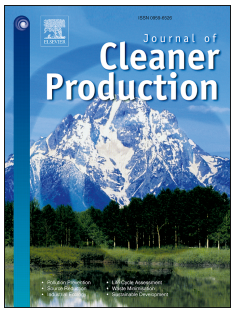

Financing urban low-carbon transition: the catalytic role of a city-level special fund in Shanghai

Yuan Peng, Xuemei Bai

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Financing urban low-carbon transition: the catalytic role of a city-level special fund

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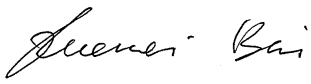
2.	Xuemei Bai	
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Financing urban low-carbon transition: the catalytic role of a city-level special fund in Shanghai

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Abstract

Financing mitigation actions in cities is critical to achieving 1.5°C emissions pathways. Direct funding, such as grants and subsidies, is a feasible financial instrument to enable local authorities to climate mitigation projects. Current literature has largely focused on the cost-effectiveness of direct-funding instruments in carbon reduction, but little on how these instruments influence other aspects of the urban low-carbon transition. A comprehensive understanding of the role of direct funding in low-carbon transition is important, as this new understanding may potentially encourage more direct investments by cities into their low-carbon initiatives. Here we examine the direct and flow-on effects of a city-level direct-funding scheme on urban low-carbon initiatives, taking Shanghai as the case study. Our findings show that the direct results of Shanghai's fund scheme include carbon reduction outcomes and a variety of policy outputs, such as a range of subsidy policies, data reporting systems, and demonstration projects. More importantly, over the 11 years of its implementation, the fund has become a catalyst for a series of institutional changes – by enabling and enhancing cooperation across numerous government departments in Shanghai. In addition, the funding scheme created avenues for the engagement of business stakeholders and raising public awareness on low-carbon and sustainability issues, through subsidizing technology adoption subsidies and low-carbon-themed campaigns. Collectively, these processes have improved the city's capacity for achieving low-carbon transition. Our study shows that a well-designed, city-level direct-funding scheme can fill the "implementation" gap between the policy intention (i.e., the low-carbon initiatives and implementation framework) and the policy outcomes (carbon reduction and the institutional formation in the transition). Such a scheme may also nurture and enable a pool of policy experiments and innovations for effective policy learning, identification of successful experiments, and upscaling. With these broader catalytic effects, a city-level direct fund could be a justifiable and attractive option in managing low-carbon transition.

Keywords: subsidy, grant, catalytic effects, urban sustainability experiment, institutions for mitigation, local capacity building

1. Introduction

Low-carbon transitions in cities are critical to ensuring a climate-safe future (Bai et al., 2018b; Bazaz et al., 2018; Broto and Bulkeley, 2013; Mi et al., 2019), but how to finance low-carbon transition cost-effectively is a primary challenge faced by local authorities (Colenbrander et al., 2018; Stern, 2007). Against this backdrop, some frontrunner cities are actively practicing a variety of approaches with commonly used policy instruments, as well as experimenting with innovative financial mechanisms (Bodnar et al., 2018; Environment, 2018; Irvine and Bai, 2019).

Some frontrunner cities have demonstrated their willingness and competence in financing urban low-carbon transition (C40 and ARUP, 2015; Deng-Beck and van Staden, 2015; Environment, 2018). For example, more than 50% of reported urban climate actions within C40, the carbonn® Climate Registry, and the Organisation for Economic Co-operation and Development (OECD) were funded by the city budget or their savings (C40 and ARUP, 2015; Deng-Beck and van Staden, 2015; OECD, 2018). In terms of investing in energy efficiency and renewable energy technologies, some cities move even faster than their national governments, driven by the energy-consumption growth due to urbanization (REN21, 2017). Yet, on a global scale, cities' financial competence for mitigation as a whole is inadequate, especially in developing regions (Barnard, 2015; Homsy, 2016; McLean and Borén, 2015). Thus, to mobilize more financial resources, a stronger justification for direct investment into urban low-carbon transition is required (Coalition for Urban Transitions, 2019; Gouldson et al., 2018).

Public funding can be vital for urban low-carbon transition, as it can be used as financial leverage to encourage private sector investment or to reduce the upfront cost for new technology adopters, often in the form of subsidies (Fuller et al., 2009; Roy et al., 2013; Zhan and de Jong, 2018). Subsidization is considered a feasible option for promoting climate action because subsidy providers do not seek a financial return on investment (Price et al., 2008). In this sense, there will be less difficulty for relevant stakeholders to accept and implement. In practice, subsidies and grants are the second most commonly used mechanism among C40 cities (C40 and ARUP, 2015). There is a compelling economic case for stakeholders in cities to make an investment at scale into cost-effective low-carbon measures (Gouldson et al., 2015). However, in reality, a higher upfront investment in carbon-efficient measures than in conventional alternatives (Schmidt, 2014) may become a barrier for adoption. In the short term, subsidies by governments can remove this price barrier to encourage the initial uptakes.

In practice, subsidies have been applied in various urban sectors to facilitate the adoption of new technologies, to encourage private sector investment or to reduce the upfront cost for adopters (Fuller et al., 2009; Roy et al., 2013; Zhan and de Jong, 2018). Examples include improving energy efficiency in buildings (Di Pilla et al., 2016; Hou et al., 2016; Krarti, 2015; Lihtmaa et al., 2018), promoting electric vehicles in the transport sector (Masiero et al., 2016; Thorne and Hughes, 2019), and encouraging rooftop solar photovoltaic (PV) installation in households and businesses (Asano and Aoshima, 2017; Frey and Mojtahedi, 2018; Fuller et al., 2009; Mah et al., 2018; Rodrigues et al., 2017) etc. Moreover, subsidies can be flexibly designed in diverse ways to fit different circumstances and policy needs. There are many examples of this, including rebates, municipal green bonds, revolving green funds, energy efficiency mortgages, and tax abatement (C40 and ARUP, 2015; Thorne and Hughes, 2019; Van der Heijden, 2017).

Subsidies as policy instruments are not without limits. The subsidy scheme may attract criticism for its market-distortion effect（Burniaux and Chateau, 2014; Owen, 2004). For example, global fossil-fuel subsidies remain large, amounting to 6.5% of global GDP in 2015（Coady et al., 2017), which in itself creates obstacles for renewables deployment and energy-efficiency improvement（Assmann et al., 2006; REN21, 2017). In addition, subsidies can be expensive; thus they are often constrained by the limits of governments' financial and administrative budgets（de Groot et al., 2001; Houde and Aldy, 2014; Price et al., 2008; Rosenow and Galvin, 2013), and also might be challenged by opportunity costs in terms of how to optimize the allocation of limited public budget.

More importantly, the price barrier is not the only obstacle to enable low-carbon actions in cities. Studies (Colenbrander et al., 2017; Gouldson et al., 2015) indicate that building local capacity, enhancing provision of information, and developing favorable institutional and policy environments are essential to enable the long-term low-carbon transition. This is because even if there is a possibility of allocating an extra budget for subsidizing urban mitigation actions, cities might face difficulties in their institutional capacity to design and implement the subsidy scheme in order to achieve desirable outcomes. In some cities, for example, there might be a lack of coordination power across key urban elements to stimulate and facilitate the transformative change, which may be caused by path dependency and lock-in in institutional behavior (Bai et al., 2016). The nature of urban low-carbon transition as an inter-sectoral, multi-level, and multi-actor process (Romero-Lankao et al., 2018; Webb et al., 2018) calls for a re-assemblage of institutions at a city level to tackle the inherent temporal, spatial, and institutional mismatches in urban low-carbon governance (Bai, 2007; Bulkeley and Luque-Ayala, 2017; Dowling et al., 2014). In this regard, the design and implementation of subsidies in low-carbon transition require institutional collaboration, and thus also has the potential to change status quo. However, there are few insights in the existing literature on the interlinks between city-level subsidies and institutional collaboration. Most existing literature focus on

the cost-effectiveness of subsidy policies and the direct carbon-reduction result, without taking into account the more comprehensive, flow-on effects of such policy measure (Dowling et al., 2014; Kalkuhl et al., 2013; Sarkar and Singh, 2010).

Moreover, from the urban sustainability transition perspective, cities' low-carbon transition requires changes in many urban sectors in a systematic matter (Bai et al., 2016), which require many trial and error. Low-carbon innovations can be tested through urban sustainability experiments (Bai et al , 2010; Berkhout et al, 2010). Policy interventions and financial support play an enabling role in initiating and adopting these low-carbon experiments (Peng and Bai, 2018), but it remains unclear how city-level financial mechanisms can stimulate and nurture such experiments.

To fill the gaps, this paper examines the direct and indirect impacts of a city-level direct-funding scheme, taking Shanghai's special fund aiming at energy conservation and emissions reduction as a case study. We focus on the design, implementation, effectiveness and direct and flow-on impact of a city level funding scheme to achieve their low-carbon policy targets. The following section presents a literature review on the role of city-level direct-funding instruments in climate mitigation. Section 3 presents the methodology for case analysis. Section 4 analyzes the fund design, size, distribution, and implementation. Section 5 evaluates the outcomes of the special fund, in terms of direct carbon reduction, spillover effects on institutions, and on enabling sustainability experiments for the transition. In Section 6, we discuss the implications and limitations of the direct-funding scheme illustrated by the Shanghai case, grounded in the relevant literature. Section 7 presents our conclusions.

2. Literature review: The role of city-level direct-funding instruments in climate mitigation

To enable the transition towards sustainability, subsidization is a widely used policy instrument for enabling energy efficiency and deployment of renewables (Assmann et al., 2006; The World Bank, 2010; Owen, 2006), with the benefit of emissions control (Dowling et al., 2014; Fischer and Newell, 2008; Kalkuhl et al., 2013; Menanteau et al., 2003; Sarkar and Singh, 2010; Tanaka, 2011). Subsidies for energy efficiency improvement are one of the most widespread fiscal incentives applied in energy-saving projects (Price et al., 2008; Tanaka, 2011), since they began in the 1970s. Subsidies as capital incentives may encourage energy users to adopt energy-efficient technologies (de Groot et al., 2001; Kemp, 2000; Tanaka, 2011). In addition, subsidized projects may also play a demonstrative role in disseminating information about the existence and user experience of these new technologies (de Groot et al., 2001). Moreover, from the government's standpoint, subsidies could be viewed – as a temporary measure – as a lever or stimulus to prepare for new regulations relating to an emerging social-technological practice. Eventually, a larger

market might be created than otherwise exists, demonstrated in the popularity and social acceptance of the subsidized energy-efficient technologies (WEC, 2004). Similarly, subsidy schemes for promoting the deployment of renewable energies are expected to facilitate the establishment of a sustainable renewable energy market (Fischer and Preonas, 2010). The most commonly used subsidy for this purpose – feed-in tariffs (FIT) – has been proven effective in promoting renewable electricity in some places (Butler and Neuhoff, 2008; Fischer and Preonas, 2010; Menanteau et al., 2003; Mir-Artigues and Del Río, 2014; Nicolini and Tavoni, 2017; Zhao et al., 2013).

On the other hand, there is a long history of subsidizing fossil-fuel energies, which continues to grow in recent years (Burniaux and Chateau, 2014; Gerasimchuk, 2015; Merrill et al., 2015; Ochs et al., 2013). This large amount of government expenditure has encouraged massive carbon emissions on a global scale and also blocks the deployment of renewable energies (Stefanski, 2017). Hereof, removing fossil-fuel subsidies may alternatively benefit climate mitigation (Burniaux and Chateau, 2014) and also save the public budget. A recent study shows that if this released budget can be wisely reinvested in other sectors, such as transportation, positive outcomes on economic growth and income distribution can be expected (Kim and Samudro, 2019). In this sense, globally, the financial gap for sustainability transition (IPCC, 2018) might be not only about the insufficient government budgets, but more a matter of the misplaced financial resources in the energy market.

At the same time, cities, as central players in global climate mitigation, may face the challenge of lacking sufficient fiscal capacity, if they need to adopt direct-funding instruments to enable their low-carbon transition (Homsy, 2016; McLean and Borén, 2015). In practice, subsidies are used as an instrument to facilitate the adoption of carbon-efficient technologies in many urban sectors. For example, subsidies are provided to retrofit buildings to decarbonize existing buildings stock. The relevant research found that the design of a subsidy is key to maximizing carbon reduction and achieving distribution equality (Di Pilla et al., 2016; Hou et al., 2016; Krarti, 2015; Lihtmaa et al., 2018). In some cities where electric vehicles (EV) adoption is being promoted, it is found that the EV price is one significant barrier to adoption (Adepetu and Keshav, 2017); therefore, subsidies on EV purchases can be one useful mechanism. The subsidy design varies according to differentiated local conditions and integrates manifold considerations such as the equity of EV subsidies and the alternative policy options in long-term policymaking (Breetz and Salon, 2018; Masiero et al., 2016; Thorne and Hughes, 2019). Another example is direct funding of rooftop solar PV, proven effective at increasing the number of installations (Asano and Aoshima, 2017; Fuller et al., 2009). The literature on this topic emphasizes the need to consider local natural, economic, and social conditions in policymaking for the cost-effectiveness of policies, such as solar radiation level, subsidization level, and cost save for self-consumption (Frey and Mojtahedi, 2018; Mah et al., 2018; Rodrigues et al., 2017). The sector-focused subsidy schemes discussed above primarily aim at promoting a specific carbon-efficient technology or project in a

certain policy domain, with diverse policy designs contingent on the technology type and varied local conditions, and also in different forms (e.g., post-purchase rebate, tax reduction, or FIT) (Mah et al., 2018; Rogge et al., 2017).

Although the subsidy design is critical to increasing the uptake of new technologies, some practical problems in implementation may affect the effectiveness of this policy instrument. For example, the free-rider problem may hamper the cost-effectiveness of policies (Houde and Aldy, 2014; Malm, 1996; Rosenow and Galvin, 2013; Thollander and Dotzauer, 2010). Also, policy administrative issues may restrict the implementation effects, causing some problems like high transaction costs and complex and long application procedures (de Groot et al., 2001; Price et al., 2008). Moreover, there might be some unintended consequences of subsidy policy design – for instance, some research (Holland et al., 2015) points out that there are land-use costs and habitat loss resulting from subsidizing bio-energy sources.

3. Research methodology

We investigated the Shanghai special fund for energy conservation and emission reduction in a comprehensive way, including the design elements (e.g., policy goals and principles, and the scope and distribution), three implementation stages, and the direct and indirect outcomes. Data were collected through two-month fieldwork in Shanghai, including interviewing government officials and collecting policy documents, which was supplemented by deskwork, including online search. Detailed information on the interviews is presented in the supplementary document 1.

A total of 12 policy domains, consisting of 41 subsidy policies, were identified and relevant data were collected. Collected data were analyzed to first understand the trend of annual fund expenditure and its distribution, and then to estimate carbon reduction from a variety of subsidized policy domains. To understand the role of the special fund in supporting local capacity building, an in-depth analysis of 167 subsidized projects under the subsidy policy of capacity building was conducted. Finally, to understand the effectiveness of the fund in enabling institutional collaborations, linkage analysis was performed on all 41 subsidy policies, identifying all institutions involved in each policy and visualizing their interaction, which also reveals the evolving focus and complexity of institutional collaborations enabled by the fund. Data collection and analysis of subsidy policies are presented in detail in the supplementary document 2.

4. Case study: The design and implementation of the Shanghai special fund

4.1 The fund design, size, and distribution

The Shanghai special fund for energy conservation and emission reduction was enacted in 2008, providing financial support to urban sustainability projects and capacity building activities (Peng and Bai, 2015, 2018). This financial mechanism plays multiple roles in Shanghai's low-carbon transition. Specifically, this policy scheme widely covers 12 policy domains, as shown in Figure 1, which may enable the city's transitions in a comprehensive way. The fund distribution indicates that air pollution reduction and industrial restructuring are the two primary policy focuses in Shanghai, due to the city's fossil fuel energy consumption status (Liu et al., 2012). In addition, Shanghai is a pilot low-carbon city of China in a national policy-learning scheme (Ohshita et al., 2015; Wang et al., 2015). To perform the city's experimenting role, the special fund also contributes by sponsoring various transition experiments. Moreover, the fund also covers the extra governmental expenditure on carbon management, such as outsourcing consultancy, staff training, and data collection and reporting, which might improve the carbon administration in the local government.

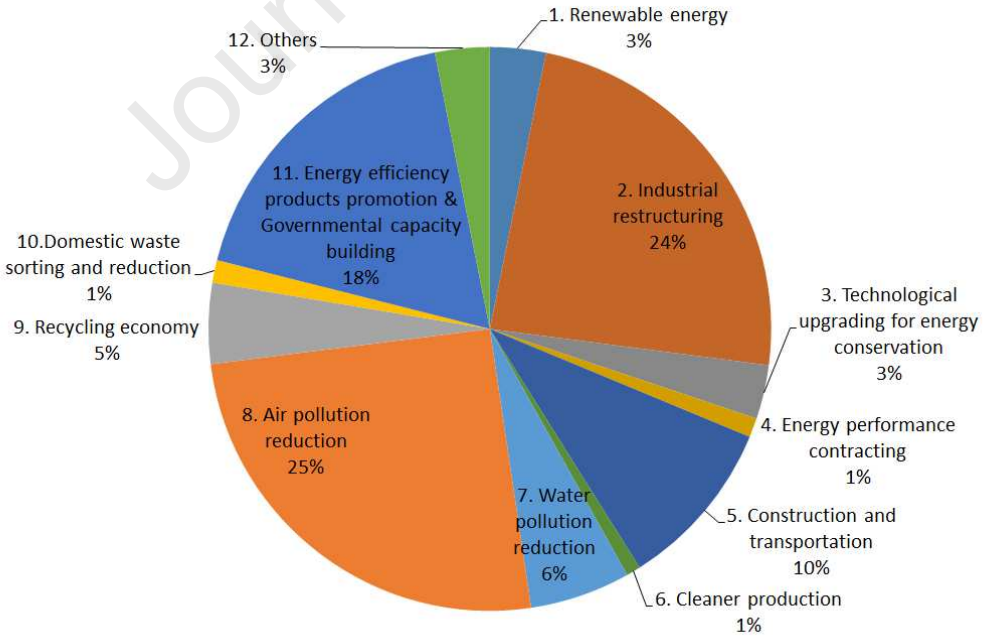


Figure 1. The fund distribution in different policy areas based on the total cost from 2009–2018 (Data source: calculated by authors based on the Shanghai government documents, details in the supplementary document 2)

Before this fund scheme, there were already some sector-based subsidy policies, with carbon reduction effects (Peng and Bai, 2018). Comparatively, this new scheme covers cross-cutting mitigation issues, with the possibility of triggering cross-jurisdiction policy coordination, by means of financially mobilizing different government departments to collaborate.

The special fund policy explicitly indicates that the sources of the special fund are from municipal fiscal budget, price-discrimination charge for electricity use, and other sources of funds allocated by the municipal government. How the local government manage their municipal finance to allocate budget is beyond the scope of the paper - the focus of this research is how allocated fund are used to enable low carbon transition.

Subsidies in this special fund scheme come in two forms. The first is direct financial incentives to engage other stakeholders, including the business sector and citizens. For example, the firms are rewarded with capital incentives based on their reduction performance. This rewarding design may drive the firms to try to achieve their best carbon reduction outcome (Wang, 2014; Zhang, 2014). The second subsidization form is to invest in policy research and in the building-up of reporting and monitoring systems, or to cover the extra cost of administration.

There is a consistent budget input in this fund scheme (Figure 2). Its share in annual GDP was fluctuating between 0.05–0.14% from 2009–2018, and the share in annual fiscal expenditure was between 0.19–0.51% during the same period. This public fund investment may indicate the Shanghai government's willingness and financial capacity for its low-carbon initiatives.

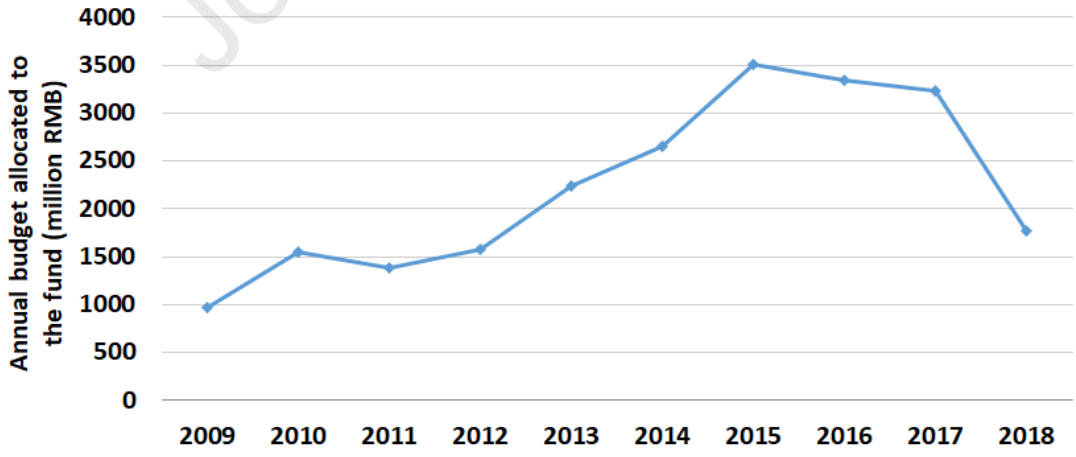


Figure 2. Annual budget allocated to the special fund

(Data source: calculated by authors based on Shanghai government documents, details in the supplementary document 2)

4.2 Fund implementation

This fund and the coordination mechanism across institutions are two pillars in Shanghai's low-carbon governmental structure (Peng and Bai, 2018). In reality, the fund mechanism operates within the framework of the coordination mechanism. Specifically, Shanghai's Municipal Development and Reform Commission (DRC) plays a joint role in connecting these two mechanisms, through the integrated duty of coordinating inter-sector collaboration and managing the fund. The DRC is responsible for making an annual reduction plan, convening institutions to collaborate, and allocating and monitoring the fund use.

The fund scheme includes two levels of policies. The master policy defines the overall purpose, principles, scope, and operating procedures. Under these guidelines, each subsidy policy making and policy implementation follow three steps – policy design, budget allocation, and policy implementation, with the first two steps primarily involving coordination within the governmental agencies, and the third step engaging more types of stakeholders.

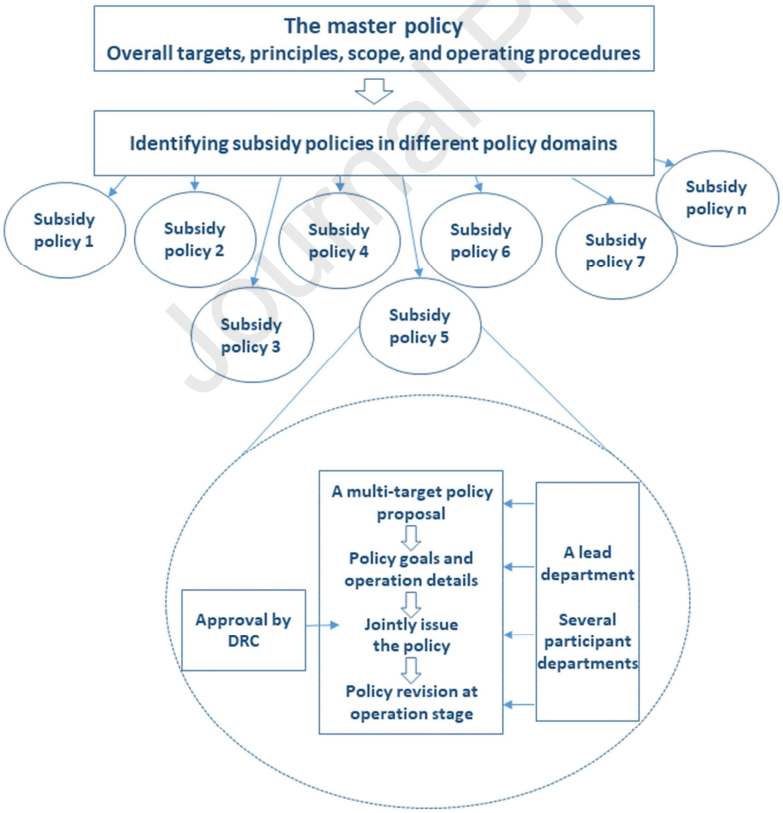


Figure 3. Policy design: the policymaking process for an individual subsidy policy

Note: DRC: Development and Reform Commission

We take one subsidy policy as an explanatory example: Promoting the adoption of electric vehicles (EV). This policy project engages seven governmental units: the DRC, the Finance Bureau (FB), the Economic and Informatization Commission (EIC), the Commerce Commission (CC), the Science and Technology Commission (STC), the Construction and Transportation Commission (CTC), and the Public Security Bureau (PSB). Each sector has its specific role in policymaking and implementation, in accordance with its jurisdiction and administrative duties.

The policymaking process for an individual subsidy policy has a "gluing effect" on governmental agencies, where these agencies are collectively working on a multi-target policy proposal. There is a lead department in policymaking and other department cooperates. All the participant department jointly issue the policy after it is approved. This policy proposal consists of both policy goals and operation details, and can be adjusted at the operation stage, integrating practical feedback and changing conditions. Following the EV adoption example, the policy details were revised twice after its initial design in 2016 and 2017, respectively.

The second step of budget allocation comes after the approval of the policy plan by the DRC, including a few rounds of interactions between the DRC (the coordinator) and other institutions, as illustrated in Figure 3. The cooperating sectors are required to report the fund demand to the DRC for annual budget planning. Then, the DRC and FB evaluate the budget request before allocating the money to this subsidy policy.

At the operational stage, other stakeholders, including individuals, businesses, or research/consultancy institutes, are engaged as subsidy recipients. Figure 5 exemplifies the policy implementation of EV promotion, collectively operated by five governmental sectors under the coordination of the DRC. There are two types of subsidies in this subsidy policy: One is the purchase rebate and the other is a free license plate to the EV buyers. Purchase rebate is covered by the fund scheme. After purchase, the fee for the plate is waived by the government as well. In Shanghai, an auction-based mechanism for a new number plate is implemented, with an average cost of around US$13,000 per plate in 2018. Required by the policy, the automobile companies apply for certification for a certain vehicle model in order to qualify for the purchase rebate. After the sale, the buyers are obliged to provide the vehicle registration documents to the sellers for them to claim the rebate. The CTC and PSB are collectively in charge of issuing the plates, and also provide registration documents to the new EV owners for the rebate-claiming procedure. The CC is also a participant department, who is responsible for setting regulations for the second-hand EV market.

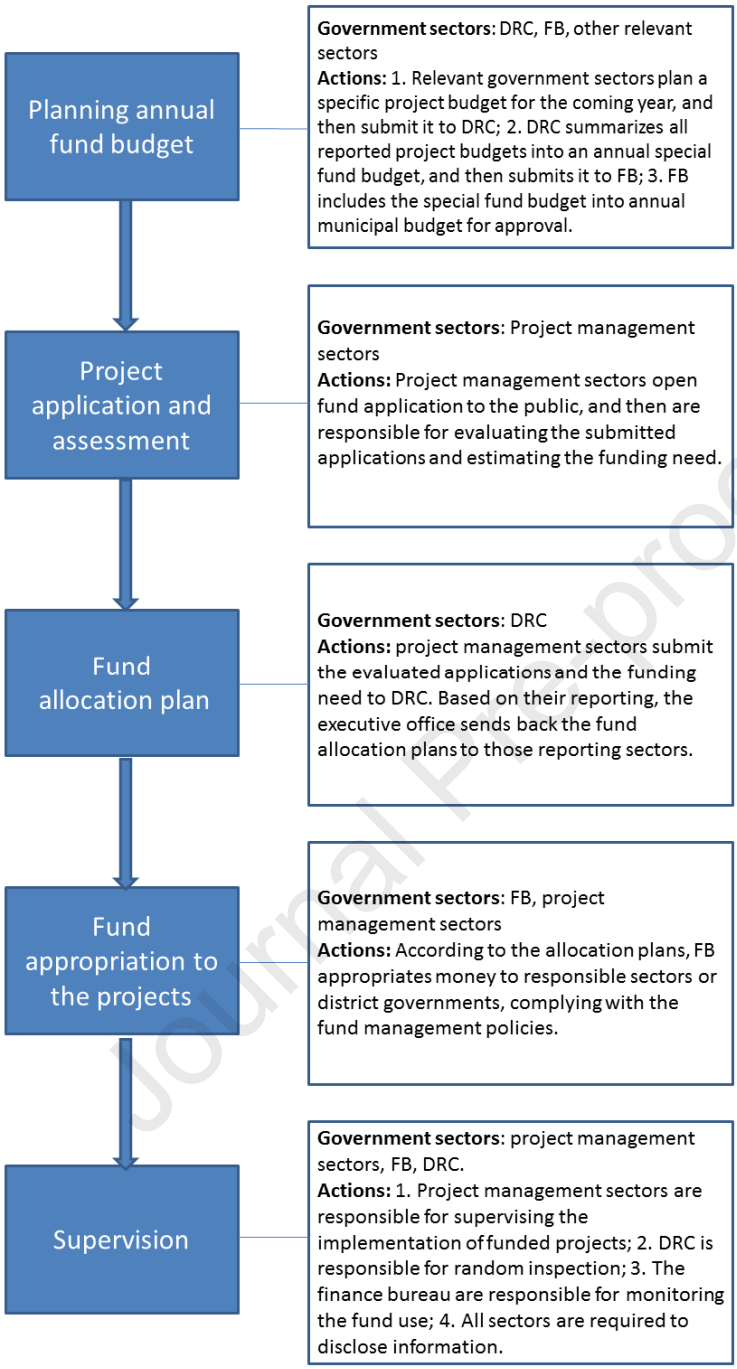


Figure 4. Budget allocation: the process of budget allocation for an individual subsidy policy

Note: DRC: Development and Reform, FB: Finance Bureau

The case of promoting EV adoption unveils various institutional cooperation under the special fund scheme. Over 11 years, a total of 41 subsidy policies in 12 policy domains have been enacted. The detailed analysis of how these policies have collectively enabled the institutional changes in the city's low-carbon governance will be discussed in the next section.

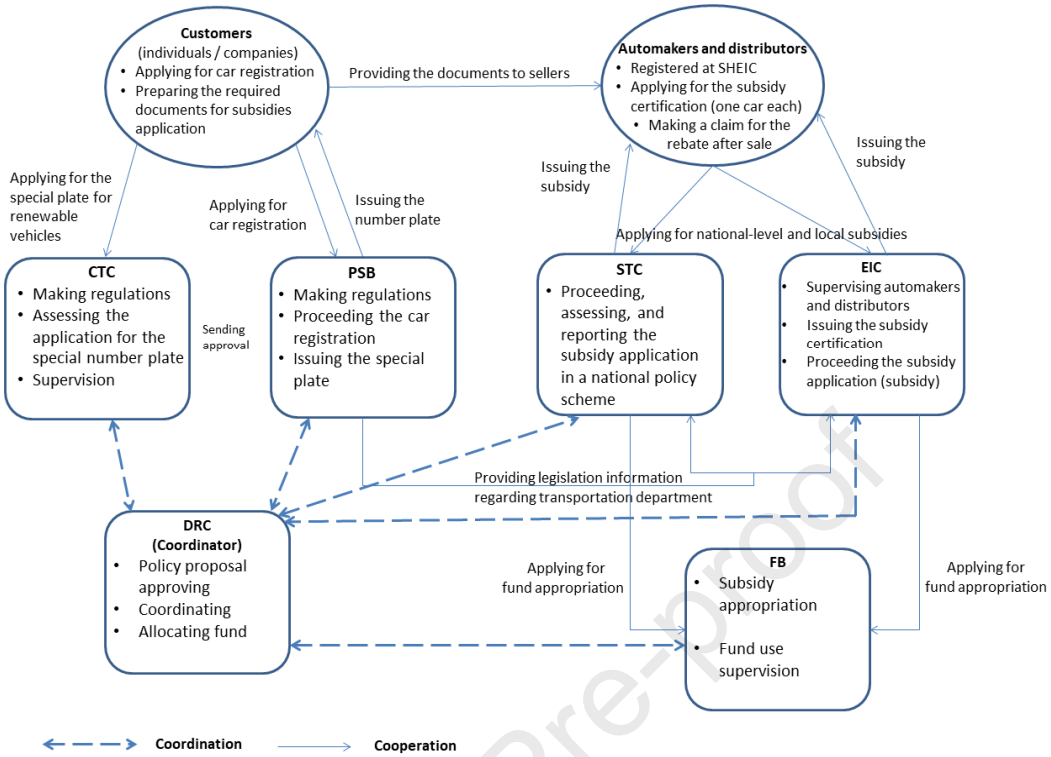


Figure 5. Policy implementation: the stakeholders' roles and interactions at the implementation stage

Note: Here coordination refers to organizing and intermediating participating departments in the projects, but not directly participating; and cooperation refers to directly working on the projects.

DRC: Development and Reform Commission, FB: Finance Bureau, EIC: Economy and Informatization Commission, PSB: Public Security Bureau, CTC: Construction and Transportation Commission, STC: Science and Technology Commission

5. Case study: Direct and spillover effects

5.1 Direct policy results

Two types of direct policy results can be identified, including carbon reduction outcomes and a series of capacity building initiatives. Based on government-released data, we estimate carbon reduction in eight policy domains from 2011–2015, where 85% of the total fund is spent, as shown in Table 1. The carbon reduction of this scheme is equivalent to 1.6% of Shanghai's energy-based carbon emissions[1] during the same period. The share of 1.6% may only represent a fraction of an aggregated outcome of all carbon-control policies in Shanghai. Besides the special fund scheme, there are other sector-based schemes with carbon reduction effect, for example, in the policy domains of energy conservation, environment protection, industrial restructuring, and technologies promotion (Peng and Bai, 2018). Comparatively, this

special fund focuses more on cross-cutting policy issues, playing a role in further reducing the emissions in addition to other existing policies. As shown in Table 1, the cost-effectiveness of different subsidy policies under this special fund scheme on carbon reduction is calculated as million RMB/ million tons, which is ranging from 55.15 to 6034.48 million RMB/ million tons. The subsidization of technical improvement for energy conservation in industries is the most efficient one.

Table 1. The direct carbon reduction and the cost-effectiveness of the fund projects

Supporting areas	The number of subsidized projects	Fund cost (million RMB)	Outcome	CO_2 Emission reduction (million tons)	million RMB/ million tons
Industrial restructuring	4,208	2,570	Saving 4.35 million tons standard coal	9.70	264.95
Replacing fossil fuels with clean energy for boilers and furnaces	5,153	560	Saving 1 million tons standard coal	2.23	251.12
Renewable energy	Wind power project: 0.473 million kilowatts Solar energy project: 0.1 million kilowatts Annual energy production: 1.2 billion kilowatt-hours	190	Saving 0.36 million tons standard coal	0.95	200
Transportation	The number of energy-saving projects in the transportation system: 153; Replacing fuel oil with clean energy for 1,243 vehicles	430	Saving 0.21 million tons standard oil	0.70	642.75
Energy performance contracting	311	90	Saving 0.148 million tons standard coal Stimulating non-government	0.33	272.73

			investment 516 million RMB		
Promoting distributed energy systems and gas-fired air conditioning	The number of distributed energy systems: 11 The number of gas-fired air conditioning: 28	70	Saving 5,210 tons standard coal	0.01	6034.48
Circular economy	46	120	Saving 500,000 tons standard coal	1.12	107.62
Technical improvement projects in energy conservation in industries	935	300	Saving 2.44 million tons standard coal	5.44	55.15
Energy-saving projects and the building-up of energy monitoring systems in buildings	The number of green building projects: 297 The number of energy-monitoring buildings: 1,288	430			
Promoting EV and building charging points	The number of subsidized EV: 54,000 The number of charging points: 21,700	1,130			
Promoting energy-efficient air-conditioners and lighting	The number of subsidized air-conditioners: 1.72 million The number of subsidized light bulbs: 7.96 million	210			

*The CO_2 emission factor for standard coal adopted in this table is 2.23 ton CO_2/ton standard coal, from the policy of the quota allocation and management plan for the Emissions Trading Scheme in Shanghai from 2013–2015.

The CO_2 emission factor for standard oil adopted in this table is 3.19 ton CO_2/ton standard oil, calculated based on the default values from the policy of the accounting and reporting guidance for greenhouse gas emissions in Shanghai.

To understand what kinds of capacity-building actions are supported and their scales, a total of 167 projects are identified in the policy category of "local capacity building" (category 11 in Figure 1) between 2009 and 2018. The projects are classified into five groups, as shown in Figure 5 (the detailed information on data collection and classification is included in the supplementary material 2). They are 1) annually updating greenhouse gas (GHG) inventory to monitor urban carbon footprint, 2) supporting demonstration projects for policy/technical learning, 3) encouraging engagement with communities and stakeholders, 4) building monitoring systems for data collection in urban sectors, and 5) funding policy research/consultancy to inform policymaking. These subsidized activities are the direct policy outputs of the fund, which may play an enabling role in developing local government's carbon management capacity and engaging other urban actors.

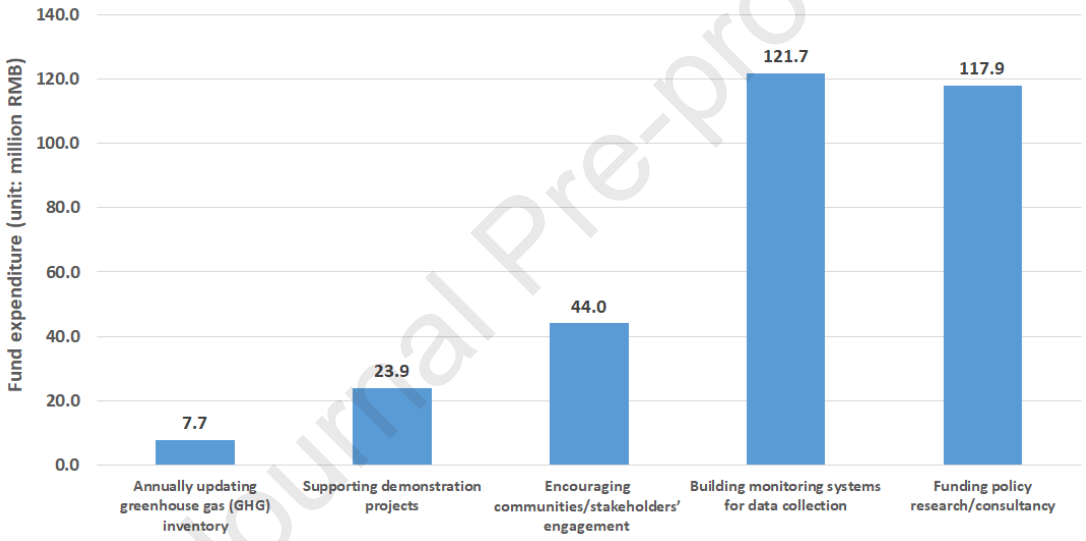


Figure 6. The categories of funded capacity-building programs and their scale from 2009–2017

5.2 Spillover impacts on institutions

Inertia in the urban institutional setting is considered as one of the main barricades to mitigation actions in cities (Betsill, 2001; Webb et al., 2018). In this section, we explore whether this funding scheme may have an impact on the institutional dimension in Shanghai.

Enabling a collaboration institution on cross-cutting mitigation policy issues

A subsidy policy framework enabled by this funding scheme is gradually established, with an increasing number of subsidy policies (shown in Figure 7) and dynamic policy focuses (shown in Figure 8) over time. Some policies are task-oriented. Once the specific object of a subsidy policy is achieved, the local government will move on

to new tasks (Peng and Bai, 2018). In each year, the local government introduces new policies, and also removes some old ones. For examples, the subsidy policy for promoting energy-efficient air conditioners and light bulbs was cancelled after these promoted products became popular enough in their own right. The policy for promoting industrial waste recycling was phased out when the waste recycling capacity in those industries had been established. But some new policy programs, such as subsidies for green buildings and comprehensive utilization of crop straw resources, were introduced. Thus, the total number of policies may vary year to year.

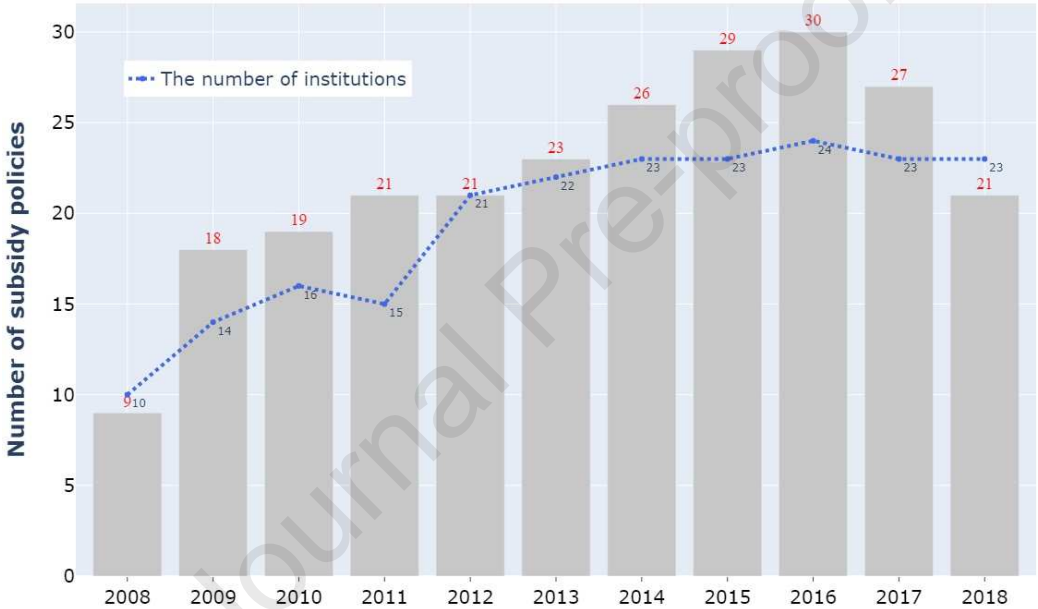


Figure 7. The total number of subsidy policies and participant governmental sectors in each year from 2008–2018

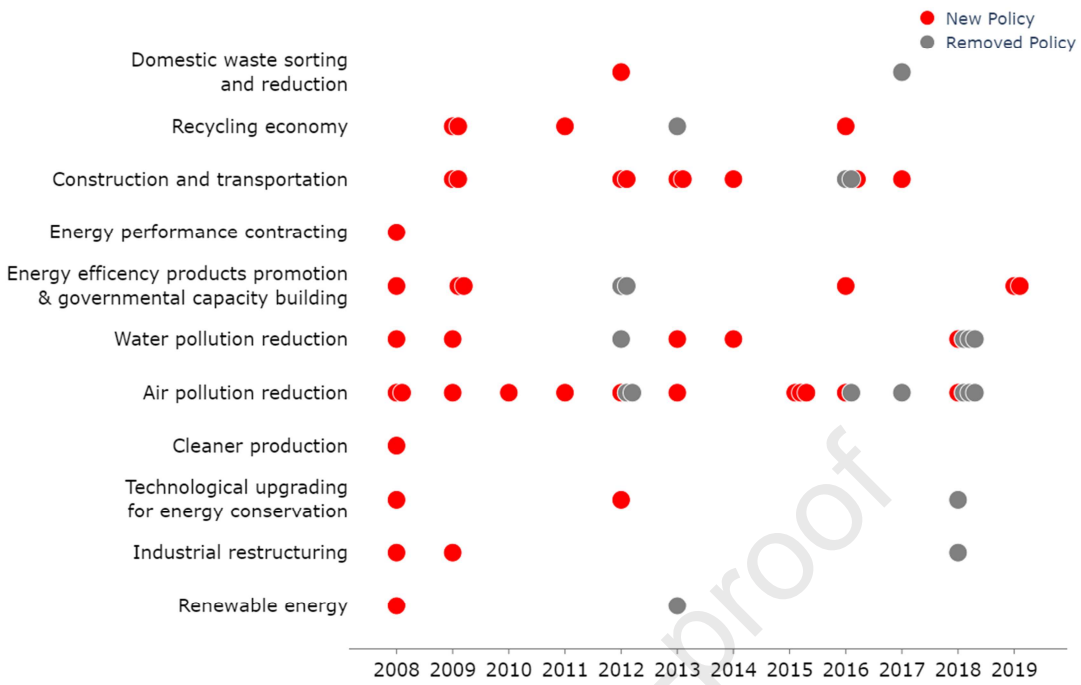
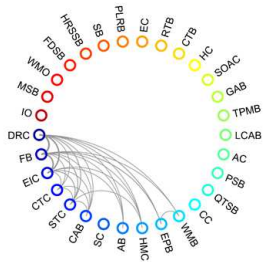
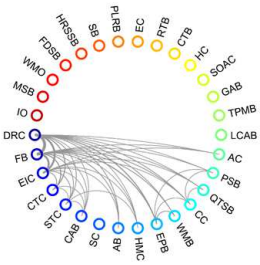


Figure 8. The changing policy focus - the type of policies funded by the special fund scheme during 2008-2018

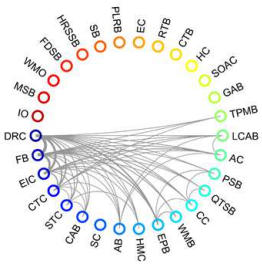
Along with a growing number of subsidy policies, cooperation across governmental institutions has gradually built up. To understand this institutional process, we adopt the chord chart in Figure 8, to visualize the collaborative links across institutions involved in policy implementation. We count the connection between two institutions as one link. For example, if four institutions work together in a subsidy policy, the total links of this policy is 6 (the detailed explanation about the development of the chord charts is included in the supplementary document 2). In the beginning, the links between different government departments were only within a small group of institutions; then the interactions increased across more governmental units over the years. There is a growth in the number of subsidy policies, which may potentially bring more government agencies to join. Moreover, the trend presented by the chord charts may also indicate a growing diversity in subsidy projects, where a variety of government sectors have opportunities to engage in urban sustainability development. An institution may have connections with many other different institutions, or have intensive links with one single institution but on different subsidy policies. On average, each subsidy policy involves four or five participant institutions. The 11 chord charts unravel an institutional formation process enabled by the funding scheme through a process-oriented approach. This process-analysis method is a novel perspective in the literature for understanding the institutional development for accommodating climate policy issues (Patterson et al., 2019).



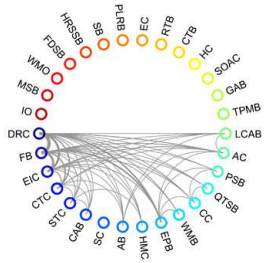
2008
- Subsidy policies: 9
- Involved institutions: 10
- Institutions/project: 4
- Total links: 52



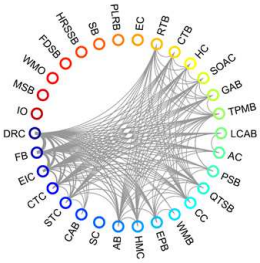
2009
- Subsidy policies: 18
- Involved institutions: 14
- Institutions/project: 4
- Total links: 102



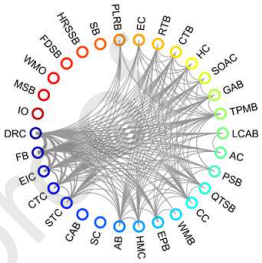
2010
- Subsidy policies:19
- Involved institutions: 16
- Institutions/project: 4
- Total links: 132



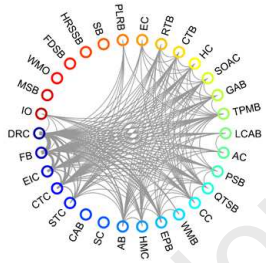
2011
- Subsidy policies: 21
- Involved institutions: 15
- Institutions/project: 4
- Total links: 138



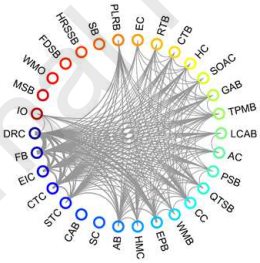
2012
- Subsidy policies: 21
- Involved institutions: 21
- Institutions/project: 5
- Total links: 272



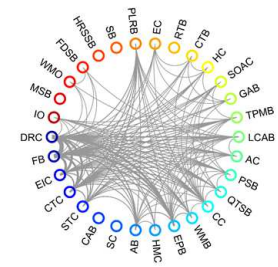
2013
- Subsidy policies:22
- Involved institutions: 22
- Institutions/project: 5
- Total links: 315



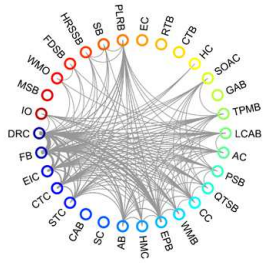
2014
- Subsidy policies: 26
- Involved institutions: 23
- Institutions/project: 5
- Total links: 357



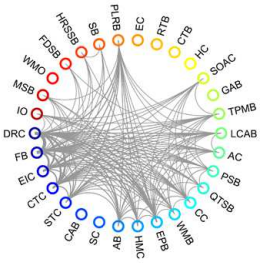
2015
- Subsidy policies: 29
- Involved institutions:23
- Institutions/project: 5
- Total links: 435



2016
- Subsidy policies: 30
- Involved institutions: 24
- Institutions/project: 5
- Total links: 349



2017
- Subsidy policies: 27
- Involved institutions: 23
- Institutions/project: 5
- Total links: 341



2018
- Subsidy policies: 21
- Involved institutions: 23
- Institutions/project: 5
- Total links: 315

Figure 9. The cooperation links across institutions under the special fund scheme from 2008–2018

Note: See the abbreviation list for the details of the full names of government departments in the figure

To identify which government units are more actively collaborating under this fund scheme, we analyze the participation level of each institution over the years 2008–2018. The participation level of an individual department is the percentage of the number of the policies this department is involved in the total number of subsidy policies over 11 years (the data and calculation process for participation level are detailed in the supplementary document 2). As shown in Figure 9, the participation level of the majority of the institutions is lower than 20%. Comparatively, five institutions are more involved (above 20%). They are the Development and Reform Commission (DRC), Finance Bureau (FB), Economy and Informatization Commission (EIC), Construction and Transportation Commission (CTC), and Environmental Protection Bureau (EPB). The DRC and FB engage in all subsidy projects due to their roles as coordinator and budget manager, respectively. The participation level of the EIC is also high, between 45–80% over 11 years, albeit with a decreasing trend from 77.8% in 2008 to 52.38% in 2018, which indicates that the mitigation activities may concentrate on the economic sector in Shanghai. In contrast, the participation level of the CTC is notably increased from 11.11% in 2008 to 52.38% in 2018. The opposite trends of those two sectors may imply a shift in policy focuses from emissions reduction in the economic domain to urban buildings and transport along with the city's ongoing transition over a decade. Moreover, the participation level of the EPB is comparatively high and stable between 20–50%. The active role of the EPB in collaborating may suggest that the cross-cutting policy issues (i.e., how to achieve synergy effects of a policy on both pollution reduction and carbon reduction) is one major policy concern for the local government, which is tackled under this scheme. This participation-level analysis reveals a degree of coherence in this collaborative network, where a few agencies might be central to conducting mitigation actions in Shanghai.

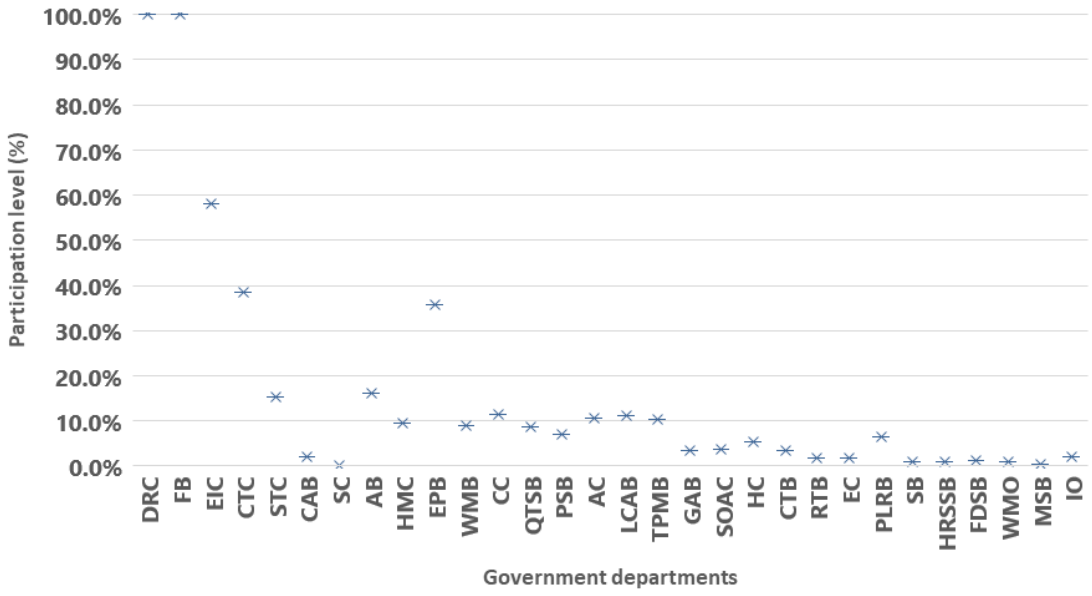


Figure 10. The participation level of an individual government department over 11 years from 2008–2018

Note: See the abbreviation list for the details of the full names of government departments in the figure

The enabling role in addressing the implementation gap

An "implementation" gap may exist between policy outputs and policy outcomes in urban mitigation. In other words, climate policy outputs may be difficult to translate into concrete actions on the ground. There might be two causes for this gap – a lack of financial resources and a lack of coordination across policy domains (Runhaar et al., 2018). In this regard, the special fund may play an enabling role in closing the gap, through directly subsidizing a variety of mitigation projects, enabling the policy plans to convert into actions, as well as catalyzing an institutional process for cross-sector cooperation. In addition, the fund mechanism is operating within the structural framework of the coordination mechanism designed by Shanghai's government. Therefore, to some degree, this fund scheme may have empowered the coordination mechanism, preventing it from existing only as an "empty frame" without financial resources to support its function in practice.

Capacity building in local actors

The special fund may have also enabled local actors' capacity building, in terms of carbon management and technological updating. The funded training and other assistance to the corporate sectors have helped them to build up their carbon management capacity. In addition, governmental incentives have encouraged local firms to replace their high-emission facilities or to adopt clean energy. For example, the fund has financially supported Shanghai's ETS institutional building-up, where a variety of local actors are engaged in this framework. The scheme has funded several fronts: 1) the policy research for making local monitoring, reporting, and verification (MRV) and trading rules, 2) the carbon-accounting training for the firms, 3) the capacity development of audit institutes to verify corporate emissions, and 4) the establishment of a trading platform. Through these processes, the influence of this special fund goes beyond the public sector, playing a role in enabling coordination of different actors in low-carbon governance. In our interview, staff members from state-owned large energy consumer industry who were assigned to carbon management duty in some local companies have acknowledge the enabling role of the fund in their internal capacity building on carbon management.

Raising public awareness

The funding scheme has sponsored a variety of awareness-raising campaigns and community activities themed on low-carbon lifestyles. It is hard to quantitatively estimate the impact of those campaigns, but they may play a role in fostering public

awareness toward sustainability, by means of spreading knowledge among citizens and encouraging behavior changes. Fostering social cognition – which is regarded as part of informal institutions in society – might benefit the transition (Munir, 2002; Zucker, 1987).

5.3 Generating a pool of experiments

The Shanghai government is open to low-carbon experiments due to its policy-learning role in a national scheme. The special fund plays a role in financially supporting the testing of innovations in policies, technologies, and social practices. For example, under the wide scope of the scheme, it financially enabled a variety of demonstration/pilot projects in technology fields such as carbon/energy efficiency, emission reduction transport, circular economy, clean production, and in the policy and social practice fields such as pilot Emission Trading Scheme (ETS) and pilot low-carbon communities. These multiple trial-and-error processes create a platform to explore solutions for the transition, although not all experiments can succeed or be popularized on a larger scale.

One case of upscaling is the impacts of Shanghai's pilot ETS in a national scheme. This pilot program provides policy-learning feedback for upper-level ETS policymaking. Moreover, in a forthcoming national market, Shanghai plays an influential role through operating a national trading platform and exporting experiences to other non-pilot provinces.

6. Discussion: The catalytic role of the special fund in urban sustainability transition

Shanghai's experience shows that, to some degree, the city-level direct-funding mechanism can play a role in reducing emissions by subsidizing mitigation actions. This finding echoes the prevailing discussion in the literature, in terms of the emission reduction effect of the subsidy instrument (Dowling et al., 2014; Fischer and Newell, 2008; Kalkuhl et al., 2013; Menanteau et al., 2003; Sarkar and Singh, 2010; Tanaka, 2011).

Shanghai's case also indicates that direct funding can play an enabling role in the city's institutional processes for mitigation. Specifically, its design for tackling inter-jurisdictional policy issues may potentially trigger cross-sector collaborations. Its actual effectiveness in implementation, in terms of establishing a cooperation institution, is evidenced by the linkage analysis. We identified that the joint role of the DRC as a coordinator and fund manager is the key to the operation process. This is because the DRC can exploit its joint role to run the subsidy policies on the structural

framework of the coordination mechanism, and, at the same time, the fund scheme has financially empowered the coordination framework. This coordination institution enabled by the fund is essential for the city's low-carbon initiatives because the transformative change needs a "whole of government" approach, avoiding policy coordination failure (Schot and Steinmueller, 2018). In addition, the special fund might play a role in addressing an implementation gap between policy outputs and policy outcomes (Runhaar et al., 2018), in terms of funding on-the-ground actions and enabling institutional changes.

Comparing Shanghai's case with other cities, the approaches adopted by many municipal governments for urban mitigation have an explicit aim to establish a coordinated institution (Anguelovski and Carmin, 2011; Betsill, 2001; Burch, 2010; Hölscher et al., 2019; Kern et al., 2017), while the primary policy goals of Shanghai's direct-funding scheme are to reduce carbon and to enable policy learning. In this regard, the institutional outcome in Shanghai's case can be regarded as a spillover effect. This finding may bring a new perspective toward the multiple impacts of a subsidy instrument on cities' transition. In the literature, the flow-on impacts of a specific urban initiative on sustainability beyond its initial goals is still underexplored, although there are a few reported cases. For example, taking the city of Durban in South Africa as a case study, Diederichs and Roberts (2016) highlighted the significant opportunities that mega-event greening initiatives offer to promote investments in resource-efficient local infrastructure and to establish local climate protection projects for long-term social and ecological co-benefits. The positive spillover effects of low-carbon policy programs, demonstrated by Shanghai's special fund and Durban's mega-event greening initiatives, may provide encouraging policy lessons - low-carbon policies, if designed well, can harness significant synergies and social-economic co-benefits across different aspects of an urban system and over a long run, which in turn underscores the importance of a systems approach in cities (Bai et al., 2018a; Bai et al., 2016).

Moreover, the fund may catalyze the building up of local mitigative capacity. Some research (Winkler et al., 2007; Yohe, 2001) indicates that the mitigative capacity includes a range of diverse resources, such as financial availability, regulatory effectiveness of government, public attitudes and awareness, technological factors, etc. To mobilize and transfer these resources into effective actions, adequate city-level climate governance – characterized by horizontal cooperation among sectors and stakeholders and vertical connections across levels – is needed (Amir Bazaz et al., 2018; Arup, 2015; Sudmant et al., 2017). In this regard, Shanghai's fund mechanism may not only leverage a variety of local resources but also mobilize them into actions. For example, it supports the adoption of carbon-efficient technologies in many urban sectors, widely engaging a variety of stakeholders from businesses and communities, which might potentially benefit the city's transformative competence in the long run. It also covers the extra governmental expenditure on carbon management issues, and

mobilizes the administrative resources of different government departments on mitigation actions, to enable institutional changes.

The enabling role of Shanghai's direct-funding scheme in local capacity building may have empirical implications in urban sustainability transition. For example, this mitigation competence might be "local-tailored" in Shanghai, considering the contextualized features of the local endowment and mitigation challenges. Some research contends that the local capacity needs could be place-based across diverse geographic, political, and cultural contexts (Dennis Tänzler et al., 2017; Raven et al., 2019). In innovation transfer study, the bespoke local capacity is a critical enabling factor in embedding introduced innovations in the cities to facilitate their transition (Peng et al., 2019; Winkler et al., 2007). In this sense, the Shanghai case might be a useful reference in terms of how to enable local capacity building to assist the contextualization of innovations in sustainability transition research.

Importantly, the fund mechanism may financially facilitate a platform for numerous sustainability experiments to exist concurrently. Those sustainability experiments – embodying a highly novel configuration – are likely to lead to substantial environmental sustainability (Bai et al., 2010; Berkhout et al., 2010), which can be purposely employed for transition management (Loorbach, 2007; Rotmans and Loorbach, 2008). Thus, to some degree, the enabling role of the special fund in nurturing sustainability experiments might be helpful in steering the urban transition. Notably, the probability of landing on a "successful experiment" could be increased by simultaneously conducting a large number of experiments. In this way, a policy-learning process stimulated by the fund might help to test and discriminate between the effective experiments (that need to be scaled up) from the inefficient ones (that need to be abandoned). If only focusing on one or a small number of experiments, there might be a risk of no gain or limited outcome.

Even if the direct-funding mechanisms can be an achievable option for cities, it may require a stable and sufficient financial capacity of a municipal government to adopt it (Winkler et al., 2007). The complexity in China's fiscal policy and institutions may have significant implications for fiscal sustainability in cities if they plan to allocate expanded municipal budget for a low-carbon special fund (Ahmad and Colenbrander, 2020). Especially, many sustainability projects may require continuous support for years, with a consistent investment before reaping benefits, making reliable revenue streams particularly critical for policy success (Hawkins et al., 2016). Shanghai is capable of self-funding from its own budget, running the special fund over 11 years. This consistency ensures that some subsidy policies may last for years to achieve the policy goals, and also give enough time for the formation of a coordination mechanism in implementation. However, for some other cities, especially cities in rapidly developing regions, other development priorities may challenge the local governments, leading to a tight budget for sustainability (Colenbrander et al., 2018;

Löffler, 2016). Setting up an overarching direct-funding scheme might go beyond their financial competence.

International financial aid may play a role in alleviating the funding-source constraints in developing cities (Acuto, 2016; Bank, 2010; Kameyama et al., 2016). Most climate funds have explicit lending criteria for a preference for investments in "hard" infrastructure (infrastructure projects built on sites), rather than "soft" infrastructure (local capacity and institutional settings for climate issues) (Fankhauser and Burton, 2011). However, this "soft" competence is particularly desirable in developing worlds for self-sustainable transition (Romero Lankao, 2007; Shemdoe et al., 2015; White and Wahba, 2019). Hypothetically, if a small amount of international aid could be re-directed into developing the soft competence in these developing cities, then the ways of how to efficiently use the freed resources for this purpose might need to be explored. On this subject, the Shanghai case may provide some experiential insights.

7. Conclusion

The impacts of direct-funding instruments on social, economic, and institutional dimensions for urban sustainability are not well established in the literature. This paper examines the influence of subsidy instruments on urban sustainability transition from a systems perspective, taking Shanghai as a case study. We examine Shanghai's special fund for energy conservation and emission reduction, looking at the policy design and implementation, and its direct and flow-on effects on the city's low-carbon transition. A linkage analysis is applied to understand the effectiveness of this scheme in enabling collaboration between institutions. The direct results of Shanghai's special fund scheme include carbon reduction outcome and a variety of tangible capacity building activities, such as data reporting systems and demonstration projects. The fund plays a catalytic role in enabling coordination and collaboration across different government departments on cross-cutting policy domains. In addition, we also identified the flow-on impacts on capacity development in other non-government actors. Collectively, the special fund may have enabled local capacity building in multiple ways, through financing the governmental capacity building, incentivizing engagement from other stakeholders, and raising public awareness. The study also shows that a well-designed, city-level direct fund scheme can fill an implementation gap between the policy outputs and the policy outcomes and may nurture and enable a pool of policy experiments and innovations for effective policy learning, identification of successful experiments, and upscaling.

Adopting the direct-funding mechanism for enabling local capacity and institutions on climate mitigation may put extra pressure on the city's budget, especially difficult for cities in developing regions. Given the many benefits such a mechanism may render, some redirection of international aid funds to developing regions could be helpful to

establish a direct-funding scheme – like in Shanghai – to facilitate local competence. The new perspectives of understanding direct and spillover impacts of the subsidy instrument in urban sustainability transition, illustrated by the Shanghai case, may encourage further investigation on its synergic outcomes in other aspects of an urban system, such as in economy or in society. This may provide evidence-based information to encourage more direct investment into cities' low-carbon initiatives.

Notes:

1. The data of Shanghai's total CO2 emissions (energy consumption based) is calculated by the author in the paper *Experimenting towards a low-carbon city: Policy evolution and nested structure of innovation* (2018).

Abbreviations:

AB: Audit Bureau
AC: Agriculture Commission
CAB: Civil Affairs Bureau
CC: Commerce Commission
CTB: Culture and Tourism Bureau
CTC: Construction and Transportation Commission
DRC: Development and Reform Commission
EC: Education Commission
EIC: Economy and Informatization Commission
EPB: Environmental Protection Bureau
FB: Finance Bureau
FDSB: Food and Drug Supervision Bureau
GAB: Government Administration Bureau
HC: Health Commission
HMC: Housing Management Commission
HRSSB: Human Resources and Social Security Bureau
IO: Information Office
LCAB: Landscaping and City Appearance Bureau
MSB: Market Supervision Bureau
PLRB: Plan and Land Resources Bureau
PSB: Public Security Bureau
QTSB: Quality and Technical Supervision Bureau
RTB: Radio and Television Bureau
SB: Statistics Bureau
SC: Supervision Bureau
SOAC: State-owned Assets Supervision and Administration Commission
STC: Science and Technology Commission
TPMB: Transport and Port Management Bureau
WMB: Water Management Bureau
WMO: Waste Management Office

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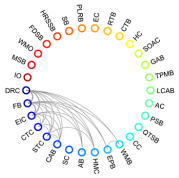
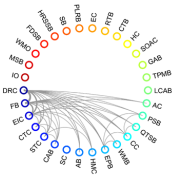
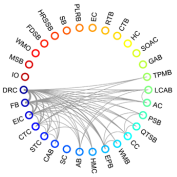


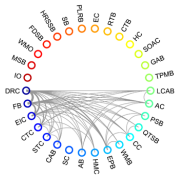
2008
- Subsidy policies: 9
- Involved institutions: 10
- Institutions/project: 4
- Total links: 52



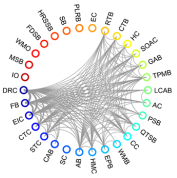
2009
- Subsidy policies: 18
- Involved institutions: 14
- Institutions/project: 4
- Total links: 102



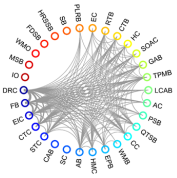
2010
- Subsidy policies:19
- Involved institutions: 16
- Institutions/project: 4
- Total links: 132



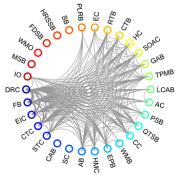
2011
- Subsidy policies: 21
- Involved institutions: 15
- Institutions/project: 4
- Total links: 138



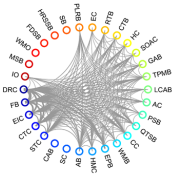
2012
- Subsidy policies: 21
- Involved institutions: 21
- Institutions/project: 5
- Total links: 272



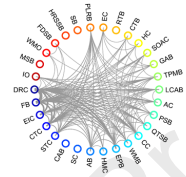
2013
- Subsidy policies:22
- Involved institutions: 22
- Institutions/project: 5
- Total links: 315



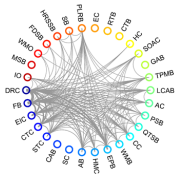
2014
- Subsidy policies: 26
- Involved institutions: 23
- Institutions/project: 5
- Total links: 357



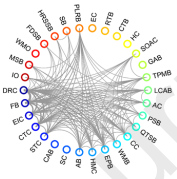
2015
- Subsidy policies: 29
- Involved institutions:23
- Institutions/project: 5
- Total links: 435



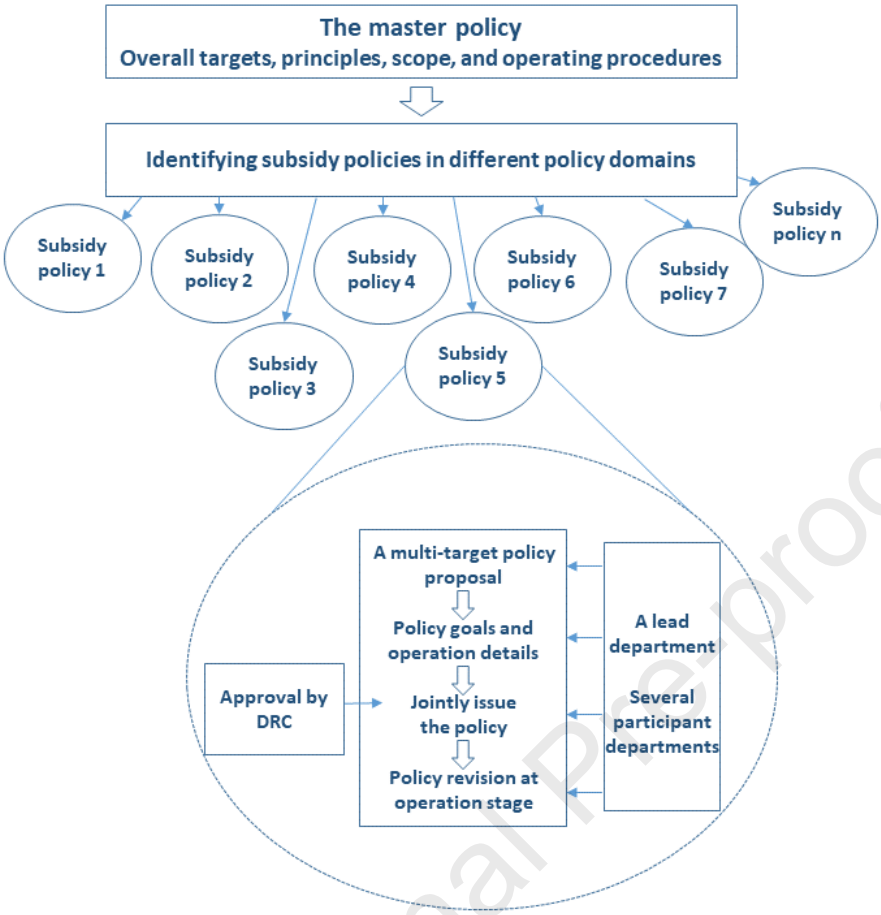
2016
- Subsidy policies: 30
- Involved institutions: 24
- Institutions/project: 5
- Total links: 349

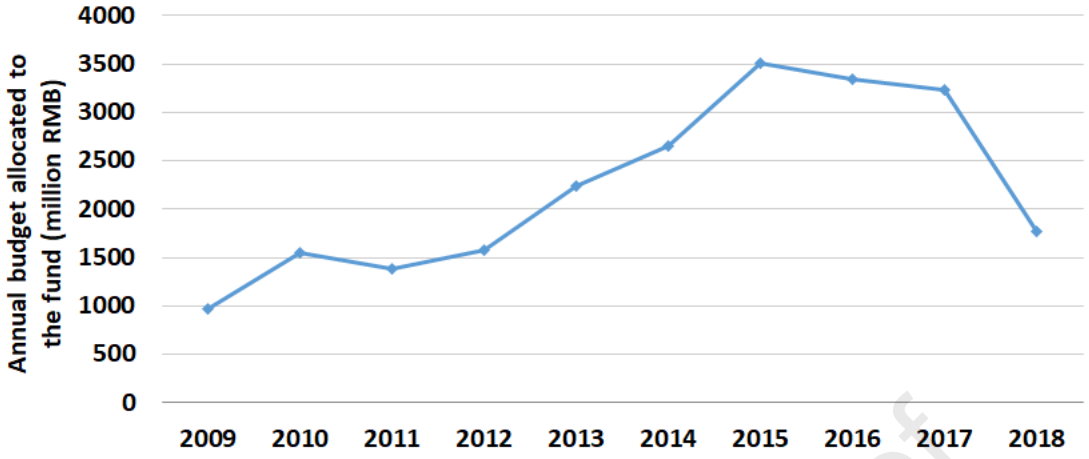


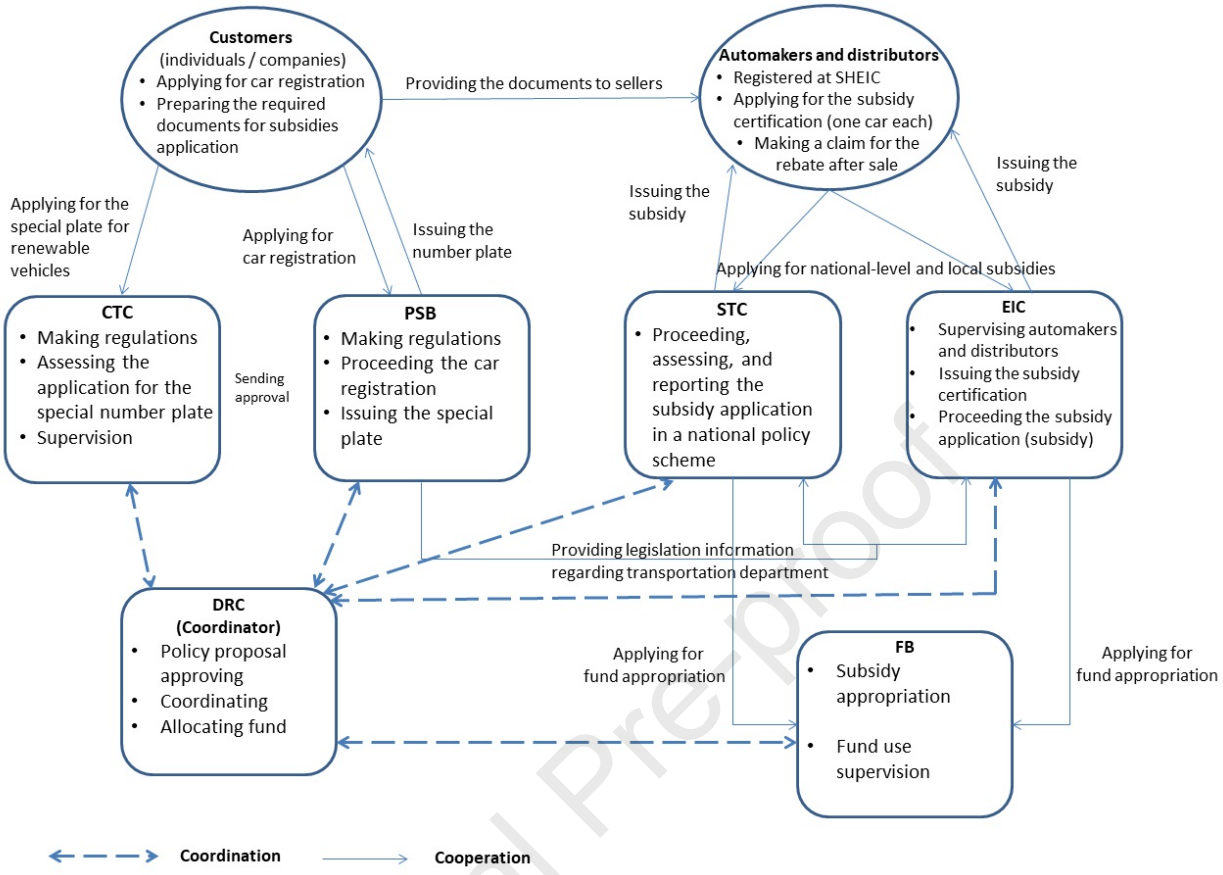
2017
- Subsidy policies: 27
- Involved institutions: 23
- Institutions/project: 5
- Total links: 341

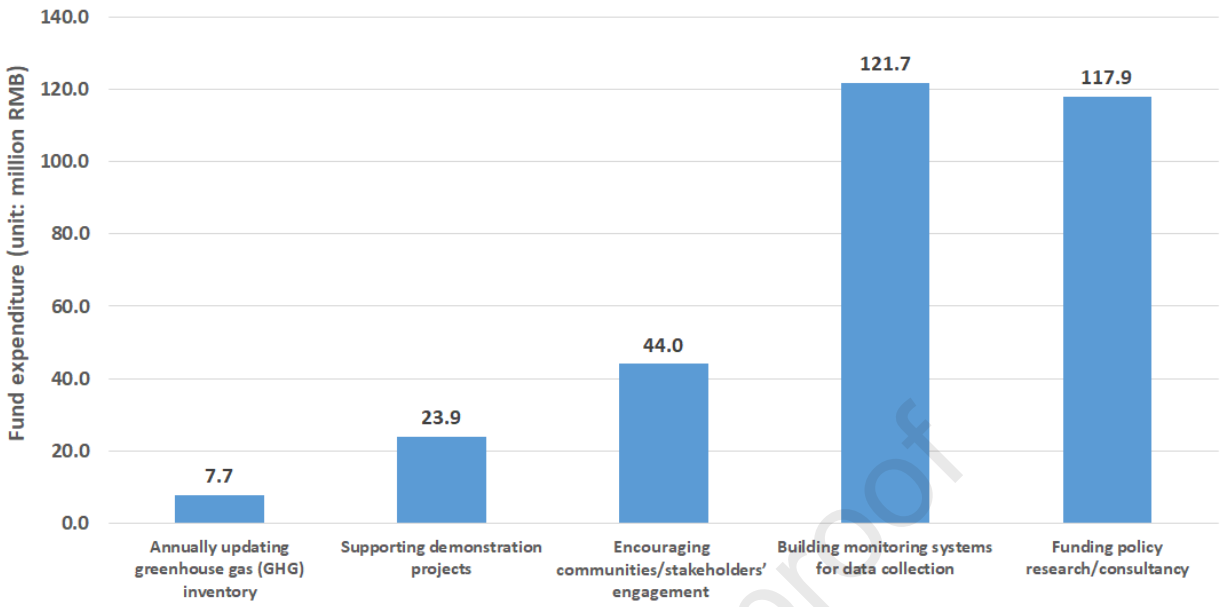


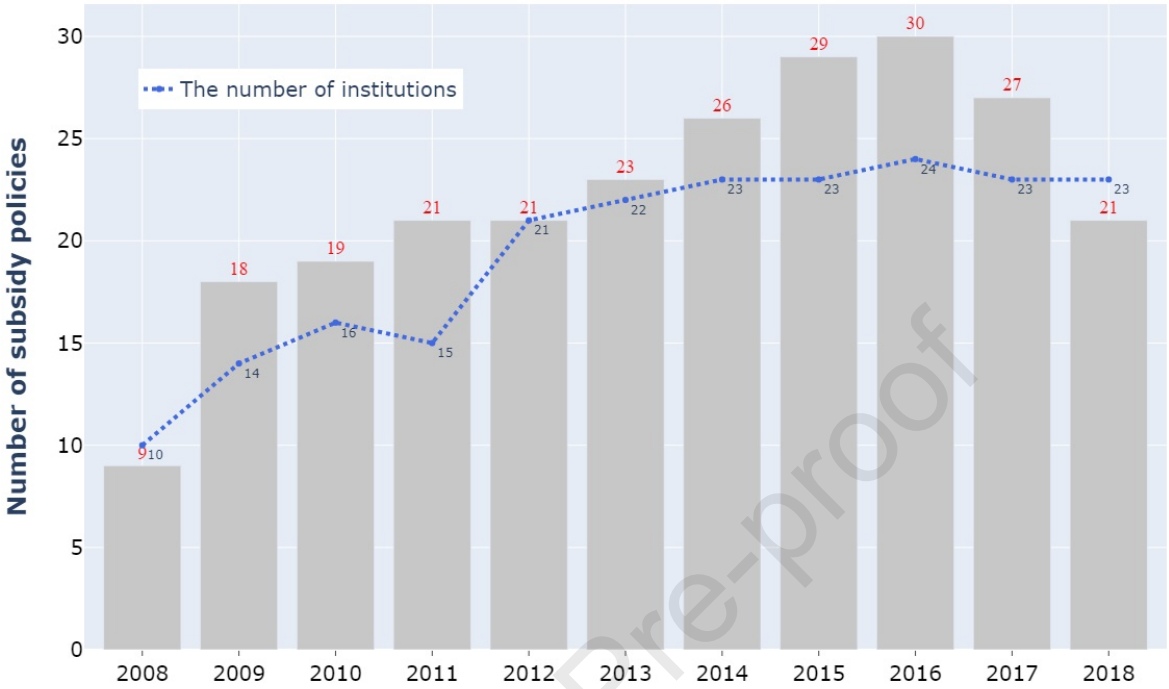
2018
- Subsidy policies: 21
- Involved institutions: 23
- Institutions/project: 5
- Total links: 315

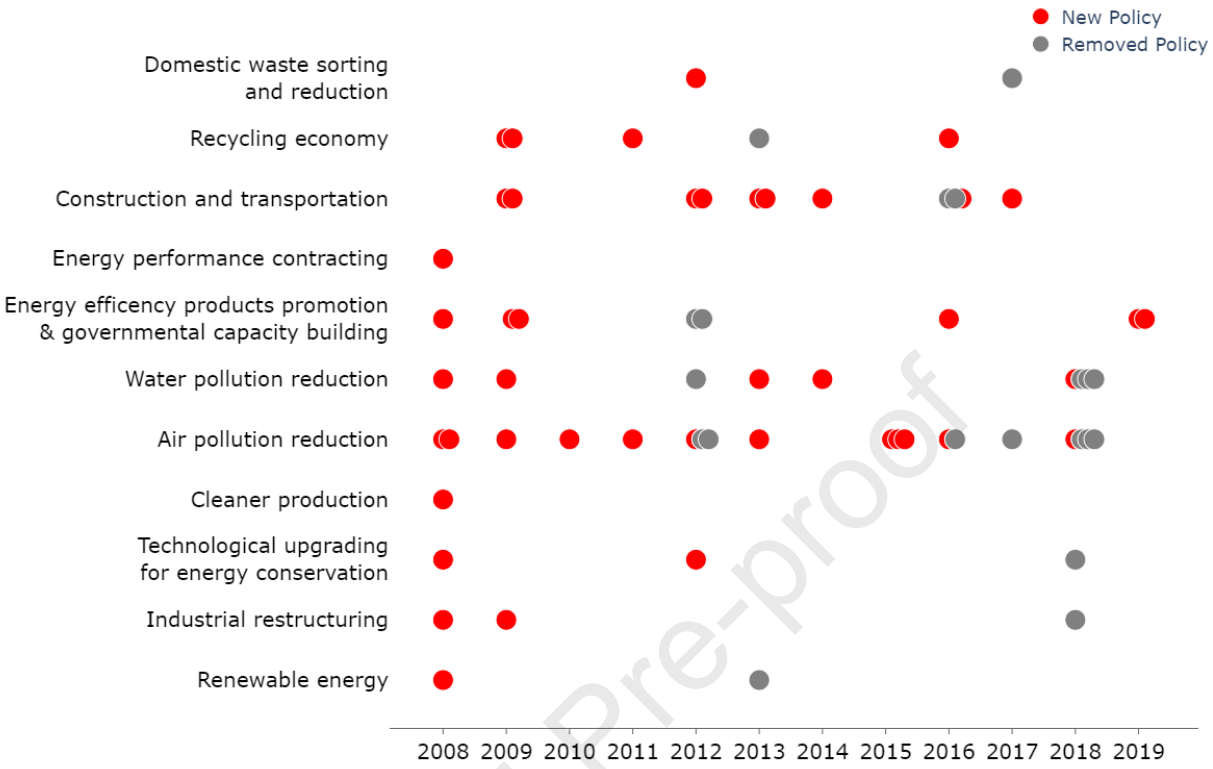


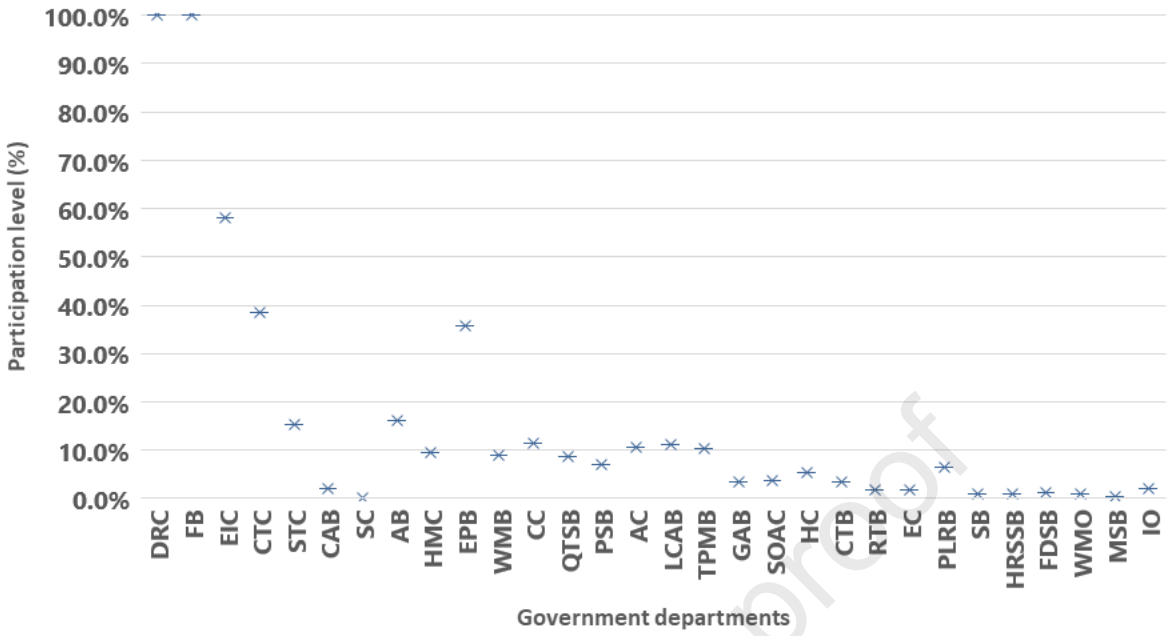


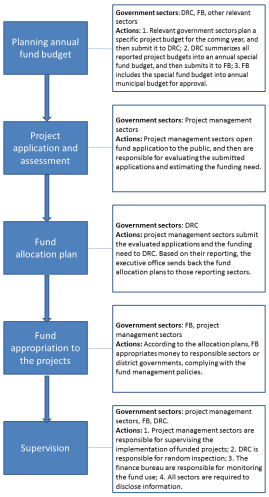


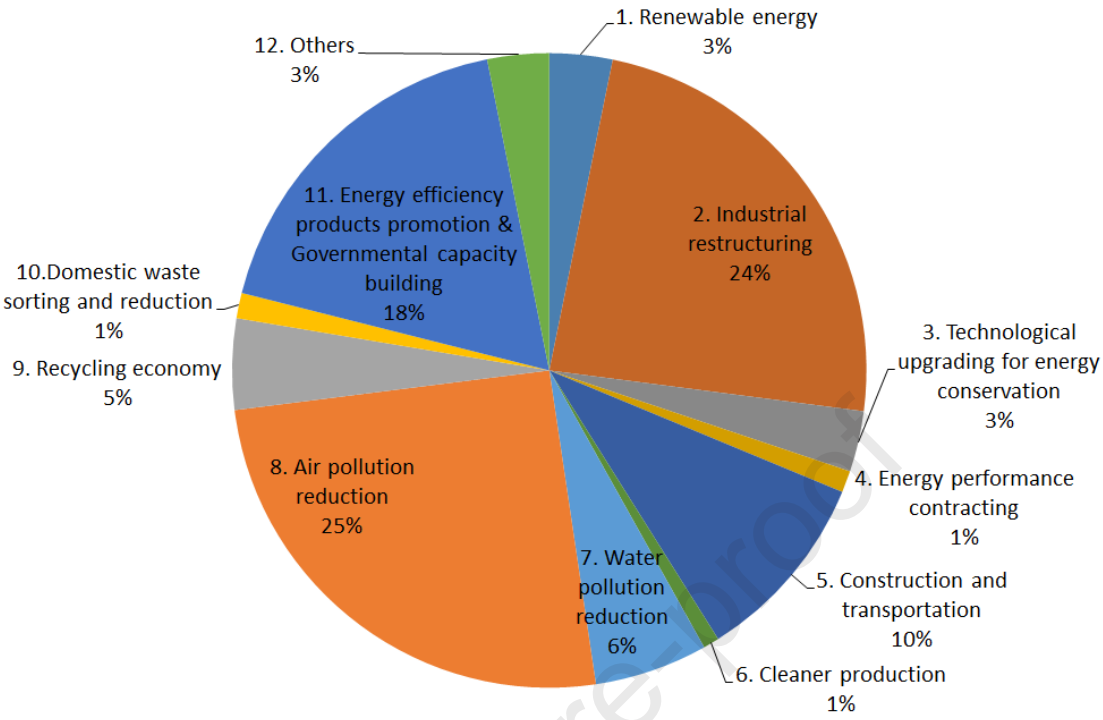












Highlight：

Understanding spillover effects of direct funding may encourage more investment

A linkage analysis is performed to visualize institutions' interaction in implementation

Urban direct funding has catalytic effects on institutions and local capacity building

Fund implementation fills an implementation gap between policy intention and outcome

Wide fund scope enables a pool of sustainability experiments for policy learning