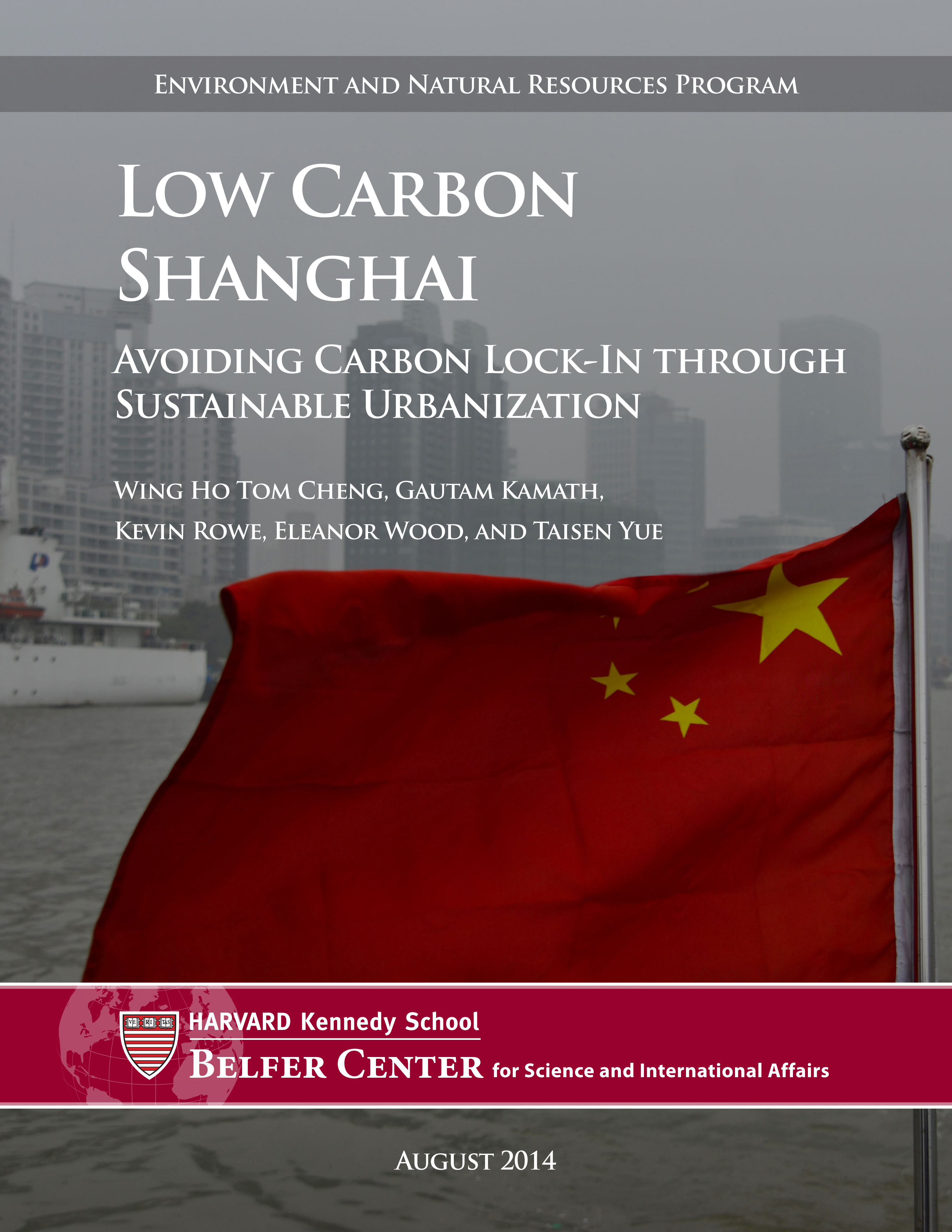

Environment and Natural Resources Program

Low Carbon Shanghai

Avoiding Carbon Lock-In through Sustainable Urbanization

Wing Ho Tom Cheng, Gautam Kamath,
Kevin Rowe, Eleanor Wood, and Taisen Yue

HARVARD Kennedy School
Belfer Center for Science and International Affairs

August 2014

Report by The Environment and Natural Resources Program

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Cover photo: A Chinese flag flutters on a sightseeing boat sailing along the Huangpu River in heavy smog in Shanghai, China, 28 February 2014. (Shen Chunchen / AP)

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The Environment and Natural Resources Program (ENRP)

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Preface

This report was written as part of a pilot initiative allowing small groups of Masters in Public Policy students to submit a team report in compliance with Harvard Kennedy School's requirements under the Policy Analysis Exercise — the school's equivalent of a Master's thesis. The five authors worked for seven months on this report, conducting extensive interviews in Beijing, Shanghai, and Tokyo with senior government officials and leading scholars. They also obtained substantial data on energy consumption indicators for Shanghai.

Reducing carbon emissions in Shanghai is a huge undertaking and involves every facet of both energy supply options and energy consumption patterns. Hence the authors selected three principal areas of focus: 1 The integration of land use, transportation and housing planning; 2. Improving building efficiency; and 3. Improving electricity use in building operations. As public concern over conventional air pollutants grows and the demand for air conditioning in the increasingly hot summers and heating in the winter rises, the potential of "locking-in" inefficient and costly energy use patterns increases. This report addresses these challenges.

Given the limited time frame, the authors have done a very good job in covering these three areas and providing recommendations for improvements.

As the faculty supervisor for the project, I was impressed by the students' dedication and hard work. I am grateful for the Harvard Kennedy School's willingness to fund the pilot and the Chinese Academy of Social Sciences' willingness to serve as the official client for this project.

Henry Lee

Senior Lecturer, Harvard Kennedy School
August 2014

Executive summary

Context

Shanghai will lock in a future of high energy costs and worsening air pollution if it does not change current policies for the planning, construction, and operation of new urban developments, particularly transportation systems, and buildings. This report assesses the policy frameworks for these systems and their implications for Shanghai's prospects as a low carbon city. The major obstacles to efficient, low carbon development are the fragmented planning system for land use and transportation, the insufficiently stringent building energy efficiency codes and the lack of investment in opportunities to encourage efficient consumer behavior.

Carbon lock-in occurs when infrastructure projects, or other developments with long lifetimes, are designed with high-carbon characteristics that are difficult to reverse later. This issue is particularly acute for rapidly-urbanizing Shanghai, where there is an emphasis on keeping project costs low and completion times short.

This report was prepared as a case study for the Chinese Academy of Social Sciences (CASS), a prominent government-affiliated think tank in China. The recommendations are addressed to the Shanghai Municipal Government. Many recommendations hold relevance for the governments of other fast-growing Chinese cities facing similar carbon lock-in challenges to Shanghai.

Scope and structure of investigation

This report evaluates the current efforts of the Shanghai Municipal Government to manage the carbon footprint resulting from rapid urbanization. The urbanization process was divided into the planning, construction, and operations stages to identify the relevant policies for investigation. For each stage, the relevant policies were assessed in terms of their ability to achieve Shanghai's policy goals in a low-carbon context.

Table 1 - Project scope: Planning, construction and operations

Stage of urban development	Areas of policy focus	Policy goal for Shanghai in low-carbon context
Planning	Land use planning and transportation	Transit-oriented development (TOD): cluster residential and commercial developments along mass transit corridors
Construction	Building energy efficiency	Minimize energy use from public and residential buildings
Operations	Electricity consumption by end users	Encourage efficient behaviors and decisions by citizens and building operators

Key findings and recommendations

Recommendations were developed for each policy area: land use planning and transportation, building energy efficiency and electricity consumption by end users. The recommendations require adjustments to the policymaking process to enable flexible policy design, increased use of baseline data and incorporation of externalities into economic analysis. Focusing on these three principles should increase the Shanghai Municipal Government's ability to implement a low carbon policy framework that can adapt to changing trends, is consistent with the city's other policy goals and facilitates ongoing monitoring and evaluation. This style of evidence-based and adaptive policy making is critical for responding to the challenges of a rapidly changing world.

Land use planning and transportation policy

The land use and transportation planning process in Shanghai impacts the carbon footprint of the urban expansion by determining the density of development and the use of public transportation versus private vehicles. The City has made in-principle commitments to transit-oriented development (TOD), which should reduce the carbon footprint by clustering high-density residential and commercial developments along mass transit corridors.

The implementation of the City's development Masterplan for 2001-2020 was assessed to determine whether the principles of TOD are being implemented effectively. This assessment found that the rapid pace of population growth and the rigidity of land use planning processes were both major barriers to implementing TOD.

Recommendations: Land use planning and transportation

Shanghai should reform land planning policies and processes to make implementation of TOD more feasible.

- Reform planning policies and processes to make them more **responsive to the market forces** driving the city's urban development.
- Introduce pricing and incentive reforms to ensure that **consumers pay the full social costs** of their individual transportation and lifestyle choices, including private vehicles and public transportation.
- Encourage more coordinated planning and investment by allowing development stakeholders to **capture the additional benefits** of new residential and commercial developments when they are coordinated with public transportation expansions. Through these reforms TOD can become a means of **financing public transit infrastructure expansions at Shanghai's urban fringe,** since it increases the profitability of both property developments and the transportation system.

Building energy efficiency

The greatest opportunity to reduce energy consumption from buildings is by investing in improvements to building envelope efficiency, before construction is completed. Mandatory standards are necessary because a variety of market barriers prevent these investments from occurring, even when they are economically viable over the lifetime of the building.

Shanghai has implemented energy standards for residential and public buildings. These standards were assessed in terms of their ability to drive the economically optimal uptake of building energy efficiency (BEE) opportunities in new buildings. The major finding was that conflicting goals and drivers for policy design have led to the implementation of codes that are not stringent enough to encourage optimal levels of BEE investment.

Recommendations: Building energy efficiency

Shanghai should increase the stringency of its BEE codes, to encourage BEE investment levels that are closer to 'cost optimal'.

- Invest in increased data collection and broaden the scope of economic modeling to **optimize the code to the economically efficient level** of BEE over a building's expected lifetime.
- **Incorporate externalities** into the calculation of economic benefits from BEE, including the health impacts of air pollution. Explicit consideration of externalities would help incorporate BEE into the city's broader low-carbon plans.
- Develop long-term projections to **account for expected changes** in energy-related behaviors, costs and prices over the coming decades, so that buildings constructed today are optimized for tomorrow's energy system.

Electricity consumption by end users

Shanghai's urban expansion is driving increasing residential and commercial electricity demand. Government policies can encourage efficient behavior by consumers using pricing, metering technologies and other demand-side management (DSM) programs.

This section analyses policy options for Shanghai to drive more energy efficient behavior by consumers. The major finding was that the current policies and programs are insufficient to achieve the levels of demand-side management investments and consumer behavior changes required for a low carbon city.

Recommendations: Electricity end use

Shanghai should pursue electricity market reforms to align the investment and behavioral incentives of all stakeholders with the city's low carbon goals.

- Grow the ESCO industry through innovative financing models such as a "Green Bank" and by actively seeking foreign investment through favorable regulations and tax incentives. Provide **incentives for ESCOs** to invest in data collection and monitoring systems such as smart meters.
- Introduce **dynamic electricity pricing and consumer education programs** such as displays on public buildings, enhanced billing, and goal setting on the end-user side. Programs can be introduced through community-based engagement. Program design and implementation should include other electricity industry stakeholders such as NGOs and utility companies
- Fund trials of innovative feedback measures with the potential to provide **large energy savings and supply cost reductions**.

Conclusion

If Shanghai continues on its current urban development path, it is likely that the city's "new town" development will lock in high levels of private vehicle use, inefficient buildings, and energy wasteful behaviors. These investments will be expensive to reverse and will hold Shanghai back as it tries to reduce carbon emissions in the future. The recommendations proposed in the report are actions that can be taken in the short and medium term to prevent the lock-in phenomenon. The Shanghai government should establish a new policy framework that will improve its ability to consider the tradeoffs involved in low-carbon development and design policies that achieve the long-term goal of sustainable economic growth.

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List of Acronyms

AQI	Air quality index
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
BEE	Building energy efficiency
BRT	Bus rapid transport
CABR	China Academy of Building Research
CAGR	Compound annual growth rate
CDD	Cooling degree days
CDM	Clean Development Mechanism
DSM	Demand side management
DR	Demand response
EE	Energy Efficiency
EPC	Energy performance contract
ESA	Energy service agreement
ESCO	Energy service company
EV	Electric vehicle
FDI	Foreign direct investment
FYP	Five Year Plan
HDD	Heating degree days
HSCW	Hot summer cold winter
HVAC	Heating, ventilation and air-conditioning
IEA	International Energy Agency
LCCI	Low Carbon City Initiative in China
LEED	Leadership in Energy and Environmental Design
MEPS	Minimum energy performance standards
MOHURD	Ministry of Housing, Urban and Rural Development
MPLRA	Municipal Planning, Land, and Resources Administration
MURCTC	Municipal Urban and Rural Construction and Transportation Commission
NDRC	National Development and Reform Commission of China
OECD	Organisation for Economic Co-operation and Development
RD&D	Research, development and dissemination
SEC	Shanghai Electric Company
SMG	Shanghai Municipal Government
SGCC	State Grid Corporation of China
SRIBS	Shanghai Research Institute of Building Sciences
TCE	Tons of carbon equivalent
T&D	Transmission and distribution
TOD	Transit oriented development
TOU	Time of use pricing
WWF	World Wildlife Fund

Chapter 1: **Introduction**

1.1 Purpose of this report

As Shanghai's population and economy expand, the city's urban footprint is growing outside the city core. These new urban developments risk locking the city into unsustainable energy- and carbon-intensive patterns of land use, construction, and building and infrastructure operation.

Inefficient urban development will have wide-ranging long-term consequences, including continued growth in energy costs and greenhouse gas emissions; persistent local air pollution; unproductive utilization of the city's increasingly scarce land resources; greater demand for—but declining social and financial return on—infrastructure investments; and labor productivity losses from compromised environmental health and job accessibility.

With a focus on new town development outside the city core, this report proposes a range of policy opportunities to promote efficient, low-carbon development in Shanghai. The policy decisions that are made today will shape the city's energy and resource use trajectories for decades to come.

In spite of the challenges it faces, Shanghai is already a national leader in urban development planning. The recommendations in this report present an opportunity for Shanghai to continue to provide leadership on low-carbon development for other Chinese cities and provinces.

This introduction begins by defining lock-in in the context of urban development, energy use, and climate change. Section 1.3 outlines the range of economic, environmental, and social consequences of following an inefficient urban development model. Section 1.4 offers a brief investigation into the economic and demographic forces driving Shanghai's rapid expansion. Section 1.5 examines current low carbon development policies. Section 1.6 describes the scope of this report and the remaining chapters.

1.2 Defining Lock-in

Poor infrastructure investments can "lock in" long-term resource consumption patterns that are irreversible or prohibitively expensive to alter for decades or longer. Decisions made today regarding land use and transport planning and building energy efficiency standards will shape Shanghai's energy consumption and emissions trajectories long into the future.

Lock-in occurs primarily because the initial design and construction of an infrastructure asset or building are the major determinant of its operating characteristics and costs for its entire lifetime. In the case of buildings, for example, the efficiency of the building envelope—which comprises the roof, walls, windows, and foundation—is the single most important determinant of a building's energy use (Li and Colombier 2009). Short of expensive retrofits or replacing the building altogether, buildings constructed with an inefficient envelope will lock-in high energy use for the 60 to 100 year life of the buildings. Box 1-1 describes some of the implications for policy analysis that are a result of these long timeframes.

What is more, infrastructure projects shape the urban characteristics of a new development and have lock-in effects that reach far beyond the operation of those assets and persist long beyond their lifetimes. Transit systems and road networks, for instance, often guide residential and commercial developments, attracting population clusters around transport nodes. Clusters that develop around roadway networks tend to affect transportation patterns differently from those that develop around mass transit networks and hence the energy use and emissions output they encourage. The former are accessible primarily by car, allowing for greater distances between buildings and separation of land uses. On the other hand, the latter are accessible primarily by mass transit, and as a result these developments tend to be denser facilitating walking and biking. Experience in many American cities has shown that roadway networks exert a powerful lock-in effect: suburban residential and commercial clusters developed along highways are often too sparsely populated for mass transit to be a feasible transportation alternative.

Energy policies and the pricing of electricity and transportation fuels affect consumer norms and behavior patterns . As living standards rise rapidly in Shanghai, the information consumers receive and the incentives they face with respect to their energy consumption will shape the role of energy-intensive goods and services in defining the lifestyle of the new middle class. Therefore, this report also examines the lock-in risk with respect to energy pricing and demand management policies.

Box 1-1: The importance of discount rates in low-carbon policymaking

Many of the recommendations in this report are focused on methods for assessing the economic costs and benefits of various low-carbon investments in infrastructure and buildings. This type of assessment must compare the upfront cost of the low-carbon investment with its benefits, mainly the reduction in energy and other costs, that result over the life of the asset. A discount rate must be applied to the benefits to express them in an equivalent value to costs borne today.

In order to select an appropriate discount rate for assessing a particular investment, policy makers must take into account whether they are only reflecting the financial opportunity costs of a particular investment, or also the ethical considerations associated with decisions affecting the social welfare of future generations. Lower discount rates place a greater weight on future benefits compared to costs today.

Because of the long lifetimes of the assets that are the focus of this report, the choice of a discount rate is very important: high discount rates mean that benefits in the future are worth less in today’s dollars, compared to estimates using a lower discount rate. This concept is referred to throughout this document as the choice of discount rate.

1.3 What is at stake: The urgency of avoiding lock-in

Urgent action is required for Shanghai to avoid locking in a future with higher emissions and energy costs, greater vulnerability to resource shocks, and a growing burden on human health and productivity. This section outlines the risks associated with locking in an energy- and carbon-intensive future, drawing on comparative experiences from cities around the world. These comparative experiences illustrate how planning and policy choices made in the urban development process have resulted in widely divergent economic, environmental, and social outcomes for cities and countries of comparable levels of economic development.

Energy demand is growing fastest outside the industrial sector

Over the past two decades Shanghai's energy supply systems, including electricity generation and network infrastructure, have expanded rapidly to keep up with rising demand. Figure 1–1 shows Shanghai's annual energy consumption for industrial and non-industrial uses, from 1995 to 2012. In this period the proportion of Shanghai's total energy consumption that is used for non-industrial purposes (including residential and commercial buildings and transportation), increased from 21% to 46%.

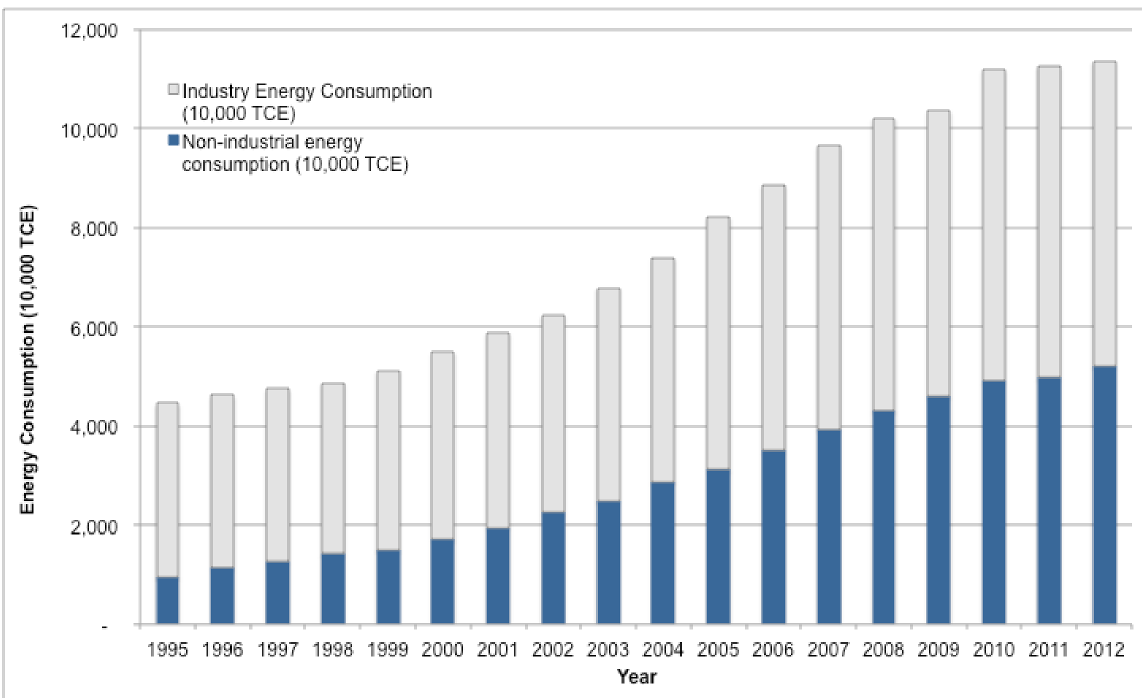

Figure 1–1 Annual energy consumption in Shanghai, 1995-2012 (Shanghai Statistical Bureau 2012)

During 2000-2008, the annual rate of increase in energy consumption of civil buildings[1] in Shanghai was 10.67%, which is higher than the annual rate of increase in total energy consumption of 8.25% during the same period (WWF 2011).

1 Per definition from "Civil Buildings Energy Conservation Ordinance of P.R.China", civil buildings in China refer to non-production-use and non-military-use buildings, including residential and public buildings.

Figure 1–2 shows that this non-industrial energy has also been increasing on a per-capita basis. The annual growth rate in non-industrial energy use per-capita from 1994 to 2012 was 7% (China Data Online 2014). Rising incomes may push per-capita energy use even higher in the future.

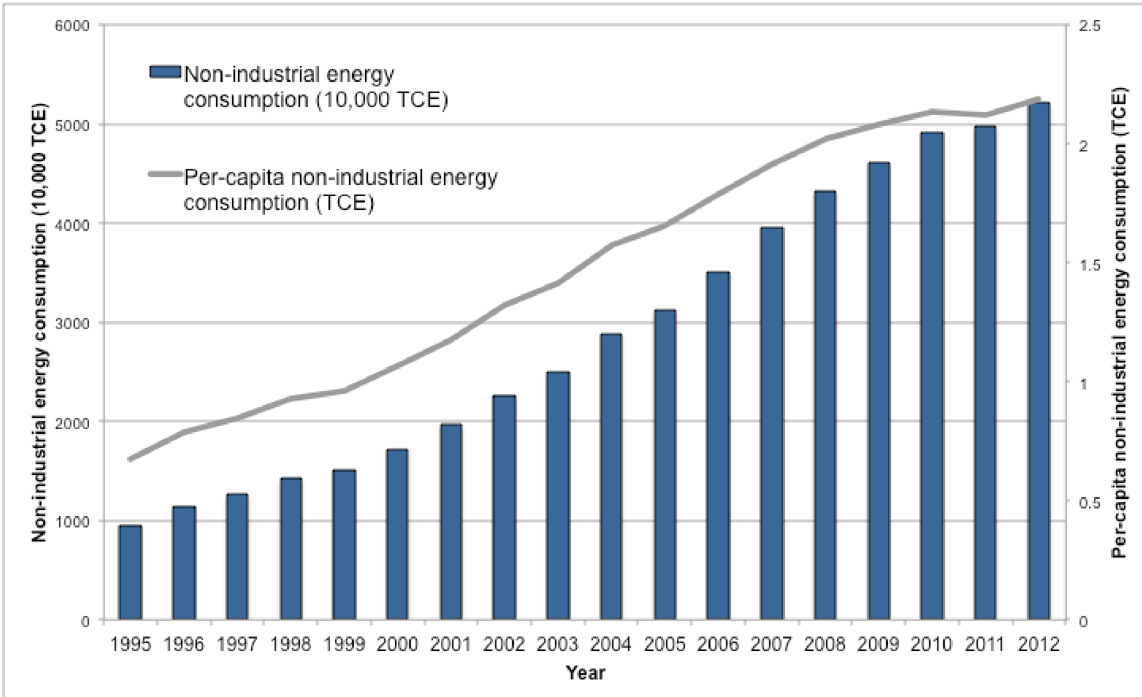

Figure 1–2 Shanghai annual non-industrial energy consumption, 1995-2012 (Shanghai Statistical Yearbook 2013)

As consumers in Shanghai become wealthier their demand for energy services increases, especially transportation, space heating, air conditioning and water heating. Low-carbon policies emphasizing public transportation and energy efficiency mean these increases in standard of living do not necessarily need to be accompanied by increases in energy demand. The contrast between the US and France is instructive: whereas the two countries enjoy similarly high standards of living, the average French consumer uses only about 55 percent of the energy used by her American counterpart (World Bank Open Data 2014).

Energy supply costs will increase faster than demand in the future

Low-carbon investments are a chance to relieve the mounting cost pressures on the energy supply system, leading to significant cost reductions for all consumers in the future. Many of these investments are a trade-off between a one-time cost from an energy-saving measure and reductions in energy costs over the life of the investment. When policymakers evaluate the optimal level of low-carbon investment in Shanghai, they must take into account the risk that energy costs over the coming decades will rise significantly, if current trends continue.

The cost of energy supply in Shanghai has increased over the past two decades, as the system has expanded to keep up with growth in demand. In the future these cost increases are likely to be larger than historical trends due to the following factors:

- **Efforts to control local air pollution or greenhouse gas emissions**. The central government's efforts to control air pollution are likely to contribute in rising energy costs, particularly in the electricity sector where clean energy investments and pollution control costs will increase. Greater efforts to control greenhouse gas emissions for climate change abatement will also contribute to these trends.

- **Increasing fuel costs.** The cost of fuels for both transportation and the electricity sector are likely to continue to rise, and become more volatile, in the future.

- **Increasing electricity network costs.** The increasing use of air conditioning and electric powered hot water in Shanghai's commercial and residential buildings will lead to increased investment in the distribution network to meet greater 'peaks' in electricity demand.

Greenhouse gas emissions, air pollution, and health effects

Because Shanghai's energy mix is dominated by fossil fuels, locking in high energy consumption will also mean locking in high greenhouse gas emissions and local air pollution. As the focus of Shanghai's development has turned to expansion and decentralization in the past 15 years, transport, buildings, and electricity have become the fastest growing sources of emissions in Shanghai.

Already Shanghai's greenhouse gas emissions (GHG) per capita are higher than those of China's other megacities and many megacities in the developed world. As of 2006, Shanghai's per capita GHG emissions were about 12.8 metric tons of CO_2 equivalent annually (Sugar et al. 2012), about 20 percent higher than those of Beijing. Figure 1–3 below illustrates the strong relationship between urban population density and GHG emissions per capita. Shanghai appears to be an outlier on this graph, with high density and relatively high per capita emissions, likely because industry maintains a much larger share of Shanghai's economy than it does in the comparison cities (Urban Development Sector Unit, East Asia and Pacific Region 2008).

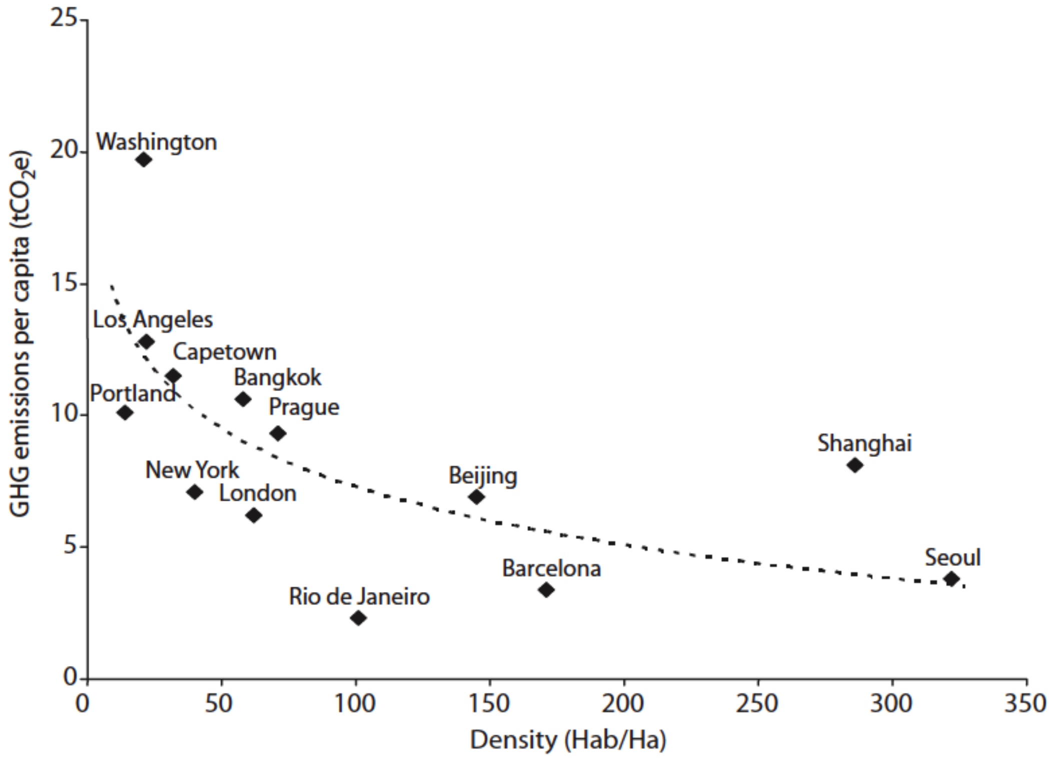

Figure 1–3 Per Capita GHG Emissions and Urban Population Density of Global Cities

Although air quality has improved in recent years in Shanghai, serving the city's rapidly rising energy needs may be the greatest single obstacle to achieving continued progress on improving

Box 1-2: Valuing externalities for low-carbon policymaking

Taking into account the external costs and benefits (sometimes referred to as co-benefits) from low-carbon investments is crucial for policymaking in this area (Jiang et al. 2013).

The health effects from air pollution are one of the largest external costs of high-carbon lock-in. If externalities are not considered, estimates of costs and benefits only include individuals' private losses and gains from the investment. In the example of building envelopes, the increased constructions costs are compared to reductions in energy bills over the life of the building. If externalities were included, the healthcare benefits for all citizens from reducing the pollution from energy supply would also be incorporated into the cost-benefit analysis.

Since the costs of these externalities are borne by all of Shanghai, policymakers should include estimates of their value in their determination of the optimal level of low-carbon investments today.

Several of the recommendations in this report are focused on methods for policy design that directly take into account the costs of these externalities when assessing the benefits of low-carbon investments. In order to implement these recommendations, policymakers will have to come up with robust estimates of these externalities.

environmental health. On December 2, 2013, the average Air Quality Index in Shanghai peaked at 317 parts per million of small particulates, the highest recording since official AQI began in 2012 and more than 12 times the World Health Organization's guideline (Ke 2013).

Other effects: labor productivity, land use, and finance

Because patterns in energy use are highly correlated with the efficiency of resource use and mobilization in other areas, such as human capital, land, and infrastructure, the implications of lock reach far beyond the energy and environmental concerns reviewed above.

- **Labor productivity.** In a city that is increasingly sprawling, workers must spend a greater share of their productive time traveling to and from work. As it develops the next phase of the Metro, rising commuting times has become a particular focus. The combination of inefficient urban expansion and increased private vehicle use will generate substantial productivity loses from reduced job accessibility (Haixiao Pan, Qing Shen, and Ming Zhang 2009).

- **Land use.** Rapid expansion of built-up area has made land a scarce resource in Shanghai. Fifteen years ago the city was less than 50 percent urbanized,[2] and land scarcity was almost unimaginable. Today Shanghai is more than 85 percent urbanized (Yin et al. 2011) China, during the transitional economy period (1979–2009. Facing increasingly strict urban development containment directives from the central government, failure to manage land use effectively will be increasingly costly.

- **Infrastructure.** Current urban development patterns outside the city core risk locking-in inefficient infrastructure investments. More dispersed development demands more infrastructure expenditure to serve the same population. This is illustrated in Figure 2, below, which shows the Shanghai Metro network, including planned lines to 2020, and population centers. For revenue-generating infrastructure like public transport and electricity distribution, reduced population density means less revenue per unit of investment.

1.4 Key drivers of Shanghai's lock-in risk

Population and economic growth are the two main drivers that are behind Shanghai's urban expansion. Both population and economic growth in Shanghai have moderated since their height in 2007[3] yet both remain high, generating continued pressure on urban infrastructure (World Bank 2008).

1.4.1 Population Growth and the urban expansion

Ever since the city's cosmopolitan bloom in the 1920s, Shanghai has been one of the most

2 "Urbanized" refers to the built-up land area as a percentage of the city's total land area.

3 According to Shanghai Statistical Yearbook, from 1979 to 2011, both population growth rate and economic growth rate (GDP growth rate) in Shanghai witnessed their peak in 2007, with population growth rate of 5.06% in 2007 and GDP growth rate of 15.2% in 2007.

populated cities in China. However the pace of urbanization over the last 30 years has been extraordinary. Years of urbanization have greatly expanded Shanghai's built up area. In 1958 ten counties of the neighboring Jiangsu Province were incorporated into Shanghai. However the increase in land pales in comparison with the growth rate of population. According to the 1982 population census, Shanghai's population was 11,859,784, and in 2010 the census figure gave us 23,019,148, more than double of the figures in less than 30 years. In 2007 alone the city added nearly one million residents.

The city is now divided into 17 districts and 1 county, of which 9 districts near the core of the city are collectively referred to as the urban areas. The population density of Shanghai increased from 1,734 persons per square kilometer in 1970 to 3,632 persons per square kilometer in 2010. Today Shanghai has the highest population density among all cities in China. The increased population becomes one of the main drives in propelling the city's energy usage in the past decade, with residential sector's energy consumption growing fivefold, rising from 2,489,800 tons of coal equivalent in 1990 to 11,417,200 tons of coal equivalent in 2012. The boom of the tertiary industry[4] is also highly correlated with the rising population, with an increase in absolute terms from 4,034,700 to 37,442,500 tons of coal equivalent from 1990 to 2012, a nearly tenfold increase in a little more than 20 years.

Although population growth has slowed since the global financial crisis, the Shanghai municipal government anticipates continued population inflows between 300,000 and 400,000 people per year through 2020. The current population stands at about 24 million and hence is projected to reach between 26 and 27 million by 2020. Table 11 shows the population growth rates from 2000 until 2010.

Table 1-1 Population of Shanghai (2000 – 2010)

Year	Total Population	Annual Growth Rate
2000	16,090,000	2.65%
2001	16,683,300	3.69%
2002	17,129,700	2.68%
2003	17,658,400	3.09%
2004	18,349,800	3.92%
2005	18,902,600	3.01%
2006	19,641,100	3.91%
2007	20,635,800	5.06%
2008	21,406,500	3.73%
2009	22,102,800	3.25%
2010	23,026,600	4.18%
2011	23,474,600	1.95%
2012	23,804,300	1.40%

Source: Shanghai Statistical Yearbook

4 In China, tertiary industry here refers to all industries that are not included in primary or secondary industry. The tertiary industry sector includes a wide range of industries, such as transportation, storage, telecommunications, banking, finance, real estates, education, public health, sports, scientific research, government agencies, wholesale and retail trade, etc.

1.4.2 Economic growth

Another major driver for rapid urban expansion is the rapidly growing economy. China's tremendous growth in the past decades was well documented. For years, GDP was being used as the major indicator for government official's performance evaluation, thus encouraging local officials to adopt different approach with the sole focus on boosting economic growth.

Annual growth rates of economic output in Shanghai have outpaced those of population for more than a decade China Data Online, "China Yearly Macro-Economic Statistics (Provincial).". In 2012 the Brookings Institute ranked Shanghai as the world's fastest growing metropolitan area in terms of income and employment (Istrate, Berube and Nadeau 2011). Likewise Shanghai has generally outperformed China as a whole. Although national policy has sought to moderate growth, including in Shanghai, the Municipal Government anticipates robust economic growth at least on par with the national rate for the foreseeable future.

The increase in economic development also brought forth foreign direct investment, which increase from 3.16 billion USD in 2000 to 11.12 billion USD in 2011, a 251.9% increase[5].

Shanghai's economic development has led to increased construction and land use development in both the residential and commercial sectors over the last few years, as shown in Figure 1–4.

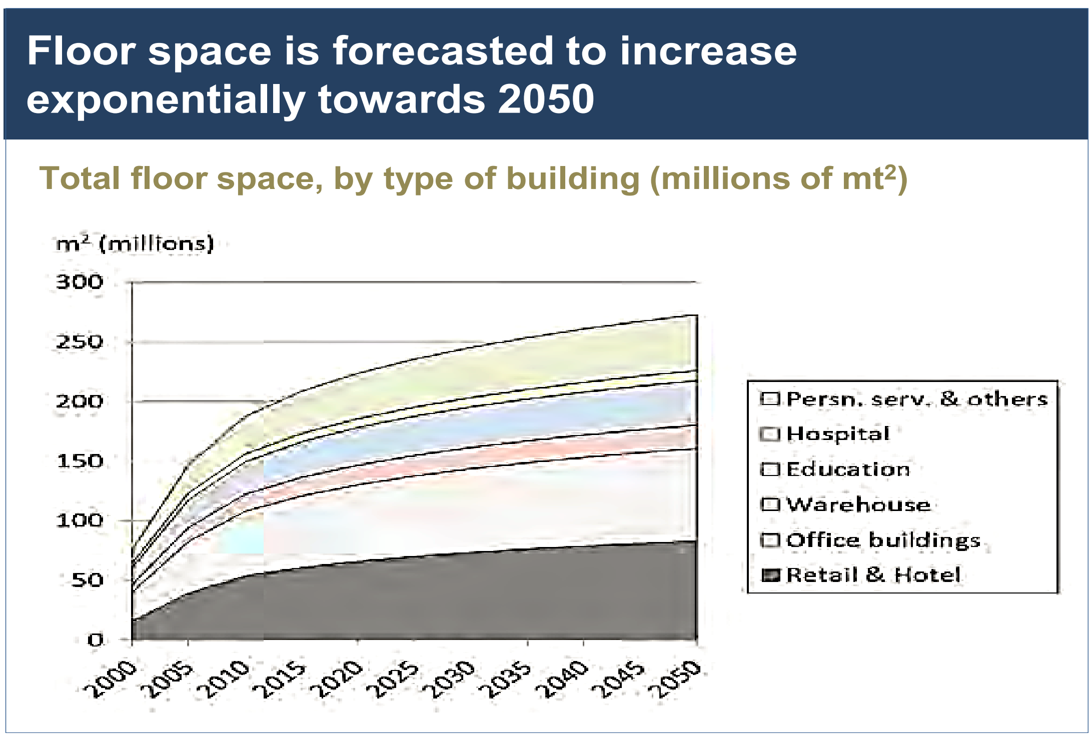

Figure 1–4 Estimates of exponential floor space increases in Shanghai (Xing et. al. 2011)

1.5 Policies for Low Carbon Development

China has greatly increased its energy consumption during its recent development process, the

[5] FDI calculated as Foreign Investment Actually Absorbed (Shanghai Statistical Yearbook).

huge environmental and social costs associated with this trend has put tremendous pressure on the government. As a result, low carbon development has recently become a popular topic in planning China's future sustainable growth. For more details about China's energy consumption profile, refer to Appendix A.

1.5.1 Low-carbon cities

The "low-carbon city" concept focuses on reducing the challenges associated with rapid urbanization and climate change. The World Bank and ICLEI – Local Governments for Sustainability have already suggested a series of initiatives to help cities around the world better plan and design their own low-carbon development paths. For more details on the different approaches to develop low carbon cities, refer to Appendix B.

In line with the increasing commitment of the national government on low carbon development, the Shanghai Expo in 2010 was the first vehicle for the city government to pioneer a series of low carbon policies that aim to improve the city's living environment and sustainable development prospects. The slogan of the 2010 Expo was "Better City, Better Life", which emphasized a symbiotic relationship between the city and the environment. Exhibitions and events were arranged to explore the challenges cities faced in order to balance urban development and environmental protection. Extensive efforts were made to upgrade urban infrastructure, improve pollution control systems and promote research in new low carbon technologies (Ping 2009). The green legacy the 2010 Expo left had improved the capacity of Shanghai to take on more low carbon initiatives in the future.

National Chinese context: the move people-centric growth

> *"We need to put people first, make improving their well-being the starting point and goal of all work, unwaveringly work for prosperity for all and ensure that everyone shares the fruits of development"*
>
> *– Premier Wen Jiabao about 12th Five Year Plan*

Low carbon development – the question of how to achieve energy efficiency and reduce energy consumption while at the same time providing for rapid economic development – has become China's biggest challenge today. This realization was best articulated in the 12^{th} Five-Year-Plan (FYP), which introduced a people-centric sustainable development model that emphasizes China's transition from high quantity to high quality-based growth (Xinhua News Agency 2011).

China planned to initiate a clean revolution that would encourage the development of low carbon energy, energy efficiency and clean technology, and pledged to reduce the nation's carbon intensity by 40-45% from 2005 to 2020. The 12^{th} FYP set up a energy consumption growth target, and included a series of policies that would phase in market mechanisms and incorporate "bottom-up" actions in provinces and cities.

1.6 Scope and Structure of the Report

1.6.1 Focus on new town developments

Low carbon development involves a wide array of topics that covers multiple aspects of policy frameworks. The Shanghai Municipal Government has already put tremendous effort in energy conservation in the industrial sector – given that this sector accounts for over 70% of all energy consumption in the city. Early assessments of these achievements show positive evidence of declining energy consumption, as shown in Table 12. However, despite these reductions in the industry sector, the table shows that electricity consumption continues to grow in other sectors of Shanghai's economy, particularly those associated with the new town developments.

Table 1-2 Shanghai Electricity Consumption by Sector (Shanghai Statistical Yearbook 2013)

	2011	2012	% Change
Total Electricity Consumption (in 100 million kwh)	1339.62	1353.45	1.03%
Agriculture	6.37	6.85	7.54%
Industry	805.76	786.25	-2.42%
Transport, Warehousing and Postal Service	38	38.74	1.95%
Commerce, Accommodation and Catering	72.04	74.72	3.72%
Finance, Real Estate, Business and Residential Services	139.01	149.12	7.27%
Public Sector and Public Management	78.48	82.77	5.47%
Urban Residential Electricity Consumption	175.22	187.38	6.94%

Therefore, for the purpose of scoping, this report concentrates on low-carbon development strategy for Shanghai in buildings and related development (specifically new buildings and development areas). The process of urban development is divided into three phases for analysis: planning, construction and operation to highlight the different intervention points for policies to avoid carbon lock-in. This breakdown of the urbanization process allows separate analysis of the different causes of carbon lock-in, to develop targeted policy recommendations.

This report focuses on three major policy areas: land use planning (with implications for transportation), building energy efficiency at the construction phase and building energy consumption at the end user side (operation). Our findings are in line with current research focusing on the specific role of buildings and related energy consumption echoed by the NDRC and WWF's "Low Carbon City Initiative in China" (LCCI). This report also aims to raise greater awareness of the lock-in effect and other co-benefits associated with improving energy efficiency in the process of new town development.

1.6.2 Structure of this report

Chapter 2 illustrates the role of land use and transit planning in the grand scheme of new town development. The chapter will further look into transit-oriented development (TOD) models in other Asian cities (Tokyo, Hong Kong, Singapore) and provides insights on their applicability to Shanghai.

Chapter 3 documents the current state of building code and ordinance for new residential buildings. The chapter will also look into the international benchmark of building efficiency standard, and how the Shanghai government can incentivize developers to utilize the most efficient building standard for new town developments.

Chapter 4 studies the possibility of using financial and behavioral incentives to drive change in end-user energy consumption through managing the operational side of Shanghai's new buildings and implementing direct policy interventions on end-users. The chapter will try to devise different policy measures to intervene energy usage behaviors, such as dynamic pricing and improving investment in demand-side management technology.

Chapter 5 draws out overarching implications for policy design and implementation and suggests that through adopting an evidence-based, externalities-inclusive and flexibly policy design process, the Shanghai Municipal Government would enhance its capacity to carry out effective measures to minimize the risk of lock-in effect.

Methodology

The methodology for analysis is based on the policy analysis framework developed by Bardach (2005). Chapters 2, 3 and 4 follow the structure shown in Figure 1–5. First, an initial problem diagnosis is outlined, assessing the current policy framework and the drivers of carbon lock-in in that area. The policy analysis is then presented. This analysis combines the findings of expert interviews with a review of the current literature. Policy recommendations are presented at the end of each chapter.

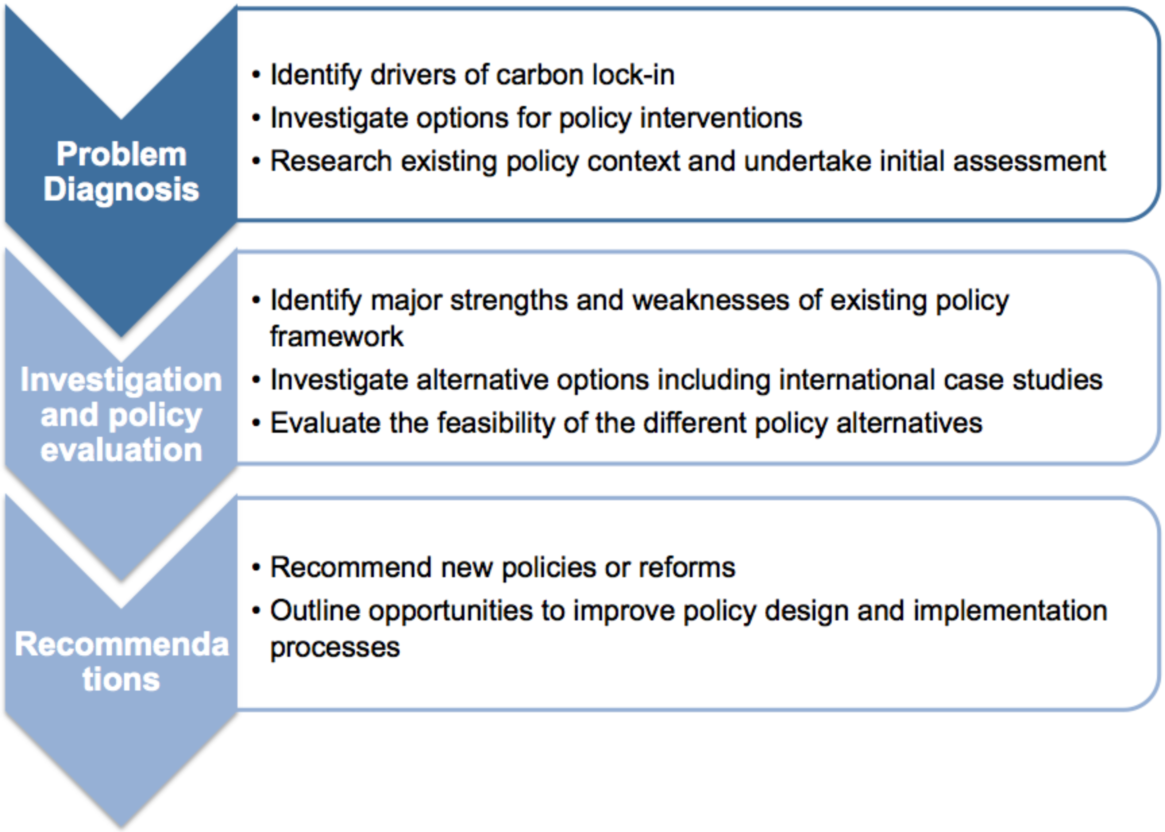

Figure 1–5 Policy analysis methodology

Chapter 1 Reference List

Baeumler, Axel, Ede Ijjaz-Vasquez, and Shomik Mehndiratta, ed. 2012. *Sustainable Low-Carbon City Development in China*. Directions in Development: Countries and Regions. Washington, DC: The World Bank.

Bardach, Eugene. 2005. *A Practical Guide for Policy Analysis*. 2nd ed. Washington, D.C: CQ Press.

China Data Online. 2014. "China Yearly Macro-Economic Statistics (Provincial)." Accessed February 1. http://chinadataonline.org.ezp-prod1.hul.harvard.edu/member/macroyr/.

Huoche.net. 2012. "Shanghai Metro Overcapacity by 135%." *Huoche.net*, November 1. http://www.huoche.net/show_128628/.

Istrate, Emilia, Alan Berube, and Carey Anne Nadeau. 2012. "Global MetroMonitor 2011: Volatility, Growth, and Recovery". Brookings Institution. http://www.brookings.edu/research/reports/2012/01/18-global-metro-monitor.

Ke, Jiayun. 2013. "Air Pollution in Shanghai Worst Since Records Began." *Shanghai Daily*, December 3. http://www.shanghaidaily.com/Metro/environment/Air-pollution-in-Shanghai-worst-since-records-began/shdaily.shtml.

Li, Jun, and Michel Colombier. 2009. "Managing Carbon Emissions in China through Building Energy Efficiency." *Journal of Environmental Management* 90 (8): 2436–47.

Liu, Z. L., Y. X. Dai, C. G. Dong, and Ye Qi. 2009. "Low Carbon City: Concepts, International Practice and Implications for China." *Urban Studies* 16 (6): 1–7.

Ping, Lo-Sze. 2009. *UNEP Environmental Assessment, EXPO 2010, Shanghai, China*. Produced by the UNEP Division of Communications and Public Information, China.

Shanghai Statistical Bureau. 2012. *Shanghai Statistical Yearbook (from 2001 to 2012)*. Official Web Site of Shanghai Statistical Bureau, http://www. stats-sh. gov. cn.

Sugar et al. 2012

The World Bank. 2013. "Applying Abatement Cost Curve Methodology for Low-Carbon Strategy in Changning District, Shanghai (Vol. 1 of 2) : Summary Report (English)". 84068. The World Bank. http://documents.worldbank.org/curated/en/2013/11/18821644/applying-abatement-cost-curve-methodology-low-carbon-strategy-changning-district-shanghai-vol-1-2-summary-report.

World Bank Urban Development Sector Unit, East Asia and Pacific Region. 2008. "The Spatial Growth of Metropolitan Cities in China: Issues and Options in Urban Land Use". Washington, DC: The World Bank.

World Bank Open Data 2014

WWF China News Center. 2008. "Shanghai and Baoding Set as Two Pilot Cities in Low Carbon City Initiative." *WWF China News Center*, January 28. http://www.wwfchina.org/pressdetail.php?id=613.

WWF Shanghai Low Carbon Development Roadmap Research Team. 2011. *2050 Shanghai Low Carbon Development Roadmap Report*. Beijing: Science Press.

Xing et al 2011

Xinhua News Agency. 2011. "The 12th Five-Year-Plan Stresses People-Centric Growth and Sustainable Development." *Xinhua News*, March 6. http://news.xinhuanet.com/politics/2011-03/06/c_13763809.htm.

Yang, Jian. 2013. "10-Year-Battle to Solve City's Air Pollution." *Shanghai Daily*, December 27. http://www.shanghaidaily.com/Metro/environment/10year-battle-to-solve-citys-air-pollution/shdaily.shtml.

Chapter 2: **Land Use, Urban Planning & Transportation**

Summary

In the past two decades Shanghai's rapid population and economic growth have resulted in a disproportionate expansion of the city's built-up area. Shanghai's built-up area grew at twice the rate of population growth during the 2000s (Yin et al. 2011). Today the city's urban expansion poses the risk of locking in inefficient land use and transportation patterns outside the core, which will have wide-ranging consequences: unproductive utilization of the city's increasingly scare land resources; greater demand for infrastructure investments; labor productivity losses from compromised environmental health and job accessibility; and continued growth in energy consumption and greenhouse emissions intensity.

The Shanghai municipal government recognizes avoiding lock-in in the land use and transport sector as an urgent priority. Among the central motivations of Shanghai's 2001-2020 Master Plan and subsequent directives is a vision of Transit Oriented Development (TOD) that aims to cluster residential and commercial development around transit stops to maximize public transportation use and land use efficiency (For a definition of TOD, see Box 1). The city has made significant strides toward realizing this vision, building one of the world's most extensive metrorail systems in less than 20 years and reducing rising private vehicle use.

Nonetheless, coordinating transit infrastructure with residential and commercial development has proven challenging. Planners today are facing a mismatch between Shanghai's dynamic land market and its rigid urban planning regime. To operationalize TOD, they require policy tools to be more responsive to these market forces, to correct distortions in these markets that favor unsustainable transit and development options, and to coordinate stakeholders in the planning process.

This chapter draws from diverse experiences with TOD in Tokyo, Singapore, and Hong Kong to identify and analyze alternative governance frameworks for coordinated transit and urban development planning. The recommendations are

1. Develop greater capability within the Municipal Planning, Land, and Resources Administration (MPLRA) to weigh the social costs and benefits of alternative projects.
2. Push modest reforms to the Detailed Development Control Planning process so that residential and commercial development around transit nodes can capture more of the accessibility benefits of transit investments.
3. Implement congestion pricing and consider parking policies to relieve congestion and pollution associated with increasing private vehicle use.
4. Provide district governments with a greater stake in operationalizing TOD by pushing for property tax reallocation.

In the past 15 years Shanghai's urban development has been characterized increasingly by sprawling expansion. Figure 2–1 illustrates the city's remarkable development during its most rapid period of population and economic growth, 2000 to 2008. This expansion was characterized by dispersion in all directions as development proceeded largely in concentric rings around the city core. During this period, built-up area increased at twice the rate of population growth (Yin et al. 2011)China, during the transitional economy period (1979–2009. As a consequence, built up area population density declined by 20 percent between 2000 and 2005 (Urban Development Sector Unit, East Asia and Pacific Region 2008).

Figure 2–1 Shanghai Built-up Area 2000-2008 (Yue et al. 2012)

Without a concerted effort to improve the coordination of new residential and commercial development with existing and planned transport infrastructure, Shanghai will lock-in a sprawling and energy- and carbon-intensive development pathway. Already, dispersed development outside the city core is generating increased demand for transport infrastructure as residents must travel farther between their homes, workplaces, and shopping destinations (Y. Li et al. 2010). Between 1995 and 2004, average individual trip distance increased by 40 percent, from 4.9 km to 6.9 km (Urban Development Sector Unit, East Asia and Pacific Region 2008).

Increasingly dispersed development is also reducing the viability of the city's public transport systems, particularly the Shanghai Metro. If current development trends continue, only 24 percent of Shanghai's population outside the Outer Ring Road will live within 2km of a Metro station by the time the current system expansion program is complete in 2020 (Urban Development Sector Unit, East Asia and Pacific Region 2008). Figure 2–2 illustrates the challenge of providing sustainable public transport outside the city core. This figure, which represents population centers with circles and existing or planned Metro rail lines with colored lines, shows that in spite of the build out of the Metro system since the early 1990s, vast areas of the outer districts—and the millions of residents who inhabit them—are not accessible by Metro.

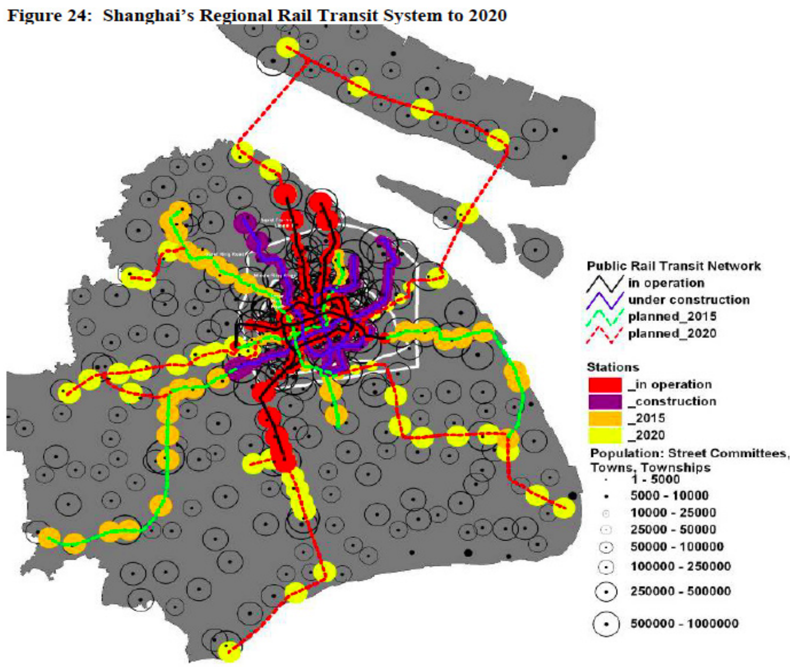

Figure 2–2 Population Centers and Shanghai Metro Expansion to 2020 Source: (Urban Development Sector Unit, East Asia and Pacific Region 2008)

Urban expansion during the 2000s, a decade in which Shanghai's population increased 1.5-fold and economic output increased 2.5-fold, was inevitable, and it was also an explicit goal of the city's 2001-2010 Masterplan. The Masterplan, however, envisioned urban expansion of an entirely different form than the sprawling concentric expansion seen in the past 15 years. Instead it sought to cluster new development in dense nodes and corridors around public transport infrastructure, namely the Metro system, in order to maximize accessibility and land use efficiency and minimize energy demand growth. Figure 2-2 suggests that this vision of transit- oriented development (TOD) has not been realized.

Shanghai's sprawl challenge has arisen in spite of immense investment in public transport. Since it began construction on the Metro in 1993, Shanghai has built one of the world's most extensive metrorail networks in the world.

- **Rapid development during the 2000s revealed deficiencies in Shanghai's urban planning system.** Shanghai's urban expansion has been enabled in large part by the gradual liberalization of its land market. Yet, while a combination of national and municipal reforms have increasingly allowed the market to lead urban development, the land use and urban planning regime remains tied to the paradigm of state-led urban development. When population growth exceeded the projections used to plan new town developments in the 2001-2020 Masterplan, the planning system was unable to adapt to the faster pace of growth. As a result, rather than accommodating new residents in denser new town development or additional urban nodes, development plans were adjusted incrementally and only resulted in further expansion.

- **On the other hand, a countervailing set of policies and incentives created primarily by national policies have promoted sprawling development**. Whereas municipalities and districts are responsible for funding much of their infrastructure development needs, reforms to the national taxation system over the past three decades have left both municipalities and districts will less and less tax revenue. Liberalization of the land market has made selling development rights a viable source of government revenue for municipalities and districts. Combined with a strong set of incentives from the central government in favor of maximizing GDP growth and expanding export industries, this policy environment led to inefficient allocation of land.

Achieving the vision of low-carbon TOD sought by the Masterplan will require reforms to Shanghai's urban development governance regime to make planning more responsive to increasingly powerful market forces and to slow the over-provisioning of suburban land to developers. This chapter draws from the experiences of other cities with managing the challenge of urban expansion to identify lessons for Shanghai as it moves to reform its urban development governance regime.

Box 2.1: Defining Transit-Oriented Development

Transit-Oriented Development (TOD) describes an approach to integrated land use and transport planning. Demonstrated in cities like Copenhagen, Tokyo, Seoul, Singapore, and Hong Kong, TOD capitalizes on the public value created by transport infrastructure development to maximize transit access and provide transit investments with a sustainable financial model. By co-locating residential and commercial development with transport nodes, TOD seeks to reduce automobile dependence and hence energy demand and carbon emissions.

Although integrated development strategies resembling what is now called TOD precede the automobile, in recent decades TOD has been employed to head off the sprawl cycle. The sprawl cycle is the positive feedback system generated by dispersed urban development and rising automobile use: more cars enable more dispersed development, which in turn requires more transportation development—generally roads—and augment demand for cars. TOD envisions an alternative positive feedback system wherein transit development increases the value of land surrounding station stops and, in turn, development near station stops ensures a stable ridership base for the transit system (Curtis, Renne, and Bertolini 2009).

TOD is an approach to urban development and transport governance, rather than a particular set of transit investments or policies. Cities that have realized highly coordinated transport and development systems have done so through a variety of policy frameworks, ranging from almost entirely market-driven, as in Tokyo, to largely state-directed, as in Singapore. Section 3 investigates these differences in depth.

The chapter is organized as follows: Section 1 investigates recent trends in Shanghai's urban development and the challenges arising from rapid development; Section 2 evaluates current policies aimed to address these challenges; and Section 3 analyzes TOD governance approaches from Tokyo, Hong Kong, and Singapore in order to identify lessons for Shanghai's reform pathway. The chapter concludes with a set of recommendations.

2.1 Problem Diagnosis

2.1.1 Drivers of urban expansion in Shanghai

The extraordinary economic, social, and political transformation across China in the recent past has fundamentally altered the role of planning in shaping land use and transport in Shanghai. National reforms, some of which were piloted by Shanghai, have increasingly enabled individuals, firms, and market forces, rather than planners, to drive residential, commercial, and industrial development. More so than ever, planning is but one set of interventions into a complex system of market forces and policies from the national, municipal, and district levels that determine urban development outcomes.

For Shanghai the market forces and policies that define this system form constraints to what conventional approaches to land use and transport planning can achieve. On the other hand, planning and policymaking conducted on the basis of an adaptive understanding of the forces driving the urban development system can enhance the capabilities of planners, and this is one of the core principles of TOD. This section briefly outlines three of the forces shaping Shanghai's urban development that may both constrain and enable planning in pursuing low carbon development.

Real estate and land market

Perhaps the strongest expansionary force in Shanghai's urban development is the city's real estate and land market. Shanghai's core contains some of the most expensive real estate in China, and prices have risen dramatically in recent years. The effect of high prices in the city core is primarily two-fold: first, heavy industry has moved out of the city center to make way for higher value-added tertiary industry and housing; second, rising housing prices have caused some residents to resettle outside the core and most new migrants to settle in outlying districts.

The gradual opening of the real estate market in Shanghai throughout the past three decades has contributed to a substantial restructuring in the city's industrial sector. Whereas prior to reforms heavy industry occupied large swaths of the city's most central districts, such as Yangpu, now these districts are occupied almost exclusively by tertiary industry and residences (Urban Development Sector Unit, East Asia and Pacific Region 2008; Yue et al. 2012)Between 1991 and 2004, land area used for industry in the city core fell by 42 percent (Urban Development Sector Unit, East Asia and Pacific Region 2008). In the 2000s, industry boomed in the outlying districts, and land use for industrial development increased by about 250 percent across Shanghai (Yue et al. 2012)

Between 2000 and 2009, inflation-adjusted land prices in Shanghai increased more than 4.5

fold, while housing prices increased by about 3.5 fold (Du, Ma, and An 2011). Due to higher prices, migrants to Shanghai are settling primarily in districts outside of the city core. Even as Shanghai's population increased by six million between 2000 and 2009, all but one of the districts of the city core lost population during this period (China Data Online 2014). In total core districts lost about 14 percent of their population during the 2000s. Meanwhile, population growth was most rapid in districts just outside the Outer Ring Road, namely Pudong New Area, Baoshan, Minhang, Jiading and Songjiang, which together added more than 3.5 million new residents during the 2000s (See Appendix for a map of Shanghai's districts).

National Policy Context

The confluence of three sets of national policies has generated powerful incentives for cities throughout China to pursue inefficient rural-urban land conversion:

- **Municipalities and districts are increasingly indebted.** During the mid-1990s national political decentralization policy left municipalities with greater financial obligations in providing infrastructure and services but substantially less tax revenue (Lichtenberg and Ding 2009).

- **Land use sales have emerged as a viable source of revenue for municipal governments.** Meanwhile, liberalization of urban land markets made land use sales a viable source of revenue for district and municipal governments (Ding 2003).

- **Focus on GDP growth has fueled competition for investment.** Intent focus by the central government on increasing annual economic output, furthermore, fueled competition among cities and among districts within cities to attract investment by providing cheap land (Yue, Liu, and Fan 2013; Wu 2008). GDP growth as the primary metric for evaluating the performance of municipal governments (Baeumler, Ijjaz-Vasquez, and Mehndiratta 2012).

Long recognizing problems of land use efficiency across Chinese cities, the central government has pursued successive reforms to prevent excessive rural-urban land construction (Ding 2003). Reacting to the rapid growth in built up area in Shanghai, the central government is now implementing a strict urban growth boundary (Shi Song 2014).

2.1.2 Land Use and Transport Challenges for Low Carbon Development: The Risk of Lock-in

The expansionary pressures outlined above are generating substantial risks of locking in an inefficient urban development pattern in Shanghai. Addressing this risk is pressing not only because the rates of expansions are unprecedented, but more importantly because the long-lived and capital-intensive infrastructure guided by land use and transit decisions form effectively irreversible resource management pathways. This section outlines the risks posed to Shanghai's resource stocks by current urban development trends.

Land. Rapid expansion of built-up area has made land a scarce resource. Fifteen years ago the city was less than 50 percent urbanized,[6] and land scarcity was almost unimaginable. Today Shanghai is more than 85 percent urbanized (Yin et al. 2011). China, during the transitional economy period (1979–2009. Facing increasingly strict urban development containment directives from the central government, failure to manage land use effectively will be increasingly costly.

Infrastructure. Current urban development patterns outside the city core risk locking-in inefficient infrastructure investments. More dispersed development demands more infrastructure expenditure to serve the same population. This is illustrated in Figure 2, below, which shows the Shanghai Metro network, including planned lines to 2020, and population centers. For revenue-generating infrastructure like public transport and electricity distribution, reduced built-up area density means less revenue per unit of investment.

Health and human capital: The combination of inefficient urban expansion and increased private vehicle use are generating productivity loses from reduced job accessibility (Haixiao Pan, Qing Shen, and Ming Zhang 2009). Productivity is further threatened by the health damages associated with air pollution caused by motor vehicles (Zhao et al. 2006; Bloomberg News 2013).

Energy, environment, and climate: The contribution of private vehicle travel to Shanghai's greenhouse gas emissions is rapidly growing (Y. Li et al. 2010; Baeumler, Ijjaz-Vasquez, and Mehndiratta 2012; Urban Development Sector Unit, East Asia and Pacific Region 2008; Organisation for Economic Co-operation and Development 2010). The impacts of rising affluence in Shanghai are illustrated in increasing reliance on private vehicle transport. Between 2000 and 2012, private motor vehicle ownership in Shanghai increased from a little more than 1 million to nearly 5 million, in spite of strict licensing requirements (China Data Online 2014; Y. Li et al. 2010).

The OECD's 2010 report *Cities and Climate Change* documented the strong relationship between urban sprawl and per capita electricity consumption. For example, Japan's cities have population densities on average about five times greater than those of Canada, and its electricity consumption per capita is 60 percent less than that of Canada (Organisation for Economic Co-operation and Development 2010).

2.2 Investigation and Policy Evaluation

2.2.1 Shanghai's Land Use and Transit Policy Framework

This section briefly reviews (a) the institutional framework for land use and transit planning and (b) the land use and transport planning process in Shanghai.

The Shanghai Municipal Planning, Land, and Resources Administration (MPLRA) is the main urban planning agency of the city government. MPLRA has broad authority not only over

[6] "Urbanized" refers to the built-up land area as a percentage of the city's total land area.

land use and transport planning, but also on issues of land rights and land use sales; land conservation and farmland protection; and administrative enforcement. MPLRA conducts the 20-year masterplanning process, which requires approval from the National Development and Reform Commission. Once approved, the plan has the force of law. The MPLRA enforces the masterplan, generates interim plans, and approves detailed land use plans.

As the main implementer of infrastructure projects, the **Shanghai Municipal Urban and Rural Construction and Transportation Commission** (MURCTC) plays a complementary role to MPLRA in land use and transport planning. The **Shanghai Urban Transport Bureau** coordinates with MPLRA in developing a transport plan as part of the masterplan, develops interim plans, and regulates transport markets.

In facilitating coordination and alignment between Shanghai's policies and national priorities, the **Shanghai Municipal Development and Reform Commission** (MDRC) shapes the development goals that the city's land use and transportation plans seek to realize. The DRC also plays a central role in planning for infrastructure investments (Baeumler, Ijjaz-Vasquez, and Mehndiratta 2012).

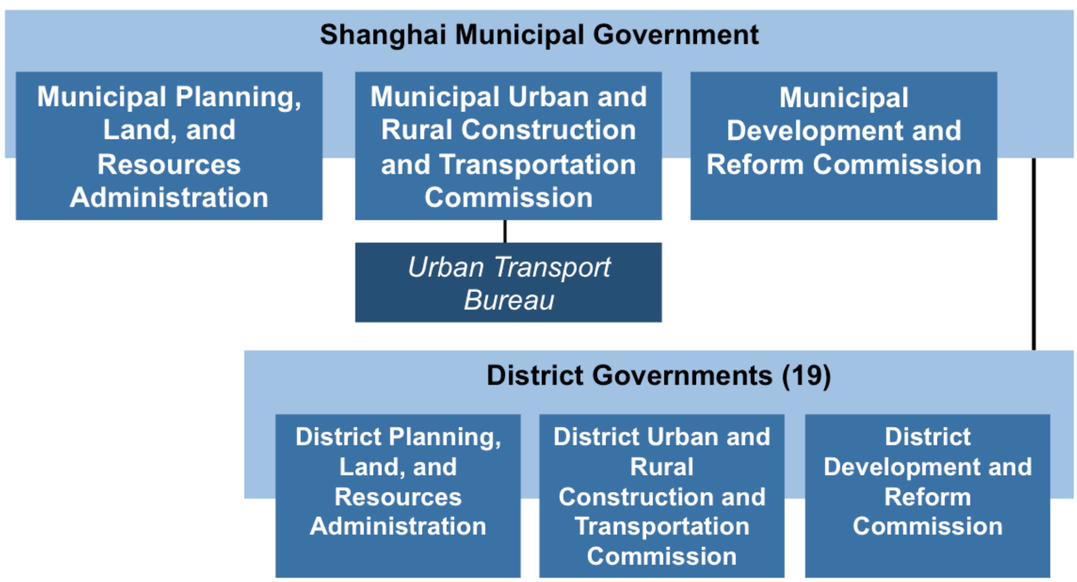

Figure 2–3 Organization of Shanghai's Land Use and Transport Planning Agencies; Sources: He 2012; Pan 2011

The 20-year masterplan guides the land use planning process, which plays out on three levels: district plans; detailed development control plans (DDCP); and detailed construction plans (DCP). DDCPs, like the masterplan, acquire the force of law once approved by MPLRA (He 2012).

Each of Shanghai's 19 district governments (including Chongming County) has a set of analogous agencies, mapped above in Figure 2–3. Whereas MPLRA and DRC conduct city-wide planning, the districts are responsible for DDCPs and hence for planning land use intensity at the street level (Urban Development Sector Unit, East Asia and Pacific Region 2008).

2.2.2 Evaluation of Current Policy in Shanghai

Shanghai has made TOD the motivating vision for its land use and transportation policy.

Since construction began on the Metro in 1990, Shanghai has built one of the world's most extensive urban rail networks. As of early 2014, the network consists of 14 lines, nearly 550 km of track, and more than 300 stations. Having developed a dense network in the city core, construction now focuses primarily on line extension through the city's outer districts.

Shanghai's bus network is even more extensive, serving about one third more passengers per day, nearly 8 million, as of 2011 (Choi and Loh 2013). Together Metro and bus make up about one third of all passenger trips (Singapore Land Transport Authority 2011).

Furthermore, the city has made a concerted effort to coordinate transit and new town development. The 2001-2020 Masterplan sought to relieve population pressure in the central city by developing transit-served new towns outside of the Outer Ring Road (He 2012). The 2006 revision to the Masterplan identified nine new towns where suburban development would be clustered, all of which are to be served by Metro stations by the 2020.

While private vehicle use continues to rise, Shanghai's vehicle registration regime has managed to check worsening congestion. In the mid-1990s, Shanghai began limiting purchases of new passenger vehicles through a license plate auctioning system. Between 2000 and 2007 the city limited license sales to about 400,000 (Hao, Wang, and Ouyang 2011). The policy has contributed substantially to Shanghai's success in mitigating congestion compared to other. By the end of 2009, the vehicle population of Beijing—whose population is smaller and less wealthy on average than Shanghai's—was more than 2.5 times larger than that of Shanghai (Hao, Wang, and Ouyang 2011).

Although shaped by a vision of Transit-Oriented Development (TOD), Shanghai's 2001-2020 Masterplan and subsequent directives have not been sufficiently adaptive to powerful market forces in urban development.

During the first ten years of Shanghai's current Masterplan, realizing the plan's vision of dense, transit-served new towns proved challenging. Figure 2–4, below, overlays the Masterplan's planned new town developments with actual development through 2010. The disparities illustrate the city's struggle to reconcile the market with its Masterplan. Planned developments both drastically underestimated population growth and, perhaps more importantly for TOD, value created by investments in transit infrastructure.

Underestimates of population growth in the Masterplan severely limited MPLRA's ability to channel new development into dense, transit-served corridors. Unanticipated population growth resulted in off-plan development sprawling out in concentric circles around the city core and, in some cases, the new towns themselves (Yaping and Min 2009). The population growth estimates that anchored Shanghai's 2001-2020 Master Plan predicted that the city's size would be 15 million in 2010 and 16 million in 2020. In reality the city surpassed 16 million in 2000 and reached 23 million by 2010 (He 2012). As a result, planned developments just outside the Outer Ring Road, such as Hongqiao (1 in the figure) and Minang (2) in the west and southwest, respectively, have been enveloped by the expansion of the city core. Meanwhile planned new towns farther afield, like Songjiang (3) in the southwest, expanded far beyond their planned extent.

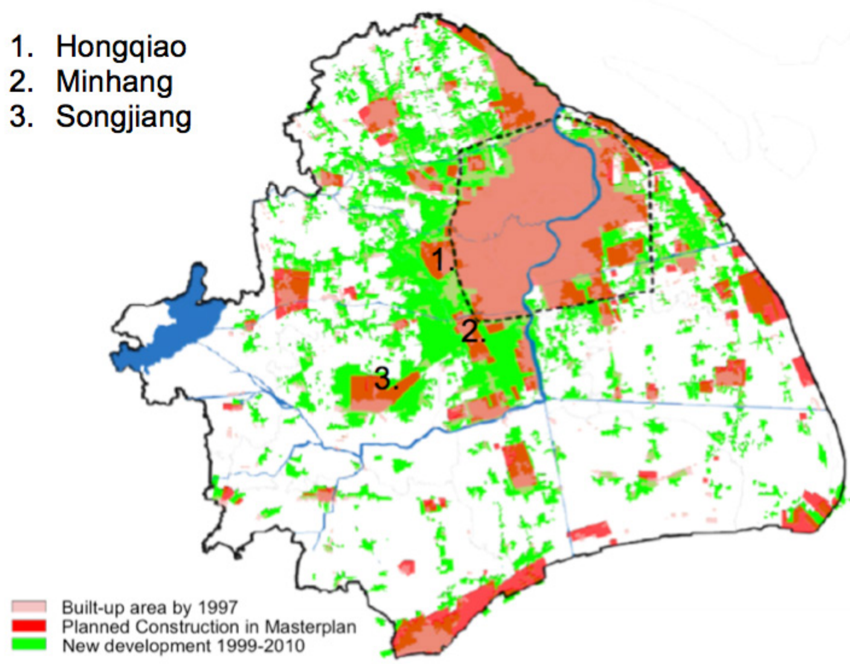

Figure 2–4 Planned vs. Actual Construction Under Shanghai's 2001-2020 Masterplan through 2010; Source: Adapted from He 2012

On the other hand, unanticipated population growth did not affect all new towns equally. Whereas Songjiang grew far beyond its plan, other new towns were built but lay largely unoccupied. These "ghost towns," which have gained international attention, are mostly located in outlying areas of the city that are not served by public transit (Shi Song 2014). The difference is explained in large part by accessibility: whereas Songjiang has been connected to the city center via Metro since 2007, the ghost towns are isolated from most public transit.

Yet district governments have underestimated the value created by transit investment in developing detailed development control plans (DDCP). Even though juxtaposition of over-developed new towns and ghost towns suggests that developers and residents value the transit accessibility of the Metro, floor area ratios (FARs) are almost the same across Shanghai's core, inner suburban districts, and outer suburban districts, irrespective of transit access (Urban Development Sector Unit, East Asia and Pacific Region 2008). In other words, DDCPs have not planned for more dense development around station stops where land is more valuable.

As a result, the off-plan clustering around transit nodes ends up causing extensification, i.e. sprawling expansion, of urban development—the opposite of the intensification effect sought via TOD—which reduces transit access but increases required trip lengths. By limiting development intensities, district governments leave on the table a great deal of potential revenue from higher priced land sales that could have been made with weaker restrictions on the amount of developable floor space on a given lot.

Distortions in land and transport markets skew transit and development alternatives.

Negative externalities from private vehicle travel—namely lost productivity from traffic congestion and health damages from air pollution—distort the relative prices of travel modes. In Shanghai, simultaneous development of the city's highway system with the Metro network has meant that the percentage of passenger trips in private vehicles grew from about five percent in 1995 to more than 20 percent in 2011 (Zhou and Sperling 2011). In spite of successful efforts to control private vehicle growth in Shanghai, increased traffic congestion and persistent air quality concerns are evidence that the private cost borne by drivers remains well below the social cost (interview with SUPDRI).

Although Shanghai has been cited for more effective management of land resources compared to other cities in China, both the central and municipal government have acknowledged the need for more efficient management of land resources in Shanghai (Zhi Liu 2014; Shi Song 2014). In spite of promoting its service sector, Shanghai's current land use patterns are suggestive of over-provisioning of land, particularly for industry: nearly 30 percent of the city's built-up was zoned for industrial use as of 2004, one of the highest proportions of any Chinese city and five to eight times greater than that of cities like Seoul, New York, London, and Hong Kong (Urban Development Sector Unit, East Asia and Pacific Region 2008b).

Misaligned incentives have hindered coordination between the municipal and district governments.

Operationalizing TOD requires institutional mechanisms for ensuring that transit and development projects reap the mutual benefits of coordination. For TOD to succeed in Shanghai, municipal government plans for transit expansion must be coordinated with district governments' DDCPs. The division of authority between the municipal and district governments in new town development, however, has posed a substantial obstacle to realizing integrated TOD projects.

National policy generates incentives for the municipal government and district governments that are frequently difficult to reconcile in coordinating development. Whereas the municipal government is primarily rewarded for meeting transit system expansion goals, district governments in recent years have faced a strong push to pursue foreign direct investment in industry (He 2012; Ding 2003).

Coordination has faced a sequencing problem as well. Current Metro expansion plans promise to serve all major new town developments. Yet for many of these new towns in outlying districts, such as Fengxian to the south of the city center, residential and commercial development must proceed for years before the Metro arrives. Although the city has sought to coordinate new town development with the Metro expansion, Metro construction delays and changes have at times scuttled the effective coordination ("Research Interview for Policy Analysis Exercise with Chinese Academy of Urban Planning and Design" 2014).

2.2.3 Governance Frameworks for Transit Oriented Development: Review of International Experiences

With a world class urban rail infrastructure now in place, Shanghai's next phase of urban development will focus on ensuring that these and future transit investments return dividends in the form of a more productive and mobile labor force, declining land, energy, and carbon intensity of economic output, and improved quality of life and environmental health. Doing so requires building a comprehensive governance framework for TOD that more effectively harnesses the powerful market forces driving Shanghai's urban development. The evaluation of current policy in the previous section identifies three priority areas in which Shanghai can improve its approach to coordinated transit and urban development:

- **Adaptive, long-range planning and strategy**: As the focus of Shanghai's Metro and bus network expansion moves outside the city core, new transit investments cannot count on the natural ridership market provided by the densely populated city center. The role for land use and transport planning in TOD is to catalyze these natural ridership markets. Shanghai's policy framework can better enable MPLRA and associated agencies to anticipate opportunities for and then spur these ridership markets to ensure that transit infrastructure resources are mobilized where they are valued most.

- **Supporting policies**: Shanghai's experience with rapid development outside the city core in the past decade demonstrates that providing access to high quality transit services is not enough to ensure efficient urban expansion outcomes. A governance framework for TOD must also address the policies that affect alternative transportation options for individuals to allow market forces to work in favor of TOD outcomes.

- **Value capture and distribution**: Facing a pressing need to increase the efficiency of land use outside the city core, MPLRA can better align the incentives of both government and private sector players in the development process through the way the costs and benefits of transit and new town infrastructure investments are distributed.

Three models of governance for TOD: Tokyo, Singapore, and Hong Kong

Policy experiences with TOD around the world offer lessons for Shanghai in developing its governance framework for integrated land use and transit planning. The diversity of institutional models, transit modes, and city scales for which TOD has succeeded suggests that TOD characterizes a broad approach to optimizing urban land and mobility policies rather than single set of policy measures (Curtis, Renne, and Bertolini 2009). The TOD governance models adopted by Tokyo, Singapore, and Hong Kong—cities for which TOD has become the planning paradigm—illustrate three alternative approaches to addressing the issues of adaptive, long-range planning, supporting policy, and value capture and distribution mentioned above. This section briefly describes each city's TOD governance model.

Tokyo offers a model of *private-led* TOD: although government policy played a central role in promoting rail development, clustering residential and commercial development around transit nodes began largely as a business strategy by private rail companies (Calimente 2012)the term rail integrated community (RIC. Tokyo has strong supporting policies, particularly on controlling private automobile use, that help tilt the transport market toward mass transit.

Although Tokyo's urban development governance contrasts sharply with that of Shanghai, this case is worth considering because Tokyo is the only city in the world at comparable scale to Shanghai that has made TOD a strong priority. On the other hand, several factors limit the applicability of Tokyo's model to Shanghai: the approach to and institutional structure of urban planning in Japan differs deeply from that of China; in Japan the private sector has played a much stronger role in guiding urban development than it does in China; and Tokyo's railway network developed in large part before automobiles were widely available to consumers.

Singapore, by contrast, offers a model of *public-led* TOD. Singapore's strong master planning guided integrated development of its rail and bus network with public housing—in which more than 80 percent of the country's population lives—and associated commercial services (Curtis, Renne, and Bertolini 2009).

The Singapore government's more proactive role in urban development planning more closely approximates that of the Shanghai municipal government than does Tokyo's system. Yet Singapore's population is only about one fifth of Shanghai's, and this difference in scale may limit the applicability of Singapore's strategies to Shanghai.

Finally, **Hong Kong** offers a *mixed public-private* model of TOD, in which both the public and private sectors played strong roles. In Hong Kong, MTR Corporation, a publicly-traded, majority government-owned company, plans, finances, builds, and operates urban rail across the city. Perhaps the most profitable urban transport firm in the world, MTRC's business model relies on a close partnership with the government. MTRC works with Hong Kong's urban planning and transport agencies to identify projects and develop projects. It benefits from receiving land at a "before rail" cost and then selling it to residential and commercial developers at the "after rail" cost. Although the urban transport sector is a monopoly, MTRC is entrepreneurial and highly sophisticated in responding to market demand.

With 7 million people, Hong Kong, like Singapore, is a city on a different scale than Shanghai. Likewise, as with Singapore, Hong Kong has geographic constraints on developable land, which generates strong incentives for highly efficient land use.

Alternative Frameworks for TOD Governance: Lessons from Tokyo, Singapore, and Hong Kong

Although their institutional frameworks differ, these cities have all succeeded in harnessing land market forces in favor of TOD outcomes. The contrasting ways in which Tokyo, Singapore, and

Hong Kong have defined the respective roles of planning and the market in resource allocation for transport investments illustrate a range of alternative approaches to addressing the three priority areas for improved TOD governance in Shanghai.

Adaptive, long-range planning and strategy

Shanghai's ongoing Metro extension campaign offers a tremendous opportunity to ensure efficient urbanization of the developing outer districts of Shanghai. During the initial build out of the Metro, lines were constructed primarily through the city center. Although the city center's redevelopment in recent years has been shaped by new metrorail construction, in large part the dense, mixed-use character of development in the city center was determined long ago. As the focus of Metro investments turns to line extensions through the rapidly developing outer districts, new lines have the potential to dramatically affect the character of simultaneous new town development. Already in areas like Songjiang, Shanghai has witnessed the strong gravitational pull that transit nodes can exert on development.

On the other hand, building rail outside the city center poses greater financial risks to transport infrastructure investments. Dense residential and commercial areas provide transit investments in the city center with a natural ridership market and generally ensure the viability (if not the profitability) of transit investments (Curtis, Renne, and Bertolini 2009). In much of Shanghai's burgeoning outer districts, however, these markets do not exist yet. The viability of investments in new line extensions, therefore, depends to a large degree on the prospect that dense development around the stations will generate a ridership market.

Having completed much of the core rail infrastructure in the city center, each of the case study cities transformed its approach to transit planning to optimize investments. Governments in Tokyo, Singapore, and Hong Kong bore most if not all the costs of building the core infrastructure. However, as each city underwent a period of decentralization much like that which is ongoing in Shanghai now, they followed divergent paths in terms of respect roles played by planners and the market in transport development. Nonetheless all three of the systems have developed a successful approach to both leading and following the land and transport markets.

Tokyo largely relied on the market to match market demand with new suburban rail development. Aside from designating development promotion and development control zones, the Tokyo Metropolitan government and Japan's central government in large part allowed development to proceed unfettered (Calimente 2012)the term rail integrated community (RIC.

Both Singapore and Hong Kong, in contrast, relied on masterplanning to direct investments both in transport and development (Curtis, Renne, and Bertolini 2009; Cervero and Murakami 2008). Large populations living in public housing provided a strong lever from shaping coordinated development in both cities.

Yet as an increasingly dynamic and liberalized property market has emerged, planning agencies in Singapore and Hong Kong recognized the importance of becoming more responsive to the market forces driving development. Singapore has accomplished this primarily through building remarkably entrepreneurial government agencies in the Land Transport Authority (LTA), the Urban Redevelopment Authority (URA), and the Housing and Development Board (HDB).

Whereas LTA has developed the capability to conduct highly sophisticated transport demand forecast modeling to inform investment decisions, URA and HDB have created large and steady revenue generation streams through property sales around transport nodes (Cervero and Murakami 2008; Barter 2008). Hong Kong has taken this approach a step further, partially privatizing its transport investments through MTRC.

The lesson from these cases for MPLRA is that capitalizing on the opportunity and mitigating the risk associated with the Metro extension into Shanghai's suburbs requires a framework for optimizing resource allocation that is responsive to the land market system. The task is twofold: (1) to be responsive to land market and demographic dynamics in siting transport in order to anticipate potential ridership markets; and (2) to use transit investments to attract clusters of dense, mixed use development that in turn catalyze these ridership markets. In short the need is to develop a policy framework for optimal resource allocation in transit infrastructure planning.

China's urban planning system has a strong focus on long-range master planning, but recent experiences has demonstrated the limits of this system's capacity to realize intended outcomes in the context of an increasingly dynamic land market. The experiences of Singapore and Hong Kong are particularly instructive here, as both cities have staked out strong, constructive roles for planning in the context of liberalized land markets.

Shanghai's investments in transit, particularly the Metro network, have generated immense social benefits, primarily by expanding mobility and mitigating growing traffic congestion and air pollution. Current land use restrictions in Shanghai, however, have prevented these investments from realizing their full potential. Shanghai may both improve transit access and the financial sustainability of the transit systems by pushing for greater flexibility in the land use planning regime to allow for intensification of development around transit nodes.

Supporting Policies

Once mass transit infrastructure investments have generated micro property markets around transit nodes, market incentives can be relied on to generate dense, transit-served development provided that supporting policies are in place to ensure that relative prices of transportation and living alternatives reflect their social cost. Supporting policies address the negative externalities associated with private vehicle travel as well as the non-transport infrastructure that affects the accessibility and convenience of using transit.

Today Shanghai is keenly aware of the negative externalities primarily from pollution and congestion associated with private vehicle growth. Currently it is considering congestion pricing policies (Government of Shanghai 2014). Singapore's system of linked road pricing and vehicle quotas may provide a replicable model for Shanghai. Singapore began its system of road pricing as early as the 1970s and today has one of the world's most sophisticated systems of congestion pricing, called Electronic Road Pricing (Suzuki et al. 2010). This policy is coupled with a vehicle registration quota system, and together these policies generate a substantial base of revenue for LTA (Cervero and Murakami 2008).

Tokyo has taken an alternative approach that may be instructive for Shanghai. Tokyo has not moved to price congestion directly, although it has a series of auto taxes and parking regulations that effectively discourage private vehicles. Yet Tokyo residents are required to prove that they have access to a parking space before they are permitted to purchase a car. On the other hand, unlike in many other cities, most new buildings in Tokyo are not required to provide any parking (Choi and Loh 2013). The result is that drivers bear a substantial cost in securing parking spaces, often forced to rent a space that can cost as much as an apartment.

Value Capture and Distribution

Successful TOD is not just an approach to transport planning, but rather an entire model for sustainable municipal public finance (Cervero and Murakami 2008). In each of the case study cities, the entities that finance transit infrastructure investment are able to recapture most or all of these costs—at times, even with a healthy return—by capitalizing these expenses into the value of the land surrounding stations.

The primary cooperation strategy in TOD value capture is cross-subsidization: most transit systems cannot cover capital investments with farebox revenues alone, and so revenue from property sales or development are used to cover the remaining costs. This cross-subsidization is clearest in Hong Kong and Tokyo, where rail companies purchase land at "before rail" prices and sell at much higher "after rail" prices that reflect the value added by transit investments (Murakami 2012). One of Tokyo's largest integrated rail companies, Tokyu Corporation, makes more than half of its profits in real estate and retail, while about one third comes from farebox revenues (Calimente 2012).

Singapore's model operates on a similar principle, although the cross-subsidization is less direct. There the Land Transport Authority, the central government agency that plans and finances rail investments, operates at a substantial loss, whereas the Housing Development Board and Urban Redevelopment Authority engage in highly profitable property sales around new stations and return those profits to the general treasury (Cervero and Murakami 2008).

2.3 Recommendations

On the basis of the analysis of these alternative government frameworks, the recommendations presented are intended to inform the evolution of a governance framework that best positions Shanghai to harness land market forces in favor of TOD outcomes.

Recommendation 1: Develop greater capability within MPLRA to weigh the social costs and benefits of alternative projects.

In concert with broad trends in national policy, MPLRA and associated agencies are shifting the way they frame urban development goals for the city. Increasingly these goals are aimed to maximize the quality of economic development rather than the quantity of economic development. Shanghai has already made strides toward setting goals on the basis of sustainable development outcomes, designating its intention to ensure that commute times are not more than 45 minutes within the city center, 60 minutes from new towns to the city center, and 90 minutes from other cities in the Yangtze River Delta to Shanghai (Government of Shanghai 2014).

Following through on these outcome-based goals demands a rigorous policy analysis framework to conduct planning in a way that is more adaptive to the changing land and property markets. Following the lead of Singapore's LTA and Hong Kong's MTRC, use ridership data, survey evidence, and demand forecast modeling in decision-making will better enable Shanghai site transport investments in order to ensure transit accessibility and the financial sustainability of the system.

Recommendation 2: Push modest reforms to the Detailed Development Control Planning (DDCP) process so that residential and commercial development around transit nodes can capture more of the accessibility benefits of transit investments.

Although Shanghai does not have direct authority to reform the land use planning process, the city has successfully piloted major national reforms, for example in land finance, in this sector in the past. A strategic push for reforms to allow greater flexibility in DDCPs could catalyze micro land markets around transit stations through dense development.

Short of national reforms, MPLRA could set city-wide standards for building heights around transit stations. They might include in these plans guidelines for making street-level development around stations accessible by bicycle and walking as well.

Recommendation 3: Implement congestion pricing to relieve congestion and pollution associated with increasing private vehicle use.

As of February 2014, Shanghai has signaled that it is considering a congestion pricing policy. Along with the vehicle registration system, congestion pricing can more effectively target the negative externalities associated with private vehicle use and correct the distortion in the price of driving relative to that of public transport.

Recommendation 4: Provide district governments with a greater stake in operationalizing TOD by pushing for property tax reallocation.

Having recognized distortions in land sale prices from governments, the central government has instituted reforms intended to ensure that land sale prices better reflect the market value of land. These reforms should allow district governments to capture more of the value of transport investments by selling land to residential and commercial developers at the "after transport" price. However, the central government could create further incentives for districts to pursue TOD by providing a modest source of revenue through property tax allocation. Once again, given its history, Shanghai could make a persuasive case to the central government in favor of such a reform.

TOD is an area in which experimentation through pilot projects or designated TOD zones, applying different combinations or variations on the following recommendations to evaluate their potential effectiveness at city scale.

Chapter 2 Reference List

Baeumler, Axel, Ede Ijjaz-Vasquez, and Shomik Mehndiratta, ed. 2012. *Sustainable Low-Carbon City Development in China*. Directions in Development: Countries and Regions. Washington, DC: The World Bank.

Bahl, Roy W, Johannes F Linn, and Deborah L Wetzel. 2013. *Financing Metropolitan Governments in Developing Countries*. Cambridge, Massachusetts: Lincoln Institute of Land Policy. http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=578698.

Bloomberg News. 2013. "Shanghai Orders Cars Off Roads as Pollution Exceeds Scale." *Bloomberg*, December 6. http://www.bloomberg.com/news/2013-12-06/shanghai-haze-forces-plane-cancellations-pollution-warnings.html.

Calimente, John. 2012. "Rail Integrated Communities in Tokyo." *Journal of Transport and Land Use* 5 (1): 19–32. TOD Indicators. doi:10.5198/jtlu.v5i1.280.

Cervero, Robert, and Jennifer Day. 2008. "Residential Relocation and Commuting Behavior in Shanghai, China: The Case for Transit Oriented Development". Berkeley, California: UC Berkeley Center for Future Urban Transport: A Volvo Center of Excellence, Institute of Transportation Studies. http://escholarship.org/uc/item/0dk1s0q5.

Cervero, Robert, and Jin Murakami. 2008. "Rail + Property Development: A Model of Sustainable Transit Finance and Urbanism." *UC Berkeley Center for Future Urban Transport: A Volvo Center of Excellence*, May. http://escholarship.org/uc/item/6jx3k35x.

Choi, Chik Cheong, and Nadiah Loh. 2013. "Transport Policies and Patterns: A Comparison of Five Asian Cities." *Journeys*, September.

China Data Online. 2014. "China Yearly Macro-Economic Statistics (Provincial)." Accessed February 1. http://chinadataonline.org.ezp-prod1.hul.harvard.edu/member/macroyr/.

Curtis, Carey, John L. Renne, and Luca Bertolini, ed. 2009. *Transit Oriented Development: Making It Happen*. Transport and Mobility. Farnham, Surrey, England ; Burlington, VT, USA: Ashgate.

Ding, Chengri. 2003. "Land Policy Reform in China: Assessment and Prospects." *Land Use Policy* 20 (2): 109–20. doi:10.1016/S0264-8377(02)00073-X.

Government of Shanghai. 2014. "Shanghai Transportation Development White Paper (上海市交通发展白皮书)." http://www.shanghai.gov.cn/shanghai/node2314/node2315/node5827/u21ai848957.html.

Haixiao Pan, Qing Shen, and Ming Zhang. 2009. "Influence of Urban Form on Travel Behaviour in Four Neighbourhoods of Shanghai." *Urban Studies* 46 (2): 275–94. doi:10.1177/0042098008099355.

Hao, Han, Hewu Wang, and Minggao Ouyang. 2011. "Comparison of Policies on Vehicle Ownership and Use between Beijing and Shanghai and Their Impacts on Fuel Consumption by Passenger Vehicles." *Energy Policy* 39 (2): 1016–21. doi:10.1016/j.enpol.2010.11.039.

He, Jinghuan. 2012. “Implementation of the Shanghai Master Plan (2001-2020).” In Ankara, Turkey.

Li, Guicai, Xiaofan Luan, Jiawen Yang, and Xiongbin Lin. 2013. “Value Capture beyond Municipalities: Transit-Oriented Development and Inter-City Passenger Rail Investment in China’s Pearl River Delta.” *Journal of Transport Geography* 33 (December): 268–77. doi:10.1016/j.jtrangeo.2013.08.015.

Li, Ye, Jianhong Ye, Xiaohong Chen, Mohamed A Abdel-Aty P E, and Min Cen. 2010. “Transportation Characteristics Change under Rapid Urban Expansion: A Case Study of Shanghai.” *Chinese Geographical Science* 20 (6): 554–61. doi:10.1007/s11769-010-0431-3.

Lichtenberg, Erik, and Chengri Ding. 2009. “Local Officials as Land Developers: Urban Spatial Expansion in China.” *Journal of Urban Economics* 66 (1): 57–64. doi:10.1016/j.jue.2009.03.002.

Murakami, Jin. 2012. “Transit Value Capture: New Town Co-Development Models and Land Market Updates in Tokyo and Hong Kong.” In *Value Capture and Land Policies*, edited by Gregory Ingram and Yu-Hung Hong. Cambridge, MA: Lincoln Institute of Land Policy.

Organisation for Economic Co-operation and Development. 2010. *Cities and Climate Change.* Paris: OECD Publishing.

Peterson, George E., and Patricia Clarke Annez, ed. 2007. *Financing Cities: Fiscal Responsibility and Urban Infrastructure in Brazil, China, India, Poland and South Africa*. Washington, DC: The World Bank. https://openknowledge.worldbank.org/bitstream/handle/10986/6735/404800Financin101OFFICIAL0USE0ONLY1.pdf?sequence=1.

“Research Interview for Policy Analysis Exercise with Chinese Academy of Urban Planning and Design.” 2014.

Shi Song. 2014. “Research Interview for Policy Analysis Exercise with Shanghai Urban Planning and Development Research Institute.”

Singapore Land Transport Authority. 2011. “Passenger Transport Mode Shares in World Cities.” *Journeys*, September.

Smith, Jeffery J., and Thomas A. Gihring. 2006. “Financing Transit Systems Through Value Capture.” *American Journal of Economics and Sociology* 65 (3): 751–86. doi:10.1111/j.1536-7150.2006.00474.x.

Suzuki, Hiroaki, Arish Dastur, Sebastian Moffatt, Nanae Yabuki, and Hinako Maruyama, ed. 2010. *Eco2 Cities: Ecological Cities as Economic Cities*. Washington, D.C: World Bank.

Urban Development Sector Unit, East Asia and Pacific Region. 2008. “The Spatial Growth of Metropolitan Cities in China: Issues and Options in Urban Land Use”. Washington, DC: The World Bank.

Wang, Lan, and Charles Hoch. 2013. “Pragmatic Rational Planning: Comparing Shanghai and Chicago.” *Planning Theory* 12 (4): 369–90. doi:10.1177/1473095213490553.

Wu, Jiaping. 2008. “The Peri-Urbanisation of Shanghai: Planning, Growth

Pattern and Sustainable Development." *Asia Pacific Viewpoint* 49 (2): 244–53. doi:10.1111/j.1467-8373.2008.00373.x.

Xin Dingding, Wang Xiaodong, and Shi Yingying. 2012. "Experts Fear Subway Costs Could Go off the Rails." *China Daily*, July 31. http://www.chinadaily.com.cn/cndy/2012-07/31/content_15633269.htm.

Yin, Jie, Zhane Yin, Haidong Zhong, Shiyuan Xu, Xiaomeng Hu, Jun Wang, and Jianping Wu. 2011. "Monitoring Urban Expansion and Land Use/land Cover Changes of Shanghai Metropolitan Area during the Transitional Economy (1979–2009) in China." *Environmental Monitoring and Assessment* 177 (1-4): 609–21. doi:10.1007/s10661-010-1660-8.

Yue, Wenze, Peilei Fan, Yehua Dennis Wei, and Jiaguo Qi. 2012. "Economic Development, Urban Expansion, and Sustainable Development in Shanghai." *Stochastic Environmental Research and Risk Assessment*, August, 1–17. doi:10.1007/s00477-012-0623-8.

Yue, Wenze, Yong Liu, and Peilei Fan. 2013. "Measuring Urban Sprawl and Its Drivers in Large Chinese Cities: The Case of Hangzhou." *Land Use Policy* 31 (March): 358–70. doi:10.1016/j.landusepol.2012.07.018.

Zhao, Shuqing, Liangjun Da, Zhiyao Tang, Hejun Fang, Kun Song, and Jingyun Fang. 2006. "Ecological Consequences of Rapid Urban Expansion: Shanghai, China." *Frontiers in Ecology and the Environment* 4 (7): 341–46. doi:10.1890/1540-9295(2006)004[0341:ECORUE]2.0.CO;2.

Zhi Liu. 2014. "Research Interview for Policy Analysis Exercise Lincoln Institute of Land Policy at Peking University."

Zhou, Hongchang, and Daniel Sperling. 2001. "Transportation in Developing Countries: Greenhouse Gas Scenarios for Shanghai, China." *Institute of Transportation Studies*, July. http://escholarship.org/uc/item/6g7500dg.

Chapter 3: **Building Energy Efficiency**

Summary

Over the coming decades Shanghai's building stock will continue to expand rapidly, accounting for an increasing share of the city's energy demand and carbon footprint. Without effective policies to encourage investment in building energy efficiency (BEE), Shanghai will lock in high levels of energy use by these new buildings, over their long lifetimes.

This Chapter focuses on Shanghai's most significant BEE policy, the energy standards for residential and public buildings. The standards were assessed in terms of their ability to drive economically optimal BEE investment in new buildings.

The assessment found that the current codes require inefficiently low levels of BEE. In particular, their stringency does not reflect the long lifetimes of buildings, or the expected increases in energy consumption and energy prices, both of which enhance the economic viability of BEE investments. The code focuses on short-term considerations as policy drivers as opposed to long-term.

An alternative approach to policy design is proposed, based on the concept of cost optimality, which requires the following changes:

- Anticipating future changes in behavior, climate costs and prices related to energy so that buildings constructed today are optimized for the energy system of the coming decades.
- Investing in increased data collection and broadening the scope of economic modeling for BEE to optimize the code to the economically efficient level over a building's expected lifetime.
- Incorporating estimates of the external costs and benefits of energy efficiency, such as reductions in the health impacts of air pollution, into the calculation of economic benefits. Explicit consideration of externalities would incorporate BEE into the city's broader low-carbon plans.

With these changes Shanghai's BEE codes become a powerful tool for pursuing Shanghai's low carbon goals.

There are significant challenges associated with these changes, such as the increased construction costs of new buildings. Successful implementation will require extensive engagement with stakeholders in the construction and developer industries. Despite these challenges, Shanghai possesses several distinct advantages. These advantages include a strong governance structure for code monitoring and enforcement, a culture of policy leadership and innovation within the Municipal Government and the potential to attract investment to grow the nascent energy efficient building materials industry.

3.1 Problem Diagnosis

This section provides the relevant background for an assessment of BEE[7] policy in Shanghai. The first section is an introduction to the technical aspects of BEE, the drivers of government policy in this area and the policy options available to city governments. The second section describes the current policy context for BEE in Shanghai. The major Municipal and Central Government policies are described, along with the government agencies involved in policy development and implementation.

3.1.1 Overview of building energy efficiency policy

Categories of BEE investments

A comprehensive policy framework for encouraging construction of low-carbon buildings must take into consideration the determinants of a building's carbon footprint, which include various elements of its design and construction.

According to the International Energy Agency (IEA) (2013a) the major opportunities to reduce building energy consumption can be captured through the following categories[8]:

1. **The building envelope**, comprising the roof, walls, windows, foundations and air leakage. Together these are the major determinant of the heating, cooling and ventilation energy load of the building.

2. **Heating, ventilation and air conditioning (HVAC) systems** including water and space heating and space cooling. The design characteristics of these systems, especially their source fuels and fuel efficiency determine the carbon footprint of the heating, cooling and ventilation energy loads of the building.

3. **Lighting, cooking and appliances,** which encapsulates the remaining energy load of the building. The carbon footprint of these elements is determined partly in the design and construction of the building, and partly by the decisions of occupants during the operating life of the building. This category is not a focus for this chapter. Opportunities to reduce carbon emissions by targeting operational decisions are highlighted in Chapter 4. Appliance standards, which play a large role in this category, are determined by the Central Government so will not be discussed in detail.

Appendix D contains a list of the major BEE opportunities in each of these categories.

Economics of BEE investments

For any investment in a BEE improvement, the net benefit of the investment is its lifetime benefits, minus its lifetime costs.

7 As discussed in Chapter 1, BEE in the context of this report refers to new buildings only.
8 In this chapter a 'BEE opportunity' refers to a potential technology, design technique or use of materials that improves BEE when implemented.

The costs of the BEE investment are usually borne at the time of construction and include:

- Increased costs for building materials such as insulation and more efficient glass.
- Increased costs for equipment such as more efficient heating ventilation and cooling systems.

The benefits of the BEE investment result from the reduction in energy use over the lifetime of the building. Apart from the reduction in direct energy costs, which usually accrue to the building occupant[9], there are also significant benefits from the reduction in the external costs which include:

- **Health:** The urban air pollution associated with electricity generation in and around Shanghai is creating significant respiratory and cardiovascular health problems for residents (Draugelis and Li 2012). The Central and Municipal Governments have already invested heavily in reducing these impacts, by closing coal fired power stations and installing equipment to reduce pollution. Energy efficiency measures reduce the need for this investment by reducing the total amount of electricity that must be generated.
- **Environmental:** The emissions associated with electricity generation create additional environmental problems such as acid rain, which impacts fresh water sources, forests and agricultural land. Power generation from fossil fuels also contributes to climate change, which is projected to have significant costs for Shanghai this century (Draugelis and Li 2012).
- **Macroeconomic:** In addition to the direct costs of treating health problems and cleaning up environmental damage, there are indirect macroeconomic costs such as reduced worker productivity and damages associated with more extreme weather events, (Ingrid Holmes and Rohan Mohanty 2012).

The cost and benefit characteristics for any particular BEE investment will vary according to the specific amount of energy saved as a result of that investment. This depends on the building design, the expected behaviors of building occupants. These behaviors in turn are heavily influenced by the local climate, which determines the heating and cooling requirements to realize certain levels of indoor comfort and income levels, which underpin energy access and affordability (IEA 2010, Draugelis and Li 2012).

The cost of a BEE investment also depends on the characteristics of the local construction industry and the costs and availability of different building materials and equipment. Innovation over time and economies of scale in production mean that the cost of a particular BEE opportunity may reduce over time as it becomes more widely adopted (IEA 2013a).

9 This benefit accrues to either the building owner, tenant, or the energy supplier, depending on the metering and energy billing process. In Shanghai, the majority of residential apartments have individual meters (see Chapter 5) for more details on metering and tariff structures). In rented apartments, energy bills are usually paid by the tenant, not the owner.

Market barriers to BEE investment

A variety of market barriers prevent the development and uptake of economically viable BEE opportunities and create the need for government intervention in this market. The major barrier to BEE investment is that the party making the upfront investment (usually the property developer) does not receive the benefits, for the following reasons:

- Energy cost savings usually benefit the building occupants, if they pay the ongoing energy costs. This problem is called a 'split incentive', where the party who has a financial incentive to make an investment is not responsible for making that investment.
- Other benefits, including those listed above, are externalities. These externalities provide benefits for all of Shanghai, whilst the direct benefit to the original investor is minimal.[10]

Implications for policy design

For most major BEE opportunities, products exist at various stages of technological maturation. For example, there are widely available glass products for high efficiency windows at the diffusion stage, but there is also significant R&D investment in new, more efficient types of glass. This presents a challenge for government policies and programs, which must simultaneously overcome the barriers to uptake of the best available mature technology, and the barriers to research, development and dissemination (RD&D) of new alternatives with promising economic and efficiency characteristics.

Scope of city government policies: supporting mature technologies

For any particular local context, BEE investments can be divided between mature technologies and practices, whose costs and benefits can be estimated with relative certainty, and new innovations whose costs and benefits are uncertain.

The majority of support for RD&D activity in universities and other institutions comes from the central government (Zhi et al. 2013). As a result this report does not focus on policies for RD&D. For the Shanghai Municipal Government it is more useful to focus on policies to encourage the uptake of mature, widely available technologies. Appendix D contains a framework for the design of a comprehensive policy framework for BEE that includes objectives and policy options for RD&D.

The goal for the Municipal Government in this context is for 'cost optimal' investment in measures to improve the efficiency of new buildings. Cost optimal in this context means that over the lifetime of the building the net benefits of the BEE investments are maximized (IEA 2013b).[11]

As described above, there are several significant uncertainties regarding BEE economics that policy makers must take into account when designing policies to achieve this goal. In particular,

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[10] See Box 2 in Chapter 1 for more information about externalities.

[11] This goal is based on recommendations from the International Energy Agency (IEA) for the design of comprehensive BEE policy frameworks in a low-carbon context (IEA 2013a). The following sections will discuss the concept of cost optimality in more detail, including how it could be interpreted in the Shanghai context.

assumptions around building lifetimes, energy price trends and the appropriate discount rate[12] have a significant impact on the calculation of net economic benefits for a particular technology.

Policy options to support mature technologies: BEE codes and standards

BEE codes set mandatory specifications for the efficiency characteristics of new buildings. BEE standards are guidelines that provide guidance for energy efficiency improvement and a benchmark for comparing the energy efficiency of different buildings (Iwaro and Mwasha 2010). Many countries have implemented building energy standards as a precursor to compulsory codes (IEA 2013b).

Building codes can be implemented by including energy efficiency requirements in existing building codes, or by creating additional codes exclusively for BEE. Because of their mandatory nature, building codes have been primarily used to target BEE opportunities that use established, widely available technologies. They set a minimum standard that generally lags the best available technologies, rather than driving continual improvements through innovation (Gann, Wang, and Hawkins 1998).

3.1.2 BEE policy in China and Shanghai

National policy context

Governance structure for BEE policy

Administrative authority for BEE policies in China is divided between the Central Government and local administrative departments at the provincial and municipal levels[13]. Funding arrangements for specific programs vary in their division between Local and Central Government financing.

Within the Central Government, the Ministry for Housing and Urban-Rural Development (MOHURD) is the main agency responsible for developing BEE policies and coordinating policy implementation. Other ministries such as the Ministry of Finance and the Ministry of Science and Technology are also involved (Kong, Lu, and Wu 2012).

The China Academy of Building Research (CABR) is the research institution affiliated with the Central Government responsible for BEE research and policy development (Shui et al. 2009).

City agencies are responsible for the implementation of most policies developed by MOHURD. The Provincial Department of Housing and Urban-Rural Development and the Committee of Municipal and Rural Construction must develop local laws and programs that comply with MOHURD policies.

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12 The choice of discount rate is important for assessing BEE investments. When high discount rates are used in economic assessments, projects with high upfront costs and benefits that accrue over long time periods appear more expensive. See Box 1-1 for more information.

13 Central Government policies are described here to give context to the actions available to the Shanghai City Government. The purpose of this report is to develop recommendations for the Shanghai City Government.

The local government is then responsible for passing those laws and ensuring implementation and monitoring. In Shanghai the Urban Construction and Communications Commission is the main organization responsible for policy development.

Central Government BEE codes

BEE codes and standards are a major element of the BEE policy framework in China. China was one of the first countries in the Asia Pacific region to implement a BEE code, in 1986 (Shui et al. 2009). Since 2007 a number of laws have been issued by the Central Government that have elevated BEE codes to equivalent importance with safety-related codes (Bin 2012).

The second revision of the Energy Conservation Law, issued in 2007, includes provisions for the administrative structure for developing and deploying building codes (Article 34), compliance with and enforcement of codes (Article 35) and the mandatory disclosure of BEE information when selling or leasing buildings (Article 36). Article 34 describes the role of MOHURD in releasing national codes and lays out the obligation for local governments to develop and implement their own codes.

The codes released by MOHURD are developed by CABR. CABR is also responsible for updating the codes (Shui et al. 2009).

Separate codes are released for public and residential buildings. For residential buildings, the code is differentiated according to five climate zones. Shanghai is in the hot summer, cold winter (HSCW) zone (Xu et al. 2013).

The scope of both sets of codes is mainly focused on the building envelope and HVAC systems, excluding other building components such as lighting and hot water systems. MOHURD releases a separate code for lighting energy efficiency.

The residential codes includes both prescriptive and performance-based measures (Shui et al. 2009)[14]. Prescriptive measures are focused on the building envelope. For each climate zone the code specifies maximum allowable heat transfer coefficients for different components as well as shading coefficients and window-to-wall area ratios based on orientations (W. L. Lee and Chen 2008).

If the building design does not comply with the prescriptive requirements, it must comply with an overall energy performance target, which specifies the maximum allowable heating/cooling energy load. In the HSCW zone the performance target for a specific building is determined by simulating the heating/cooling load of the designed building, if it had complied with the prescriptive requirements (W. L. Lee and Chen 2008).

The latest national code for public buildings was released in 2005. The latest residential code for the HSCW zone was released in 2010.[15] City Governments are responsible for developing and implementing their own BEE codes for residential and public buildings. City Governments can

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14 Prescriptive requirements in a BEE code set an absolute minimum level of energy efficiency allowed for a particular building element, such as the building envelope or windows. Performance-based measures set a minimum level of BEE for the building overall, allowing greater flexibility for how that level will be achieved. See Appendix D for more information.

15 A new building code has been drafted and is now circulating in draft form.

use the MOHURD code as the basis for their own codes, or include additional efficiency measures that go beyond the MOHURD level (Xu et al. 2013).

BEE code compliance, monitoring and enforcement

The compliance and approval process for BEE codes is divided into two phases, design and acceptance. This ensures that both the original design and the final constructed building meet the BEE requirements: design codes must be approved at the design stage, while compliance with acceptance codes occurs during and after construction. MOHURD is responsible for the overall compliance process, which is implemented by local construction agencies working with semi-governmental organizations called quality supervision stations and testing centers and labs.

Private companies play a large role in BEE code compliance and monitoring in China. These companies are registered with local construction departments and must meet certification requirements set by MODURD (Bin 2012). Certification must be renewed every five years and includes official qualification requirements for employees such as architects and engineers.

Table 3-1 lists the government agencies and private companies involved in the design and acceptance phases.

Table 3-1 Organizations involved in BEE code compliance and monitoring (Bin 2012)

Name	Organization type	Responsibilities
Local construction department	Local branch of MOHURD	In charge of local compliance and enforcement including regulation of other organizations.
Drawing inspection companies	Third-party company	Inspect and approve building design for compliance with design standards. This approval is required for the developer to apply for a construction permit.
Construction inspection companies	Third-party company	Conduct frequent on-site inspection activities during construction, to ensure compliance with acceptance codes.
Quality supervision stations	Semi-governmental agency	Supervise the work of third parties. Conduct scheduled and random on-site inspections during construction to ensure compliance with the construction phase.
Testing centers and labs	Semi-governmental agency	Provide testing services for the quality supervision stations.

Evaluations of BEE monitoring and enforcement in China

Effective monitoring and enforcement are crucial for realizing BEE improvements through BEE codes (Evans et al. 2010a). Since 2008 MOHURD has taken several steps to enhance its enforcement system, in coordination with local agencies across China. According to MOHURD's annual national inspection for compliance in urban areas, the compliance rate stage has improved from 53% for design and 21% for construction in 2005 to 99.5% and 95.4%, respectively, in 2010 (Bin 2012, Evans et al. 2010b, Draugelis and Li 2012).

Bin (2012) investigated both the changes to the enforcement process, and the process for MOHURD's annual inspection, to determine how such dramatic improvements could be achieved in five years, and whether they are likely to be overstated. There was strong evidence that compliance rates had improved and that any overestimation in the annual inspection results is probably minor.[16] The success was attributed to the following five factors:

- Increased regulatory support provided by the Central Government as part of the 2007 Energy Conservation Law revision.
- Stable budgetary support.
- Strict regulation of the third party companies that undertake inspection and compliance activities.
- Clear penalties for non-compliance (although these penalties are relatively low).
- Compliance within a province is investigated and reported by teams of MOHURD and CABR officials from outside the region. Provinces with low compliance rates are publicly exposed in an annual report from MOHURD.

Shanghai policy context

Local climate and new buildings

As described in Section 3.1.1, the local climate is one of the major determinants of a building's energy requirements because it dictates the heating and cooling load required to maintain a particular level of thermal comfort. Shanghai, in the hot winter/cold summer zone, has a shorter heating season than some of China's northern cities, and a shorter cooling season than cities in the southeast.[17] The number of heating degree days (HDDs) and cooling degree days (CDDs) are measures of the heating and cooling requirements of buildings in different cities, respectively. Shanghai has a similar number of HDDs to San Francisco, in the US, and a similar number of HDDs and CDDs to Osaka, in Japan (BizEE Software 2014).

Most new buildings being constructed in Shanghai are multistory apartment blocks ranging from low-rise to hi-rise, and large public buildings[18] that serve business, government and other commercial tenants (S. Yu et al. 2014).

BEE policy framework

The Shanghai Municipal Government has incorporated BEE goals into its local development plans and developed its own BEE regulations. The 11th five year plan includes a clear target for the total increase of energy consumption of residential buildings in 2015 from the 2010 level

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16 Some of the concerns identified were that the sample size for the survey was too small and that the compliance rate only reflects compliance with mandatory items in the local BEE code.

17 According to (J. Yu et al. 2009) buildings in Shanghai have a heating season from December 1st to March 15th and a cooling season from June 15th until September 15th.

18 In this report, "public buildings" does not include industrial facilities. The major building types in this category are commercial and government buildings, educational facilities, hospitals, shopping malls and hotels

should be no more than 7 million tons of coal equivalent (Shanghai Municipal Government 2010). Policies for BEE in public buildings are targeting a 65% reduction in energy use compared to consumption levels in 1983 (E. Lee et al. 2012).[19]

The Shanghai Ordinance of Building Energy Conservation was passed by the Shanghai People's Congress Standing Committee on Sep 17, 2010. The Ordinance provides the regulatory support for BEE policies and programs, including BEE codes for residential and public buildings and financial incentives for BEE investments (Shanghai Municipal Government 2010).

Box 3-1: Shanghai's carbon reduction goals for buildings

The Shanghai Municipal Government's publicly stated goals for BEE are to reduce energy use in public buildings by 65% compared to 1983 and to limit the increase in residential building energy use from 2010 to 2015 to 7 million tons of coal equivalent. When expressed using these metrics it is unclear how strict the resulting BEE codes are, or whether they are sufficient to avoid carbon lock-in. The investigation in Section 3.2 assesses these goals and their suitability for avoiding carbon lock-in.

Shanghai BEE codes

The Shanghai Municipal Urban and Rural Construction and Transportation Commission (MURCTC) is the Municipal Government agency responsible for the development of BEE codes for public and residential buildings that meet the requirements of the current MOHURD codes.

The process for developing the codes involves a number of stakeholders and considerations. The following organizations developed the technical aspects of the most recent BEE codes:

- Shanghai Research Institute of Building Sciences Co., Ltd. (SRIBS)
- Shanghai Building Materials Industry Market Management Station
- Shanghai Xian Dai Architectural Design Group Co., Ltd
- Tongji University

The design of the code must take into account any legislated targets or constraints from both the Central Government and local laws and regulations, including:

- The minimum requirements for residential buildings set by MOHURD's HSCW code.
- The minimum requirements for public buildings set by MOHURD's 2005 public buildings code.
- Targets for energy use reductions for both types of buildings set by the Shanghai Municipal Government.

[19] The rationale behind these targets and their use in policy design is discussed in more detail in Section 3.2.2.

The current standards for residential and public buildings were released by the MURCTC in 2011 and 2012, respectively. The standards are:

- DGJ08-205-2011: Design Standard for Energy Efficiency of Residential Buildings (Shanghai Municipal Urban and Rural Construction and Transportation Commission 2011).
- DGJ08-107-2012: Design Standard for Energy Efficiency in Public Buildings (Shanghai Municipal Urban and Rural Construction and Transportation Commission 2012).

Although they are entitled 'standards', not codes, both include several mandatory elements with the same enforcement procedures as building codes. The mandatory features combine prescriptive and performance based measures, similar to the MOHURD codes. They cover:

- Thermal performance of the building envelope
- Window to wall ratios
- HVAC system design

Importance of BEE codes in the HSCW region

Yu et al. (2014) investigated the potential for BEE codes to reduce building energy use in China's various climate regions. Their study found that codes had the greatest potential to reduce the energy consumption characteristics of individual buildings in the cold and severe cold regions, where building heating loads are the highest. However, the region with the greatest potential to reduce energy consumption on an absolute scale was the HSCW region, where Shanghai is situated, due to its predominance in population and building floor space.

Summary: Strengths and weaknesses of Shanghai's BEE policy framework

For the purposes of avoiding carbon lock-in through inefficient buildings, an effective BEE policy framework must include the following:

- The **aims of the policy** are consistent with avoiding carbon lock-in.
- The **design of the policies** and programs incorporate these aims.
- The **implementation** of the policies and programs is effective.
- There is ongoing **monitoring and evaluation** of the policy that leads to revisions and changes when necessary.

Table 3-2 describes the major strengths of Shanghai's process for each of the steps above.

Table 3-2 Shanghai BEE policy process

	Features of Shanghai process	Strengths
Determining aims	Shanghai Municipal Government policy sets goals for reductions in energy use from public and residential buildings (See Box 3-1).	BEE codes are designed to contribute to the city's carbon reduction goals.
Design of policies and programs	Compulsory public and residential BEE codes are designed to comply with MOHURD requirements. Additional complementary policies are designed with financial incentives for further BEE investments.	Policies include compulsory BEE codes and financial incentives for exceeding the minimum standards set by the codes. BEE codes are more stringent than the minimum levels set by MOHURD codes.
Implementation	The local construction department oversees monitoring and compliance processes consistent with MOHURD requirements.	Compliance with BEE codes has reached high levels across China. There are several local and national policies and programs to support BEE code implementation.
Monitoring and evaluation	BEE codes have been revised over the past decade and updates were issued.	Both codes were updated relatively recently (2011 and 2012)

The major weakness of the current process is that the goals of BEE policy are sufficient to avoid carbon lock-in.

3.1.3 Summary: Issues for investigation

The aim of BEE policy is to estimate an optimal level of BEE, considering all of the costs and benefits of BEE investment. This estimation is extremely difficult, for the following reasons:

- Baseline and historic data sources on building energy use may not exist, or may be incomplete or inaccurate, making it difficult to establish current characteristics and trends in consumption and behavior.
- Many of the costs and benefits that must be analyzed are uncertain, including the significant external benefits from reducing energy use (described in Box 1-2).
- Future changes in consumption, energy prices and the cost of different BEE opportunities must be taken into account. This requires the development of projections that are inherently uncertain.
- Cost benefit analysis must be performed with long time horizons, making the choice of discount rate crucial in determining whether a particular level of BEE investment is

economically viable (as described in Box 1-1).

The following section evaluates Shanghai's BEE codes by comparing the stringency of the code to those in other countries and jurisdictions, and determining how the process for code design addresses and deals with the challenges described above.

3.2 Investigation and Policy Evaluation

This section presents an assessment of Shanghai's BEE codes. The data and analysis is based on current literature and expert interviews conducted in Shanghai, Beijing and Tokyo in January 2014.

3.2.1 Comparative stringency of Shanghai's BEE codes

Table 3-3 contains the heat transfer coefficients (U factor[20]) for building envelope components from Shanghai's current BEE standards for public and residential buildings.[21]

Table 3-3 Heat transfer coefficients (U factor) for Shanghai BEE codes (W/m2)

Building element	Public buildings DGJ08107-2012	Residential buildings DGJ08-205-2011
Windows	2.84	3.2
Walls	0.8	1.2
Roof	0.5	0.8

Figure 3–1 and Figure 3–2 compare these U factors with the equivalent residential and public building codes and standards from a range of jurisdictions. Lower U factors indicate more stringent BEE requirements.

For residential buildings, figures are quoted for the building type that most closely resembles a high-rise apartment building, the most common residential buildings being constructed in Shanghai. Where codes include multiple climate zones, the zone with the most similar climate to Shanghai was selected. The heating degree days (HDD) and cooling degree days (CDD) are shown for each code to give an indication of the similarity of the climate to Shanghai.

The jurisdictions compared and the relevant codes and standards are:

- **Japan**: The residential standard is the 1999 Design and Construction Guidelines on the Rationalization of Energy Use for Homes (DCGREUH). Figures are quoted for Climate zone 4, which includes Tokyo and Osaka. The residential building type is for reinforced concrete structures. No public building standard is used. Japanese building standards are discussed further below.

[20] The U-factor is the rate of heat transfer across an envelope assembly per degree of temperature difference on either side of the envelope component. U-factor is a function of the materials and their thickness. U-factor includes air film resistances on inside and outside surfaces. The lower the 'U', the higher the insulating factor.

[21] Both codes contain a range of U factors for different building types. The values in Table 33 are for concrete buildings more than 3 floors high.

- **California**: Figures for residential and public buildings are from the Title 24 legislation of 2013. The building type for both is metal framed buildings with 4 or more residential floors. The climate zone is Zone 3, the San Francisco area.

- **United States**: The 2007 industry standard by ASHRAE was used, with the climate zone 3C, northern California. This is the most widely-used voluntary standard used by the US construction industry.

- **United Kingdom**: The compulsory 2006 building codes are used (Building Regulation Approved Document L1A & L2A, 2006). This code is not split into climate zones. HDD and CDD are shown for London.

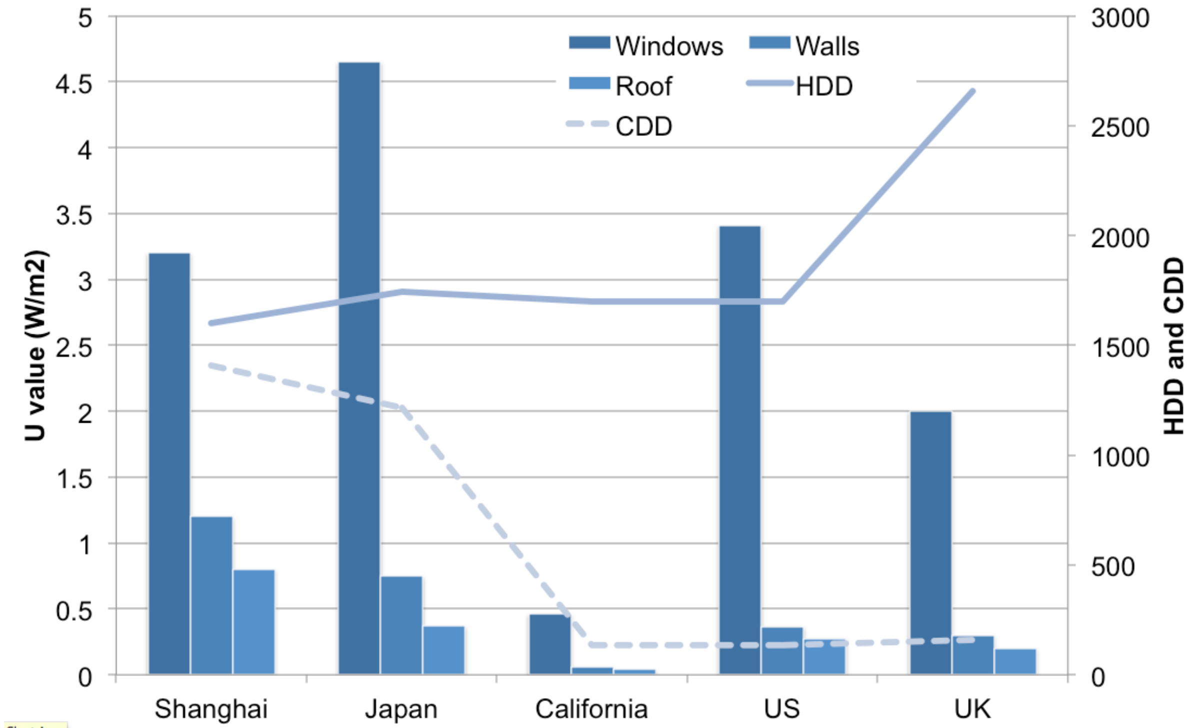


Figure 3–1 Residential buildings: Comparison of U-factor requirements for building envelope components from different BEE codes and standards (Evans, Shui, and Takagi 2009), (Xu et al. 2013), (Li 2008), (California Energy Commission 2013).

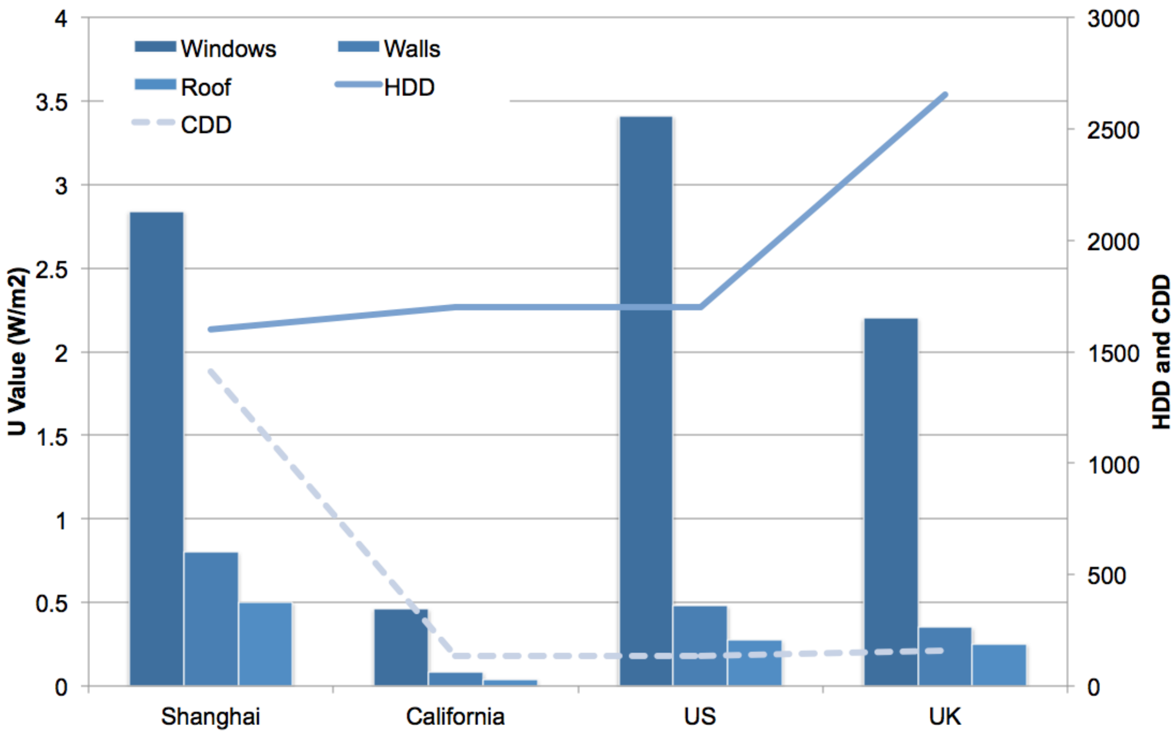


Figure 3–2 Public buildings: Comparison of U-factor requirements for building envelope components from different BEE codes and standards (Evans, Shui, and Takagi 2009), (Xu et al. 2013), (Li 2008), (California Energy Commission 2013).

The figures show significant variation in the minimum requirements for building envelope efficiency, even in jurisdictions where the BEE code is being used as the major policy driver for BEE improvements. California's compulsory building code has much more stringent requirements than the ASHRAE standard for the same climate zone, which is voluntary. The United Kingdom has a relatively stringent code, which is a strong driver of BEE in that country, despite having U values much higher than the California standard.

Evolution and stringency of Japanese BEE standards

Figure 3–2 shows that the Japanese 1999 BEE standard is the closest to Shanghai's for residential buildings. It is less stringent than Shanghai for window efficiency and the requirements for the walls and roof are closer than the other codes. There is evidence that these standards have not been stringent enough to achieve the Japanese Government's BEE policy goals (METI 2014).

Japan's standard is currently being converted to a compulsory code, following a major revision of the design and evaluation methods in 2013. This review recognized the potential to significantly reduce building energy use by improving the U factors of windows and insulation beyond current industry practices (METI 2013). The review also found that the construction industry did not have the capacity to comply with more stringent energy efficiency requirements for building envelopes, because of the cost and limited availability of efficient building materials (METI 2014).

In response to this finding, the Ministry of Economy, Trade and Industry (METI) and the Ministry of Land, Infrastructure, Transport and Tourism (MLITT) have both developed new policies to improve the performance of building envelopes. For BEE codes, both a prescriptive thermal insulation standard and a performance-based standard for whole-building energy consumption must be met (MLITT 2013). In addition, insulation and windows have been incorporated into the 'Top Runner Program' for energy efficiency. This means that manufacturers will have to meet increasingly strict requirements for product efficiency over the coming decade (METI 2013).

These issues are discussed further as a case study in Appendix E. This appendix describes how the Japanese Government has approached the design and implementation of BEE policy over the past two decades and how this has impacted the efficiency characteristics of their current building stock and the capacity of the construction industry to comply with more stringent BEE codes.

Evaluation of Shanghai's BEE code stringency

With the exception of Japan, Figure 3–1 and Figure 3–2 show that Shanghai's BEE codes are significantly less stringent than the codes in other jurisdictions.[22] This is an imperfect comparison, due to the complexity of the codes, the differences in building industry practices and the different combinations of other compulsory elements in each code, apart from the walls, windows and ceilings. However, this analysis suggests that the BEE investments mandated by Shanghai's codes might be below cost optimal.

Several academic studies have also produced evidence that the stringency of Shanghai's current codes is such that BEE opportunities with relatively short paybacks are not taken up. For example, Lee et al. (2012) found opportunities to increase efficiency beyond the code requirements with simple payback periods of 1.5 years, through more efficient window materials and design. Yu et al. (2014) modeled the potential for BEE codes to improve building efficiency throughout China in the coming decades. The study found that there are significant opportunities to achieve economically efficient energy use reductions by decreasing U-value requirements for building envelope components in the HSCW region.

Development of BEE codes compared to other energy efficiency policies

One reason for the low stringency of Shanghai's BEE code may be the lack of historical emphasis on buildings for energy efficiency improvements in Shanghai, and China more broadly. Several experts explained that buildings, particularly building envelopes, have not been a major policy focus in China since the Central Government began prioritizing energy efficiency in the early 1990s. Given the relatively recent introduction of mandatory BEE codes in 2005, there may be a perception among policy makers that the construction industry needs time to adjust to the change, so stringency should not be very high (Yanbing Kang 2014).

Historically, China's most scalable and cost-effective opportunities to reduce carbon emissions have been from industrial energy use and power generation. However, as explained in Chapter 1,

[22] Neither the US nor the Japanese codes shown are entirely compulsory. However, both are useful indicators of the minimum performance of new building envelopes in these countries. See Appendix E for more details.

emissions associated with buildings have risen significantly and will increase further as urbanization continues.

There has also been a historical emphasis on increased appliance efficiency as a means to reduce energy consumption from buildings dating back to 1990. Chinese officials have recognized that improved appliance standards reduce building energy use and improve the competitiveness of Chinese products globally (Tan Hongwei 2014, Zhang Jian Long 2014).

3.2.2 Costs and benefits of BEE in Shanghai

As identified in section 3.1.3 it is difficult to estimate the costs and benefits of BEE for the purposes of code design. This section discusses three major challenges for Shanghai in this process: anticipating consumer trends, dealing with uncertainties in BEE costs and incorporating externalities into policy design.

Residential energy prices and consumption patterns in China

As Chinese citizens grow wealthier, the use of energy for space conditioning in residential and commercial buildings increases. However, in 2013 Chinese citizens still used significantly less energy for space heating and cooling than OECD nations (IEA 2013a). Energy prices in China are also lower than in most developed countries (see Section 4.1.1). Both of these factors imply that lower levels of BEE investment are required in China, compared to OECD nations, because they both reduce the amount of energy cost savings that result from the efficiency improvement:

- If space conditioning is not common, the *energy savings* from improving the building envelope efficiency are minimal.
- If energy prices are low, the *cost savings* to residents from each kWh of energy saved is lower.

According to some experts, these factors justify a lower level of building envelope efficiency in China than in countries where demand for energy services is higher and people spend more of their income on energy (Yanbing Kang 2014).

However, basing BEE code design on these factors is problematic because using current behaviors as a major driver for code design may lead to buildings that are poorly suited for future changes in preferences. Box 3-2 explains the importance of changing trends in air conditioning for BEE code design. Air conditioner use is one example of increasing energy use by consumers. Shanghai's economy and population are transforming so rapidly that significant other changes in behavior and preferences are likely in the coming decades (Eom et al. 2012, IEA 2013a, S. Yu et al. 2014). If these changes are not taken into account, BEE codes will lock in inefficient design characteristics. For example, a BEE code designed for air conditioner ownership rates in 2000 would require less efficient building envelopes, locking in higher rates of energy use once air conditioners are installed.

Box 3-2: Implications of air conditioners

The recent trend of growing air conditioner ownership is likely to continue in Shanghai, as residents' incomes grow. Assumptions around air conditioner usage impact BEE code design in the following ways:

- Improvements in building envelope efficiency are **more valuable** if consumer preference for air conditioning is higher. Therefore BEE codes that anticipate increases in air conditioner use will mandate a higher level of efficiency.
- Increased air conditioner use will be a **driver of increased electricity costs**, because air conditioner use increases summer peak demand loads, leading to increased investment in networks and generation. These cost increases are likely to lead to higher electricity prices over the coming decades.
- Increased electricity prices in turn increase the value of improvements in building envelope efficiency, because the **electricity savings over the building lifetime are higher**.

Cost and availability of building insulation materials

According to building industry experts, there is limited availability of some high-efficiency building materials in Shanghai, and China more broadly. This may be the case for cost-effective insulation products (Fuchun Du 2014).

In 2009 there were a number of fires in hi-rise buildings in China. Investigations revealed that several fires were exacerbated by the use of insulation materials such as polystyrene and polyurethane (Sun, Hu, and Zhang 2013). Since then several materials have been banned and others face strict regulations (Global Insulation 2013).

The purpose of the new insulation regulations is to improve public safety and minimize future incidents of fire. In the short term there may be reductions in the choice and availability of insulation products for developers, as manufacturers change their production practices to adapt to these regulatory changes.

If BEE codes are designed based on the current availability of insulation materials, they will not be stringent enough to optimize building energy savings over the coming decades. In most cases, insulation manufacturers have a proven track record of increasing production of new and alternative insulation products that comply with the most stringent regulations. The restrictions on organic insulation materials have already led to growth in the production of alternatives such as mineral wool and fiberglass insulation (Global Insulation 2013). From 2013 to 2016 the Chinese insulation industry is expected to grow from 42 billion Yuan to 66 billion Yuan, driven largely by demand from existing BEE codes (Freedonia 2013).

Externalities in the BEE code design process in Shanghai

Some of the greatest benefits from improving BEE are externalities. BEE codes are designed to drive a level of BEE investment that would not be achieved without considering these externalities. In Shanghai, the government has assessed energy use in buildings and determined goals for energy use reductions, as described in Box 3-1. These goals are then used to determine the stringency of BEE codes (Zhu Daijan 2014).

This use of long-term goals is the principle way in which Shanghai's BEE codes account for the positive externalities from increasing energy efficiency. This approach may not lead to a cost optimal level of BEE investment, because the choice of the target is an incremental process based on judgments of what is feasible at the time.

An alternative approach is to determine the BEE level that maximizes total benefits, by calculating the costs and benefits of different levels of BEE over a typical building's lifetime. This approach requires externalities to be incorporated directly into the analysis, with specific RMB values being attributed to specific benefits, such as the public health benefits of avoiding 1 MWh of power generation. Whilst there are significant technical challenges associated with this approach, it has significant advantages for optimizing BEE investment because it forces an explicit comparison between the upfront costs and the lifetime benefits.

3.2.3 Cost optimal BEE codes

Cost benefit analysis of BEE investments that incorporate externalities is an important feature of the design process for 'cost optimal' BEE codes. Cost optimal codes have the potential to significantly enhance Shanghai's approach to BEE policy, by addressing many of the concerns outlined in Section 3.2.2. This section describes cost optimal codes and the process for their implementation.

The aim of a BEE code is to optimize BEE investment in new buildings at the time construction. Optimization in this context means minimizing the lifetime energy-related costs of a building, including the upfront capital investments and lifetime energy costs. The 'cost optimal framework' is a methodology developed by the European Commission that incorporates these three principles as central to the process of BEE code design.[23] The following sections describe the concept of cost optimality and its potential application for building code design in Shanghai.

Figure 3-3 depicts the process for developing cost-optimal BEE codes.

[23] This methodology was designed to assist European Union countries that much comply with the 2010 Energy Performance Building Directive. This directive requires countries to set minimum energy performance requirements for buildings to achieve cost optimal BEE investment (IEA 2013b).

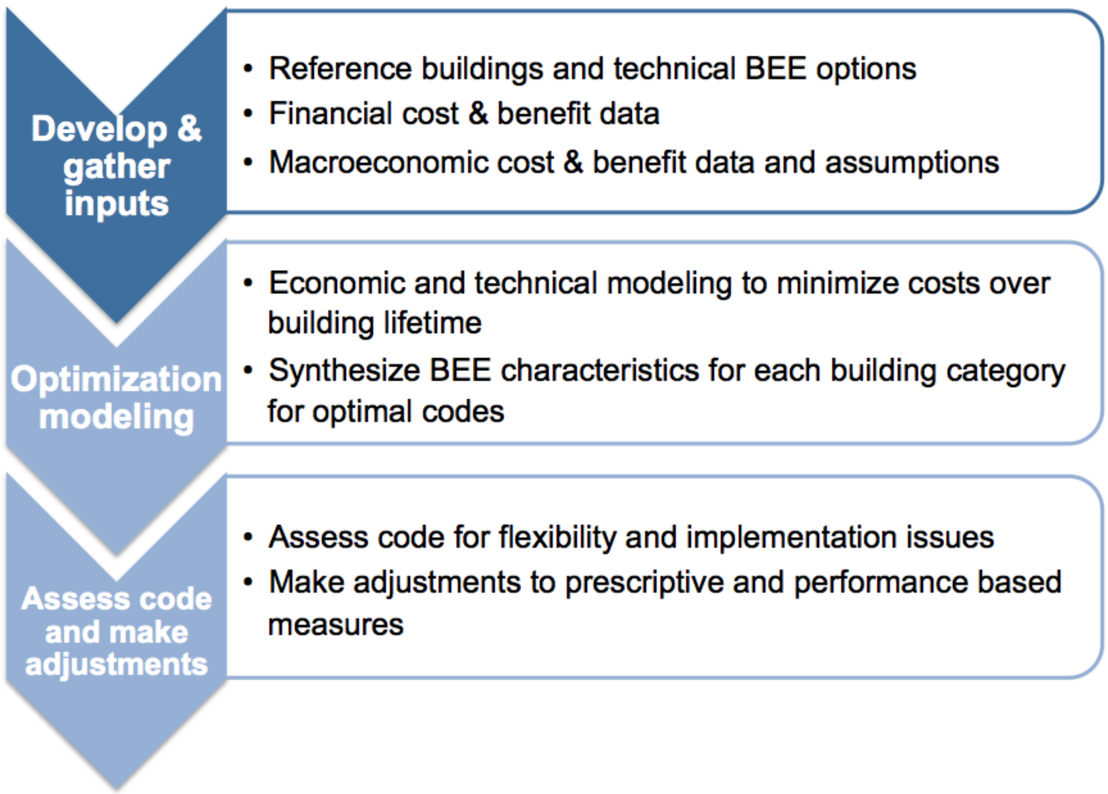


Figure 3–3 Process for developing cost optimal BEE codes

The first step is to gather data and develop modeling inputs. The distinctive features of the cost optimal framework, as compared to the existing Shanghai process, include (from (European Commission 2012)):

- The reference buildings are developed to represent the most prevalent and construction practices, as well as any trends that are expected to become more common. Inputs for the energy consumption habits in each building category are also developed. If major changes to these habits are expected over the building lifetime, forecasts of these changes are also developed as modeling inputs. An example of this type of modeling is the Global Change Assessment Model (GCAM) used by Eom et al. (2012) and Yu et al. (2014) in long-term studies of China's building energy demand. GCAM simulates the evolution of the building stock and energy service demand in terms of China's socioeconomic development and interactions with the global economy and global energy system dynamics.

- Cost and benefit data inputs are determined for both financial and macroeconomic factors associated with each BEE opportunity. Conceptually, the financial costs and benefits are considered solely from the perspective of the private developer and the building occupant. The macroeconomic costs and benefits also take into account externalities. These may include reductions in energy subsidies, environmental and health impacts, as well as improved indoor air quality, energy security and industrial development. Since many macroeconomic and financial costs and benefits occur over the lifetime of the buildings, thirty-year projections and forecasts of these factors, such as energy prices, are also included in the input data.

The second step is optimization modeling. Lifetime energy-related costs and benefits for the reference buildings are optimized using a 20 or 30-year lifetime, a low discount rate, and incorporating forecasts of changes to costs, benefits and energy consumption over time.

The modeling outputs describe the BEE characteristics for each building type that produce the optimal investment outcome. These outputs must then be assessed and converted into implementable and flexible BEE codes. Adjustments may be made between prescriptive and performance-based elements of the code, to provide flexibility and efficiency opportunities for developers, as described in Section 3.1.1.

Box 3-2: The benefits of cost optimal BEE codes for Shanghai

The cost optimal approach will result in significant improvements in policy outcomes, compared to the current process. These improvements are the result of:

1. Longer timeframes for analysis that reflect buildings' long lifetimes.
2. Incorporation of externalities into analysis of individual investment opportunities for a more complete assessment of the costs and benefits of BEE.
3. Broad data inputs that will improve policymakers understanding of trends.

Why change the policy design process?

If Shanghai adopts a cost optimal methodology, new buildings will be constructed with efficiency characteristics that are optimized for Shanghai's future. Following this change, the public health and environmental benefits from BEE policy will be comparable with other policy areas such as industrial energy efficiency and renewable energy. The Government will improve its understanding of the extent of BEE improvements possible in Shanghai in the coming decades and use this information to improve its overall approach to low carbon planning.

3.2.4 Feasibility assessment of the cost optimal approach to BEE code development in Shanghai

This section is an introductory evaluation the strengths and weaknesses of a cost optimal approach to BEE code design for Shanghai, including challenges associated with policy design and implementation.

Stakeholder involvement in policy design

Under Shanghai's current process the following organizations are involved in the development of the codes:

- **Shanghai Municipal Urban and Rural Construction and Transportation Commission (MURCTC):** manages the process of code development and releases the official codes.

- **Shanghai Research Institute of Building Sciences Co., Ltd. (SRIBS):** contracted by the MURCTC to design the residential building code.

- **Shanghai Building Materials Industry Market Management Station:** collaborated with SRIBS to design the code.

- **Shanghai Xian Dai Architectural Design Group Co., Ltd:** contracted by the MURCTCto design the public building code.

- **Tongji University Department of Architecture:** collaborator in public building code design

This list of organizations suggests that the emphasis of the current code development process is on the technical feasibility and upfront costs of different BEE measures. The shift from the current approach to a macroeconomic cost optimal approach will require the involvement of a new set of government or private stakeholders with expertise in macroeconomic modeling.

Modeling and data requirements

From a data and modeling perspective, the key changes from current practices that will be required are:

- Increased use of long-term projections.

- Improving baseline data sets to support the development of these projections.

- Integrating economic and technical modeling for evaluating the optimal level of BEE investment for different building types.

These data requirements are complex and interrelated. Some will require data collection via surveys, or with the input of industry stakeholders. Projections over 20-30 years will be uncertain and require the modeling of multiple scenarios to account for a range of possible futures.

At a minimum, baseline data and projections will be required for:

- Energy consumption habits of building occupants that takes into account the particular socioeconomic characteristics of new building occupants and possible shifts in climate, increasing the demand for air conditioning.

- Cost of different materials and BEE technologies.

- All factors with major impacts on the costs and benefits of energy supply, including energy tariffs, energy subsidies, costs of expanding energy supply systems, costs of health and environmental externalities related to energy supply.

- Energy tariffs, including projections. Future increases in the costs of energy supply are likely to put substantial pressure on energy tariffs in China in the future (Zhao, Li, and Ma 2012).

Both the uncertainties inherent in projections and the lack of available baseline data were raised as barriers to more stringent BEE code design in interviews with industry experts (Zhang Jian Long 2014, Fuchun Du 2014, Yanbing Kang 2014, Zhu Daijan 2014). Absence of baseline data has also been a major barrier to BEE code development in OECD countries (IEA 2013b).

In order to address the risks of lock-in, Shanghai must manage the tradeoff between taking action soon to update BEE codes and waiting to collect better baseline data. In some cases where there is a lack of baseline data, the use of case studies from outside Shanghai may be useful to inform the development of projections.

BEE governance structure in Shanghai

Many governments experience difficulties implementing cost optimal BEE codes for the first time, due to the high levels of BEE mandated by the code and the complex governance structures and degree of coordination required to effectively implement, monitor and enforce them (IEA 2013b).

The governance structure for BEE code implementation, monitoring and enforcement in Shanghai was described in Section 3.1.2. As discussed in this section, recent efforts to strengthen this structure have led to very high levels of compliance with existing BEE codes in Shanghai.

The success in implementing existing codes suggests that the governance structure and levels of stakeholder coordination for BEE code implementation in Shanghai is already well established. The government is therefore in a strong position to implement more stringent codes based on the cost optimal methodology.

Affordability and construction industry acceptance

If Shanghai implements a cost optimal BEE code the major advantage would be economically efficient investment that avoids high-carbon lock-in and minimizes the social costs of building energy use. By including externalities in the assessment of energy supply costs this new code would also increase the consistency between building energy efficiency policy and other low-carbon policies and programs.

The main disadvantage associated with a cost optimal code is the increased construction costs for new buildings, which affects developers, construction companies and residents. These cost increases are likely to draw opposition from local construction industry stakeholders.

Options for managing this opposition include:

- **Engagement:** Stakeholder engagement throughout the code development process. The emphasis of this engagement should be to communicate the broader, long-term aims of the government's BEE policies, and the planned measures for assisting industry in adjusting to the new codes. Industry opposition in Shanghai should be tempered by the fact that BEE codes have already been in place for many years and recent efforts to increase compliance have led to the vast majority of developers engaging with the existing requirements (Bin 2012). This has also led to the development of significant technical capacity and expertise in BEE code implementation and compliance among government and non-government stakeholders.

- **Capacity building:** Providing free training and compliance materials and programs for industry stakeholders, including software packages. The first step in developing effective training and compliance materials is to review existing construction profession capabilities (IEA 2013b).

3.3 Recommendations

Shanghai's building codes are not stringent enough to avoid carbon lock-in in new residential and commercial buildings. The codes should be updated so that the full extent of the economic and low-carbon benefits of building energy efficiency can be realized. The update should make use of cost benefit analysis of different levels of BEE in typical buildings being constructed in Shanghai.

Recommendation 1: Compare the current process for BEE code development to the cost optimal framework and identify opportunities for improvement

The current process for developing BEE codes should be assessed against the macroeconomic cost optimal framework described in Section 3.2.3. The exact process outlined by the European Commission in developing this framework methodology will not necessarily be appropriate for the Shanghai context. However, this comparative assessment should highlight some potential shortfalls of Shanghai's current system and the potential for improvement.

Recommendation 2: Design and implement a revised process for BEE codes

The guidelines for cost optimal BEE codes can be used to make adjustments to the current process for developing codes. The adjustments should include:

- Increasing the use of baseline data as a basis for modeling and projections.

- Accounting for externalities in energy supply costs.

- Assessing costs and benefits over the whole lifetime of buildings using an appropriate discount rate.

- Integrating the economic and technical assessment of BEE opportunities to determine the optimal level of BEE to be included in the code.

When this process is implemented, the resulting code is likely to be more stringent than the current codes. In order to successfully implement this revised code there must be engagement with a wide range of stakeholders to justify this introduction and push back against the short-term concerns that are driving the current approach to code design.

Reference List: Chapter 3

Bin, Shui. 2012. "Third Parties in the Implementation of Building Energy Codes in China". American Council for an Energy Efficient Economy (ACEEE). http://www.aceee.org/research-report/i121.

BizEE Software. 2014. *Degree Days Weather Data*. Accessed January 3. http://www.degreedays.net/.

California Energy Commission. 2013. *Title 24 Part 6 and Associated Administrative Regulations in Part 1*. *CEC-400-2013-002-SD*. http://www.energy.ca.gov/title24/.

Dai, Yixin. 2014. "Research Interview for Policy Analysis Exercise. Tsinghua University, Department of Public Policy."

Draugelis, Gailius, and Shawna Fei Li. 2012. "Chapter 7: Energy Efficiency in Buildings." In *Sustainable Low Carbon City Development in China*, edited by Axel Baeumler, Ede Ijjasz-Vasquez, and Shomik Mehndiratta. World Bank Publications.

Eom, Jiyong, Leon Clarke, Son H. Kim, Page Kyle, and Pralit Patel. 2012. "China's Building Energy Demand: Long-Term Implications from a Detailed Assessment." *Energy* 46 (1): 405–19. doi:10.1016/j.energy.2012.08.009.

European Commission. 2012. "Guidelines Accompanying Commission Delegated Regulation (EU) No 244/2012 of the Council on the Energy Performance of Buildings by Establishing a Comparative Methodology Framework for Calculating Cost-Optimal Levels of Minimum Energy Performance Requirements for Buildings and Building Elements." *Official Journal of the European Union*, April. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2012:115:0001:0028:EN:PDF.

Evans, Meredydd, Bin Shui, Mark A. Halverson, and Alison Delgado. 2010. "Enforcing Building Energy Codes in China: Progress and Comparative Lessons". Pacific Northwest National Laboratory. http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19247.pdf.

Evans, Meredydd, Bin Shui, and T Takagi. 2009. "Country Report on Building Energy Codes in Japan". Pacific Northwest National Laboratory. http://asiapacificpartnership.org/pdf/BATF/country_report/PNNL_(2009)_Country_Report___India.pdf.

Freedonia. 2013. "Insulation in China to 2016 - Demand and Sales Forecasts, Market Share, Market Size, Market Leaders." http://www.freedoniagroup.com/Insulation-In-China.html.

Fuchun Du. 2014. "Research Interview for Policy Analysis Exercise. Nikko Shanghai Xingtian Architectural Design Group."

Gann, David M., Yusi Wang, and Richard Hawkins. 1998. "Do Regulations Encourage Innovation? - the Case of Energy Efficiency in Housing." *Building Research & Information* 26 (5): 280–96. doi:10.1080/096132198369760.

Global Insulation. 2013. "Global Insulation 2013 Review." In *Global Insulation Conference and Exhibition 2013*. http://www.globalinsulation.com/conferences/global-insulation/review/gic-2013-review.

International Energy Agency (IEA). 2010. “Energy Performance Certification of Buildings: IEA Policy Pathway”. Paris: International Energy Agency.

IEA. 2013a. *Transition to Sustainable Buildings: Strategies and Opportunities to 2050*. Paris: International Energy Agency (IEA) Directorate of Sustainable Energy Policy and Technology.

IEA. 2013b. “Modernising Building Energy Codes: IEA Policy Pathway”. Paris: International Energy Agency & United Nations Development Programme.

Ingrid Holmes, and Rohan Mohanty. 2012. “The Macroeconomic Benefits of Energy Efficiency”. London: Third Generation Environmentalism Ltd (E3G).

International Energy Agency (IEA). 2013. “Transition to Sustainable Buildings. Strategies and Opportunities to 2050”. Paris: OECD.

Iwaro, Joseph, and Abraham Mwasha. 2010. “A Review of Building Energy Regulation and Policy for Energy Conservation in Developing Countries.” *Energy Policy* 38 (12): 7744–55. doi:10.1016/j.enpol.2010.08.027.

Kimura, Osamu. 2010. “Japanese Top Runner Approach for Energy Efficiency Standards.” *Socio-Economic Research Centre, Central Research Institute of Electric Power Industry*. http://www.climatepolicy.jp/thesis/pdf/09035dp.pdf.

Kong, Xiangfei, Shilei Lu, and Yong Wu. 2012. “A Review of Building Energy Efficiency in China during ‘Eleventh Five-Year Plan’ Period.” *Energy Policy* 41 (February): 624–35. doi:10.1016/j.enpol.2011.11.024.

Lee, E, X Pang, A McNeil, S Hoffmann, A Thanachareonkit, Z Li, and D Yong. 2012. “Assessment of the Potential to Achieve Very Low Energy Use in Public Buildings in China with Advanced Window and Shading Systems.” *Building Research & Information (unpublished)*, December.

Lee, W.L., and Hua Chen. 2008. “Benchmarking Hong Kong and China Energy Codes for Residential Buildings.” *Energy and Buildings* 40 (9): 1628–36. doi:10.1016/j.enbuild.2008.02.018.

Li, Jun. 2008. “Towards a Low-Carbon Future in China’s Building sector—A Review of Energy and Climate Models Forecast.” *Energy Policy* 36 (5): 1736–47. doi:10.1016/j.enpol.2008.01.029.

Li, Jun, and Michel Colombier. 2009. “Managing Carbon Emissions in China through Building Energy Efficiency.” *Journal of Environmental Management* 90 (8): 2436–47. doi:10.1016/j.jenvman.2008.12.015.

Ministry of Economy, Trade and Industry (METI). 2014. “Research Interview for Policy Analysis Exercise. Ministry of Economy, Trade and Industry Agency for Natural Resources.”

METI. 2013. “Trends in Final Energy Consumption in Japan”. Presentation. Tokyo, Japan: Ministry of Economy, Trade and Industry.

Ministry of Land, Infrastructure, Transport and Tourism (MLITT). 2013. “Policy and Programs for Energy Efficient Houses and Buildings in Japan”. Presentation. Tokyo, Japan:

Ministry of Land, Infrastructure, Transport and Tourism.

Shanghai Municipal Government. 2010. *Shanghai Ordinance of Building Energy Conservation*. http://www.shjjw.gov.cn/gb/jsjt2009/node1290/node1709/userobject7ai4412.html.

Shanghai Municipal Urban and Rural Construction and Transportation Commission (MURCTC). 2011. *Design Standard for Energy Efficiency of Residential Buildings, Shanghai Engineering Construction Standards*. *DGJ08-205-2011*.

MURCTC. 2012. *Design Standard for Energy Efficiency of Public Buildings, Shanghai Engineering Construction Standards*. *DGJ08-107-2012*.

Shui, Bin, Sriram Somasundaram, M Evans,, B Lin, Bo Song, and W Jiang. 2009. "Country Report on Building Energy Codes in China". Pacific Northwest National Laboratory. http://asiapacificpartnership.org/pdf/BATF/country_report/PNNL_(2009)_Country_Report___India.pdf.

Sun, Jinhua, Longhua Hu, and Ying Zhang. 2013. "A Review on Research of Fire Dynamics in High-Rise Buildings." *Theoretical and Applied Mechanics Letters* 3 (4): 042001.

Tan Hongwei. 2014. "Research Interview for Policy Analysis Exercise. Tongji University Green Building and New Energy Research Center."

Xu, Luyi, Junjie Liu, Jingjing Pei, and Xu Han. 2013. "Building Energy Saving Potential in Hot Summer and Cold Winter (HSCW) Zone, China—Influence of Building Energy Efficiency Standards and Implications." *Energy Policy* 57 (June): 253–62. doi:10.1016/j.enpol.2013.01.048.

Yanbing Kang. 2014. "Research Interview for Policy Analysis Exercise. Energy Research Institute Beijing."

Yu, Jinghua, Changzhi Yang, Liwei Tian, and Dan Liao. 2009. "Evaluation on Energy and Thermal Performance for Residential Envelopes in Hot Summer and Cold Winter Zone of China." *Applied Energy* 86 (10): 1970–85. doi:10.1016/j.apenergy.2009.01.012.

Yu, Sha, Jiyong Eom, Meredydd Evans, and Leon Clarke. 2014. "A Long-Term, Integrated Impact Assessment of Alternative Building Energy Code Scenarios in China." *Energy Policy* 67 (April): 626–39. doi:10.1016/j.enpol.2013.11.009.

Zhang Jian Long. 2014. "Research Interview for Policy Analysis Exercise. Tongji University Department of Architecture."

Zhao, Xiaoli, Na Li, and Chunbo Ma. 2012. "Residential Energy Consumption in Urban China: A Decomposition Analysis." *Energy Policy* 41 (February): 644–53. doi:10.1016/j.enpol.2011.11.027.

Zhi, Qiang, Jun Su, Peng Ru, and Laura Diaz Anadon. 2013. "The Evolution of China's National Energy RD&D Programs: The Role of Scientists in Science and Technology Decision Making." *Energy Policy* 61 (October): 1568–85. doi:10.1016/j.enpol.2013.06.044.

Zhu Daijan. 2014. "Research Interview for Policy Analysis Exercise. Tongji University Institute for Sustainable Development and Management."

Chapter 4: **Operations and end-user behavior**

Summary

This chapter addresses Shanghai's rapid urbanization and its impact on energy consumption in the residential and commercial sectors. Specifically, rapid growth in urbanization has created challenges in meeting demand for electricity and ancillary energy services while increasing energy efficiency and decreasing carbon emissions. The main objective of this chapter is to provide a **framework for solving problems on the demand side given the current context in Shanghai**, informed by existing literature, international successes and the local market.

This approach involves investigating the key drivers of energy consumption growth in Shanghai – with the aim to extract topics for benchmarking and further research. These topics are then organized under two categories – financial incentives (electricity pricing, ESCO ecosystem, investment) and behavioral incentives (feedback measures, community engagement).

Key findings:

- Understanding demand response requires an understanding of both the financial and behavioral incentives that drive consumption. This understanding can only be built through evidence-based policy design (benchmarking best practices and improving data collection).
- Integrated planning is essential to entangle conflicting incentives driven by different structural factors (for example, electricity market reform drives pricing models and investment which in turn drives consumption).
- In general, financial incentives tend to be demand inelastic in the short-run, however these can be effective in achieving energy goals when combined with behavioral incentives and better financial models
- Some behavioral interventions work better than others (for e.g. feedback measures and community-based initiatives work better than public engagement campaigns)
- Demand-side management must be deliberate, well-coordinated, and data-driven.

4.1 Problem Diagnosis

This section provides an initial assessment of the key drivers for Shanghai's policy responses for introducing low-carbon principles at the operations and demand side. By focusing on assessing the current state of energy consumption in the residential and commercial sectors, and then investigating the state of electricity reform and low carbon strategy in Shanghai, this section will articulate an alternative method to think about Shanghai's current policy framework and then proceed to analyze those proposals in the following sections.

4.1.1 Drivers of increasing energy consumption in Shanghai

Urbanization and the rapid influx of new migrants

It is commonly accepted that if you want to bear witness to the rapid economic rise of China in the last decade, you just need to visit the Bund and gaze across the Huangpu River at Pudong on a clear day. One building in particular towers over all others, the Shanghai Tower, set to open in 2015, and when it's complete it will have a total floor area of 574,000 square meters, contain 143 elevators, and measure 632 meters in height. By comparison, the soon-to-be-completed One World Trade Center in New York will measure just 541 meters. Given the massive size of the structure, it has been built with cutting edge green technology – for example, the twisted tapering crown is embedded with wind turbines that will generate 54,000 kWh/year in renewable electricity sufficient to power external lighting. Gensler, a global architectural firm that designed the tower calls it a "city within a city".

Not every new building earns the same LEED Gold, China Green Building three-star rating. As we have discussed at length in Chapter 3, there is much to be done to ensure sustainability and low carbon technology in construction and BEE. As discusses in section 1.2.1, each new residential and commercial development that is not built to the highest energy efficiency standards is locked in to a future of increasing energy costs and carbon emissions.

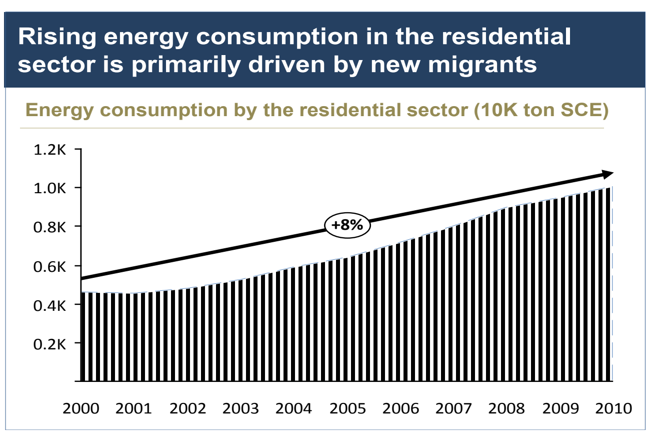


Figure 4–1 Energy consumption in the residential sector in Shanghai (2000-2010)

Electricity consumption in the residential and commercial sectors continues to grow due in part to the increasing number of residents in the city, but also preferences of existing residents change over time. As shown in Figure 4–2, rise in incomes have fueled a surge in electronic appliances and heating, ventilation and air-conditioning (HVAC).

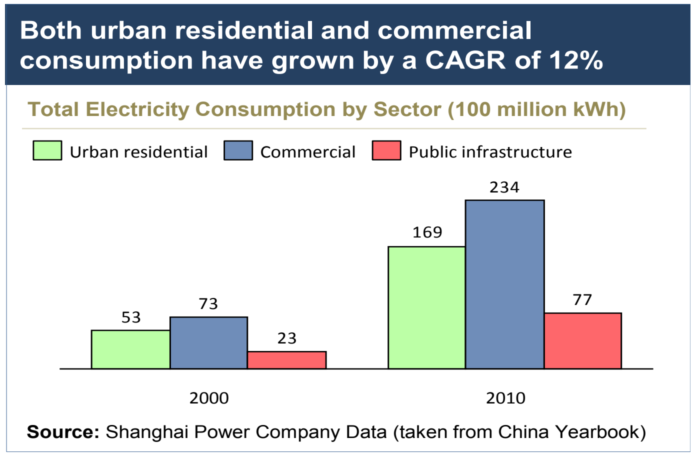


Figure 4–2 Electricity consumption and growth in Shanghai (2000 and 2010) by sector

Rising incomes and changing consumer preferences

Figure 4–3 shows that total retail spending has multiplied over three times during the last decade. This is a symptom of rising affluence, which leads to high usage of consumer electronics (both at work, and at home), changing preferences as a result of getting used to comfortable HVAC systems at work and the increased use of private automobiles for transportation. All of these increase energy consumption.

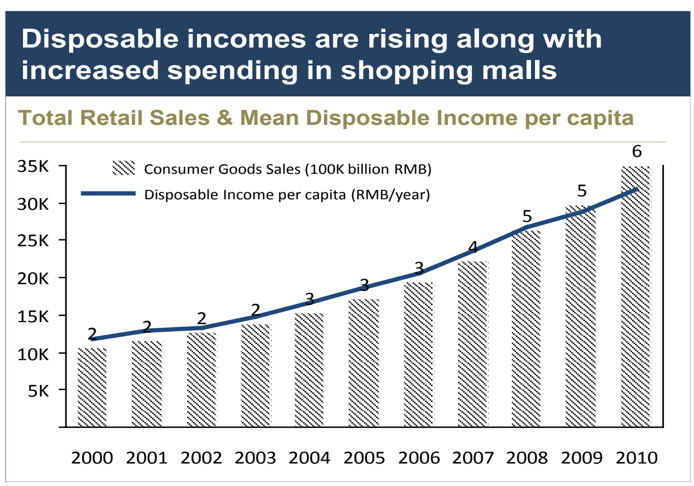


Figure 4–3 Disposable income and Retail Sales in Shanghai (2000-2010)

Alongside hard data, plenty of anecdotal evidence suggests Shanghai is on the cusp of a much larger increase in electricity and energy consumption. Take the example of proliferation of indoor air-conditioners (a/c) in residential buildings along the periphery of the city: between 2000 and 2010, air conditioner use had grown at a CAGR of 27%, slightly outpacing the growth of mobile phones (Shanghai Statistical Yearbook, 2012). These changes are shown in Figure 4–4. The pace of change will require the authorities to be proactive in redoubling efforts to manage energy demand and improve efficiency.

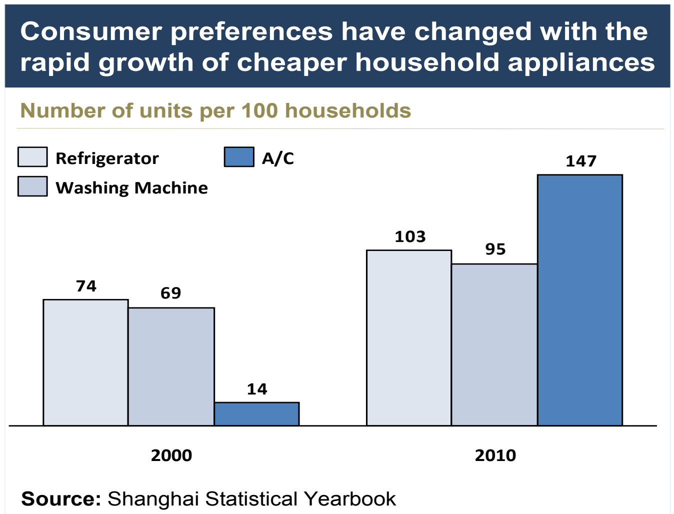


Figure 4–4 Use of Consumer Goods per 100 rural households in Shanghai (2000 v. 2010)

Shanghai municipal authorities are aware of these challenges; however, the view that residential consumption might not increase exponentially is also prevalent. For example, one expert suggested that one of the reasons why per capita residential consumption was low was due to the fact that "Chinese people generally conserve electricity at home" (by turning off the lights, opening windows, etc.). The vast majority of older residential buildings in Shanghai have not been constructed with centralized HVAC systems given the historically milder temperate climate. As the growth of indoor a/c units suggests, consumer preferences are changing in sync with their growing affluence as well as climate change. Last year, Shanghai broke a 140 year record for maximum temperatures (105.4º F or 40.8º C) and was over 100º F (37.8º C) for ten straight days between July 22nd and August 1st.

As new residential construction uses better technology and building materials for design and insulation, the demand for centralized HVAC systems will only grow. Several experts have pointed out that A/Cs and central heating are "increasingly becoming standard in affluent residential blocks", and integration through demand side management (DSM) systems is being piloted in select public and commercial buildings with plans to connect the entire city grid in the long run. However, robust investment in R&D in Demand Side Management (DSM) systems has been slow.

Lack of sufficient investment in R&D and DSM Technology

Demand side management (DSM) is an umbrella term that encompasses a wide range of industrial, IT and telecommunications related interventions to curb and manage electricity demand, including smart metering, virtual power plants (VPPs), online transmission and load management systems (see Section 4.2.2, "Investment in DSM and Smart Grid Technology"). DSM has emerged as a major theme in China's low carbon development initiatives.

Implementing DSM options has historically been limited by difficulties in obtaining adequate financing for capital investments and the problem of "split-incentives" (tenants/building operators don't benefit from making energy efficient choices).

4.1.2 Context: Reform and investment in the electricity sector

Investment environment

In China, utilities and government institutions have been making investments in three distinct areas – 1) improving infrastructure (transmission lines, DSM systems), also known as *strong grid* interventions; 2) adding digital auto demand response (DR) systems on the front-end and allowing for *smart* interactive engagement with the end-user; and 3) investment in R&D and smart-grid technologies (smart metering, VPPs, etc), as well as reform in business processes and management (through ESCOs). The idea is that the benefits of these disparate interventions can be integrated into a coherent *smart* electricity ecosystem – including internet portals (for online payments and monitoring usage) on the consumer side, and auto DR systems, smart metering and modified "shared control" thermostats on the transmission and distribution side.

In order to understand the current condition of smart-grid implementation across China and more specifically in Shanghai, it is essential to first understand the respective roles of key stakeholders in the decision-making process: public utilities companies (companies like State Grid Corporation of China–SGCC, Shanghai Electric), central government (NDRC, Ministry of Science and Technology), local government (Shanghai municipalities/districts), regulators (National Energy Agency- NEA, and State Electricity Regulatory Commission- SERC), power lobbies (China Electricity Council- CEC), and private sector foreign and domestic players (DSM technology and R&D companies like Honeywell, local equipment manufacturers, architecture and design firms, ESCOs, etc.). Each stakeholder has different interests: consumers want to pay less, utilities want to retain earnings, equipment manufacturers want to see higher investment in upgrades, and regulators want to meet performance and efficiency standards. Coordinating these interests in the context of electricity market reforms remains the biggest challenge for attracting investment in DSM and smart-grid technologies.

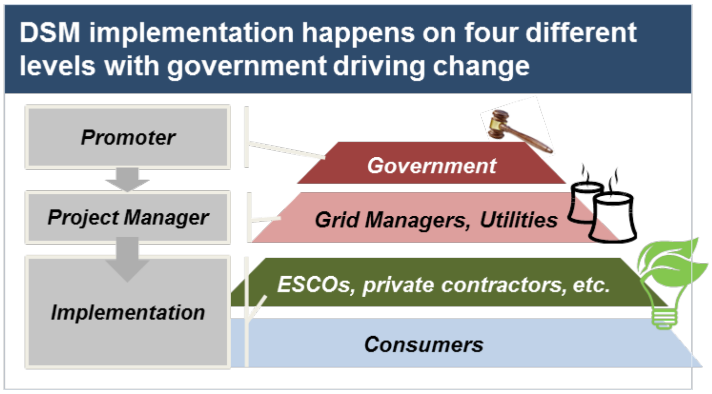


Figure 4–5 Government leads DSM strategy, but change driven by utilities (Hu et. al. 2013)

China's leaders have understood the need for electricity reform for over two decades. Prioritizing investment in DSM systems can be traced back to the first round of comprehensive reforms of the electricity sector (1989-1997) after the Ministry of Power was reorganized in 1997; reform separated the functions of the government from those of operations. This meant that while the burden of drafting legislation is now handled by provincial development and reform commissions or economic and trade commissions, actual DSM implementation is handled by power companies. In other words, electricity reform has made "power distribution companies the most qualified entities to implement DSM methods". (ESMAP, World Bank, 2005). The central government has become proactive in setting stringent targets, for the first time in 2010, the federal NDRC has instructed power companies to achieve annual dual targets of energy savings and load reduction of 0.3% (NDRC, 2011). However, in order for reform to be effective, target-setting needs to be accompanied by creating incentives for power companies to meet these targets.

In addition, public utilities often prefer to prioritize investment in upgrading infrastructure on the supply side (transmission & distribution) instead of at the end-user level, given the high, guaranteed return on investment. Lower retail prices and stringent performance targets have meant that utilities are unwilling to transfer capital investment on the demand side – while those stakeholders that do have these incentives (equipment manufacturers, building designers, developers, etc.) often lack access to capital. Table 4-1 shows that SGCC's forecast investment in *smart* technology focuses primarily on transmission and distribution (T&D) equipment, rather than smart meters or sensors on the end-user side, indicating this misallocation of resources and incentives.

Table 4-1 SGCC Investment Forecast in Smart-Grid Technologies

US $ Billions	2010	2011	2012	2013	2014	2015	CAGR
Software & Hardware	4	5	6.7	8.5	10.6	13	26.6%
Smart Meters	1	1.4	1.9	2.5	3.1	3.9	31.3%
Sensors	3.9	4.5	5.5	6.4	7.4	8.5	16.9%
Comm. & Wireless Infrastructure	2.5	3.6	5.1	6.9	9.3	12.5	38.0%
Smart T&D Equipment	4.5	6.5	9.4	13.1	17.1	21.2	36.3%
Other	1.1	1.3	1.5	1.8	2	2.3	15.9%
Total Smart Grid Investment	**17.1**	**22.3**	**30.1**	**39.2**	**49.6**	**61.4**	**29.1%**

Misaligned or split incentives

Another driver of the lack of investment has been misalignment or split incentives between different stakeholders. For example, building operators are not subsidized adequately to invest in energy efficiency retrofitting; or end-users are not penalized enough for overuse during peak hours. One key reason is pricing – as shown in Table 4-2 – electricity prices have been low in the past. Pressure from both market forces (rising demand) and government policies indicate they may increase significantly in the future. In 2012, the NDRC introduced time of use (ToU) pricing in phases all over China, putting pressure on average residential electricity prices to rise significantly in 15 different cities and provinces. In December 2013, the NDRC announced that by 2015, every house in the country should be equipped with smart-meters that charge consumers different prices based on the time of day or usage threshold, and had spend about $4.2 billion on installing 62 million smart meters. The rationale behind this policy shift is two-fold: firstly, the government wants to create incentives for end-users to curb demand (by conserving electricity and adopting more efficient appliances); and secondly to ensure that utilities are able to raise enough revenues to fund capital investments in DSM.

Table 4-2 Average electricity prices in select provinces and cities

Price in RMB/kWh	2008	2009	2010	CAGR
Beijing	0.337	0.308	0.28	-9%
Tianjin	0.346	0.317	0.29	-8%
Chongqing	0.366	0.336	0.3	-9%
Zhejiang	0.374	0.342	0.31	-9%
Shanghai	**0.385**	**0.351**	**0.32**	**-9%**
Tibet	0.399	0.346	0.29	-15%
Guangdong	0.445	0.408	0.37	-9%
Qinghai	0.245	0.224	0.21	-7%

There are several approaches the municipal government can use to optimize the investment environment: 1) aligning incentives between stakeholders by creating an optimal environment for ESCOs to provide adequate financing for retrofitting old buildings; 2) setting up government funded research and development institutes (for example, the Shanghai Energy Efficiency Center); 3) attracting foreign companies to invest in Shanghai's electricity market; and 4) taxing end-users, especially in the industrial sector to bear some of the investment burden. Currently the Shanghai government has introduced a number of such measures:

- **ToU pricing:** The main objective of this policy is to harmonize electricity pricing and incentivize lower peak use by charging time-of-use tariffs to the industrial and residential sectors. However, it is unclear whether this initiative will be able to nudge behavior in the residential sector, given that prices increases affected less than 20% of end-users. Furthermore, it remains to be seen whether any of the increased revenues will be directed towards investment in ESCOs and DSM programs in the city.

- **ESCO ecosystem and encouraging foreign investment:** The municipal government has undertaken several measures to encourage both domestic and foreign ESCOs – for e.g. in 2012, Honeywell conducted pilot DSM programs in Shanghai's Changning District as part of a broader US-China cooperation framework. Our team interviewed experts in Shanghai's Energy Efficiency Center (SEEC) on current activities being conducted – including surveying the entire electricity market (building a database of over 1000 companies), managing targeted subsidies to select players, and providing energy efficiency services (building testing, energy audits, advocacy training).

Despite these encouraging developments, Shanghai has to scale up investment and R&D in DSM and smart grid technologies, enhance the ESCO ecosystem and encourage demand reduction on the commercial and residential side through behavioral incentives. The following section will dissect these problems and investigate possible solutions through benchmarking best practices, and investigating opportunities to strengthen the existing policy framework for municipal, local and national level policymakers.

4.1.3 Research methodology

As mentioned above, the main objective of conducting the problem diagnostic in Section 4.1.1 and 4.1.2 was to extract key drivers of the challenges faced by municipal and national policymakers in introducing low carbon strategies on the operations/demand side. Through identifying key drivers that contribute to the lock-in effect, the following section will address potential opportunities to assist Shanghai city officials in developing a comprehensive low carbon development strategy. The relationship between the drivers, interventions and topics are shown in Table 4-3.

Table 4-3: Research framework

Key Drivers	Potential policy interventions	Opportunities
Rise of new migrants	- Mandate stringent standards for new construction (DSM, EE appliances) - Encourage retrofitting projects in older public buildings - Financial incentives to reduce peak load (time-of-use (ToU) pricing)	- Building operation certification standards and processes in Shanghai (Chapter 3) - Benchmark successful implementation of ToU tariffs
Changing preferences	- Conduct awareness campaigns on energy conservation and other advocacy activities - Incentivize both the use and manufacture of energy efficient appliances	- Efficacy of advocacy programs in modifying end-user behavior (Fudan University) - Evidence of impact of changing preferences in other developing countries and successful interventions
Challenging peak load management	- Set up ESCOs to finance investment in demand response - Install smart metering in new residential buildings	- International best practices for DR and DSM implementation
Inadequate financing structures	- Set up ESCOs to finance investment in demand response - Encourage foreign investment through partnership projects - Raise funds through innovative pricing	- Examples of successful ESCOs ecosystem that improved financing - Benchmark innovative public financing models that encourage green behavior (NY, Connecticut)
Misaligned incentives between stakeholders	- Create a market for energy efficiency certification for new buildings - Subsidize/incentivize building operators/tenants for DSM investment	- Benchmark other stakeholder ecosystems through case studies (Japan, UK)

4.2 Investigation and Policy Evaluation

4.2.1 Evaluation of current policy in Shanghai and identifying areas of focus

Having identified a number of key policy interventions and topic areas to further investigate, the following section will place these topics in the context of Shanghai's own policy framework and extract recommendations that could be useful for Shanghai's municipal government.

Current policy framework in Shanghai

It is important to understand the policy context of Shanghai – the most important metropolis in China. Figure 4–6 shows how Shanghai's overall CO2 emissions per capita has been high like other Chinese megacities (Beijing, Shenzhen, Guangzhou, etc.) with the main culprit being the industrial sector. While residential consumption is on par with other international cities, large numbers of new migrants have skewed the picture.

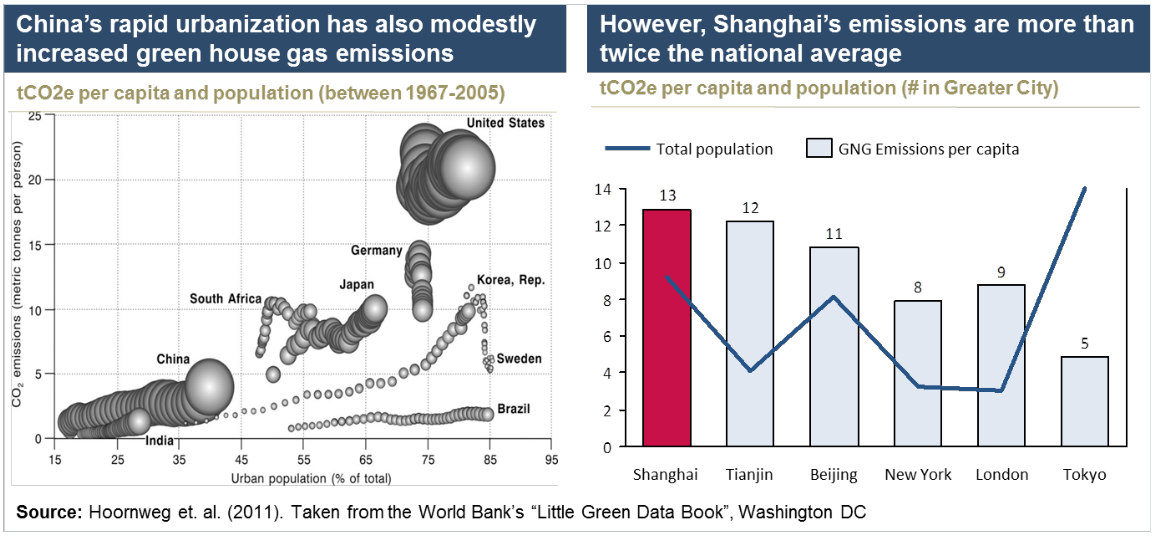


Figure 4–6 Global context of China and Shanghai's greenhouse gas emissions

Aside from the well-documented incidents of air-pollution plaguing Beijing and Shanghai, the push to reduce GNG emissions has spurred the central government into prioritizing low carbon strategies. The national strategy (formulated by both national and local NDRCs in the form of directives) for low carbon development includes specific targets on the provincial and local levels for both reducing CO2 emissions and improving energy efficiency (energy intensity v. consumption). Shanghai has been at the forefront of implementing these new regulations – in fact many of the NDRC funded infrastructure projects were first piloted in Shanghai before being rolled out nationally. Examples of this include interventions such as time of use pricing, smart metering, smart-grid upgrades, distributive generation (to use renewable energy) and innovative awareness campaigns.

As rapid urbanization put pressure on Shanghai's authorities and utilities to meet national goals, DSM was recognized as an opportunity to collect modest, long-term gains on energy demand.

Areas of focus

Dynamic pricing serve to solve two linked problems – 1) discourage electricity and energy use through price discrimination and; 2) raise funds for utilities and building operators to invest in operational efficiencies. In terms of demand incentives, **differential pricing** was introduced all over China (except in Xizang (Tibet) and Xinjiang provinces) in 2012 as part of the NDRC's electricity reforms. The results so far have been mixed – some have argued that the tiered pricing restrictions are too lax to affect behavioral change in the residential population, but are more effective in modifying behavior in the commercial and industrial sector.

In light of this context, our objectives for literature review are two-fold – identifying case studies where 1) innovative pricing models have been used to drive behavioral change and extracting lessons for Shanghai and 2) institutionalize the reinvestment of these funds into necessary DSM and *smart* infrastructure, and 3) leverage additional funding sources for investment (ESCOs, partnerships, CDM, etc.)

Investment in DSM and *smart* technologies reduces the long-term cost of meeting customers' energy demand growth through higher energy efficiency gains and effective load management. Though DSM first surfaced in China during the early 1990s, the urgency to invest in DSM programs was first felt during the early spring of 2008, when natural disasters (snowstorms, sleet) forced rolling blackouts in parts of southern and Western China. Given this need, investment has picked up and several cutting edge smart grid technologies are being piloted in the main Tier-1 cities including Shanghai, Shenzhen, Tianjin, Beijing, etc. Examples of such pilot projects in China include Honeywell TEDA SmartGrid implementation in Tianjin, or DSM implementation by the NDRC in public buildings in the Changning District of Shanghai.

The World Bank points out that "China lacks an adequate and stable DSM-funding mechanism. International experience shows that public and/or utility funding for DSM is critical to DSM success" (World Bank, 2008). One of the core focuses of this investigation is to uncover innovative financing models to incentivize investment in DSM and smart-grid technology (through ESCOs).

Behavioral incentives are an important subset of low carbon policy on the demand side – to ensure that consumption on the end-user side reduces overall through adopting energy efficient appliances, modifying behavior to conserve electricity (turning of the lights, closing windows, etc.) and conducting awareness campaigns on the merits of a "low carbon lifestyle". The Shanghai World Expo in 2010 provided an excellent opportunity for municipal authorities to solicit public participating in promoting awareness – with multiple PR campaigns organized by NGOs, government agencies and community groups, both during the run up to the EXPO, and during the EXPO itself. Examples include Earth Hour in 2009 (where 163 commercial buildings, 15 universities, 71 neighborhoods all turned off their exterior lighting during the stated hour).

Having said that, there are very few active international environmental NGOs in Shanghai (UNEP, 2010), and NGO engagement still remains relatively lower than in Beijing. Furthermore, there is very little research on the efficacy of low carbon public service campaigns in China – one example is the Fudan experiment, (Jiang et. al, 2013a) where the entire university campus participated in a low-carbon behavioral intervention pilot. Changing preferences are manifesting itself in widespread discontent about the lack of centralized HVAC systems in public buildings (malls, offices, etc.) and the resultant growth in space heating/cooling systems. Given that demand will only rise, awareness building will become essential. The literature review section (Section 4.3) will benchmark proven cases of effective advocacy campaigns combining community engagement and capacity building that have yielded results in changing end-user behavior.

4.2.2 Financial incentives

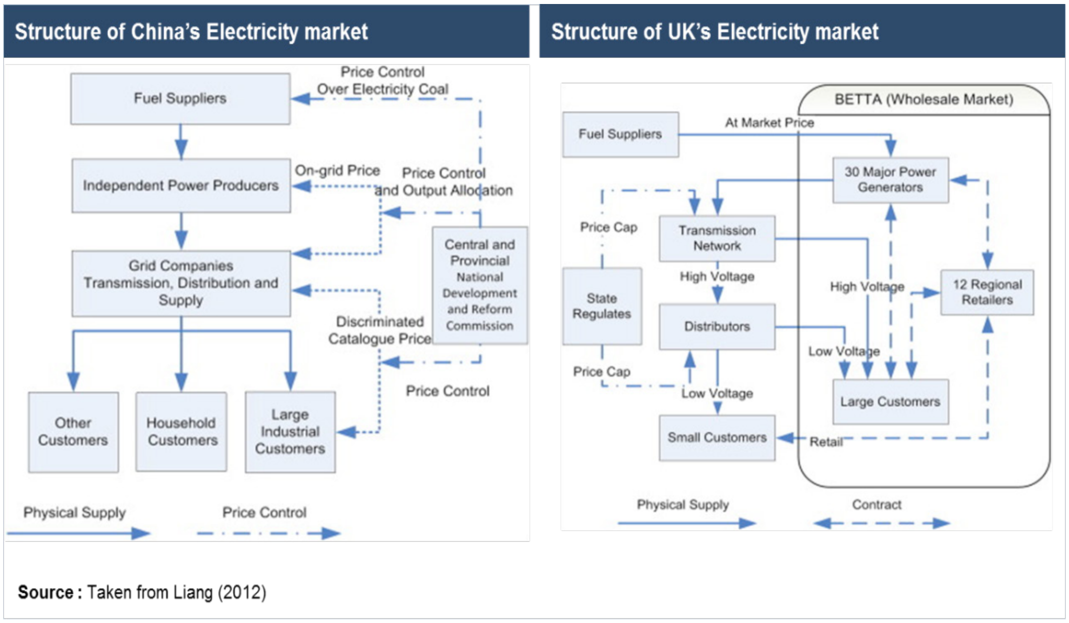


Figure 4–7 Key institutional structure of pricing decisions in China and UK electricity market

In this section, two separate topics exploring the role of financial incentives are examined: 1) innovative dynamic pricing models designed to incentivize lower demand; and 2) utilizing ESCOs and other funding mechanisms to raise capital for building operators and end-users to make necessary behavioral changes on the demand side. The report will conduct a thorough literature review on pricing models and extract the key lessons, while at the same time examine case studies both in China and overseas where funding for DSM and smart-grid technology has been robust. In order to do this, the current condition of the demand side of the electricity market in Shanghai must first be examined, starting with the institutional decision-making model and stakeholder incentives.

Market oriented v. "partially-reformed" electricity market

Liang (2012) has pointed out that China's electricity market is "partially-reformed" with market forces only directing low carbon investment in technology and R&D on the supply side (renewable energy like solar and wind) while neglecting the demand side of the market (transmission, demand management, end-users). China's central government policy has traditionally been to direct utilities to keep prices low, with tariffs being determined through limited bargaining between power companies (producers) and the NDRC and local authorities. Each power producer is given tailored prices at which it sells power to the grid. On the demand side however, provincial and local NDRCs to control prices that utilities (grid companies) ultimately receive from end-users, thereby leaving very little room for funds to be reinvested on upgrading transmission and demand response systems.

However, this changed in 2013, when the NDRC stopped setting the benchmark price for coal and allowed market forces to influence input prices to power companies. Much like the electricity market in the UK, where competition and vertical integration among the big power companies forces both retailers and producers to charge a premium to end-users (see Figure 4–7), the removal of "partial reforms" will propel end-user prices to go up significantly in the future, especially when coal prices rise due to increasing demand. According to calculations by Liang (2012), residential end-users are charged 79% higher than industrial consumers, while actual costs for power companies represent just 26% of price charged to residential and 11% to industrial end-users (indicating a high profit margin). Higher prices for residential end-users create direct incentives to both conserve energy and improve efficiency (by purchasing energy saving appliances, using less electricity generally, etc.). Increase in profits for power companies and retails are then re-invested to transform both the supply and demand side. This difference is critical for low carbon development. In a partially reformed market structure, financial incentives to increase investment in DSM and *smart* technologies are misaligned –neither utilities nor consumers have the correct financial motivation to improve energy efficiency and reduce demand – and therefore investments are only focused on the supply (transmission and distribution) side where returns are more direct.

Analysis of pricing model in Shanghai

Fixed electricity prices are a result of a **negotiated outcome** between different stakeholders of the electricity companies – 1) power companies, 2) grid operators, 3) NDRC (provincial and municipal) and 4) retailers/end-users leading to the loss of social surplus (as the absence of incentives to reinvest in demand-side infrastructure hampers energy efficiency) (Liang, 2012).

Table 4-4 Pricing schedule in Shanghai for residential customers

Tier	Electricity level (kwh/household/year)	Peak/Low period	Price (RMB/kWh)
1	0 – 3120	**Peak**	**0.617**
		Low	0.307
2	3120 – 4800	**Peak**	**0.677**
		Low	0.337
3	> 4800	**Peak**	**0.977**
		Low	0.487

Time of use (ToU) tariffs have been around for at least fifty years in the United States – and there is general scholarly consensus about the benefits of time-varied pricing versus time invariant pricing among economists and energy policy experts. Specifically, time-variant pricing works because "(a) the demand for electricity varies widely; (b) it is uneconomical to store electricity in most applications; and (c) the optimal mix of generating capacity to balance supply and demand at all hours given (a) and (b) can be achieved with more information on peak capacity and demand" (Wolfram & Joskow, 2011). In China, the NDRC has committed to time variant pricing through implementing a combination of block pricing (varying price according to amount used) and time-differential pricing (designating fixed prices during fixed periods).

The introduction of differential ToU tariffs all over China (including in Shanghai) in 2010 has tried to harmonize the pricing model – with average prices forecasted to rise by 4% since the change. Given that the vast majority of Shanghai's residential buildings have no central HVAC systems, municipal authorities announced that this "basic needs" ceiling (see Table 4-4, refer to Tier 1: 260 kWh per month or 3120 kWh per year) would be raised to 350 kWh per month during the summer (July & August) and winter (December & January) while remaining lower (210 kWh per month) during the rest of the year. Furthermore, "larger" households (forming about 18% of total households) will be given an additional 100 kWh per month.

However many experts (including renowned economist Mao Yushi) have warned that prices are not high enough to affect change – as more than 80% of households consume less than the electricity level specified in the Tier 1 ("basic needs" or 260 kWh per month) and would be entirely unaffected by the price rise. More importantly, Shanghai's current pricing model is not really "dynamic" – prices do not change in response to market conditions, and thus, efficiency gains through effectively managing peak demand are not realized to their full potential. At best, the ToU tariff structure *might* incentivize reduction of peak demand in less than 20% of the end-users in the residential sector, while showing better results in the public and commercial sectors given the higher tariffs (0.81 yuan per kWh, versus the average residential tariff of 0.47 yuan per kWh) and the long-term trend of increased A/C usage in both commercial and residential buildings.

Furthermore, demand in Shanghai is varied based on location – for e.g. in a 2009 World Bank survey of the primarily commercial Hongqiao area in Changning District residential electricity consumption accounted for just 17%, while commercial buildings accounted for 74% of the total. Even within the commercial sector, buildings in Hongqiao consumed 20% more energy than the average commercial building in Shanghai due to poor insulation and the inefficiency of air conditioning systems (World Bank, 2009).

Therefore, while ToU pricing is the first step in the right direction – considering additional measures to complement the use of pricing to influence demand is also critical. Demand is only going to increase rapidly in the next few years (energy consumption indicators on buildings, number of new migrants, rising standards of living all point to this trend). Secondly, demand is generally price inelastic in the short-run (there is an adjustment lag as new equipment and materials begin to penetrate the marketplace). Finally, demand is varied based on myriad factors (location, type of use, demographic profile) and specific, tailored responses (down to the district, block level) need to be designed for different circumstances. In the following section, we will discuss these lessons further, and draw from case studies elsewhere.

Lessons for Shanghai on pricing

1. ***Power demand will continue to grow:*** An average household in Australia consumed roughly 551 kWh per month (Australian Government, 2014), while commercial buildings in Hongqiao consumed more energy per floor area than in Japan, but significantly less than in the United States (World Bank, 2009) indicating significant room for demand to increase with increasing per capita income in Shanghai in both the residential and commercial sector. Further, changing preferences due to hotter summers (and increasing A/C use) and improved quality of life will continue to accelerate demand growth (Section 1.2.1).

2. ***Demand is price inelastic in the short run:*** Given that electricity consumption is a small

part of an average Shanghai household expenditure budget, people view peak use as a "necessity", and would rather bear the costs than make any significant modifications to behavior. Several studies in different cities where prices are low show this effect – for e.g. Thorsnes et al (2012) used Auckland data to demonstrate almost no effect on demand by higher prices in the short-run. Therefore, the NDRC needs to set prices high enough to elicit a significant demand response on the end-user side.

3. ***Demand varies significantly across different variables:*** Lillard & Agner (1984) first articulated the difference in demand responses between households with and without air conditioners in California – similarly, Shanghai's household consumption should significantly vary by time of day, temperature, household income, education, etc (Shi, 2012). In the commercial sector, the size of the property, the usage type (mall, hospital, etc.) and the location will also affect consumption. These differences need to be taken into account when designing the pricing model and additional measures need to be undertaken: for e.g. the rise of the use of space heating/air-conditioners means that implementing ToU alone will not elicit significant demand responses in the residential sector (as heating/cooling might be viewed as "basic necessities").

4. ***Demand can be made price-elastic in the long run:*** Two factors are said to be influential in increasing the price elasticity of demand – 1) the presence of enabling technologies (dynamic pricing as opposed to standard ToU pricing) and 2) behavioral interventions to counter changing preferences. Faruqui et al (2009) show long-term responses to ToU pricing of 2% to 6% annual drop in demand, a 10% to 12% drop through critical peak pricing (CPP), while the use of enabling technology combined with dynamic pricing show a dramatic drop of between 27% to 44% in the US. Phillipini (2011) shows how behavioral interventions have been effective to reduce demand in 22 Swiss cities. There are clear lessons for Shanghai's NDRC here: innovative pricing models need to be accompanied with relevant education for the customers, and increased control of demand by utilities through *smart* technology. In essence, demand can be made price-elastic if pricing models are designed alongside other measures.

5. ***Pricing models cannot be effective in isolation:*** Dynamic pricing has fast emerged as a much better alternative to more traditional ToU pricing models given that ToU prescribes a rather "rough" way to estimate expected generation costs (Wolfram & Joskow, 2011). Setting up the required *smart* infrastructure has been prohibitively costly in the past; however, technological advancement is improving communications (wireless) and metering technology (smart-meters) and significantly reducing costs in data transmission, storage, processing and acquisition. Furthermore, the NDRC has recognized that investment in DSM needs to be scaled up to accommodate rising demand, and with this in mind, Shanghai has been at the forefront with several DSM pilots (including setting up a virtual power plant (EPP) in Changning district) launched in recent years. Finally, educating the consumers is critically important in the successes of time variant pricing models – for example Toronto Hyrdo introduced ToU pricing without expensive investments in smart-meters in 2010, and its rapid adoption was credited to a well-designed, simple website, and excellent call-center training.

Investment in DSM and smart-grid technology

Shanghai's rapid urbanization has created an urgent need to effectively manage and distribute demand for electricity. To this end, gains through limiting losses (by improving transmission infrastructure) can be significantly complemented by savings through cutting costs during peak load times. However, in order for efficient allocation of peak capacity (supply), Shanghai will need to increase investment in demand side management (DSM) systems. In general, smart-grids use technology and impact demand on two distinct levels:

- *Distribution*: Smart-grids allow for both traditional power sources and renewable power sources to sell back to the grid (allowing for flexibility in distribution).
- *Consumption:* Demand response systems allow utilities to collect information on energy consumption in real-time, and then allocate capacity based on this information. Further, the introduction of smart-meters makes energy use visible to end-users, and provides them with the means to optimize energy consumption. However, this report focuses strictly on the demand-side impact of investing in DSM systems, without examining the supply-side implications.

One way to enhance demand is to create ancillary services markets – where consumers are incentivized to manage peak demand through obtaining financing for using energy efficient appliances, installing smart-meters in residential units, undertaking operational investments, etc. Steps have been taken in this direction with setting up of an ESCO (Energy Savings Company) ecosystem in Shanghai to institutionalize energy performance contracts (EPC). It is important to note that these steps are recent, and it will take time before these measures start bearing fruit, which is why it is important to examine specific case studies where similar measures have worked.

Analysis of ESCO Ecosystem in Shanghai

In general, a healthy ESCO ecosystem serve to create market incentives for financing energy savings projects (retrofitting buildings, installing smart meters, conducting monitoring and evaluation, etc.) and requires three important factors – 1) market access, 2) technological capability and 3) access to capital (through innovative financing – for example, energy savings performance contracts). The structure of financing is simple – the customer signs an energy performance contract (EPC) with an ESCO, and agrees to make performance-related payments throughout the duration of the contract (as energy efficiency is increased, the ESCO will directly receive revenues which come out of cost savings from the customer). The customer then takes this EPC and uses it as collateral to finance the project through lenders/investors. The resultant energy savings should ideally pay-back these initial costs over time (see Figure 4-8).

Given that the ESCO market in Shanghai (and more generally in China) is relatively new, access to the market and capital remain major hurdles. While there are plenty of smaller ESCOs providing similar services, EPC projects are generally fraught with three types of risks – 1) technological risks (related to ESCOs capacity); 2) capital risk (inability to obtain financing for projects) and 3) measurement risk (being able to verify energy savings accurately). In general, business owners, building operators, etc. are concerned about the technical and financial capacity of ESCOs – are they accurate in their predictions for energy savings? How are they supposed to articulate these risks associated with EPCs to financial intermediaries?

The Shanghai municipal government has conducted a number of initiatives to minimize these risks – most importantly by setting up the Shanghai Energy Conservation Service Industry Association" and "Shanghai Energy Performance Contracting Credit Rating and Financing Service Platform" in 2013 aimed to address two of the most prominent barriers: market access and capital financing. The former quasi-governmental body serves to regulate and incentivize the ESCO ecosystem – acting as a bridge between talent, technology, capital and projects so that competent ESCOs can have more efficient and targeted market access. The latter body serves to act as a bridge between existing ESCOs and financial institutions, providing technical assessments, and establishing a credit-rating system for ESCOs to clearly articulate risks associated with specific projects to obtain financing.

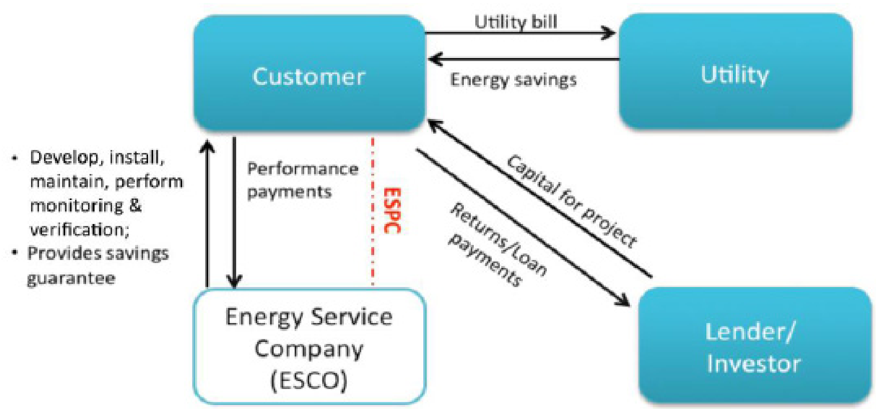


Figure 4–8 ESCO model structure (Kim 2013)

Furthermore, the municipal government's Economic and Information Technology Commission set up a special arrangement between the department and 13 local banks. These 13 local banks (including Bank of China Shanghai Branch, Shanghai Pudong Development Bank, etc.) together promise to give out loans worth 13 billion RMB to EPC projects during the 12th Five Year Plan period, with right to future earnings of ESCOs as collateral. The acceptance of the right to future earnings of ESCOs as collateral indirectly upgrades the credit ratings for ESCOs in the market – creating a direct financial incentive for ESCOs to pursue EPC projects, and reduces the financial burden on clients of ESCOs who would traditionally have to seek financing to bear the EPC project costs (Zhao, 2013).

Finally, the municipal government has set up the Shanghai Energy Efficiency Center (SEEC, a government-organized Non-Governmental Organization affiliated to Shanghai Economic and Information Technology Commission) to act as a liaison between ESCOs, energy users, third-party energy auditors and energy-saving equipment manufacturers by providing certification, conducting research, connecting experts and disseminating information. In 2013, the SEEC organized a large trade fair to match the needs of ESCOs with that of equipment manufacturers, consumers, etc. While these steps are welcome, they seek to address gaps in energy efficiency financing for two distinct types of end-users – public infrastructure buildings (government, schools, hospitals, etc.) and commercial buildings (shopping malls, hotels, etc.) without really solving financing gaps in the residential sector.

The importance of innovation in energy efficiency financing

According to Kim et. al (2013), there are several major hurdles in energy efficiency financing that could equally be applicable to both the residential and commercial sectors in Shanghai – 1) "first cost" hurdle (how to finance capital investments at no cost to the end-users, and how to incentivize potentially expensive, but more efficient upgrades); 2) timing mismatch (upgrades in existing buildings for HVAC systems might have longer lives than the current tenant's contract – especially where developers rent out properties through fixed contracts); 3) split incentives (see Section 4.2.1); 4) scalability (ensuring that smaller projects aggregate to larger ones); 5) existing property financial and contractual restrictions (mortgages, debt-financing) and 6) appraisal of baseline measurement (in performance contracts).

Myriad innovative financing structures have emerged, primarily in the United States, that leverage both conventional and new financing models to overcome the shortcomings of the EPC model. For example, one idea is to use energy services agreements (ESAs). Under the scheme, an ESA provider arranges for an ESCO to conduct the efficiency upgrades, and then owns finances and manages the improvements throughout the duration of the ESA, while the end-user continues to pay for energy saved ("negawatts"). Other variations of this model include MESAs (where the ESA provider manages all the customers' energy needs acting as an intermediary between the end-user and the utility) that remove both problems of timing and split incentives. There have been more recent innovations in energy financing, including PACE (Property Assessed Clean Energy – where local governments use land-backed municipal financing to manage "portfolios" of EPCs) and crowd-funding (getting several smaller investors to put money in an ESCO or set of projects). There are several structural lessons to learn by investigating each of these different types of financing models for Shanghai.

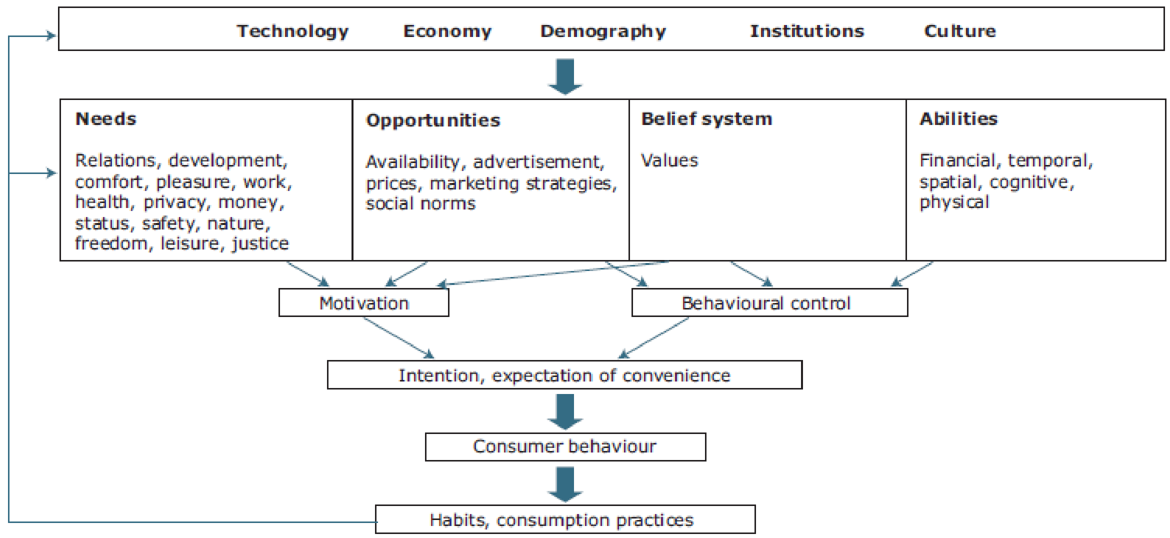
An additional related problem is of policy formulation – how to use public money for energy efficiency financing, especially in the context of China's (and Shanghai's) complex stakeholder landscape. An excellent benchmark is the Connecticut (U.S.) Clean Energy Finance and Investment Authority (CEFIA), notable for being the US's first "green bank". Set up in 2012, the CEFIA provides an extensive set of financing tools to the Connecticut Department of Energy and Environmental Protection, including the Commercial Property Assessed Clean Energy Program (C-PACE) to provide loan financing for commercial properties, a Special Capital Reserve Fund (SCRF) to issue bonds for programs that self-support from efficiency savings, a new electric conservation adjustment mechanism to allow the state to treat efficiency as a resource to be procured through customer rates at lower cost than generation resources, residential financing and a clean-tech fund to invest in R&D and DSM infrastructure . This "green bank" is financed from surcharges on residential and commercial electric bills (an additional "green tax") and federal funding, and is designed to leverage private capital (CEFIA, 2013). Viewing its successes, New York has announced a similar initiative – setting up a $1 billion dollar "green bank" to replicate the CEFIA's integrated approach (Governor of NY, 2014).

Lessons for Shanghai on energy financing

Similarly, the Shanghai municipal government must be proactive in applying these examples and taking the lead in ensuring that the ESCO ecosystem is strengthened, both by raising financing, and by smoother coordination and regulation. Creating financial incentives that benefit all stakeholders to invest in DSM projects is essential to ensure that both building operators and end-users are able to transform their behavior without too many switching costs. Specially, the following lessons can be learned:

1. **Split incentives can be overcome through innovative structuring:** The Shanghai municipal government should benchmark best practices in structuring financing – already some progress has been made with the introduction of the ESCO/EPC model.
2. **Certification of ESCOs and harmonizing performance standards:** Much of the business risk for building operators and ESCOs alike is the challenge of quantifying energy savings. Using the SEEC or similar quasi-government or non-profit body to regulate ESCOs and ensure performance measurement through similar standards is critical to ensuring that both end-users and ESCOs are able to have both market access and financing.
3. **Inclusion of financial institutions:** It is important to educate financial institutions about handling the credit-risk and culture of energy efficiency projects, and devise specific structural financial products intended to serve the sector. While some financing models might bear similarities to existing structures (for e.g. the ESCO/EPC model bears a resemblance to REITs), other models might require specialized training and education.
4. **Integration of supply and demand side financing**: ESCOs tend to be highly specialized given the different technologies required for specific projects. Therefore, relying solely on utilities to drive investment on the demand-side has obvious problems (split-incentives, differing end-users). One solution to this is the creation of an integrated government-driven financial institution (similar to NYC's recently launched "Green Bank") that will allocate funds to both the supply and demand side where necessary.
5. **Customizing financial incentives to end-user needs:** Different financing models work well with different types of end-users (for e.g. ESCOs/EPC model helps commercial and industrial users, but fails to drive change in the residential sector, where demand is price inelastic and timing/split-incentives hamper investment). Therefore, the municipal government needs to think about how to raise funds from different end-users differently (adding a system benefit charge (SBC) to residential users, might work better than ToU tariffs for e.g.). This will also help with raising awareness and bringing about behavioral change in both commercial and residential end-users.

4.2.3 Behavioral incentives



Source: Adapted from the NOA model described in Darton 'Methods and Models'.

Figure 4–9 The emergence of consumption practices (EEA 2013)

This section will address important issues at the intersection of human behavior and policy, specifically with the intention to enhance behavioral incentives to limit energy consumption in Shanghai. In order to avoid negative lock-in effects of rapid urbanization, it is necessary for all stakeholders involved - the Shanghai municipal government, power companies, environmental NGOs, community organizations, ESCOs, universities and even common citizens – to undergo a paradigm shift in mindset regarding energy conservation and efficiency. To do this, the government will need to orchestrate a clear strategy for building awareness that is evidence-based with proven efficacy (similar to the campaign during the 2010 Shanghai World Expo). This analysis will provide a framework for these stakeholders to think about designing effective behavioral incentives that drive measurable change.

Key drivers of behavioral change

Behavioral change has been studied by a multitude of different disciplines, including psychology, sociology and marketing, and several different behavioral models exist based on context and application. In Figure 4–9, we see that individual motivation and behavioral control are the two key drivers of behavior, while consumption practices are also impacted by external factors like technology, economy, institutions and culture. While traditional behavioral models have focused on individual consumption practices, recent research has shown that "collective consumption" practices (social norms) has a significant effect on modifying behavior – for e.g. successes in anti-tobacco marketing and legislation in the United States (Shove, 2003). However, literature review shows that for community engagement to be successful there needs to be a concrete, comprehensive set of goals that are part of a larger framework of initiatives (energy pricing, taxation, electricity reform, etc.) that are relatable to the intended audience. Examples of these include EcoTeams in the UK and the Netherlands, or the Shanghai "Green Expo" campaign.

Furthermore, direct and indirect feedback measures were found to be the most effective type of behavioral intervention for significant energy savings (see below). Feedback measures include any initiative designed to provide feedback to consumers on energy consumption – including the installation of smart-meters, display panels on appliances, consumption limiters, frequent bills with discounts on efficiency measures, dynamic pricing, informational updates from utilities, etc. More structured feedback measures also include energy audits (especially in the SME and commercial sector). In general, these measures work best in concert with community engagement and norm-building, as more information empowers people to reinforce enhanced social norms. These findings are corroborated by a recent study on Fudan University's low carbon efforts to induce behavioral change (Jiang et. al., 2013). Jiang argues that the traditional top-down approach of "simply telling people what to do" is not an effective strategy to motivate change – it is much more effective to foster a communal sense of responsibility and shift attitudes "intrinsically" rather than punitively.

Lessons from literature review

The European Union (EU) has been at the forefront of adopting behavioral interventions designed to elicit demand responses through a number of different directives (2005/89/EC on the adoption of real time demand management; 2006/32/EC on the introduction of smart-meters, etc.). Several types of interventions have been pioneered in many EU member states, including community engagement, energy audits, and a number of feedback measures (installation of smart-meters, enhanced billing and goal-setting, etc.). Literature review shows us several successes where such incentives have worked – for e.g. NRGi's smart-meter rollout in Denmark (between 2009 and 2012) or Finland's monthly feedback and energy-saving advice program. This study will focus on two areas that proved particularly effective in spurring behavioral change –feedback measures and community engagement.

Direct Feedback Measures: By far the most effective behavioral intervention, direct feedback measures are designed to empower the end-user through accurate, real-time information on consumption and provide avenues for goal-setting and designing financial incentives (dynamic pricing). According to a recent study of residential demand response in 57 countries, (Donnely et al, 2010) energy savings of direct feedback ranged between 5% and 15%.

One of the most common methods is the installation of smart-meters, which could be coupled with real-time displays (RTDs) and interactive feedback through a multitude of networked media where payments could be made via smart-cards or online. In the past, the main hurdle to incorporating smart-meters in households has been the required costs for installation – in fact till 2010, just 1% of United States residential consumers were billed using ToU principles, and only a small number of U.S. utilities offered dynamic pricing given that consumers were generally put off by higher electricity bills (due to the fact that each smart-meter cost between $250 to $500 in 2009). With technological improvement, costs to install smart-meters have dropped - Glen Canyon, a San Antonio based manufacturer has supplied smart meters to China for under $25 in 2012, given that Yuanta Securities estimates that the Chinese government's ideal price for meters is around $32 (John, 2012).

Smart-metering programs have been implemented in most EU member states, starting in 2009

– with mixed results due to patchy implementation (Figure 4–10). Experts have argued that smart-metering should be accompanied with a clear strategy to elicit demand response.

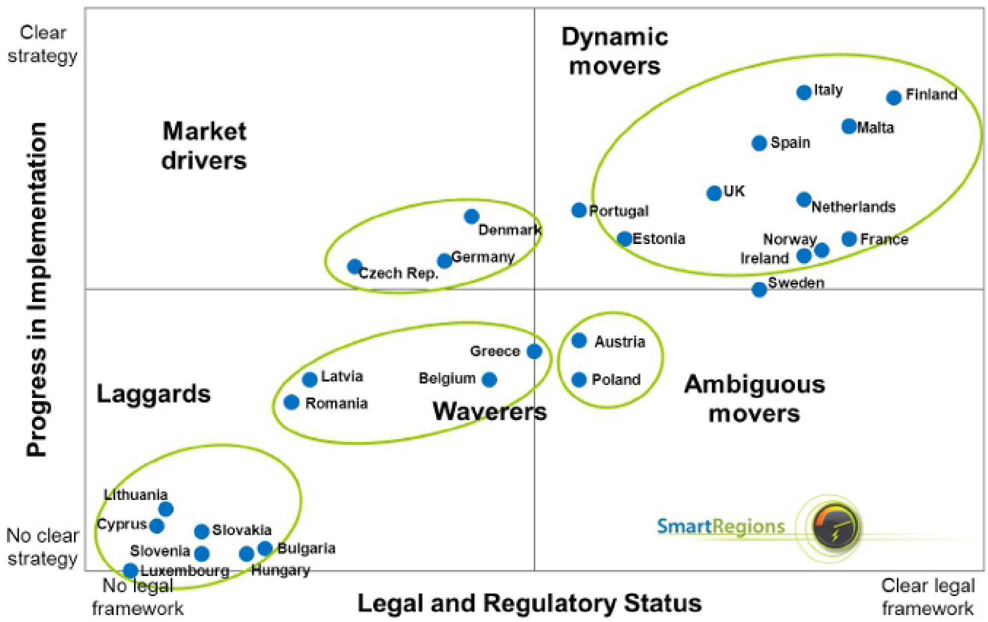


Figure 4–10 Implementation of Smart-Metering Programs in the EU (EEA, 2013)

Indirect feedback measures: Enhanced billing has been significantly effective in incentivizing behavioral change – with energy savings in the range of 4% to 19% (EEA, 2013). In general, enhanced billing can be described as providing end-users with detailed, frequent and accurate consumption information, while also supplying offers, rebates, discounts on energy saving activities (energy audits, etc.). This combination of indirect feedback catalyzes mindset shifts, as end-users break established patterns of consumption through improved information and reflection. Enhanced billing also often includes the possibility of goal-setting, which has proven to be remarkably effective in several studies (Becker, 1978; De Young, 1993; McCalley & Madden, 2002). Through goal-setting, end-users are supplied with historical consumption information, and a consumption roadmap to meet targets which directly influences their consumption habits. These benchmarks can be implemented directly by the Shanghai municipal government by mandating power companies to provide feedback, while also rolling out smart-metering programs.

Community-based initiatives: Pro-environmental behavioral change has traditionally relied on public awareness campaigns utilizing mass media for advocacy and outreach. However, community-based interventions have been gaining currency in recent years, where groups of likeminded people (between 10 and 100 people) come together and decide on certain behavioral modifications and advocacy efforts. The context is important – most of these groups comprise of neighbors, co-workers, students, etc. – people who already have established, trust-based relationships with each other.

Further, these types of interventions work best as part of a comprehensive program of behavioral incentives (often involving feedback measures) or in light of some larger context (e.g. Shanghai Expo). The key success factors of these interventions lie in the duration of engagement – often these initiatives comprise of prolonged, frequent contact with beneficial information – leading to the creation of new social norms and stronger motivation for change. For example, one study examining the impact of Dutch EcoTeams (Fisher & Irvine, 2010) found that even after two years of the program's conclusion, treatment groups were continuing to maintain or improve performance. There are several lessons for the Shanghai municipal government on how to design such initiatives in an implementable fashion – through engaging the private sector (corporate social responsibility), empowering NGOs and involving other stakeholders (sponsorships by power companies, etc.).

Other policy options: Several other policy options exist – including building certification, appliance labeling and efficient design, distributive generation, transportation alternatives (EVs, bicycles), stricter regulation, public-service campaigns, etc. that have all been showed to be effective in inducing behavioral change. These approaches have had mixed successes contingent on contextual factors – and therefore for the purposes of this study, they have been omitted. The most important takeaway in evaluating policy options is that of evidence-based design: the Shanghai government needs to commission similar projects and devise an integrated strategy that is durable, sustainable and effective.

4.3 Recommendations

This chapter has focused on uncovering insights on the end-user side of energy use in Shanghai, specifically in the residential and commercial sectors and different approaches to induce change and lower both consumption and emissions. The key drivers of increasing consumption – rapid urbanization, changing preferences and lack of investment in DSM and *smart* infrastructure have propelled Shanghai on a path of unsustainable growth in energy use. Given below are a set of general recommendations in the form of financial and behavioral incentives that could potentially mitigate the risk of high energy consumption:

1. **Encourage participation of all stakeholders in reform:** Reform of the electricity market should be ongoing, and should seek to align stakeholder incentives on low-carbon development. Liberalizing pricing to reflect input costs should help create monetary incentives for end-users, while innovative structuring of markets (ESCOs, ESAs, etc.) will allow for new players to provide viable low carbon services. For example, financial institutions will be incentivized to build capacity in energy efficiency financing only if government makes energy efficiency markets more accessible through regulation that empowers the ESCO ecosystem. Furthermore, increased engagement with end-users through feedback measures and community-level initiatives will result in greater energy savings. Therefore, the Shanghai municipal government should conduct a comprehensive stakeholder mapping exercise and identify areas where they could solicit increased participation in policymaking, especially during the planning phase.

2. **Improve information/measurement:** Much of the risk associated with financing DSM investment involve energy baseline measurement, and this problem can only be solved through better use of technology to provide transparent, engaging information to both end-users (building operators, tenants) and power companies. Further, feedback measures are widely seen as effective to curb consumption. Therefore, improving

information should be a critical priority for the municipal government – through measures such as the installation of smart-meters, displays on public buildings, frequent billing and goal-setting, etc.

3. **Reform electricity pricing:** Evidence has shown that ToU pricing is not effective in reducing energy consumption when prices are low. Dynamic pricing incorporates real-time information to drive consumption behavior (through price increases). However, it is also important to educate and engage consumers while introducing time-based pricing – as lack of information will likely mean resistance from end-users (as electricity bills will rise). Shanghai's power companies can learn a lot from utilities such as PG&E and Arizona's Salt River Project who have managed demand responses through a combination of providing clear information and installing smart-metering while creating cost-savings through efficient allocation, as well as lower consumption. When utilities are able to explain cost-savings to customers, there will be much less resistance to higher prices (this is done through adding surcharges, providing subsidies, etc.)

4. **Empower ESCOs through innovative financing:** Shanghai has already made good progress by engaging with financial institutions in energy efficiency financing, and improving credit risk through setting performance standards. However, Shanghai can also learn from examples overseas – integrating energy efficiency financing models through a centralized "Green Bank" and actively energizing the ESCO ecosystem through joint ventures with private companies (for expertise in project management) through favorable regulations, tax incentives, etc.

5. **Actively rollout feedback measures:** Shanghai's NDRC should partner with utilities and consider conducting feasibility studies on installing smart-meters and providing detailed direct and indirect feedback to end-users. The national-level NDRC has already promised a large-scale rollout of most households by 2015. This should be accompanied with additional feedback measures including enhanced billing, goal-setting, periodic detailed updates, etc.

6. **Introduce integrated community based initiatives:** The Shanghai Municipal Government should actively seek models of effective community-based engagement and implement an integrated campaign that targets behavior change at all steps of the consumption cycle that is tailored to different end-users (in the residential and commercial sectors). Furthermore, through actively engaging all stakeholders involved (consumers, landlords, offices, utility companies, ESCOs, NGOs, etc.), the government should drive an integrated plan of action that is not only expansive, but directly measurable through creating platforms for periodic monitoring of behavior.

Reference List: Chapter 4

Australia Government, 2014, Energy Made Easy. URL: http://energymadeeasy.gov.au/bill-benchmark/results/3660/4 . Accessed on February 20th 2014.

Becker L.,1978, Joint effect of feedback and goal setting on performance: a field study of residentioal energy conservation, J Applied Psycholoigy 63, 428–433.

Chen, F., Zhu, D., 2013. Theoretical research on low-carbon city and empirical study of Shanghai. Habitat International 37, 33–42.

Clean Energy Finance and Investment Authority (CFEIA), 2013, The State of Connecticut. Comprehensive Plan, FY2013 through FY2015. URL: http://www.ctcleanenergy.com/Portals/0/FY13%20Comprehensive%20Plan.pdf . Accessed on December 26th 2013.

De Young, 1993, Changing behaviour and making it stick: the conceptualisation and management of conservation behaviour, 25 (4), 485–505

Ehrhardt-Martinez, Karen; Donnelly, Kat A. and John A. 'Skip' Laitner. 2010. 'Advanced Metering Initiatives and Residential Feedback Programs: A Meta- Review for Household Electricity-Saving Opportunities', Washington, D.C.: American Council for an EnergyEfficient Economy.

Fisher, J., and Irvine, K., 2010, Reducing household energy use and carbon emissions: the potential for promoting significant and durable changes through group participation, Paper presented at the IESD PhD Conference: Energy and Sustainable Development, Leicester, United Kingdom

Governor of New York, Press Office, 2014. Governor Cuomo Annouces NY Green Bank is Open for Business, Published in Albany, NY on February 11th 2014. URL: http://www.governor.ny.gov/press/02112014Green-Bank . Accessed on February 20th 2014.

Gu, Q., Ren, H., Gao, W., Ren, J., 2012. Integrated assessment of combined cooling heating and power systems under different design and management options for residential buildings in Shanghai. Energy and Buildings 51, 143–152.

Huang, B., Yang, H., Mauerhofer, V., Guo, R., 2012. Sustainability assessment of low carbon technologies–case study of the building sector in China. Journal of Cleaner Production 32, 244–250.

Jiang, M.P., Tovey, K., 2010. Overcoming barriers to implementation of carbon reduction strategies in large commercial buildings in China. Building and Environment 45, 856–864.

Jiang, P., Chen, Y., Xu, B., Dong, W., Kennedy, E., 2013a. Building low carbon communities in China: The role of individual's behaviour change and engagement. Energy Policy 60, 611–620.

Jiang, P., Dong, W., Kung, Y., Geng, Y., 2013b. Analysing co-benefits of the energy conservation and carbon reduction in China's large commercial buildings. Journal of Cleaner Production 58, 112–120.

John, J., 2012, Glen Canyon Promises the $25 smart meter, GreenTech Media, January 6th 2012.

Accessed on December 25th 2013.

Li, B., Yao, R., 2012. Building energy efficiency for sustainable development in China: challenges and opportunities. Building Research & Information 40, 417–431.

Li, J., Colombier, M., 2009. Managing carbon emissions in China through building energy efficiency. Journal of Environmental Management 90, 2436–2447.

Li, L., Chen, C., Xie, S., Huang, C., Cheng, Z., Wang, H., Wang, Y., Huang, H., Lu, J., Dhakal, S., 2010a. Energy demand and carbon emissions under different development scenarios for Shanghai, China. Energy Policy 38, 4797–4807.

Li, L., Chen, C., Xie, S., Huang, C., Cheng, Z., Wang, H., Wang, Y., Huang, H., Lu, J., Dhakal, S., 2010b. Energy demand and carbon emissions under different development scenarios for Shanghai, China. Energy Policy 38, 4797–4807.

Liwen, F., Huiru, Z., Sen, G., 2012. An Analysis on the Low-carbon Benefits of Smart Grid of China. Physics Procedia 24, Part A, 328–336.

Ma, J., 2011. On-grid electricity tariffs in China: Development, reform and prospects. Energy Policy 39, 2633–2645.

Mao Yushi, 2012, Dialogue on Low-Carbon Road, Transcript published in China Daily. URL: http://www.chinadaily.com.cn/bizchina/lowcarbon/mao.html. Accessed on February 20th 2014.

Price, L., Zhou, N., Fridley, D., Ohshita, S., Lu, H., Zheng, N., Fino-Chen, C., 2013. Development of a low-carbon indicator system for China. Habitat International 37, 4–21.

Ru, G., Xiaojing, C., Xinyu, Y., Yankuan, L., Dahe, J., Fengting, L., 2010a. The strategy of energy-related carbon emission reduction in Shanghai. Energy Policy 38, 633–638.

Ru, G., Xiaojing, C., Xinyu, Y., Yankuan, L., Dahe, J., Fengting, L., 2010b. The strategy of energy-related carbon emission reduction in Shanghai. Energy Policy 38, 633–638.

Shanghai Daily, 2012, 20% Facing Higher Power Bills. Published in Shanghai on April 12th 2012. URL: http://www.china.org.cn/business/2012-04/27/content_25253392.htm. Accessed on December 26th 2013.

Shove, E.,2003, 'Converging conventions of comfort, cleanliness and convenience.' In: Journal of Consumer Policy, Vol. 26, No. 4, 12.2003, p. 395–418.

Yu, Y., 2010. Policy redesign for solving the financial bottleneck in demand side management (DSM) in China. Energy Policy 38, 6101–6110.

Yu, Y., 2012. How to fit demand side management (DSM) into current Chinese electricity system reform? Energy Economics 34, 549–557.

Chapter 5: **Conclusions**

The purpose of this investigation was to provide recommendations for the Shanghai Municipal Government to mitigate high-carbon lock-in from its rapid urban expansion. Chapters 2, 3 and 4 provided recommendations for specific policy reforms in the policy areas of land use planning and transportation, building energy efficiency and electricity end use. This chapter describes three overarching principles that were identified as crucial for enhancing policy design and implementation in these areas.

Enhancing policy design and implementation

This report highlighted a range of opportunities for the Shanghai Municipal Government to mitigate high carbon lock-in by reforming current policies. These reforms should prioritize the following three principles for policy design and implementation:

1. Use of evidence and data for policy design.
2. Incorporation of externalities into cost and benefit considerations.
3. Anticipating changing trends and incorporating flexibility mechanisms into policy design and management.

Evidence-based policy making and goal setting

The Shanghai development Masterplan 2001-2020's failure to predict the city's growth trajectory has already cost the city, and cannot be repeated in the next development cycle. An evidence-based policy design framework must first begin with improving the city's ability to gather accurate and reliable data. With reliable data on end user energy consumption behavior, transit development impact and existing building efficiency ratings, it will inform the authority on how to draft the most optimal plans.

At the same time, a wide range of opinions from different stakeholders that are not commonly sought after before (civil societies, utility operators, etc.) shall be included in the new round of design planning, these stakeholders' opinions and know-hows will include valuable insights on different aspects of the city's new town development, including building code design and demand side incentives, which will give policy makers a more comprehensive scope in designing future policies.

Externality-inclusive policy design

The social and environmental externalities created by rapid urban expansion must be taken into calculation in the cost-benefit analysis of Shanghai's future new town development, including exponential growth in energy consumption, and increase in GNG emissions. A standardized unit reflecting the economic impact of externalities should be adopted to allow policy makers to have a clear metric to rank the impact of different policies.

Similar design should also be incorporated in the building code design process, where the code design should not just take into consideration construction and operating costs, but also public externalities, such as impacts on health and the environment. Externality measurement would also be useful to incorporate in determining flexibly energy pricing mechanism that will reflect the actual cost of energy consumption to mitigate macroeconomic shocks.

Adaptive policy management

Technology advancement and behavioral pattern are unpredictable and constantly changing. It is very likely that a best-designed plan will be outdated within months after it completes a long approval process. As a result, flexibility must be built into the design process to ensure the policies can react to the rapidly changing environment.

In the planning phrase, a more market-based transit oriented development (TOD) model will improve Shanghai's ability to react to potential market shifts due to social or technological factors. At the construction level, building code design must also take into consideration future technological and behavioral changes. On the operation side, flexible pricing mechanisms and financial incentive schemes will give the policy maker a stronger tool to selectively nudge different parts of the energy consumption cycle. Furthermore, ideas for innovation to influence behavioral change could be fueled through benchmarking exercises from successful case studies.

The need for urgent action

As Shanghai's urban expansion continues the city risks locking in high carbon emissions and inefficient energy use for decades to come. The carbon footprint of new town developments is heavily impacted by the Shanghai Municipal Government's policies for land use planning and transportation, building energy efficiency and electricity end-use. Under current policies, these developments are planned with insufficient access to public transportation, new buildings are inefficient and opportunities to encourage efficient energy use by building occupants are missed.

Shanghai cannot afford the costs of high-carbon lock-in. Continued increases in private vehicle use and energy demand require expensive expansions of road networks and the electricity supply system. These systems are also having an untenable impact on the citizens of Shanghai, through the illness driven by air pollution and traffic congestion. Increases in energy demand and private vehicle use also contribute to climate change, which will be a major threat to Shanghai's environment in the long term.

This report aims to lay the groundwork for potential policy approaches to tackle this problem. Through implementing recommendations provided in each of the three phases of urbanization – planning, construction and operations, the Shanghai Municipal Government can shift to a low carbon development strategy.

Appendix A: **China's Energy Consumption**

To satiate the rapidly growing energy demand of the country, China has increased its imported energy in the past few years (Figure 5–1). The economic cost and environmental impact associated with this surge of energy demand will soon become a hindrance to China's continuous development. The Chinese government has recently elevated low carbon and sustainable energy development among one of the country's top priorities.

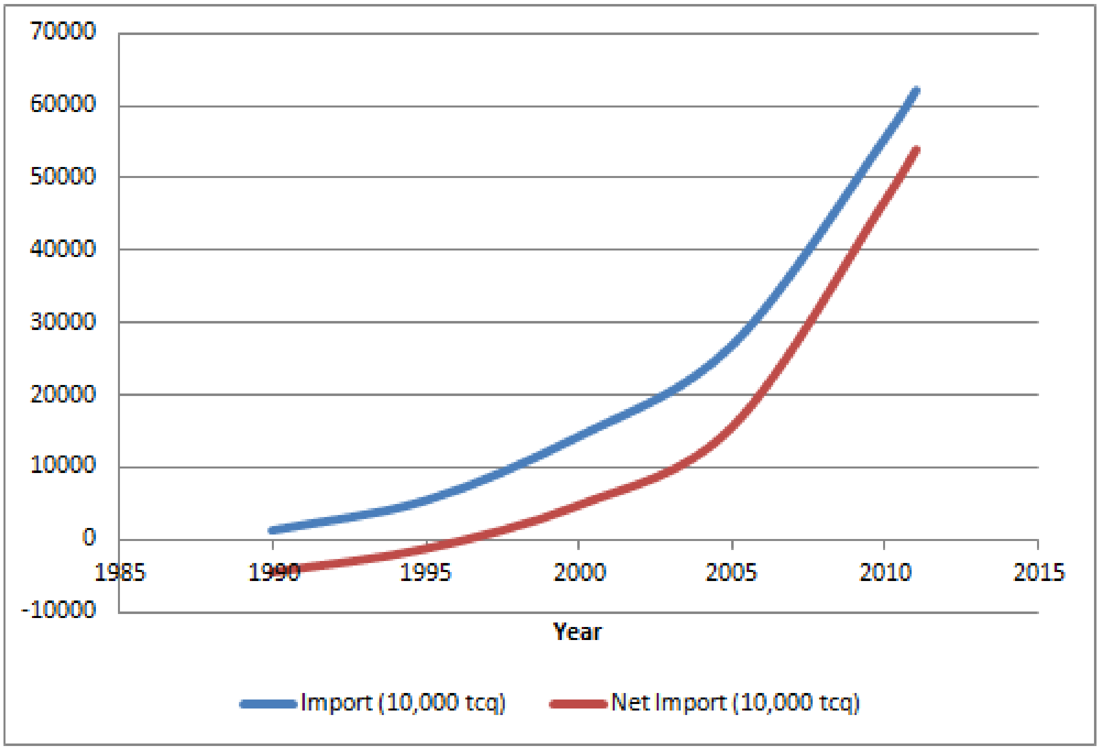


Figure 5–1. China's Total Energy Import and Net Import in Recent Years (China Statistical Yearbook 2013)

	11th FYP (2006 – 2010) (Target)	11th FYP (Actual)	12th FYP (2011 – 2015) (Target)	13th FYP (2016 – 2020) (Target)
Indicator				
Energy Intensity (% reduction in 5 years)	20%	19.1%	16%	Not Set
Carbon Intensity (% reduction in 5 years)	Not Set		17%	40-45% vs 2005
New Energy (% of generating capacity)	10%	9.6%	-	15%
Growth Rates				
Primary Energy Consumption (Annual Growth)	4%	6.3%	3.75-5%	-
Electricity Energy Consumption (Annual Growth)	-	11%	8.5%	(5.5%)
Electricity Generating Capacity (Annual Growth)	8.4%	13.2%	8.5%	(5.6%)
GDP (Annual Growth)	7.5%	10.6%	7%	-

Table 5-1. Key Energy and Climate Policy Goals and Indicators in China (2006 - 2020) (Delivering Low Carbon Growth)

Appendix B: **International Low Carbon City Concepts**

Low-carbon city is a concept that focuses on reducing the challenges associated with rapid urbanization and climate change. The World Bank and ICLEI – Local Governments for Sustainability have already introduced a series of initiatives to help cities around the world better plan and design their own low-carbon development paths (Liu et al. 2009).

United Kingdom

The concept of low-carbon city was first introduced by the United Kingdom (UK) in the government's 2003 published report – "Our Energy Future: Creating a Low Carbon Economy". In the report it stated that the idea of low carbon economy is to improve economic production and living standard by reducing the reliance on nonrenewable energy sources and limiting the associated environmental damages. Through the opportunity to develop and export new technologies, UK would create new job opportunities and sustain the country's future development. UK set a target of reducing CO_2 emission level by 20% (of 1990 level) in 2010 and 60% (of 1990 level) in 2050. To facilitate the cooperation between the private and public sector in developing low carbon technology, a private organization – Carbon Trust – was established. Three pilot cities (Bristol, Leeds and Manchester) were included initially in the Carbon Trust's Low Carbon Cities Programme (LCCP), and major objectives included:

- Setting carbon emission reduction as standard for evaluating policies
- Promoting the application of renewable energy, improving energy efficiency level and controlling energy demand
- Emphasizing carbon emission reduction in buildings and transport
- Combining the strategic and application aspects of policies (focus on policies that have the highest impact-cost ratio)
- Promoting low carbon life style in city, enlisting public involvement and support

In essence, the UK model emphasizes on improving the efficiency of its low-carbon energy source, and tries to reduce the carbon emission through technological breakthrough in key energy sectors.

Japan

Japan has a different concept about low-carbon city, which focuses heavily on reducing the country's overall carbon emission level as well as managing its energy consumption behaviors. In 2007, Japan set the target CO_2 emission reduction to 70% of 1990 level in 2050. In a 2008 report, titled "A Dozen Actions towards Low-Carbon Societies", it stated three principles in guiding the country's low carbon development policies:

1. Reduce carbon emission in all government agencies

2. Transform society from consuming high quantity to high quality of energy

3. Reinforce the mandate to protect and conserve the environment

According to the "2050 Japan Low- Carbon Society scenario", the key features of Japan's low carbon society development included:

- Adopting a flexible low carbon development strategy: Plan A focuses on creating clusters of high-density city to improve efficiency and maintain GDP output; Plan B focuses on diffusing population and resources to create a less energy-intense life style

- All government agencies / departments have to minimize their individual carbon emission level

- Encouraging private sector to provide more low carbon products, and promoting low carbon products (solar panel) to facilitate shift in household life style and energy consumption behavior

- Focusing low carbon policy application on transport, residential buildings, industry, consumption behavior, agricultural and forestry sectors, etc.

- Government to take control of low carbon development agenda: through improving public transport network, introducing environmental tax, subsidizing low carbon economic development, etc.

- The Japanese understanding of low carbon city is geared more towards changing the behaviors of its citizens and agencies, and through the efforts of its public sector to reset the country's energy consumption pattern.

China

With its rapid urbanization pace and rise of megacities, the concept of low-carbon city would have a critical impact on China's future low carbon development. Because of the country's unique development characteristics, China's idea of low-carbon city is heavily subjected to its policy agendas. Government needs to take initiative to spearhead low carbon policies, with strong supports from the market (private sector) and household.

One of the leading arguments in China is that the country could not fully adopt developed countries' low carbon development strategy, and the country's low carbon policies must not jeopardize the its economic growth (Liu et al. 2009). The concept of building a low-carbon city with Chinese characteristics is to plan the city's future low carbon development through shifting the existing economic development model, consumption mentality and life style, with the guarantee of continuous improvement of living quality. This idea includes:

- Sustainable development
- Reduce the carbon emission rate in comparison with the rate of social development (decoupling)
- Contribute to global effort to reduce carbon emission (either through local carbon emission reduction or through application of native technology in other regions)
- Innovative technology and system (requires public involvement to make sure effective policy implementation)

The bottom line here is that China's low carbon development must take into account its rapid economic development, and the country is only adopting policies to minimize carbon emission that would guarantee a certain threshold of economic development.

Appendix C: **Chapter 2 Tables and Figures**

Table A1: Population in Shanghai by District, 2000-2009

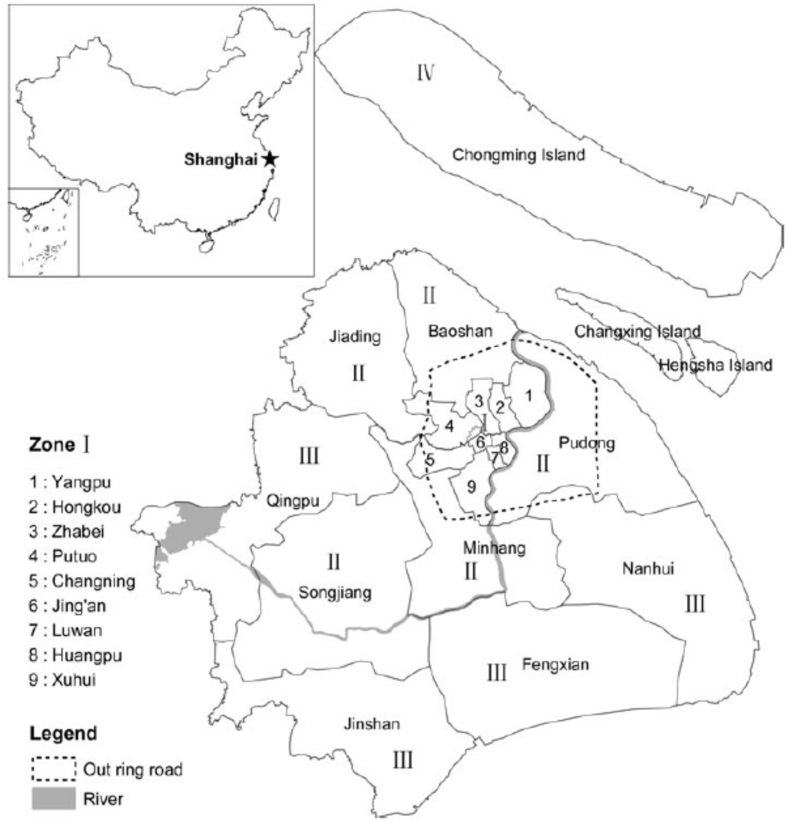
Zone I	**2000**	**2005**	**2009**
Yangpu	127.63	120.32	120.62
Hongkou	94.74	78.26	77.08
Zhabei	85.23	75.81	76.03
Putuo	107.38	110.6	113.59
Changning	76.76	67.18	64.4
Jing'an	40.44	25.65	24.84
Luwan	40.44	27.13	26.94
Huangpu	75.61	50.88	53.2
Xuhui	110.08	98.59	96.27
Total	**758.31**	**654.42**	**652.97**
Change		***0.863***	***0.998***
Zone II	**2000**	**2005**	**2009**
Pudong New Area	238.42	279.19	419.05
Baoshan	118.39	130.54	136.55
Minhang	113.5	170.76	181.43
Jiading	74.04	94.28	110.54
Songjiang	68.6	88.58	118.99
Total	**612.95**	**763.35**	**966.56**
Change		***1.245***	***1.266***
Zone III & IV	**2000**	**2005**	**2009**
Jinshan	59.09	59.21	69.1
Qingpu	62.71	73.75	81.55
Nanhui	81.45	88.57	**
Fengxian	63.48	73.44	81.9
Chongming	70.76	65.68	69.24
Total	**337.49**	**360.65**	**301.79**
Change		***1.069***	***1.109***

Source: China Statistical Yearbook

Note: Zone I districts are in the city core; Zone II districts are located along or just outside the Outer Ring Road; and Zone III and IV districts are outlying (Yue et al. 2012)
**Note: In 2009 Nanhui was merged with Pudong.

Figure A1: Districts of Shanghai

Fig. 1 Location and administrative divisions of Shanghai



Source: (Yue et al. 2012)

Appendix D: **Overview of Building Energy Efficiency and Policy Options**

Table 5-2 lists the major opportunities for energy efficiency in the building envelope and heating/cooling/ventilation system categories.

Table 5-2 Building energy efficiency opportunities by category ((International Energy Agency (IEA) 2013) p. 244)

Category	Building energy efficiency opportunities
Building envelope	Passive design Advanced facades Insulation Reflective roofing Air sealing High efficiency windows
Heating, cooling and ventilation systems	High-efficiency gas space heating Ground-source heat pumps Gas thermal heat pumps High-efficiency gas water heating Heat pump water heating Solar heating and cooling

Goals for comprehensive BEE policy frameworks

The following three goals incorporate this uncertainty and provide a comprehensive set of objectives for BEE policy:

1. **Optimal investment in established BEE measures:** New residential and public buildings are constructed using all BEE measures that are economically justified over the lifetime of the building.

2. **Demand for new technologies and innovations:** There are incentives for the construction industry to test and deploy new innovations that have the potential to provide net economic benefits.

3. **Research and development for new innovations:** There is ongoing investment in innovative research and development of new energy-saving technologies and techniques by the construction industry, as well as universities and government research agencies.

Market barriers to BEE investment

As described in Chapter 3, the technologies used in BEE investments vary in their stage of technological maturity and market development. Established technologies, that have been available for many years, are affected by different barriers to new technologies that have not yet been tested in the market.

Figure 5–2 is a basic schematic showing the main stages of technology maturation, the dominant market barriers at each stage and the aim of government interventions in each stage.

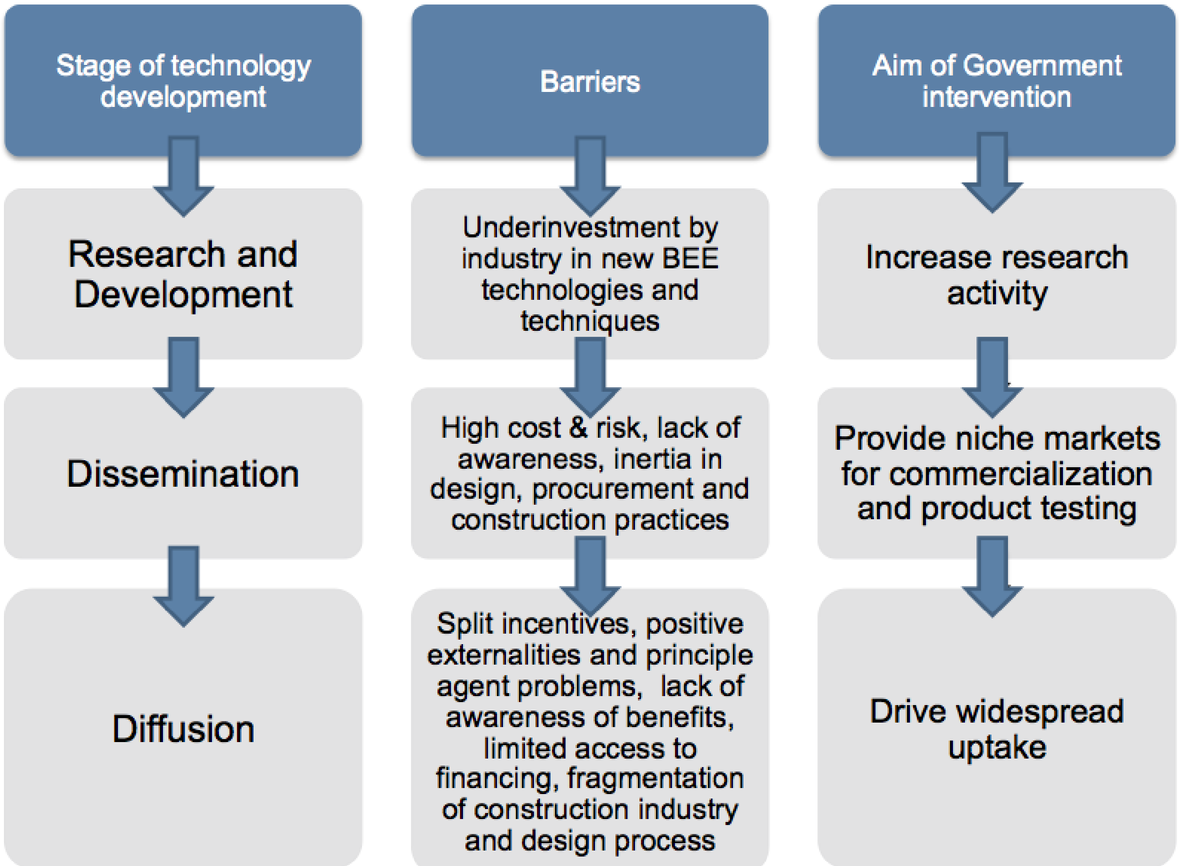


Figure 5–2 Stages of technology development, market barriers and government actions (International Energy Agency (IEA) 2013) and (J. Li and Colombier 2009)

Policy options for BEE

Table 5-3 lists commonly used policy options for targeting BEE opportunities at various stages of technological maturity. Some of the most prominent policy instruments are described in more detail in the following sections.

Table 5-3 Component-level and system-level policy options for building energy efficiency

Technological development stage	Policy options
Research and development	Government funding for research and development Forums for industry, government, university collaboration
Dissemination/early market development	Public procurement programs Labeling and certification programs Marketing and public education programs Financial incentives
Mature technology	Mandatory minimum energy performance standards Building energy codes High-efficiency district heating systems[24]

The policy options listed in Table 5-3 can be used to target individual building components, or the entire building as a system. For example, mandatory minimum energy performance standards can apply to a single appliance, such as an air-conditioning system, or to a building as a whole using a building energy code. Similarly, research and development funding can be provided to programs focused on a single technology, or to programs focused on whole-building approaches to efficiency improvement.

The major policy options from each category are discussed in more detail below.

Funding research and development

Public funding of universities and research agencies for BEE innovations can overcome the underinvestment in R&D by private actors. Government-sponsored R&D will be most likely to produce innovations that are successful in the market if there is significant consultation with private industry actors on where to target funding (Gann, Wang, and Hawkins 1998).

The government can also encourage private R&D activity by providing companies with financial incentives, such as tax exemptions for R&D spending.

Dissemination policies/early market development

For technologies at the dissemination stage, policies that lead to marginal increases in demand for the opportunity include measures to increase awareness of the opportunity and its benefits, or financial incentives for its purchase.

[24] District heating is sometimes used to provide space heating for buildings in cold climates. In Shanghai there is currently no district heating. The scale and complexity of system required suggests that a significant feasibility study would be required. This issue is not pursued in this report.

Labeling and certification programs are the most commonly used policies for increasing awareness of specific BEE opportunities. Labeling has been used for large energy-consuming equipment such as water heaters, air conditioners and appliances. New and advanced products can receive a high rating that makes them attractive to buyers who are willing to pay a premium for energy or environmental benefits. Certification programs have been used in a similar fashion to promote leading energy efficient buildings that go beyond the efficiency level dictated by compulsory regulations.

Financial incentives can be used to reduce the upfront costs of high-efficiency technologies and increase their initial market share. Commonly used incentives include tax credits and policies that increase access to financing for BEE projects.

Additional information on BEE codes

An effective BEE code has the following characteristics (IEA 2013b):

- Suitable to local climate: The code is tailored for the local climate.
- Flexible and up-to-date: Balances stability and certainty for industry with evaluation and updates to reflect changes in the availability and cost-effectiveness of BEE technologies.
- Broad coverage: Covers all major BEE opportunities that are cost-effective to implement at the design and construction stage, including the building envelope, heating, cooling and ventilation equipment. Some BEE codes also cover electric lighting.
- Balances prescriptive vs. performance specifications: discussed below.

Prescriptive versus performance-based specifications

Performance-based specifications set a maximum level of energy use for the building, usually according to floor space. The use of performance-based specifications gives industry the flexibility to comply with a BEE code using a variety of techniques or approaches, fostering creativity and innovation. It also allows industry actors to meet BEE requirements in the most cost-efficient method available for their circumstances.

Many jurisdictions, including California and Japan, have implemented performance-based BEE codes that also contain prescriptive measures for some pieces of equipment (IEA 2013b). The use of targeted prescriptive measures is important for ensuring the use of high-efficiency technologies or techniques that face significant market barriers. In the absence of a prescriptive specification, there would be low uptake by industry of these measures, leading to a strong risk of technological stagnation.

The prescriptive approach can also be used to target specific appliances or pieces of equipment using mandatory minimum energy performance standards (MEPS). MEPS have been used successfully to phase out the use of inefficient air conditioning systems, water heaters and appliances in countries such as Japan (Kimura 2010). MEPS are usually set at a national level to provide a clear signal to equipment manufacturers and importers and prevent carbon leakage from equipment being moved between jurisdictions with different standards. China has had national MEPS for a range of BEE products, including air conditioners, since 1990 (IEA 2007).

Appendix E: **Building Energy Efficiency in Japan**

This appendix describes Japan's approach to building energy efficiency policy, highlighting useful lessons for Shanghai.

Energy efficiency policy in Japan before 2011

Japan imports most of its fossil fuel energy supply and has made energy efficiency a policy priority since the oil crises of the 1970s. Historically, the most aggressive policies have focused on increasing the efficiency of energy-consuming machinery, equipment and appliances. Energy prices in Japan are also higher than in most OECD countries, which has encouraged the development of efficient practices and behaviors by consumers.

In 2011, following the Fukushima nuclear accident and shutdown of many nuclear power plants, Japan's energy supply challenges were exacerbated, forcing the Government to reassess its energy efficiency policies. The policy review found that since 1990 energy consumption in the residential and commercial sectors had grown more rapidly than the transportation and industrial sectors (METI 2013). Improving BEE was identified as a policy priority for strengthening the existing energy efficiency framework.

Policy implementation: stakeholder management issues

Prior to the 2011 review, Japan did not have compulsory BEE codes. Voluntary standards for public and residential buildings were first introduced in 1980, and then reviewed in 1993 and 1999. Despite the historical lack of compulsory BEE codes, Japanese residences are among the most efficient in the OECD. This is shown in Figure 5–3, which shows the climate corrected primary energy consumption per household in a range of countries.

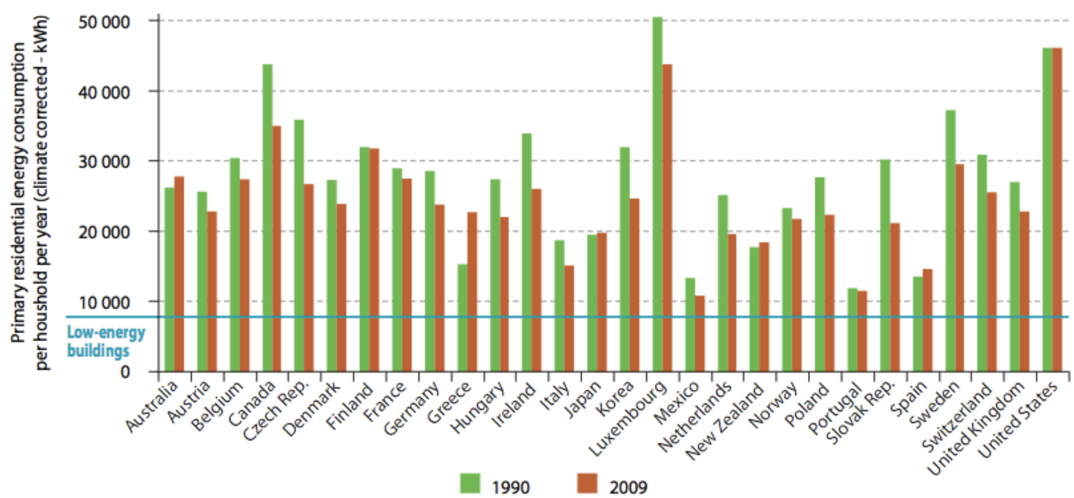


Figure 5–3 Climate corrected annual residential primary energy consumption per household in kWh (OECD 2013b, page 39)

Since the initial development of building energy standards there have been multiple proposals to convert them to compulsory standards. However, each time there has been resistance from various stakeholders, particularly within the construction industry (MLITT 2013). The housing construction industry in Japan is quite fragmented, with a large number of small companies. According to some experts, a compulsory BEE code would have been a significant burden for these companies.

The delay in implementing a compulsory code was also justified by some stakeholders because the success of other energy efficiency programs meant that houses already had low energy use, so the benefits of improving building envelope efficiency would not be substantial (METI 2014). However, the 2011 policy review found that there was significant potential for energy savings by improving building envelope performance.

Since this review, there has been further resistance to implementing a compulsory code. Public buildings and houses have been divided into compliance categories, with the implementation dates for the codes staggered from 2017 to 2020, which represents a considerable delay.

The Japanese experience highlights the long-term advantage Shanghai will gain from implementing compulsory BEE codes early on, rather than relying on voluntary standards. In Japan, some companies chose to comply with the voluntary standards, did not change their practices and continued to construct buildings with poor envelope performance. In 2008 only 18% of houses satisfied the 1999 standard. This had increased to 48% by 2011. For public buildings the percentage satisfying the standards was greater than 80% from 2004 to 2011.

Another consequence was that demand for high-efficiency materials, especially building insulation and windows, has not grown rapidly enough to encourage innovation in this industry. Compared to countries such as Germany and the UK, the availability of cost-effective efficient materials is relatively low. In response to this, the Ministry for Economy, Trade and Industry (METI) has included building insulation and windows in the Top Runner Program, Japan's flagship energy efficiency policy.

Over the next few years, manufacturers of these products will have to meet mandatory targets for the efficiency of these products. They will also have to meet cost targets for the products, to ensure they remain affordable. A panel of industry experts and METI officials sets the standards. The most efficient manufacturer in the industry is named the 'Top Runner', and usually forms the baseline for the standard, with an additional 'technological improvement factor'.

The Top Runner Program has been used to drive substantial efficiency improvements in automobiles, refrigerators, air conditioners and other products. The inclusion of building materials reveals that the Government believes there are significant efficiency gains in building envelopes that have been overlooked for the past decade or so.

Policy design: Using data for effective code development

Stakeholder opposition has been a major barrier to implementing BEE codes in Japan. A major strength of the Japanese process has been the collection and use of sophisticated data and modeling techniques to design the BEE code.

Since the first voluntary standard was developed in 1980, a range of stakeholders have been involved in gathering data on building energy use and developing expertise in building energy modeling. This activity is coordinated by the Ministry of Land, Infrastructure, Transport and Tourism (MLITT). Other major departments, including METI and the Ministry of Environment, are also involved however to ensure that BEE policies are consistent with the Government's broader goals in energy conservation.

When the major review of the standards occurred after 2011, there was already considerable capacity within MLITT and its partner organizations to develop an effective BEE code that achieves the following:

- Mandates an efficient BEE level based on extensive analysis of data collected since 1980. This includes information about energy consumption trends in different building types, as well as data on the energy characteristics of buildings themselves, such as how heat loss is distributed across different building elements (windows, ventilation, etc.) in different building types.
- Balances performance and prescriptive measures to allow construction companies to minimize their costs whilst still complying with the minimum level of BEE.
- Encourages buildings to install BEE measures beyond the code, with the long-term goal of achieving zero-energy buildings, through a 'eco-points' system that engages homebuyers.

Conclusion

Japan's major strength in BEE code development has been the involvement of a range of stakeholders in data collection and modeling, for designing an efficient code. Various government and non-government stakeholders have been involved in this policy area since the first standard was developed in 1980. The current code is designed to prepare the construction industry for the long term goal of zero-energy buildings in Japan.

Since 1980, the construction industry has resisted the implementation of these codes, and the delay in implementing a compulsory code has had significant negative consequences. Compliance with the voluntary standard was low, and Japan has constructed many buildings with poor envelope efficiency, locking in higher energy use than there would have been under a compulsory code. The ongoing resistance has led to further delays in code implementation, such that all buildings will not have to comply until 2020.

The construction materials industry has also lagged behind international best practice in producing low-cost, high-efficiency insulation and window products. The Japanese Government has been forced to play catch-up by including these products in the Top Runner program, to force the industry to improve energy efficiency performance.

References

Ministry of Economy, Trade and Industry (METI). 2014. "Research Interview for Policy Analysis Exercise. Ministry of Economy, Trade and Industry Agency for Natural Resources."

METI. 2013. "Trends in Final Energy Consumption in Japan". Presentation. Tokyo, Japan: Ministry of Economy, Trade and Industry.

Ministry of Land, Infrastructure, Transport and Tourism (MLITT). 2013. "Policy and Programs for Energy Efficient Houses and Buildings in Japan". Presentation. Tokyo, Japan: Ministry of Land, Infrastructure, Transport and Tourism.

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