident to encourage implementation of BEE measures, Japan's shift from nuclear to fossil fuel electricity generation has triggered a 40% spike in the carbon intensity of the Tokyo's electricity supply (Tokyo Metropolitan Government 2015). When factored in, this essentially erases the majority of emission reductions attained in TCTP and CRRP. Mirroring the Seoul case, this indicates that the effectiveness of even the most sophisticated BEE instruments at city-level ultimately hinges on the nature of nationally (or state) determined energy mixes.

4.4 BEE instruments in the City of Sydney

In the early 2000s, Australia's three main cities (Brisbane, Melbourne, and Sydney) competed for status as the nation's most environmentally sustainable city. This occurred in response to growing national concerns about climate change and urbanisation driven GHG emissions, and frustration about lack of intervention in this area by the Federal Government. In this national context, the City of Sydney (covering the CBD and several of its landmarks) laid out its climate mitigation plans in the vision document *Sustainable Sydney 2030* (City of Sydney 2008). Underpinned by ten targets, it expresses the ambition that Sydney (henceforth referring to areas under jurisdiction of the City of Sydney) will become a "green, global, and connected city" (Acuto 2012). The two principle targets are to reduce Sydney's carbon emissions 70% by 2030 from 2006 levels, and to meet 100% of electricity demand with local energy generation. Sydney, represented by its lord mayor Clover Moore, has since been a visible and proactive member of the C40 network. As in other cases, this vision targets buildings as the greatest opportunity for GHG reductions.

Contrary to other cities discussed, Sydney cannot introduce local mandatory BEE standards since responsibility for doing so lies with the state (New South Wales) government. To govern energy efficiency in existing buildings and maintain status as a national leader in progressive and influential environmental policy, Sydney's principle approach has been to build voluntary programmes that seek complementarities and synergies with supra-city (national) initiatives. To appreciate these, the following supra-city (national) instruments are relevant, all of which mandate or incentivise BEE performance disclosure both nationally and in Sydney:

- *NABERS:* A six-point rating scheme for disclosing BEE performance (Australian Government 2010). First launched as a voluntary programme by the New South Wales Government in 1998, then scaled up to national level in 2010 when the Australian Commonwealth Government passed the Building Energy Efficiency Disclosure Act, this requires owners or lessors of office buildings larger than 2,000 m^2 to disclose the energy efficiency rating during a sale or new lease agreement through a NABERS certificate. This Act only requires disclosure, with no minimum level of rating requirements for low rated buildings.
- *Green Star:* A voluntary building certification programme demonstrating environmental performance on a six-point rating. Property owners and tenants can use these for marketing or public image improvement purposes. Launched by the Green Building Council of Australia (GBCA) in 2003, Green Star especially serves tenants of prime real estate (large office buildings located downtown) willing to pay a premium for environmentally sustainable property. GBCA has recently expanded its scope, now providing other certifications, including for apartments (GBCA 2013). Green Star

stipulates compliance with a specific NABERS rating in order to be eligible for Green Star certification (Van der Heijden 2017b).

- *BASIX:* A mandatory rating scheme for disclosing energy efficiency performance of residential buildings (homes and multi-unit buildings). BASIX certificates are mandatory for new construction and home alterations above AU $50,000. As with NABERS, only certification is mandatory, with no minimum requirements certification levels (NSW Government 2009).

This mix of national-level mandatory and voluntary instruments forms the backdrop from which the City of Sydney addresses carbon emissions and energy efficiency in new and existing buildings. Three flagship, voluntary programmes form the city's BEE program portfolio, each tailored to a distinct stakeholder group and building type.

- *Better Buildings Partnership* (BBP), targeting owners of large office buildings. Launched in 2011, initially, this brought together the City of Sydney with 14 major property owners representing over half of office space in Sydney's CBD. Adopting the Sustainable Sydney 2030 target, BBP calls for carbon emissions reductions of 70% by 2030 from 2006 emissions. This programme builds on peer-pressure, information sharing, and involvement of property owners in Sydney's development policies. In 2015, BBP expanded to target smaller property owners (Better Buildings Partnership 2015).
- *CitySwitch Green Office:* Targeting office tenants, CitySwitch incentivises reductions in office energy consumption through technological and behavioural changes. Originally launched by the City of Sydney in 2010, this was later scaled-

up in 2011 as a national program for administration by local governments (CitySwitch 2015).

- *Smart Green Apartments*, targeting apartment owners. This offers tailored audits to identify cost-effective energy efficiency improvements, technical support and grants to guide implementation of innovative ideas for apartment upgrades and cutting-edge technologies, and additionally, an online platform to track and manage energy consumption. First piloted in 2011 (Takagi et al. 2014) and later formalised in 2015, this spun off into a national programme *Smart Block* by the Australian Commonwealth Government in 2013 (City of Sydney 2015).

Complementarities

Coverage complementarities in Sydney's BEE programme portfolio are evident. The above three programmes collectively achieve coverage of both large office buildings and high-rise apartment buildings—the dominant types of buildings in inner Sydney—and also include existing buildings and new development. In addition, they specifically target either owners or tenants. Of particular interest, however, are the facilitation complementarities sought with national instruments whose objectives (i.e. raise energy efficiency and diffuse certifications in market) correspond with those in Sydney's programmes. For example, in Smart Green Apartments, owners can apply for financial support to help achieve a higher BASIX rating. Similarly, Sydney's BBP helps property owners acquire information on how high NABERS and Green Star ratings can be achieved. Sydney's CitySwitch even requires its participants to achieve a 4-star or higher NABERS rating (higher than average). In this way, local programmes directly interact with and facilitate the implementation and performance of national programmes, which in turn, serves the goal of reducing building energy consumption in Sydney. These facilitation complementarities appear particularly important for overcoming the weakness of the previously discussed supra-city instruments—the lack of requirements mandating higher levels of certification.

Strategies to attain synergy across programmes are observable in Sydney's mix. Since 2014, administrators from BBP and CitySwitch are actively collaborating to create a two-way, symbiotic relationship. During interviews, administrators recounted realisations from initial programme experiences that individual market actors can only achieve so much. To increase building energy efficiency, property owners (targeted with BBP) need support from tenants. Similarly, tenants (targeted with CitySwitch) require property owner cooperation. To increase uptake and results of each initiative, BBP administrators attempt to recruit a building owner into that programme when two or more tenants in that building participate in CitySwitch. Conversely, CitySwitch administrators work to improve the effectiveness of tenant energy reduction strategies by reaching out to landlords to explain the advantages of building retrofitting and the supportive role that BBP could play to this end. Remaining mutually autonomous but connected to each other's owner and tenant participants through information sharing and event organizing, administrators expressed hopes that this two-way interaction across programmes will achieve collectively higher energy reduction and retrofitting outcomes than has been possible with separate efforts.

Lost complementarities and challenges

Interviews with building industry representatives pointed to a coverage gap in Sydney's BEE mix—small and medium sized commercial property. In BBP, whilst such buildings are invited to join, the programmes' specific focus on large office buildings, the ambitious energy reduction target, and nature of incentives provided may not resonate well with property owners of smaller to medium buildings. Such stakeholders often lack time to participate in programmes such as BBP, and even when given information about the ease and advantages of retrofits, funding limitations can restrict implementation. For this group, more traditional financial support like subsidies was cited as a potentially more effective means of accelerating energy efficiency retrofits**.** The same may hold for single family houses, which are not currently targeted under Smart Green Apartments. At present, subsidies under this programme focus on promoting installation of emerging technological innovations (suitable for larger apartment operations) rather than spurring broad application of well-trialled and cost-effective interventions for smaller properties.

5. Discussion and conclusion

Seeking to understand different complementarities in policy mixes and how these can be achieved, this paper looked to city government efforts to promote energy efficiency and retrofitting in private sector buildings. To increase insight into policy mix enhancing strategies for policymakers, we specifically sought to determine empirically various mechanisms for designing complementarities. As emphasised, scholarship to date has extensively documented processes by which policy mixes can be assembled such as layering (Thelen 2009), patching (Howlett and Rayner 2013, Kern, Kivimaa, and Martiskainen 2017) and packaging (Givoni 2014, Howlett and Mukherjee 2014). It has also identified horizontal/vertical and internal/external pathways by which interactions can occur across instruments (Nilsson et al. 2012, Oikonomou and Jepma 2008, Sorrell et al. 2003, Schmidt and Sewerin this issue). Yet what was not well understood was how in practice differencing forms of complementarities can arise—by design or chance—within a policy mix. This article has made some first steps to better understand this process. In what follows, we distinguish the complementarities observed in our four cases with an analytical typology that draws upon relevant literature:

- ***Coverage complementarity:*** The scope of existing instruments is expanded or new instruments introduced so the totality of the mix collectively achieves wider sectoral coverage (Cunningham et al. 2013). Literature suggests that coverage might concern not only the type of technological or urban artefact, but equally, differing lifecycle stages (Cunningham et al. 2013) and types of stakeholders (Flanagan, Uyarra, and Laranja 2011). In our cases, we saw examples of instruments combining to collectively increase coverage of differing buildings (commercial, industrial and residential; large and small), stakeholders (owner and tenant etc.) and stages in the building lifecycle (new construction and existing). The NYC case suggested policy makers can phase-in policy coverage by successively lowering minimum thresholds in targeted buildings.
- **Temporal complementarity:** A suite of policy instruments is calibrated to encourage or mandate different actions at differing points in time. As a result, the intensity of interactions across instruments differs temporally (Kern, Kivimaa, and Martiskainen 2017, Cunningham et al. 2013). NYC's case illustrates this superbly. Energy use reporting and disclosure take place annually, energy audits and retrocomissioning every ten years, and installation of lighting and sub-meters once before 2025. The

points of direct interaction between instruments are therefore scattered across a ten-year period. Both literature and findings suggest that temporal complementarity is achieved as policymakers introduce policies in sequence (Oikonomou and Jepma 2008, Gunningham and Grabosky 1998) or replace old programmes with new ones, as was the case in Tokyo's transition from a former carbon reporting programme to a cap-and-trade.

- **Facilitation complementarity:** One instrument interacts with another to enhance or accelerate its implementation, functioning or outcomes. Research from Taeihagh, Givoni, and Bañares-Alcántara (2013) suggest that one-way interactions across instruments is a defining feature of this complementarity. Our cases demonstrated several strategies for achieving facilitation complementarities. To significantly improve the outcomes of a policy, one strategy involves introducing another to provide financial incentives or knowledge capacity raising to facilitate either compliance with a regulation or encourage more ambitious actions (like retrofitting or shifting data storage to an energy efficient cloud server) than what is mandated. Designed to literally 'accelerate' translation of auditing identified energy saving opportunities into actual retrofitting projects, NYC's Retrofitting Accelerator programme illustrates this nicely by enhancing the outcomes of the auditing regulation. Sydney's case also suggests that another strategy may involve using a voluntary programme at the local level to recruit participation and drive uptake of another voluntary programme at the national level.
- **Functional complementarity:** Different policy instruments perform similar or overlapping functions. Whilst the combined effects of this increase the collective

effectiveness of the policy mix (Anderies et al. 2013), this can be achieved without direct interaction across policy instruments like articulated above. As concrete illustrations, in Tokyo, two measures (public disclosure of an individual building or organisation's carbon emissions and creation of rating-like carbon report cards to show building carbon intensity) serve a common function of raising market transparency around BEE. Similarly, in NYC, multiple instruments (benchmarking, auditing and sub-metre requirements) combine to provide differing forms of quantitative and qualitative BEE information to the market.

- **Synergistic complementarity:** As we articulated in Section 2, two or more policy instruments interact to achieve a two-way, symbiotic relationship (Taeihagh, Givoni, and Bañares-Alcántara 2013, Matt et al. 2013) and, due to feedback effects, generate a result where the whole (i.e. the mix) surpasses the sum of the parts (Duguma, Minang, and van Noordwijk 2014, Freeman and Farber 2005). By aligning two voluntary programmes and using each to recruit participants for the other and enhance respective outcomes, Sydney's case demonstrated an interesting strategy to attain synergy and symbiosis across instruments.

This typology moves well beyond earlier policy mix literature. It provided a finer-grained understanding of how exactly relations and interactions can occur across multiple instruments. It indicates that not all complementarities are equal, and that the ultimate ambition for policymakers could (or perhaps should be) to aim for synergistic complementarities. The typology and case examples also indicate that different strategies are required to achieve a specific type of complementariness, and that different types of complementarities may result in different policy outcomes.

This argued, our chosen research design—a small sample of comparative cases built on primary and secondary data from interviews and document analysis—inherently results in bounded findings. Our typology and conclusions should therefore be understood as 'moderatum generalisations' (Payne and Williams, 2005) rather than empirical generalisations. That is, although scholars studying other sectors or cities may find related types, processes and outcomes of complementarities in policy mixes, it is possible that findings would not completely mirror the following five ideal types derived from our analysis of empirical findings and policy literature. We also acknowledge that real world complementarities may be complicated to classify with this typology due to overlap between types. Future scholarship could further refine or expand the types presented here. It would also be interesting to learn whether one type of complementarity may help or hamper the achievement of others.

Moving beyond definitional issues, the cases suggest that the above complementarities are largely anticipated by policy makers and constitute common strategies to increase the consistency and effectiveness of policy mixes. We also observed that these can occur both horizontally and vertically across policy landscapes. In addition to careful design stage foresight and planning, our empirical findings suggest that important enabling factors to achieve complementariness across instruments include active collaboration across differing policy administrating sectors and alignment of voluntary policy instruments with mandatory ones. Another important finding is that intentions and 'designing for complementarities' do not guarantee results. Conversely, we also observed that complementarities can arise by accident or serendipity. There is evidentially a large degree of unpredictability in achieving complementarities. This challenges scholars of policy design to further explore the conditions under which designed complementarities are likely to materialise (Howlett and Lejano 2013). Additionally, although we found strong evidence of policymakers attempting to align policies to achieve synergistic complementarity, we were unable to identify concrete evidence mirroring idealised scholarly conceptions of how in practice two instruments can achieve a result surpassing the sum of the parts. Future scholarship could therefore focus on this topic. It could explore empirically how multiple policies can enhance each other in a symbiotic relationship that might involve positive feedback loops.

An additional observation meriting reflection concerns the temporal aspects of some complementarities. Temporal complementarities may provide policymakers with an interim tool to work towards achieving future synergies when these cannot be designed or achieved in the present or immediate future. This temporal dimension and the emergence of complementarities over time may also provide an additional instrument to the toolkit of historical institutionalists who are interested in understanding gradual rather than rapid change. Whilst their current work is often interested in the mechanisms that explain such change—such as layering, or conversion (Mahoney and Thelen 2010)—our study indicates that it is of value to assess also the interactions between different policies, and ways by which these occur.

In closing, we anticipate that knowledge on complementarities presented herewith would harbour both practical value for policymakers and theoretical value for scholars. For example, we can see the relevance of the above described types of complementarities for policymakers designing or anticipating interactions across the various components of policies mixes in other environmental fields such as transport and energy, and potentially, other science/technology domains such as health and innovation. For scholars, we anticipate that consideration of complementarities occurring across policy instruments will strengthen understanding into the particular roles that policy mixes can play in driving innovation and socio-technical changes towards sustainability at the scale of entire cities.

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