SUSTAINABLE ENERGY AND URBAN FORM IN CHINA:

THE RELEVANCE OF COMMUNITY ENERGY MANAGEMENT

by

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B.A. Honours Carleton University 1995

RESEARCH PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF NATURAL RESOURCE MANAGEMENT
in the

School of Resource and Environmental Management

Report No. 218

SIMON FRASER UNIVERSITY

December 1998

Approval

Abstract

Chinese cities are experiencing major environmental effects from fossil fuel based energy consumption for mainly residential and, increasingly, urban transportation uses. Community Energy Management (CEM) is a sustainable energy strategy which looks at how purposely shaping the built environment and designing urban services in consideration of energy production, distribution and use could affect both the long term demand for energy and type of energy. This approach is particularly relevant to Chinese cities because of considerable expansions in urban infrastructure and building stock.

This study explores what CEM is in a Chinese context by analyzing trends in land use planning, urban transportation and residential energy, and then suggesting CEM strategies that would be appropriate in directing urban development towards a more sustainable energy path. Key strategies include the following.

- Maintaining and encouraging land use that will reduce the demand for travel and stimulate the penetration of environmentally benign energy supply technologies such as district energy.
- Reducing travel by personal motorized vehicle modes through transportation management.
- Encouraging site and building design that minimizes heat and cooling energy losses to the environment.
- Encouraging local energy supply and delivery systems such as renewable energy, cleaner fuels and more efficient use of coal energy.

Based on this analysis, a spreadsheet model was built that evaluates the aggregate energy-related emissions in the year 2010 from two alternative scenarios of urban growth throughout China. The scenarios evaluated are a ‘Development of Current Trends’ scenario which reflects trends that have occurred since China began a pattern of rapid economic growth, and a ‘Community Energy Management’ scenario which incorporates a number of CEM strategies into future urban development. The model focuses on how energy demand, residential energy technology penetration and transportation mode choices are affected by factors of density, mix of use in neighbourhood development, development control, energy technology penetration and transportation mode choice. The results of this modelling exercise suggest that China can achieve urban residential and transportation emissions reductions of approximately 14% for CO_2, 10% for SO_2, 40% for NO_x and 14% for particulate emissions in 2010.

Issues around the implementation of CEM are also addressed by examining key institutional and policy issues involved in land use planning, site and building design, alternative energy supply and transportation management. Recommendations and implementation strategies are then suggested. Key recommendations include:

- Consistent and transparent procedures in urban planning and energy project evaluation need to take place
- Urban planning needs to recognize the relationships between comprehensively developed housing projects and the location of the workplace since that link is no longer directly made as part of economic development.
- The development of a leasehold land system rather than a system based on private land ownership is favourable because the state can specify development requirements favorable to CEM objectives.
- Programs to encourage energy supply and energy efficiency need to take advantage of changes to ownership and financing structures.
- Policies and investment across energy subsectors need to be better coordinated.

Acknowledgments

Many thanks to those who have seen me through my Masters degree quest:

- My supervisory committee, fellow students and ERG researchers for their research guidance.
- The Canadian Institute of Energy and Simon Fraser University for their financial assistance.
- My family, friends and partner for their encouragement, patience and support.

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Introduction

Under its present course of industrialization, energy demand in China is projected to triple by 2020. Energy supply to meet this demand is to be met primarily through the use of coal, and through centralized mega-generation projects. Additionally, a shift towards increased automobile use is augmenting the demand for other fossil fuels -- the entire motor vehicle fleet averaged a 15 percent annual growth between 1985 and 1993 (Stares and Liu Zhi, 1996). The environmental implications of this trend, including increases in atmospheric pollution and productive land destruction, are major. China's combustion of high-sulfur coal (mainly in the Southwest) has worsened acid precipitation both in China and in Southeast Asia.[1] China is the world's second largest carbon emitter. Considering the continuing central role of coal in projected energy use, significant growth of CO_2 emissions is expected.

In seeking ways to minimize the environmental impacts of energy use, countries have begun shifting the focus in energy development towards planning in relation to the end use demand for energy, primarily at a technology use rate, technology and building scale. A further focus has been to examine how purposely shaping the built environment and designing urban services in consideration of energy production, distribution and use, could affect the long term demand for energy and type of energy supplied. This approach has loosely been termed, 'community energy management' (CEM) or 'community energy planning' (CEP). It is based on the premise that a significant proportion of future residential, commercial and transportation energy consumption is predetermined when land use and urban form is designated.

This energy policy perspective may be particularly relevant to China, since it is experiencing rapid urbanization from a relaxation of residence restrictions, as well as from a high economic growth rate which focuses on urban industrialization. It took three decades for China's urban population to double from about 10 to 20 per cent of the total population, whereas it more than doubled to over 50 percent in only eight years in the 1980s (Xiangming Chen, 1991). The rate of new urban infrastructure and construction has corresponded with this demographic shift. One study estimates that at least one half of all the urban structure in China, measured in terms of square meters, was added during the last

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[1] The acid rain problem has extended to the region beyond both the Yangtze and the Yellow Rivers, and now encompasses an area of 2.8 million km^2 (Byrne et. al., 1996).

decade alone (World Bank,1993a). Given these trends, consideration of CEM is crucial in addressing China's energy challenges.

Study Objectives

This study will focus on examining the potential benefits of adopting a community energy management approach in Chinese urban areas.[2] The primary objectives of this study are to determine:

1. What CEM is in a Chinese context and how it would differ from the present approach, specifically in terms of land use planning, transportation management, site and building design, and energy supply strategies.
2. Why a CEM approach is important and relevant to Chinese energy policy.
3. What the specific environmental and economic benefits of this approach are, including potential effects on CO_2, SO_2, NO_x and particulate emissions.
4. How present institutional and economic structures may facilitate or limit the application of CEM, and to discuss, given these constraints, how CEM could be implemented (also outlining institutional and economic reforms that could be relevant to successfully implementing CEM).

Report Structure

Chapter One provides background information on the unique aspects of urban form and energy use in China, and uses this to develop CEM approaches and strategies in a Chinese context. Chapter Two presents a broad estimate of the environmental benefits of applying CEM by evaluating the aggregate energy-related air emissions from two alternative scenarios of urban growth. Chapter Three attempts to address some of the major issues around how CEM could be implemented, by exploring the

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[2] Energy issues for the residential and commercial sectors have had minimal importance in China's energy planning (Feng Liu, 1993). Additionally, while the rural energy situation in developing countries has been the object of a large amount of study, there has been comparatively little research on urban energy use (Sathaye, 1989).

institutional and economic characteristics of present urban infrastructure and energy decisions. Implications of this study are drawn together in the conclusion.

Chapter 1

CEM and Chinese Urban Areas

Community Energy Management (CEM) is directed at residential, commercial and transportation energy use. CEM studies have been primarily undertaken in an industrialized country context where the nature and composition of residential, commercial and urban transportation, as well as urban spatial form are considerably different than in China. This chapter presents background research relating to these aspects and then goes on to suggest CEM strategies that are appropriate to China. The scope of this study is limited to exploring CEM's application to urban areas, and thus the background information and strategies focus on this aspect.[1]

1.1 Background Research

1.1.1 Chinese Urban Spatial Form

Unlike urban areas in North America and Europe, the specialization of districts in a central business core, industrial parks and suburban residential development, has not significantly taken place in China. Prominent characteristics of Chinese urban form are high density, continuously built up city cores, and lower density post-1949 suburbs characterized by mixed use and low rise standardized development. The majority of Chinese buildings are single-storey or low rise (2-3 stories), and commercial space is interspersed with residential space. In addition, much of a city's industry, factories and warehouses are located in the built up areas of the city, often within the boundaries of the 1949 city. During the 1950s through to the early 1970s, urban planning was limited. Due to the responsibility of work units to provide not only employment but housing and other services to its workers, the 'work unit compound', a mixed use urban form within walled compounds, was the principal unit of constructed urban space.[2] For example, the oil industry city of Rengin consists of 20 large courtyards occupied by 98,000 people (Hu Zhaoling & Foggin, 1995). New construction during this time period tended to locate wherever

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[1] Rural residential energy is remarkably different than urban.

[2] Economic production and employment has been organized through 'work units.' They remain a fundamental organizational feature of Chinese society. In addition to providing housing and employment space, facilities within work unit compounds often include dining halls, provision shops, medical facilities, recreation facilities, meeting rooms, and administrative offices.

vacant land was available, regardless of land use compatibility (Fulong Wu, 1997). The building density of this area is generally low (Gar-On Yeh & Fulong Wu, 1995).

Cities still have a large portion of pre-1950s building structures which complicate any simple characterization of the urban form. Many Chinese also continue to live in housing separated from their workplace, and in housing not provided by their own work unit. Older dwellings are found in the core of the cities, which are quite dense compared to those found in North America. The infrastructure in the central areas of cities is generally poorly serviced. Most of the existing urban roads, except those that are newly built, are narrow and in poor condition. The ratio of road to land space is also low compared with other countries. The peripheries of many large urban areas contain 'satellite towns' which are sited 20 to 40 km from the city centres to draw urban populations away from them. They are disconnected from the built-up area of the city and use land quite extravagantly.[3] They also rely on substantial regional transport networks, because of the lack of local services and close job proximity. Basic infrastructure development is not advanced in satellite towns because resources have been spread quite thinly.

Major changes to land use patterns are taking place. For example, a study which examines changes in land use patterns between 1986 and 1993 in Shanghai found that there has been a 'dramatic' change in the spatial distributions of employment and population -- residential growth is now mostly located at the periphery, employment growth in the central district, and mixed land use is disappearing (Qing Shen, 1997). Urban areas are developing more specialized forms at many scales, resembling increasingly what is seen in the West. Trends in land use patterns include:

- The formation of central business districts through the large scale addition of office buildings in the city centre.
- The development of residential districts, often on the urban fringes.
- The reduction of residential densities.
- The relocation of manufacturing and industrial firms from city centre to suburbs.
- Targeted development zones, new subcentres and foreign enclaves.
- The separation of commercial, retail and social spaces from residential ones.

- The restoration of some historical districts.

(Stares & Liu Zhi, 1996; Gaubatz, 1995; Hu Zhooliang & Foggin, 1995; Qing Shen, 1997; Fulong Wu 1997)

Changes in urban land use patterns are attributed to a reduction in the planning power of individual work unit compounds, an increase in overall municipal planning, and the proliferation of work units which are too small to provide housing. Large work units are also purchasing housing in peripherally located developments in order to relieve overcrowding in their more conveniently located but aging work unit compounds (Gaubatz,1995).[4] The self-sufficient closed yard style construction has been widely abandoned (Yichun Xie & Costa, 1993). Ideally, new housing developments are expected to provide a variety of social services for their residents in order to maintain 'convenience' in the residential system, but few of them achieve the ideals of functional integration (Gaubatz, 1995).[5] There is greater freedom to choose where to live. The trends mentioned above are likely to increase the number of commuters.

Strong economic growth beginning in the early 1970s has resulted in a fast-paced, piecemeal development of outlying areas of cities particularly along highways, which is forming a radial fringe-belt pattern marked by poor institutional and public infrastructure (Wu Jin, 1993). For example, in Hangzhou a huge zone of disjointed, low-density residential and industrial development called the 'Northern Extension' emerged during the 1980s (World Bank, 1993a). This growth is represented by both an outward expansion of the city guided by the municipality, and rural initiatives of setting up industrial enterprises close to the city. This growth has been guided by a preference for developing greenfield sites. Planned development of new satellite towns also characterizes urban fringe development, although they are more commonly named 'Economic Development Districts'. For example, both Guangzhou and Shanghai have extensive planned development of this nature. The more recent attempts at satellite settlements have established industry in advance of infrastructure. The pace of employee housing construction often does not match that of the workplace construction, and as a result inner-city residents commute to outlying areas. Those employees who relocate to the outlying

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[3] Minghang and Wujing, satellite towns of Shanghai, have a land area per person density in 1990 of 145.21 m^2/person and 123.34 m^2/person respectively, while the city proper has a density of 30.59 m^2/person (World Bank, 1993a).

[4] For example, the Fanzhuang development in southeastern Beijing. Residents commute to work either in public buses or in shuttle buses provided by the work units. Places of employment for most residents are beyond easy bicycle commute range.

[5] Additionally, retail development is a common component of the more upscale housing developments in China, but it is designed to cater to a less comprehensive range of the needs of the residents than did the work-unit compound ideal.

areas in turn must travel into the city for shopping and social services not yet developed in their new neighbourhoods (Gaubatz, 1995).

1.1.2 Urban Residential, Commercial and Transportation Energy

Nature of Urban Residential and Commercial Energy

In China, the commercial and residential sectors comprised a 25.2% share of final energy consumption in 1992 (Wang Qingyi et. al., 1995). Consumption of residential energy by end use is different than in developed countries. In 1988, space heating, cooking, lighting and appliance end uses contributed 36%, 55%, 3% and 6% respectively to the energy used by urban households (Feng Liu, 1993). Urban household energy consumption is also quite low by North American standards, but is increasing. Between 1985 and 1988, the average annual growth rate of household-energy consumption throughout urban China was 4.6%. Coal is the largest source of residential energy and is used mainly for heating, cooking and stove heated hot water bathing. In 1991, coal constituted about 75% of urban residential energy use. Honeycomb briquettes, burning with 25 percent efficiency, constitute approximately a third of total coal use while commonly used bulk raw coal, which delivers heat with no more than 10 per cent efficiency, constitute the rest (Peters, 1997). The use of other fuels is increasing -- the growth rate of electricity and gaseous fuel from 1985 to 1990 averaged about 17% and 18% per year. However, a large decrease in coal use in the residential sector is unlikely, because of the plentiful domestic supply of coal and the strong use of coal for space heating (Feng Liu, 1993).

The dominance of high sulfur coal for urban uses has particularly strong environmental quality implications. Particulate concentrations in Chinese industrial and urban areas are commonly at levels encountered in Europe and North America two generations ago, and are well above the World Health Organization standards for healthy air. SO_2 emissions are also strikingly high -- Shenyang, Guangzhou and Beijing are among the highest monitored concentration of SO_2 in the world. As a result, China is experiencing a growing incidence of acid rain (Byrne et. al.,1996).

Cooking

Coal use dominates cooking energy. However, coal gas and liquefied petroleum gases (LPGs) have made recent inroads in supplying energy for cooking uses in some urban areas, particularly in large cities and in those areas close to producers. Gas stoves have more than double the efficiency of coal stoves. The degree of gas distribution systems in urban areas varies; overall, only about 10% of urban households use gaseous fuels for cooking (Feng Liu, 1993). The share of coal in cooking fuel tends to drop as income levels rise[6], suggesting that the share of gas fuels in household energy mix will continue to increase with economic development and higher living standards (Qiu Daxiong et. al., 1994). Piped gas also has a wider presence in newer, multi-family dwellings, because the connection costs are not borne by the individual households. The extent to which fuel mix will change depends upon supplies of gaseous fuels. Barriers to the development of natural gas have been significant, and may limit this progression.

Heating

Household heating has been tightly regulated. All together, 40% of the urban population, 134 million people, require space heating in the winter (Fuqiang Yang et. al.,1996). China is divided into three zones according to the number of days in the 'heating season', and central heating is only provided in the 'Central Heating Zone' where the sum of days in the 'heating season' -- when the average daily temperature is steadily less than or equal to 5° Celsius -- is more than 90 days.[7] Energy for urban heating is almost completely coal based. More than half of coal heating, even in the Central Heating Zone, is produced through individual coal stoves, resulting in significant health problems caused by indoor coal pollution. Central space-heating systems are confined to multi-storied buildings and account for approximately a third of total heating in this zone (Feng Liu, 1993). District heating accounts for a small portion of total heating and the use of waste heat for residential use is very limited.[8] The growth of energy for heating is potentially enormous. Because of the increasing wealth of people and a loosening of central control, it is expected that space-heating energy demand will be driven up to satisfy a higher comfort standard and to better meet the heating needs of the population outside the Central Heating Zone (Feng Lui, 1993).[9]

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[6] In Beijing, coal accounts for 18% of cooking fuel use in low-income households. At higher income levels, the use of coal drops to 3%, and the share of gaseous fuels expands.

[7] The other zones are the Transition Zone and the Non-Heating Zone. The Transition Zone covers areas where the sum of the days in which the average daily temperature is steadily less than or equal to 5° C is between 60 and 89 days; or where the temperature is steadily less than or equal to 8° C for 75 days or more. The Non-Heating Zone covers what remains.

[8] At the end of 1990, district heating accounted for 12% of the total residential heating space in the north, or about 123 million GJ for 213 million m^2 of floor space. District heating systems have made remarkable progress since 1980--a 25% annual growth rate--but still fell far behind residential construction (Fuqiang Yang et.al., 1996).

[9] According to a 1990 survey of 35 cities in the Central Heating Zone, heating fuel intensities (kgce/m^2) have risen over their respective 1981 values. All areas in the Transition Zone actually need extensive space heating according to Western standards. However, in the Transition Zone it is often economically unfavorable to construct central heating systems

Cooling

Most areas outside of the Central Heating Zone have a very warm and humid summer season. At present, most households and commercial buildings use electric fans to drive off summer heat. Since more than half of the nation's population live in these areas, there is a great market potential for room air conditioners, particularly if one considers hotels, hospitals and shopping centres. Some wealthy areas of China already show a significant increase in air conditioning use. If growth in other urban areas follows Hong Kong's example, energy used in air conditioning will be considerable. In Hong Kong, air conditioning is the single largest electricity consuming item. Electricity consumption for air conditioning rose 535% from 1979 to 1993 (Lam, 1996).[10] However, limits to air conditioning growth in China include inadequate electric circuits and constraints in electricity generation capacity.

Other Uses of Electricity

Another major growth area for electricity is the demand for lighting and appliances. In urban centers, electricity is predominately supplied from a regional network through transformer substations. Though average electricity consumption per household is less than 120 kilowatt-hours a year, the requirement for electricity has increased quickly with the increase in living standards. From 1980 to 1990, the annual growth rates of residential and commercial electricity use were 16% and 12%, respectively, leading the growth of electricity use among all sectors (Feng Liu, 1993).

Transportation

Pedestrian, cycling and public transportation dominate urban transportation increasingly due to low per capita income, a history of policies governing the use of motor traffic, and the close proximity of work, shopping and residences. China's per capita motor vehicle ownership remains among the lowest in the world at eight vehicles per thousand population, of which only one is a passenger car (Stares & Liu Zhi, 1996). The nature of automobile use also differs from patterns found in more developed countries. According to a study of land use and transportation in Shanghai, the passenger vehicle trips which are residential in their origination or destination only accounted for about 17% of total trips.[11] Rail

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because of a much shorter heating season. Gas heating is also not available, because of the lack of gas supply. Possible outcomes could be the spread of electric heaters and small-boiler central heating systems (Feng Liu, 1993).

[10] The average annual growth rate during that period was 14%.

[11] For passenger vehicle, the biggest trip generation volume is generated in various land use for public buildings, including the government and business offices, hotels, cultural and recreational facilities and various schools, which accounted for 46% of the total. For freight vehicles the biggest trip generation occurred in various industrial land uses, which along with the construction sites and farming land, generated 45% of the total trip volume (Chen Shenghong, 1990).

transport, such as subways and light rail transit, are relatively undeveloped. Personal cars are only accessible to the wealthy. For the majority of urban residents, the choices are between walking, cycling, motorcycle/scooter, hired cars (taxis) and light utility vehicles, or various types of public transportation (Sathaye et. al.,1994).

Energy for transportation in China is in a major process of transition. A huge potential exists for substantial motorization. Recent indications suggest that China is attempting to develop a vehicular transportation system along the lines of the U.S., Western Europe and Japan (Elliott et. al., 1997). Already, the growth rate is rapid -- the country's entire motor vehicle fleet (excluding motorcycles) averaged an unprecedented 15 percent a year growth between 1985 and 1993 (Stares & Liu Zhi, 1996). Motor transport will most likely continue its rapid increase, as more households approach the point where car ownership is a possibility.[12] The effects of increased fossil fuel burning is great when considered along side the environmental implications of residential coal burning. Growing numbers of cars, trucks and buses in urban areas, their poor maintenance, and traffic congestion are already bringing higher seasonal smog levels to many large cities. Congestion is already being seen in Chinese cities at a small fraction of car ownership levels in more developed countries, in part because of inadequate road infrastructure. Between 1986 and 1991, traffic volume of motorized vehicles on the main streets of the central district in Shanghai increased by over 40% (Qing Shen, 1997). Bicycles and motor traffic are usually unseparated in the road system, resulting in a large number of accidents.[13]

Public transportation has always played a major role in transportation, but it is associated with significant challenges. In many areas the number of people riding to work per unit of time greatly exceeds the carrying capacity of the public transport system.[14] In recent years, the reliance on public transport in Shanghai has decreased relative to bicycles and motor vehicles. Trucks, cars, microbuses and other vehicles belonging to various enterprises, organizations and government agencies ('paratransit') carry large numbers of passengers outside of the direct control of public bus services and municipal transportation bureaus. According to Sathaye et. al. (1994), paratransit appears to be a popular mode of transportation for middle-income city dwellers in Asian cities who are unable to

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[12] The Institute of Techno-Economics of the State Planning Commission study implies that a household with an annual income of 50,000 yuan would be able to afford a subcompact car that costs 60,000 yuan to purchase and 6,000 yuan a year to operate (Stares and Liu Zhi, 1996).

[13] Despite Beijing's current low level of automobile ownership, several hundred fatalities per year from traffic accidents were reported in the early 1980s (Newman, 1996).

[14] It is reported that during peak hours in Beijing, passengers standing in buses can become as dense as 12 persons/m^2 (Yu Qingkang & Shi Young, 1988).

purchase private vehicles, but are willing to pay slightly higher fares for the more flexible routes, faster speeds and more comfortable routes that intermediate modes offer over buses.

1.2 Community Energy Management Strategies

Community Energy Management centers on purposely shaping the built environment and designing urban services in consideration of energy production, distribution and use, in order to affect the long term demand for energy and the type of energy that can be supplied. It is an integrative planning process that focuses on strategies that can be implemented at the local level which link energy, sustainability and community objectives.

CEM typically encompasses four broad areas:

- Land Use Planning
- Transportation Management
- Site and Building Design
- Energy Supply and Delivery Systems

CEM strategies are proposed below for each of these areas. They are not intended to be a comprehensive description of community policies, but are intended more as a general presentation of the types of initiatives that would be important in directing energy use in urban areas towards a more sustainable path. They are also not necessarily intended to suggest practices that are not currently being pursued.

1.2.1 Land Use Planning

As noted in Section 1.1.1, urban form is undergoing a significant transition in China which will ultimately have substantial energy ramifications. It is important to shape and direct these changes, preserving advantages of past land use, while allowing Chinese cities to grow and economically develop. The main objectives of urban land use planning need to be:

> *To maintain and encourage land use that allows communities to reduce the need for travel by bringing employment and other needs closer to homes.* The piece-meal nature of new suburban development makes it difficult for residential growth to be structured reasonably close to new workplaces and for sufficient social and commercial amenities to be provided to reduce

transportation demand. Without a carefully implemented land use planning program, distances will limit walking and cycling opportunities as well as mass transit efficiency.

To maintain and encourage land use that supports waste heat utilization, and promotes environmentally benign and efficient energy supply. Disjointed and uncoordinated investments delay and make infrastructure development more difficult, which is already challenging due to a shortage of funds for infrastructure. The pattern in which urban form unfolds affects the ability to plan energy investments that are more environmentally sustainable. Urban form has a significant impact in influencing the economics of district energy which is highly dependent on thermal load density and load shape.

These objectives can be supported through a number of strategies.

- *'Development Zones' should be carefully planned so that they integrate with the existing dynamics of the city.* Activity centers and local neighbourhood services need to follow outward extensions of the city. In addition, the number and scope of new Development Zones should be coordinated within the region.

- *The creation of discrete satellite towns and economic development districts should be discouraged.*

- *Existing mixed use communities (for example the old Lilong neighbourhoods in Shanghai) should be reconstructed and renovated.* Transportation needs are minimized because relocation is minimized. Geographical relationships should be kept intact and existing social structures should be maintained.

- *Major freight terminals should be moved away from congested city centers.*

- *The density of development should be controlled to ensure the support of CEM objectives such as transportation and district energy, particularly in fringe urban areas*. At the same time, CEM objectives need to be balanced with the health and social objectives of the community such as reducing population density in some excessively dense areas.

- *Factories that are relocated should be replaced with commercial, service and light industrial development to maintain employment.*

- *More holistic and comprehensive redevelopment needs to take place.*

- *A strict urban boundary should be established.*

- *New development should be targeted to areas with underutilized infrastructure, or areas where incremental investments in improved transit service or district heating are about to occur.*

1.2.2 Influencing Site and Building Design

While land use planning addresses broader community design issues, strategies can also be implemented at a micro-level which are targeted at increasing energy efficiency and allowing for the penetration of alternative energy supply technologies. These strategies include:

- *Designing the micro-climate to influence heating, cooling and lighting demand.* For example, street trees can be used to shade buildings and paved areas can be strategically located to reduce cooling requirements. Additionally, dwellings should be built which relate to the natural features of the site. Wang Dehua (1992) notes that currently there is no in-depth analysis of the environmental features formed by the local nature and historical human landscape.

- *Integrating commercial and residential space.* This strategy reduces heating demand by maximizing shared walls and by allowing residences to take advantage of the fact that commercial space is generally a net producer of heat.

- *Encouraging passive solar design in both community layout and individual buildings.* For example, this can be achieved by orienting blocks, lots, building glazing and roof pitch for maximum solar gain. Chinese buildings have traditionally contained some of these design aspects. For example, builders and architects already adhere to a sun angle calculation.

- *Planning new developments to integrate well with existing development in order to minimize cost of energy infrastructure (i.e. allowing maximum adoption of gas).*

- *Building to maximize the 'shape coefficient' -- the ratio between the outer surface area and the enclosed volume of a building.* Measurements have shown that everything else being equal, an increase of 1 per cent in the shape coefficient will result in approximately a 0.5% increase in the heating load (Feng Liu, 1993). High rise buildings usually have lower shape coefficients, which correspond to better thermal integrity, while low rise or single-storey buildings have higher shape coefficients.[15]

- *Encouraging energy-efficient building and retrofitting.* There is a large potential for energy efficiency improvements in this area (Wang Qingyi, 1997). Modernized building techniques, such as factory-built windows, and improved wall insulation, would improve building efficiency significantly. Builders should also ensure that buildings can be easily and economically retrofitted for technologies such as district heating and solar power as these become commercially available.

1.2.3 Transportation Management

Strategies for transportation planning and management need to reflect unique aspects of transportation dynamics in China; namely to plan effectively given extremely limited road capacity, and to take advantage of the wider options available compared to the West, since significant motor vehicle-guided investment has not yet occurred. A key principle of transportation management should be to ensure that roads carry the maximum number of passengers, not vehicles (Allport, 1996). The road capacity required for each automobile traveler can accommodate approximately 4-5 bicycles, 8-10 pedestrians, or 15-20 transit riders (Qing Shen, 1997).[16] The current income-based transition in travel modes should be actively shaped to limit automobile use. Seeking to expand road systems to cope with projections of increased automobile use in high-density cities disrupts the urban fabric and displaces large numbers of people. As city transport systems and spatial structures become increasingly automobile oriented, those who cannot drive or cannot afford motor vehicles become increasingly disadvantaged (Newman, 1996). Car dependence and economic prosperity are not synonymous. Munich and Paris, both among the most prosperous cities in Europe, along with three of the most prosperous Asian cities (Tokyo, Singapore, Hong Kong) have a very low automobile dependence with public transport, walking and cycling more important than cars (Newman, 1996).

Strategies to limit car growth and improve urban transportation include:

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[15] It is estimated that popular five-to six-story buildings usually have a shape coefficient of 0.28 - 0.3. And single-story buildings can have a shape coefficient as high as 0.5-0.6.

[16] Based on observations made in Shanghai.

- *Facilitating bicycle and pedestrian transportation*. This could be accomplished through the planning of well-designed bicycle track systems for new districts, the improvement of bicycle parking, and the separation of motor and non-motor vehicle flows. Transportation modes should also be better integrated according to both geography and operation schedule. For example, bicycle parking should be constructed in close proximity to transit stops.

- *Improving the quality of public transportation.* Public transportation planning should be responsive to the existing needs of the city, while aiming towards a long term extensive transit coverage typical of many European centres. There is a considerable range of technological options, varying in price, capacity and speed. These include options such as express busways that do not require heavy investments. A flexible fleet makeup (buses, vans, taxi ride-share programs) should be an important feature of a public transit program. It is also possible to 'upgrade' as demand rises and as cities grow in size and wealth (Newman, 1996). This should naturally build on the existing informal paratransit services that already exist in urban areas.

- *Switching transit vehicles over to environmentally friendlier fuels and technologies in stages.*

- *Implementing street management as an alternative to road expansion or replacement.* This involves making the best use of existing street networks through the adoption of innovative approaches to urban traffic management. Proudlove and Turner (1990) suggest that human powered and engine powered traffic can be segregated; sidewalks widened and maintained at high standards; and, where the width of street allows, marked out spaces for commerce should be designated on specially widened sections of the sidewalk. Additionally, motor vehicle flow can be regulated to allow priority for public transportation, including providing transit priority traffic signals at congestion locations.

- *Targeting the transfer, development and introduction of technologies in key areas.* For example, the fuel cell has been identified by the China Council for International Cooperation on Environment and Development as offering especially great promise for transportation in China. The Beijing Public Transportation Company has appropriated 50,000 yuan to start a preliminary prefeasibility study (China Council(a), 1996).

- *Developing employer-sponsored commuting services.* For example, housing development companies can potentially coordinate joint efforts involving major parties of new residential developments to sponsor these services (Qing Shen, 1997).

- *Implementing Traffic Management Strategies.* These might include area licensing schemes, computerized area traffic control, adaptive traffic control, the provision of real-time information about services at all bus and tram stops, and the use of exclusive bus lanes.[17]

1.2.4 Energy Supply and Delivery Systems

A key aim of CEM is to encourage local supply and delivery systems which make sense from an economic, social and environmental perspective. Strategies may include:

- *Prioritizing the use of non-coal energy in densely populated urban areas where environmental and health effects are strongest.* Non-coal sources include LPG, gas (natural and coal) and electricity.

- *Harnessing geothermal energy for residential heating in northern areas*. Only 0.01% of the nation's total exploitable geothermal resources is currently being tapped (Wang Jianzeng, 1997).

- *Developing small hydro where appropriate such as in remote rural communities*. China can draw upon its strong history of developing small hydro resources.

- *Encouraging renewable technology appropriate to the end use task*. This strategy should direct energy use as new end uses are developed. China is already the world's largest manufacturer and user of solar water heaters. There is still more potential to expand, for example, as higher incomes influence a growth in private bathing. Northern China usually enjoys lasting sunny weather in the winter.

- *Increasing the use of gaseous fuels*. Very large efficiency gains come from the replacement of coal stoves by gas-burning devices, and gas burning is considerably cleaner. There is some potential to

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[17] In Singapore, these schemes saved: 1043 GJ a day - Area Licensing Scheme, 307.4 GJ - Computerized Area Traffic Control, 96.2 GJ - Adaptive Traffic Control, 64.6 GJ -Exclusive Bus Lanes (Fwa & Ang, 1996).

tap into low-cost town gas from industrial processes such as coke-oven, blast furnace and refinery gas, though this is limited by location and scale. Price reform in natural gas may divert more natural gas to the residential sector.[18] The high cost of gas supply infrastructure has also been a barrier to gas access, thus it is critical that development is coordinated and compact. The priority for residential gas use is for cooking. Supplying gas involves difficult tradeoffs. For example, due to the rising demand for transportation fuels, the government is forced to decide whether the refining industry should produce more LPG instead of transportation fuels. Tradeoff decisions need to be guided by a comprehensive analysis of financial, environmental and social costs.

- *Tailoring the type of energy supply and distribution to existing community conditions*. It is critical that distribution infrastructure is minimized and duplication avoided. Where gas infrastructure is available, district energy may be less suitable, compared to encouraging heating with gas. Gas for heating may be particularly important where heating demand and densities are not sufficient for the development of district heating outside of the Central Heating Zone.

- *Targeting the transfer, development and introduction of technologies in key areas.* For example, a promising new approach in Chinese cogeneration technology is to supply steam, electricity and gas for cooking. Other efficient coal utilization technologies should be encouraged.[19]

- *Developing an urban biogas strategy*. Biogas already plays a significant role in rural areas. The potential exists to generate biogas from urban sewage plants and landfills.

- *Replacing decentralized and uncontrolled coal combustion in individual apartment blocks and dwellings, with district energy facilities that incorporate environmental controls.* Coal combustion should be made cleaner and more efficient. Small coal-fired boilers are not as efficient as large

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[18] At present, more than 80 percent of China's natural gas is used in the industrial sector. Only about 10 percent is consumed in the residential sector. Recent discoveries of natural gas have added to the reserves and fueled optimism that this trend will continue and permit the expansion of natural gas utilization in China from its present minor role (China Council (a), 1996).

[19] This includes technologies such as: coal gasification, coal preparation and cleaning, improved boiler systems, heat recovery equipment, process controls, coal briquetting technology, and emission control devices such as electrostatic precipitators and bag filters.

boilers and pollution control is more difficult to maintain.[20] The popularity of small boilers may be attributable to their low cost and easy installation.

- *Giving higher-quality coals priority for residential and commercial sectors*. For example, the allocation of washed and/or briquetted anthracite for residential uses should be the top priority. Raw bituminous coal generates 25 times more particulate emissions than washed anthracite and 20 times more than anthracite briquettes (World Bank -- Annex 5, 1991).

- *Developing cogenerated district energy further, emphasizing larger-scale, integrated systems*. The residential and commercial sectors do not benefit much from the existing cogeneration capacity; most of the existing cogeneration plants only supply heat to industrial users (Feng Liu, 1993). Power stations should be built as cogeneration whenever possible. District heating can be made more economical by developing district energy systems that supply cooling in the summer, and which supply hot water to public bath houses and private dwellings.[21] Absorption chillers driven by high-temperature water or steam could be used to satisfy cooling demand through centralized, local and decentralized cooling systems. Absorption chillers also primarily operate with water/lithium bromide binary solutions which are relatively harmless to both humans and the environment (Kalkum, 1996).

- *Developing small scale, site-based power generation, strategically located to provide reliability and voltage support for weak points in the distribution system*. For example, this could include fuel cells and solar photovoltaics.

- *Encouraging the interaction of industrial energy provision with community energy*. Industrial energy provision should be linked to considerations of how communities can interact with industrial activities so that waste heat can be utilized and the provision of cogeneration/district heating can become more affordable. Many industrial enterprises in the built-up city are being relocated, which may give the opportunity to integrate plant design with community energy needs.

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[20] New and retrofitted cogeneration facilities are required to meet minimum stack height limitations and emission standards. As an effective environment preservation technology, a low-priced, semi-dry process simplified flue gas desulfurizer is currently available (China Council (b), 1996).

[21] This is particularly important in areas where a shorter heating season may not justify the capital costs of district heating.

This can be part of a broader industrial ecology initiatives of linking material and energy flows in industrial systems to make better use of limited resources.

Chapter 2

Modelling Exercise

2.1 Objective

This modelling exercise seeks to broadly estimate aggregate energy-related environmental effects of alternative scenarios of future Chinese urban development and residential energy planning. Two alternative future scenarios of urban development in the year 2015 are evaluated. The first scenario, "Development of Current Trends" (DCT) outlines a future that reflects some of the trends which have occurred since China began its pattern of rapid economic growth, as well as the experience of newly industrialized countries. This scenario draws upon the discussion in Section 1.1 and includes such trends as the evolving separation of land uses and the steady growth in motorized vehicle ownership levels. The second scenario, "Community Energy Management" (CEM) incorporates a number of CEM strategies into future urban development. These strategies are discussed in more detail in Table 2.1 and are based on those outlined in Section 1.2.

Environmental effects addressed in this study are limited to present and future atmospheric air emissions -- CO_2, NO_x , particulates, and SO_2 which emanate from both residential and urban transportation energy sources. The exercise also limits energy end uses to those uses which are influenced by CEM strategies, and in particular, those that are affected by factors of density, mix of use in neighbourhood development, and policies which influence the level of development control, enforcement of building regulations and codes, and new technology penetration.

Table 2.1 CEM Scenario Strategies

Area	Strategies
Land Use Planning	• Land use planning control resulting in more coordinated development. • A tendency towards mixed land use and the maintenance of dispersed business centres. • A tendency towards maintaining a relatively high density, but not to the detriment of local environmental quality.
Transportation Management	• A greater emphasis on public transportation development. • The facilitation of bicycle and pedestrian transportation. • The implementation of transportation management strategies to discourage automobile growth. • The development of employer sponsored commuting services and other high occupancy vehicle travel.
Site & Building Design	• Building to maximize the shape coefficient. • Ensuring that buildings are built so that they can be easily and economically retrofitted for district heating and/or cooling.
Energy Supply & Delivery Systems	• The replacement of decentralized and uncontrolled coal combustion in individual apartment blocks and dwellings. • Encouraging the interaction of industrial energy provision with residential uses. • A faster introduction of new fuels and technologies (such as district cooling, waste heat). • Increased gas penetration for cooking and heating.

2.2 Methodology

2.2.1 Overview

The methodology used to evaluate the future scenarios described above consists of two overall steps:

I. The present and future urban population of China are divided into 'development classes' -- groupings which characterize different residential building patterns (i.e. mix of use, type of building). The CEM and DCT scenarios differ in their relative distribution of development classes.

II. Total emissions for each scenario are determined by multiplying the population in each respective development class by the per capita emissions for each development class ('Development Class Emission Rates').

Each step is developed in greater detail below.

I. Development Classes

In each future scenario, the projected urban population is divided between different types of 'development classes'. These are described in Table 2.2. The type of development class guides the choice of end use technologies that are adopted and the level of energy consumption, which in turn impacts the level of air emissions. Specific development classes have been advanced which characterize the nature of building types and the mix of land use in Chinese communities, based on urban spatial and urban form patterns discussed in the literature (Gaubatz, 1995; Feng Liu,1993; World Bank, 1993a).

Table 2.2 Description of Development Classes

Development Class	Definition	Example
L1	Low rise, Mixed use	1-3 stories -- mainly old pre-1950's buildings
L2	Low rise, Non-mixed use	1-3 stories -- new villas, exclusive suburbs
M1	Medium rise, Mixed use	4-10 stories -- mainly 1950's-1980's development, and some new development
M2	Medium rise, Non-mixed use	4-10 stories -- mainly new, 1980's+ development in rapidly changing cities, as well as older development in areas of low 'non-productive' investment such as satellite cities
H1	High rise, Mixed use	11+ stories -- mainly new development which maintains mixed neighbourhood
H2	High rise Non-mixed use	11+ stories -- new development in rapidly changing urban areas

II. Development Class Emission Rates

Determining the total per capita emissions for each development class involves the following steps:

1. End uses, and the technologies (and/or fuels) that provide energy for those end uses, are specified.

   This modelling exercise is limited to residential and urban transportation energy, and does not include analysis of the commercial sector. Four categories of energy end use are considered -- space heating, space cooling, cooking and transportation. The choice of end uses and the technologies that are associated with them have been limited to those that relate to broad community infrastructure development, and the effect of urban form on that development. Thus micro-site decisions such as solar design and landscaping are excluded. Hot water heating is not considered as a separate end use, because existing household hot water uses are included as part of cooking, and a large percentage of hot water use takes place outside of the home (i.e. public bathhouses). Technologies considered for each type of end use are as follows:

- Space Heating -- coal stoves, central heating (coal), district heating (coal), district heating cogeneration (coal), electric heaters and gas (coal gas & natural gas).
- Cooling -- individual air conditioning, district cooling, and district cooling (cogeneration). Although electric fans are currently the dominant form of cooling, they are not included because they are not considered to be equivalent to air conditioning as an end use.
- Cooking -- coal, piped gas, liquefied petroleum gas (LPG).
- Transportation -- transit, informal and contracted high-occupancy vehicles, pedestrian, cycling, motorcycle and automobile. The automobile mode includes state-owned vehicles, work unit vehicles and taxis. 'Informal and contracted high-occupancy vehicles' refers to paratransit and prearranged ride-sharing (for example, minibuses and vans).

2. Emission rates for CO_2, NO_x, SO_2, particulates (T/GJ) are determined for each technology.

3. For the present and for the competing future scenarios, technology market shares are described which indicate the relative technology penetration in each development class for each end use.

   The penetration rates of the different technologies used to accomplish the end uses considered in this model are estimated for each development class. Shares are given for both the initial period and the two future scenarios. Market shares total one hundred percent, thus it is assumed that a development class will have some technology penetration for each end use. The degree of energy use is reflected in composite figures (discussed in step 5). The determination of technology shares is based on the scenarios outlined in Table 2.1. For example, the technology share of natural gas for cooking is greater for the CEM scenario.

4. Overall emission rates are determined for each development class ('*development class emission rates*') by multiplying each technology share by its respective technology emission rates (T/GJ) and summing them for all technologies in that development class.

5. Present and future per capita yearly energy consumption (GJ/capita/year) figures (*'composite energy values'*) are calculated for each end use. The method for calculating these differs by end use and is explained in detail in Section 2.2.5.

6. Where appropriate, a *'development class multiplier'* is calculated for different development classes which estimates the difference a development class has on overall energy consumption due to non-technology factors (i.e. the effects of shared walls; changes in trip generation).

7. The total per capita emissions (GJ/capita/year) for each development class are finally determined by multiplying '*development class emission rates'* by the '*development class multiplier'* and the *'composite energy values.'*

Archetypes and Zones

In order to reflect regional and economic differences in energy use and supply, the urban population is grouped into six 'zones', and is subsequently divided into two 'archetypes'. The zones reflect per capita GNP and climate, and the archetypes reflect city size. Distinctions between zones are integrated into the various steps of the model.

Zones

Climate and per capita GNP are two major factors which account for differences in residential energy consumption in China. The number of factors used to classify zones and archetypes have been limited to keep the model relatively simple. The model definitions of these zones are described in Table 2.3.

Table 2.3 Description of Zones

Zone	Description
1	Central Heating Zone/ Average per capita GNP is greater than 1963 Yuan.[1]
2	Central Heating Zone/ Average per capita GNP is less than 1963 Yuan.
3	Transition Zone/ Average per capita GNP is greater than 1963 Yuan.
4	Transition Zone/ Average per capita GNP is less than 1963 Yuan.
5	Non-heating Zone/ Average per capita GNP is greater than 1963 Yuan.
6	Non-heating Zone/ Average per capita GNP is less than 1963 Yuan.

Climate affects the demand for heating and cooling energy. This model adopts the official categorization of climatic regions for residential energy purposes stipulated in the *National Standard Design Code for Heating, Ventilation and Air conditioning*. China is divided into the following:

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[1] '1963 Yuan' represents the average of provincial per capita GNP values derived from China Statistical Yearbook (1992).

- *The Central Heating Zone* -- where the sum of the days in which the average daily temperature is steadily less than or equal to 5° C, is more than 90 days in the whole year. Presently, central heating is only allowed and provided for in this Zone.
- *The Transition Zone* -- where the sum of the days in which the average daily temperature is steadily less than or equal to 5° C is between 60 and 89 days; or where the temperature is steadily less than or equal to 8° C for 75 days or more.
- *The Non-Heating Zone* -- everywhere else.

Per capita GNP is also used to categorize urban areas because regional differences in wealth are significant in China and rising incomes have been a key factor in the surge of urban residential energy use. Per capita GNP is chosen to reflect both the ability of urban areas to afford certain types of investment such as public transportation, and in trying to reflect differences in personal consumption between urban areas.[2] Aspects of per capita residential and urban transportation energy use (i.e. level of energy use, technology adoption) generally relate with measurements of 'wealth'. For example, Qing Shen (1997) states that a causal factor behind the dramatic increase in the demand for urban transportation in Shanghai has been economic and income growth in Shanghai.

Archetypes

Archetypes characterizing city size are used to further break down urban areas in Step 1. These are described in Table 2.4. Cities over and under 1 million are quite different in terms of urban form, density, gas infrastructure and transportation infrastructure.

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[2] Personal per capita non-agricultural consumption correlates with per capita GNP according to data in China Statistical Yearbook (1992).

Table 2.4   Description of Archetypes

Archetypes	Description	Average Density[3] (pers./km^2)	Examples
I	Urban centres greater or equal to 1 million	1636	Beijing, Dalian, Tianjin, Anshan
II	Urban centres less than 1 million	351	Changde, Lanxi, Fuyu

2.2.2 Population

The modelling exercise focuses on urban areas in China -- towns and rural populations are excluded.[4] The Chinese definition of a city is "as a place where the total population exceeds 100 000, at least 70 per cent of whom are non-agricultural people, or alternatively, a place which must be an important strategic centre for the region or the country" (Zhang Xing Quan, 1991). The city population used in this study excludes counties and includes only the permanent population in those cities.[5] The study's population therefore does not include the peri-urban population. The data is obtained from the China Statistical Yearbook 1992. To facilitate data analysis, provincial data rather than individual city data are used. The base year for the model is 1991, which corresponds with the most recent published English language information about residential/ transportation energy use and supply patterns. The urban population growth rate is based on United Nation's (1995) urban projections, and varies around an average of 4%.[6] Hong Kong is not included due to its significant differences in energy consumption patterns and per capita GNP.

2.2.3 Initial and Future Distribution of Population Between Development Classes

Figure 2.1 shows the initial distribution of development classes estimated for the higher per capita GNP (Zones 1, 3, 5) and lower per capita GNP (Zones 2, 4, 6) zones. The initial breakdown is based on the

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[3] Based on Table T17.2 in China Statistical Yearbook (1992).

[4] Energy patterns in town and rural areas are considerably different.

[5] This should be made explicit because Chinese urban population statistics can also include county population. Official population figures do not include 'the floating population', those individuals who work and live in the city but do not have residency. In some cities, this population is significant. Population figures include the agricultural population in urban areas since only a very small portion of the urban agricultural population is actively engaged in farming (Kam Wing Chan, 1994).

[6] Provincial urban population growth rates are based on projected growth rates for cities in those provinces listed in Table 29 of United Nation's Compendium of Human Settlements Statistics (1995). Their method is based upon extrapolating into the future the most recently observed urban rural growth difference. The average growth rate of 4% is in keeping with Kam Wing Chan (1994) finding of an 4 to 5% average annual urban population growth rate in the 1980s.

categorization of building structures for a number of Chinese cities found in Lang Siwei et.al. (1992).[7] These categorizations suggest that the smaller the city, the greater the percentage of residential floor area that is accounted for by one storey and low rises. Other key assumptions made in forming the development class divisions based on zone and archetype are:

- High rises are costly, therefore cities with less per capita GNP will have fewer high rises.[8]
- High rises will be built in areas of greater density.
- Climatic region will not have an effect on the type of development classes defined in this study.
- Higher per capita GNP areas will have less low rise, mixed use development (LI) because more recent building spurred by economic activity will have replaced more traditional one storey dwellings.
- High rises as presently built are associated with a separation of land uses (Leaf, 1995).
- Traditional land form is associated with mixed use (Treister, 1987).

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[7] The breakdown of building types is given for Beijing, Anshan, Hohhot, Dandong, Manzhouli. Archetype I is assumed to be similar to Beijing and Anshan which are both cities with more than 1 million residents. However, based on Leaf (1995) allowances are made for the fact that Beijing has a less built up core than most large cities.

[8] High rises require more advanced materials, mechanized construction techniques and vertical transportation (Lang Siwei and Fan Youchen, 1990).

Figure 2.1 Initial Development Class Distribution

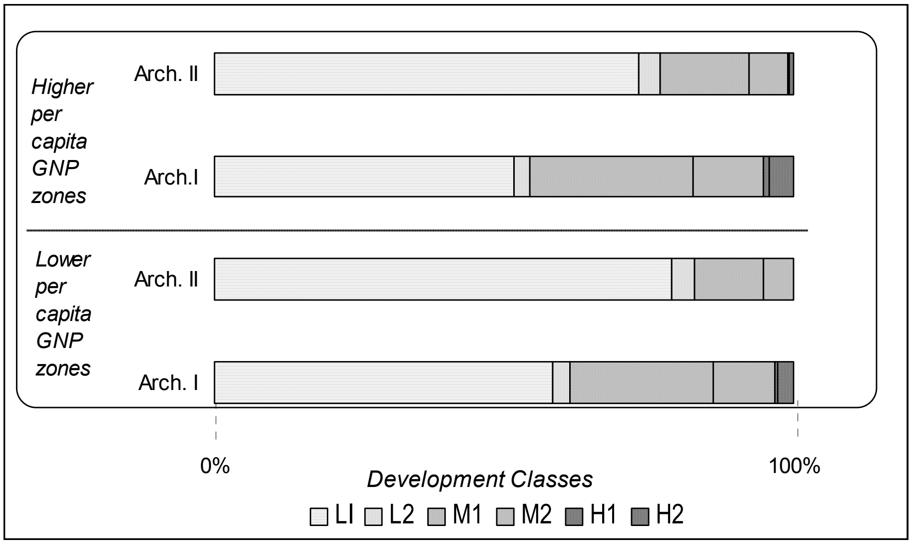

Figure 2.2 shows the distribution of urban population between the six development classes for each of the future scenarios. This distribution is based on the distribution of existing stock plus new residential building stock to house increased populations. The growth in residential housing stock is estimated to be 130 million m^2 per year, amounting to a growth of 3,887 million m^2 between 1991 and 2015 (cited in Siwei Lang and Fan Youchen, 1990).[9] Initial urban residential housing stock is assumed to be 7000 million m^2. The categorization of new residential building stock in development classes is based on observations of new building construction in Shanghai and Nanning (Treister, 1987) and on the general trend of increased medium and high storey buildings construction in commercial oriented cities (Leaf, 1995).[10] Assumptions are made that the lower the per capita GNP, the fewer high rises will be built due to their higher cost; and that the bigger the city, the higher the density, and the greater demand for high rises. The addition of new stock alters the distribution of development classes of the total stock. The future mix takes into account only the development class changes that result from the growth of housing stock and does not include alteration in the mix of the existing stock.

The distribution of new housing growth is assumed to be different for the DCT and CEM scenarios. These development class distributions in the DCT scenario reflect:

- The present trend away from mixed use and walking-scale neighbourhoods (Gaubatz, 1995).

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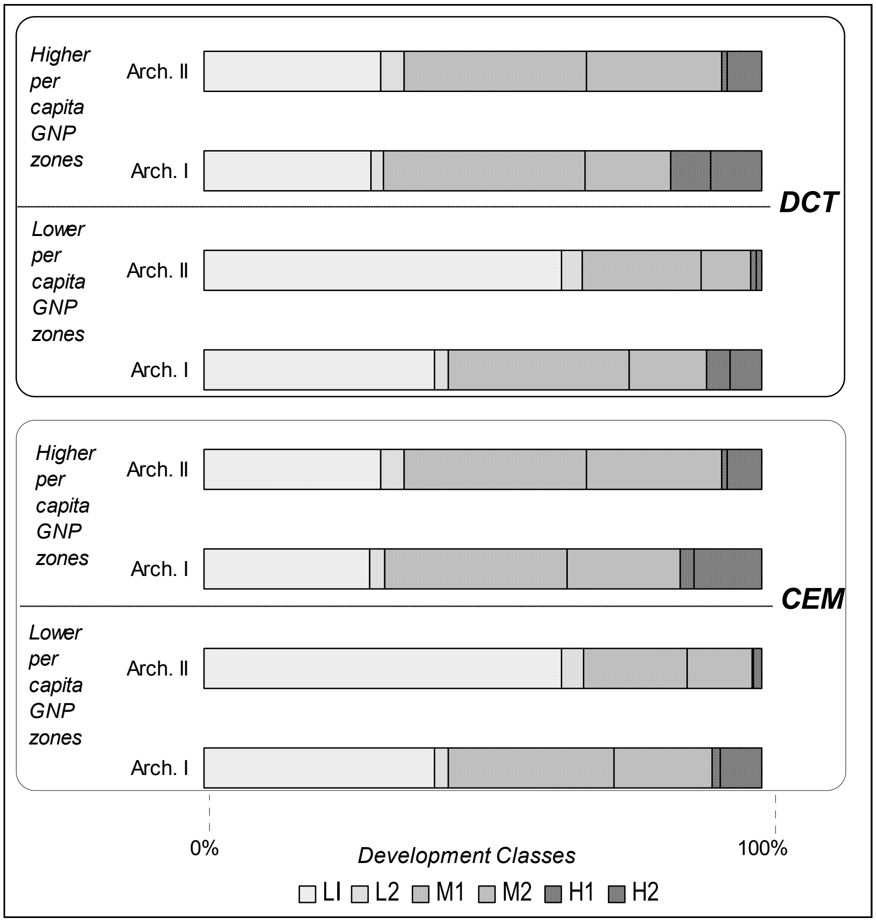
[9] The same degree of growth is assumed for each year.

[10] The paper notes that of new housing built in Shanghai, 30% is high rise and the remaining is mid or low rise, and that in Nanning, the average number of stories of new complexes is six.

- That the separation of land uses that is currently associated with high rises (Leaf, 1995).
- Difficulties which are experienced in encouraging shops and services in new greenfield (outer ring) development (Buck, 1984).

The CEM scenario has a greater percentage of growth occurring in the medium and high rise development classes (MI, M2, H1, H2), and in particular those classes with a greater land use mix (M2, H2).

Figure 2.2 Future Development Class Distribution



2.2.4 Development Class Emission Rates

Technology Market Shares

Key assumptions used in developing market shares are described below. Assumptions represent realistic "what-if" values rather than rigorous estimates.

2.2.4.1 Heating

Initial

Zones 1 and 2 (Central Heating Zone)

Feng Liu's (1993) overall breakdown of heating technologies for the Central Heating Zone is used as a starting point. He estimates that the breakdown by type of heating in 1991 is: stoves 75%, small boilers 20%, district heat (cogeneration) 2.75%, and district heat (non cogeneration) 2.25%. Gas is used almost exclusively for cooking, rather than for heating, and the use of industrial waste energy for heating purposes is very limited (World Bank -- Annex 8, 1991). Differences in per capita GNP between Zones 1 and 2 result in differences in the degree of district heating that uses cogeneration, the use of electrical heaters to supplement coal stove heating, gas penetration and waste heat. It is assumed that the penetration of these technologies differs by a factor of 20%. Further classification of technologies according to development classes are based on the assumptions that:

- Almost all single and two storey dwelling are heated by coal stoves (Qiu Daxiong et. al., 1994). [11]
- Most multi-storey buildings are centrally heated (Qiu Daxiong et. al., 1994). [12]

Zones 3 and 4 (Transition Zone)

Heating is much more limited in these zones. There has been no past provision of central heating (including district heating), because it has not been officially sanctioned. Winters in many areas of these zones are cool and damp. The predominate means of heating is through the use of extra coal in cooking stoves, and in areas of higher per capita GNP, residents are beginning to employ electric heaters to provide heat. No distinction is made between development class, because of the limitation of heating options. 10% less heating is assumed to occur by electric heating in the lower per capita GNP zone (Zone 4).

Zones 5 and 6 (Non-Heating Zone)

No heating is assumed to occur in these zones.

Future Scenarios

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[11] Based on observations in Beijing.

Zones 1 and 2 (Central Heating Zone)

DCT

The following trends are reflected in the future technology shares for heating. In this scenario it is expected that:

- Gas makes only minor inroads in providing heating energy. The penetration of gas occurs little in the low rise development classes. Greater density in the other development classes encourages investment in those classes.

- Electric heaters are used increasingly to supplement heat supply, particularly in Zone 1. Their use is more widespread in the low rise development classes, because the level of heating is more inadequate in those classes (Qiu Daxiong et. al., 1994).

- More district heating is built, so that 20% of all delivered heat is provided by district heating in 2015.[13] Slightly less than half of the share is provided by cogeneration. Penetration of district heating is greatest in the high rise development classes, because of the higher density of that type of development.[14] It is also greater in mixed land use development classes, particularly for cogeneration.

- A higher per capita GNP allows for a higher penetration of district heating.

- Coal stoves are being phased out, particularly in the medium and high rise development classes.

- Waste heat does not make any inroads in providing heat.

CEM

The following trends are reflected in the future distribution of technologies for heating. In this scenario it is expected that:

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[12] Based on observations in Beijing.

[13] It is estimated that district heating will be extended to 15% of residential floor space by 2000 (Fuqiang Yang et.al., 1996). The estimate of 20% in this study was arrived at by taking into consideration other cities besides major cities, and the pace of urban construction relative to the increase in district heating systems. District heating systems have made strong progress since 1980 (25% annual growth rate), yet they still fell far behind residential construction (Fuqiang Yang et.al., 1996).

[14] The viability of district energy is strongly dependent upon the 'thermal load density' of a community which is affected by building density (total amount of floor space in a neighbourhood) and the 'load factor' which is the ratio of total annual energy use to the total possible annual consumption if the peak were supplied continuously for a year. A high load factor can be better obtained through a pattern of mixed land use.

- The penetration of district heating is slightly greater than for the DCT scenario. Twenty-three percent as opposed to 20% of urban areas are covered by district heating. However, a greater share of district heating is through cogeneration, because there is greater coordination of development in this scenario.

- The penetration of gas is greater than in the DCT scenario due to more coordinated construction and a prioritization of residential end uses in overall national allocation of natural gas. Gas penetration occurs more in the low rise development classes (L1, L2) because medium and high rise development classes (M1, M2, H1, H2) are able to take better advantage of central and district heating investment.

- Waste heat makes some inroads in providing residential heating, increasing from an assumed market share of 0% in the DCT scenario to 0.2% in the CEM scenario.[15]

- Coal stoves are being phased out.

Zones 3 and 4 (Transition Zone)

A 20 % difference in the penetration of district heating, gas and electric heating is assumed between Zones 2 & 4 due to the effects of differences in per capita GNP.

DCT

The following trends are reflected in the future distribution of technologies for heating. In this scenario it is expected that:

- Electric heaters take a sizable market share, and coal continues to provide heating energy.

- There is an increase in central heating and district heating, but much less than in the Central Heating Zone (Zones 1 & 2) where the longer heating season makes these types of investments more economical.

CEM

The following trends are reflected in the future distribution of technologies for heating. In this scenario it is expected that:

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[15] World Bank (1991) suggests that there is probably a great scope for this in the future.

- More heating demand is met by central heating, district heating, waste heat and gas relative to the DCT scenario.
- There is a greater share of district heating and cogeneration than in the DCT scenario because development is more coordinated, and because cogeneration cooling is pursued which balances the load and makes cogeneration projects more economical.

2.2.4.2 Cooling

It is assumed that all air conditioning is achieved through the use of room air conditioning only. There are no distinctions made between development classes. Because room and central air conditioners are close in C.O.P[16], only room air conditioning is considered.

Initial

Cooling is through room air conditioners only.

Future Scenarios

DCT

It is assumed that there is only a very small penetration of district cooling under this scenario, of which none is cogenerated. Zones have different abilities to pay up front for capital costs for district cooling. The penetration of district cooling is not as widespread as it is for district heating in the heating section. This is because of the expense of district cooling relative to district heating due to higher distribution costs. Additionally, buildings with room cooling units or direct expansion systems must be converted to central water systems, which is an expensive process. This will tend to limit district cooling penetration to new building stock. The Transition Zone (Zones 3 & 4) has less investment in district cooling because of the higher costs of providing the infrastructure due to lower cooling loads.

CEM

This scenario assumes that there is slightly more penetration of district cooling and that the penetration of central cooling is slightly greater than the DCT scenario. There is also some penetration of

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[16] C.O.P refers to the coefficient of performance and is equal to the useful cooling capacity divided by the equivalent power input.

cogenerated district cooling. The economics of district cooling provision is improved by coupling district cooling systems with district heating systems in the Transition Zone.

Note: No cooling is assumed to occur in Zones 1 and 2 (the Heating Zone).

2.2.4.3 Cooking

Initial

The initial cooking technology shares are based upon the following breakdown of urban residential cooking fuels for all urban areas in China given in Feng Liu (1993).[17]

	Mtce	Share
Coal	40	88%
Liquefied Petroleum Gas	2.3	5%
Piped Gas	3.1	7%

'Piped gas' includes natural and coal gas. 'Coal' includes both raw coal burning stoves and coal briquettes stoves. 'Liquefied Petroleum Gas' (LPG) includes a small amount of kerosene. 'Share' refers to the share of total Chinese urban energy used for cooking .

The technology shares are varied for each development class -- the share of gas is assumed to be greater in the multi-storey and high storey classes. Gas has made minimal inroads in old, low-storey buildings because individual residences are responsible for the cost of hook-up which is not the case in multi-storey dwellings (Feng Liu, 1993). LPG is available to dwellings that have no gas hook-up, and is therefore a popular alternative fuel to coal. It is assumed that the use of LPG is not influenced by development class.

The breakdown for the higher per capita GNP zones (1, 3, 5) is different than the lower per capita GNP zones (2, 4, 6). Income level has a major influence on cooking energy use patterns. The share of coal in the cooking-fuel mix tends to drop as income rises (Qiu Daxiong et. al.,1994).

Future Scenarios

DCT

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[17] It is assumed that the share of households using each fuel approximates the share of total energy for cooking by fuel. The share of gas may be slightly underestimated because of gas' higher end-use efficiency.

The future technology shares for this scenario are based on an expected annual growth rate of 6% for piped gas for cooking and of LPG for all Chinese urban areas. Approximately 50% of the urban population is assumed to be covered by 2015 (Piped gas 29.30%, LPG 20.42%). This draws upon an estimate by the Urban Construction Administration that by the year 2000, about 120 million people, or about 30 million households, will be supplied with some form of gas; thus, 20-30 percent of the total urban population will be covered (World Bank -- Annex 8, 1991). The relationships between the technologies and development classes are mostly similar to the initial distribution, however it is also assumed that the penetration of LPG will be greater in the lower-storey development classes, because the penetration of gas infrastructure is lower there.

CEM

In the CEM scenario, the penetration of both piped gas and LPG is assumed to be greater. This could occur through a greater prioritization of natural gas for residential uses and the further use of coal gas from mine sites, coke ovens and biogas from urban waste. It is assumed that LPG and piped gas grow an average of 7% a year so that in the year 2015, the piped gas will supply 36.7% of cooking and LPG 25.6% for all of urban China.

2.2.4.4 Transportation

Initial

The estimates for transportation shares vary according to the per capita GNP level of the zones and not according to the climate distinctions. Differences in density between different urban areas are taken into account by the initial breakdown of the population into archetypes (see Table 2.4).

In order to determine the initial technology (mode) shares, an average overall distribution of market shares was derived from transportation share data from Shanghai, Changchun, Shenyang, Tianjin and Xuzhou (Yang Zhao-Shang et. al., 1991; Qing Shen, 1997). The average distribution is assumed to be:

Transit	Bicycle	Walking	Other
17.2%	41.2%	37.3%	4.1%

These cities would all be considered to be part of the higher per capita GNP zones. This breakdown was adjusted slightly to accommodate the starting auto vehicle figures derived from official statistics which vary according to the per capita GNP of the zone (China Statistical Yearbook, 1992).[18] Cycling and pedestrian modal shares were combined because their emissions are identical. The following breakdown estimates modal shares for urban Chinese areas[19]:

	Transit	HOVs	Ped/Cycle	Auto	Motorcycle
Higher per capita GNP zones	17.2%	0%	81.5%	0.4%	0.9%
Lower per capita GNP zones	13.8%	0%	85.3%	0.2%	0.6%

Motorcycles and high occupancy vehicles (HOVs) are also included. The share of motorcycles is estimated from urban per capita ownership statistics (China Statistical Yearbook, 1992). Little is known about the present degree of HOVs; it is assumed to be zero. The technology share breakdown also reflects assumptions about differences by zone. It is assumed that the higher per capita GNP zones would have more of an ability to make capital public investments, and would therefore have more transit.

Modal share differences by development class were determined by using the overall breakdown above, and assuming that it is most reflective of the development class 'M1' (mixed land use, medium rise). The other development classes were adjusted by the following factors that reflect the influence of density and mix of use on modal share:

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[18] It is assumed that ownership of a motor vehicle translates to 100% trips by that mode. According to Sathaye & Meyer (1989), once a passenger vehicle is owned, the household tends to use it for much of its transport needs.

[19] This estimate is based on limited studies of relatively large Chinese urban centres and may not fully reflect transportation modal shares in the smaller centres.

Differences from base case	Transit	Auto	Motorcycle
Less community mix	-10.0%	+5.0%	+10.0%
Less density	-10.0%	+10.0%	+10.0%

For example, it is assumed that development class 'L1' (non-mixed land use, low rise) would have transportation modal shares that have 20% less transit, 15% more automobile and 20% more motorcycles than the respective modal shares in development class 'M1'.

The key relationship reflected is that with greater density and greater mix of land use, there is less demand for transportation forms that are suitable for longer distances -- automobile, motorcycle, transit and HOVs, and a corresponding increase in walking and cycling.[20] The weaker influence of the community mix on automobile share is due to the fact that many automobiles are currently publicly owned, suggesting that the travel demand linkages between level of community mix and modal share may be less strong than in the North American / European context. For example, because fewer automobile trips are assumed to be made between residences and workplaces, manipulating density and mix of land use to shorten travel distances would have less of an effect on total automobile travel. However, it is fair to assume that publicly owned automobiles are used for at least some part of private activities as they are in other countries (Thomas et.al., 1993).

Future Scenarios

In the future scenarios, the influence of the community mix of the development class on the share of automobile travel is assumed to be stronger, because more vehicles are owned by households and are used for home-based travel.

DCT

The level of ownership of motorized means of transportation is expected to rise significantly, in keeping with trends Chinese urban areas have experienced recently. There is a strong documented relationship between ownership growth and per capita income growth. Therefore, income elasticities of motor

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[20] The basis for the trends is the time duration of travel. According to Kneebone (1991), the bicycle appears to be preferred to walking for trips in excess of 15 minutes duration and bus travel appears to be preferred to bicycles for trips in excess of 35 minutes duration. Nevertheless, modal shares will also be affected by bicycle ownership levels, the availability of public transport services and the extension of these to serve new outlying residential and industrial areas.

vehicle ownership are used as the basis for the projection.[21] An income elasticity of 1.58 is used which is drawn from a recent cross-country study by Kain and Liu (1994) that includes China in the sample (cited in Stares & Liu Zhu, 1996). While automobile growth levels in Chinese cities are currently higher, over the long term it is anticipated that the rate may slow down as urban areas reach their saturation point from congestion, and that these two trends would compensate one another.[22] The projection for Zones 1, 3, & 5 assumes that GDP grows at a rate of 9% a year, and 7% a year for Zones 2, 4 & 6.[23] The model predicts a future passenger vehicle ownership level of 97 per 1000 (for the higher per capita GNP zones) which lies between Thailand's 1993 level of 50 per 1000 and Malaysia's level of 111 per 1000 (Asiaweek, 1993). In Bangkok, traffic volumes on major arteries now exceed 90% of capacity throughout virtually the entire day. During evening rush hours, the average traffic speed along most major roads in the city drops to less than 10 km/hr (Sathaye et.al., 1994).

The growth of passenger vehicle ownership is translated into shares for HOV and automobiles. In this scenario, HOV's make up 10% of passenger vehicle growth. Growth in the level of motorcycle ownership is assumed to be the same as for other passenger vehicles.[24]

CEM

The CEM scenario differs by assuming that the adoption of transportation management measures slows down the rate of passenger vehicle and motorcycle growth. According to Sathaye et. al.(1993), Asian cities such as Hong Kong and Singapore, which have implemented policies such as increases in vehicle taxation, parking controls and increased tolls, have been able to slow down the rate of growth. It is assumed that under the CEM scenario, the Chinese government is able to implement policies that slow the rate by one third for both motorcycles and passenger vehicles. This is a relatively conservative estimation -- during the 1980s, the rate of vehicle growth in Singapore and Hong Kong was one third of that of Calcutta and Jakarta, although a portion of that difference may be explained by other factors (Sathaye et. al., 1993).

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[21] An income elasticity measures the percentage change in ownership from a one percent change in income.

[22] Chinese urban areas have a very low land to road ratio.

[23] World Bank (1993b) cited in Stares & Liu Zhi (1996) predicts that the growth rate will be between 7 and 9%.

[24] There is poor information about motorcycles for China overall. Guangzhou and Shantou have experienced 35-40% motorcycle growth between 1980-1993 (Stares & Liu Zhu, 1996). In urban areas in Asia, the growth of two-wheeler sales has been found to dwarf the expansion of car fleets (Sathaye et.al. 1994). However, a number of Chinese cities such as

The share of public transit in the CEM scenario is also higher (by 10%), due to a higher prioritization of transit investment. The portion of HOV as a share of passenger vehicle growth is greater. In the CEM scenario it is 25%.

Emissions

Emission rates used in this modelling exercise are shown in Table 2.5. The same emission rates are assumed for the initial period as well as for the future periods; however differences in model results from the varying evolution of the technologies are analyzed in the uncertainty discussion. Emission rates incorporate end use efficiency.

Shanghai and Beijing are actively trying to control the growth of motorcycles. In this model, the same rate of growth as passenger vehicles was chosen to be conservative and to reflect this uncertainty.

Table 2.5 Emission Rates Used in the Model

Technology		End use Efficiency	NO_x	SO_2	Particulates	CO_2
Heating		%	T/GJ	T/GJ	T/GJ	T/GJ
	Coal Stove	46	0.00015	0.00030	0.00020	0.166
	Gas	61	0.000002	0.00005	0	0.086
	Central Heating	50	0.00014	0.00026	0.00005	0.155
	District Heating	65	0.00010	0.00020	0.00001	0.119
	District Heating (cogenerated)	*see note 4	0.00003	0.00008	0.00001	0.031
	Electric Heaters	21	0.00032	0.00080	0.00013	0.307
Cooling		C.O.P.	T/GJ	T/GJ	T/GJ	T/GJ
	District Cooling (cogenerated)	*see note 4	0.00003	0.00008	0.00001	0.031
	Air Conditioning	2.6	0.00012	0.00031	0.00005	0.118
	District Cooling	4	0.00008	0.00020	0.00003	0.077
Cooking		%	T/GJ	T/GJ	T/GJ	T/GJ
	Coal Stoves	21.5	0.00032	0.00064	0.00044	0.355
	Piped Gas	40	0.000003	0.00007	0	0.131
	LPG	40	0.00018	0	0.000008	0.163
Transportation		GJ/passkm	T/PKT	T/PKT	T/PKT	T/PKT
	Transit	0.0034	0.00007	$1.34x10^6$	$9.09x10^6$	0.015
	HOV	0.0011	0.00047	$6.91x10^6$	$3.02x10^6$	0.072
	Pedestrian/ Bicycle	n/a	0	0	0	0
	Automobile	0.0002	0.00133	$1.96x10^6$	$8.56x10^6$	0.203
	Motorcycle	0.0012	0.00053	$5.56x10^5$	$1.01x10^5$	0.053

Table 2.5 Assumptions

1. Coal emission rates and calorific rates are taken from World Bank, Annex 5 (1991). Coal NO_x emissions are assumed to increase by a factor of 1.2 for higher burning temperatures in electricity generation (based on a difference in a separate study in World Bank, Annex 6 (1991)).
2. Coal stove emission rates assume 29% briquettes (Qiu Daxiong, 1994). In addition, the majority of briquettes are assumed to be 'honeycomb' briquettes made with anthracite coal as a feedstock (World Bank -- Annex 5, 1991).
3. Raw bituminous coal is used for electricity generation, and raw anthracite coal is used for central and district heating (non-cogen). Non-briquetted coal burned in stoves is assumed to be predominately unwashed anthracite, with some use of unwashed bituminous, unwashed lignite and washed anthracite (Feng Liu, 1993).
4. The emissions of cogenerated district heating and cooling are determined by using a factor that represents the 'electricity loss per unit of heat extracted at district heating plant' and a loss for transmission. Thus it assumes that except for that portion, the emissions are zero, because of the electricity generated.
5. Gas emission rates are based on Peters (1997) except for all LPG rates and the NO_x rate for natural gas which are derived from EPA (1996). Piped gas assumes 65% natural gas and 35% coal gas (Feng Liu, 1993).
6. Electricity generation is 80% thermal (Advanced International Studies Unit, 1998).
7. Particulate emission removal: coal stoves - none, central heating - 30%, district heating - 85%, electricity/cogeneration - 95% (World Bank -- Annex 6, 1991) (Advanced International Studies Unit, 1998).
8. No SO_2 or NO_x removal for any technologies.
9. Efficiencies are based on Fuqiang Yang (1997) for heating technologies, Peters (1997) for cooking technologies, People Republic of China Yearbook (1997) and Wang Jianzeng (1997) for electricity, Hao Liu (1998) & Metro Toronto Opportunities Investigation Group (1995) for cooling technologies, and Sathaye & Meyers (1991) and Failing (1995) for transportation.
10. Transportation emissions are averages for the 1995 U.S. in-use vehicle fleet (Newell, 1998). Figures for the Chinese fleet could not be obtained. Use of U.S. figures will tend to make the results conservative as China's motorized vehicle fleet is older and less well maintained. Transit assumes 100% buses.
11. SO_2 rates reflect the lower end of estimations.

2.2.5 Per Capita Energy Consumption Values

As outlined in the Section 2.2.1, present and future per capita yearly energy consumption (GJ/capita/year) figures are calculated for each end use, except for transportation in which average passenger kilometres traveled, per capita, per year (pkt/capita/year) are determined. All energy consumption is defined as 'useful energy' (end use efficiency is incorporated as part of emission values).

Heating

Composite energy values for heating (GJ/capita/year) are determined based on assumptions about heating load per square metre, average heated area per household and household size. Heating loads are based on assuming Beijing's heating load per m^2 is representative of the Central Heating Zone (Zones 1 & 2), and that Shanghai is representative of the Transition Zone (Zones 3 & 4). Heat loads are based on a simulation of a 'typical multilevel' Chinese building (Huang, 1989). Currently, average indoor room temperatures are significantly lower than average U.S. indoor conditions (Huang, 1989).[25] Average living area is based on World Bank, 1991 (assuming a 10% difference between the lower and higher per capita GNP zones). Household size is based on data in the China Statistical Yearbook (1992).

It is assumed that in the near future, the rising standard of living will see an increase in the heating load per square metre to satisfy comfort levels. By 2015, in the higher per capita GNP zones, it is assumed that heating load will be enough to satisfy an 18° Celsius constant thermostat setting. In addition, living space increases and household size decreases.

Table 2.6 Heating Energy Demand (GJ/capita/year)

Zone	Initial	2015
1	2.2	4.8
2	2.0	4.0
3	0.1	2.2
4	0.0	1.1
5	0	0
6	0	0

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[25] Average indoor temperature is 12.9 degrees C during the heating season in Beijing, and is 11.2 degrees C during the 3 winter months in Shanghai (Huang, 1989).

Cooling

Initial useful cooling demand figures are shown in Table 2.7. These figures are based on a possession level of air conditioners per 100 households translated into a per capita figure (China Statistical Yearbook 1992), and an estimated electricity use per air conditioner of 250 kWh/year (Hao Liu, 1998). A coefficient of performance of 2.6 is used to calculate a useful cooling demand in GJ per capita, per year.[26]

Table 2.7 Initial Cooling Demand

Zone	Possession of Air Conditioners per 100 hslds 1991	Possession per Capita	Electricity Use (kWh/Year)	Useful Cooling Demand (GJ/Capita/Year)
3	0.58	0.002	0.425	0.0143
4	0.58	0.002	0.421	0.0142
5	6.25	0.018	4.555	0.1535
6	0.57	0.002	0.417	0.0140

Future cooling demand assumptions are shown in Table 2.8. Estimates are based on an annual average growth rate of air conditioning estimated for the different zones. Estimations are based on Lam's (1996) estimation of an annual average growth rate of 14% of electricity use for air conditioning in Hong Kong during the 15 year period from 1979 to 1993. Growth rates are distinguished between zones based on:

- Differences in wealth -- Lam (1996) suggests that air conditioning growth is closely related to wealth, and that increased wealth has resulted in greater consumption of energy for air conditioning.
- Climate -- a higher penetration of air conditioning is assumed in Zones 4 and 5 (Non Heating Zone), because the climate is hotter than the other zones.

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[26] C.O.P. of air conditioners in Hong Kong vary between 1.7 and 3.5 (Lam, 1996). 2.6 was chosen as an average rate.

Table 2.8 Future Cooling Demand

Zone	Growth Rate	2015 Useful Cooling Demand (GJ/capita/year)
3	12%	0.060
4	10%	0.039
5	14%	0.990
6	12%	0.059

Cooking

Composite cooking values are based on household surveys in Beijing and Nanning in Qiu Daxiong et.al., (1994). The differences in the value by zone are based on the assumption that the higher per capita GNP zones consume more meals outside of the home (Qiu Daxiong et.al., 1994). The model assumes that the useful energy for cooking does not change over time.

Transportation

An initial average of 4796 passenger kilometers traveled per capita per year (pkt/capita/year) is derived from data on average trip rates and distances traveled in Shanghai.[27] It is assumed that this value will rise to 6661 pkt by 2015, based on the relationship that the number of trips taken per day will increase from 1.8 to 2.5 with rising incomes.[28] Trip length is not changed in order to avoid double counting since trip length will result from changing land use patterns which is manipulated in the future scenarios.

2.2.6 Energy Consumption Multiplier

'Energy consumption multipliers' estimate the difference made by each development class on the overall energy consumption for each type of end use due to non-technology factors. The multipliers used in the model and the relationships they represent are described in Table 2.9.

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[27] A daily average trips per person of 1.8 is assumed (Chen Shenghong, 1993). Average trip distance is assumed to be 7.3 km based on Comtois' (1993) finding of 7 km in 1990 and assuming a growth of 0.3 km a year (Qing Shen, 1997).

[28] A relationship exists between rising incomes and trips per persons. Average trips per person in the Lower Mainland of British Columbia, Canada was 3.11 in 1994 (GVRD, 1995).

Table 2.9 Energy Consumption Multipliers

End use	Multiplier (by development class)	Relationship
Heating/Cooling	L1/L2 - 1.34 M1/M2- 1.00 H1/H2 - 0.98	Effect of shared walls
Transportation	L1 - 1.27 L2 - 2 M1 - 1.10 M2 - 1.83 H1 - 1 H2 - 1.73	The effect of community mix and density on trip lengths

Heating and cooling multipliers are based upon Keyes (1976) cited in Owens' (1986) study of average annual net energy requirements for heating and cooling typical housing units in the Baltimore-Washington area. Heating and cooling factors do not reflect the differences in dwelling size.

Transportation multipliers are based on the following:

Density effects

- Estimates of the differences in emissions due to density are based on Dunphy & Fisher's (1996) exploration of the relationship between density and travel based on 1990 U.S. National Personal Transportation Survey (NPTS) results. This study was chosen because it relates density to person miles traveled (pmt) as well as to the more commonly used indicator of vehicle miles traveled (vmt).[29] Given China's low level of motorization, this is a more appropriate indicator of density effects.[30] The study also highlights differences in the effect of density of travel according to different levels of density, which is also quite appropriate given China's current high relative density compared to North America.
- For the purposes of determining the density effects on travel, it is assumed that the 'low rise' development classes have an average density of 3,000 persons/km^2, the 'medium rise' classes 6,000

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[29] Most studies exploring this relationship focus on measurements of VMT and/or gasoline use, i.e. Holtzclaw (1990), Kenworthy & Newman (1990).

[30] Density appears to have a stronger effect on VMT as opposed to PMT according to the NPTS survey results.

persons/km^2 and the 'high rise' classes 12,000 persons/km^2. Thus each development class represents a doubling of density.[31]

Development mix

- For the purposes of determining the development mix effect on travel, it is assumed that 'mixed development' refers to a situation where there is 100,000 square feet of office space (333 employees) for every 500 units of housing, and where all shopping is within 4 km of residences.
- The effect of mixing work and residential space is determined by making assumptions about the amount of commuting trips made for the 'mixed' as opposed to the 'non-mixed' development classes, and then determining the extra travel distances that would be undertaken for additional commuting trips. Commuting trips are considered to be those trips where the distance is too far to be made by walking and cycling modes. The relationship is loosely based on a table in the California Energy Commission's *Energy Aware Planning Guide* (1993) on the potential reduction in commute trips from adding housing to office developments.
- Similarly, the effects of mixing shops and residences are determined by estimating the difference in the amount of shopping trips that are not made by walking or cycling. In the 'mixed' development classes, all shopping trips are made by walking and cycling because they are within a 4 km radius, which is the average distance for cycling trips in 10 cities (Welleman et. al., 1996).

2.3 Results of Model Run

The development class emission rates are multiplied by the energy consumption multipliers and the composite energy values to come up with total annual air emissions for the two scenarios and for the initial time period. The results are shown by emission type in Figures 2.3 - 2.6, and for energy consumption in Figure 2.7. Contributions of each end use to total emissions are shown in these figures in order to give a sense of the growth of each end use from the initial period to 2015, and to show what end uses are contributing most to reductions in emissions between the DCT and CEM scenarios. Emission reductions that occur from the DCT scenario to the CEM scenario are described in Table 2.10.

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[31] Densities were extrapolated based on assumptions about dwellings per acre of each development type. These reflect those found in Figure 1.11 in Center of Excellence for Sustainable Development (1996), but are adjusted to account for differences in average unit sizes in China.

Further breakdown of the technology, end use and zone relationships which have produced these results is presented in Section 2.4, 'Interpretation of Model Results.'

Figure 2.3 Total Annual CO_2 Emissions for the Initial Period and Future Scenarios.

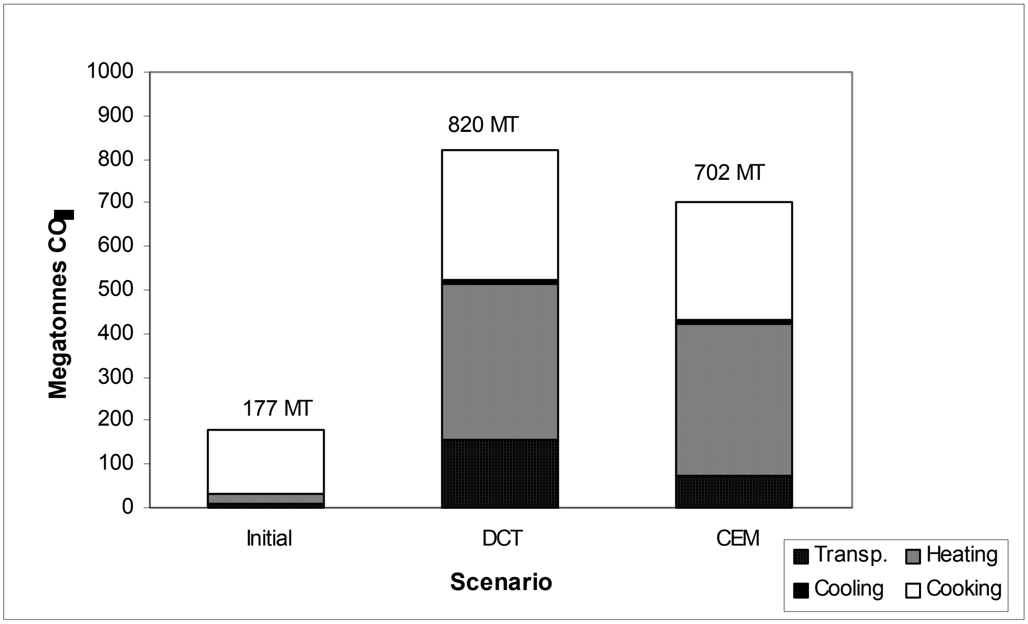

Figure 2.4 Total Annual SO_2 Emissions for the Initial Period and Future Scenarios.

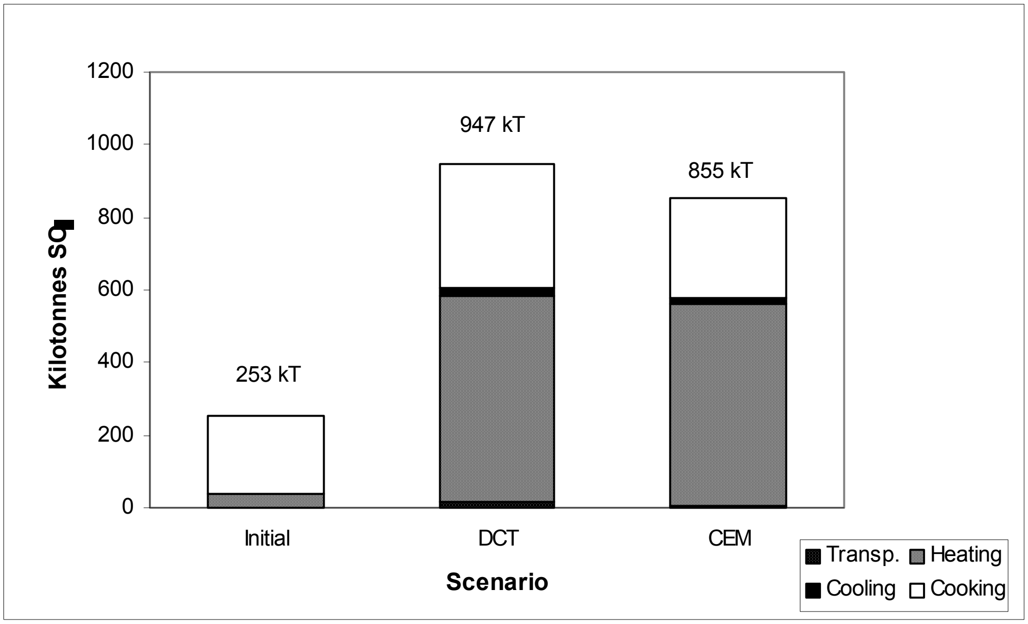

Figure 2.5 Total Annual NO_X Emissions for the Initial Period and Future Scenarios.

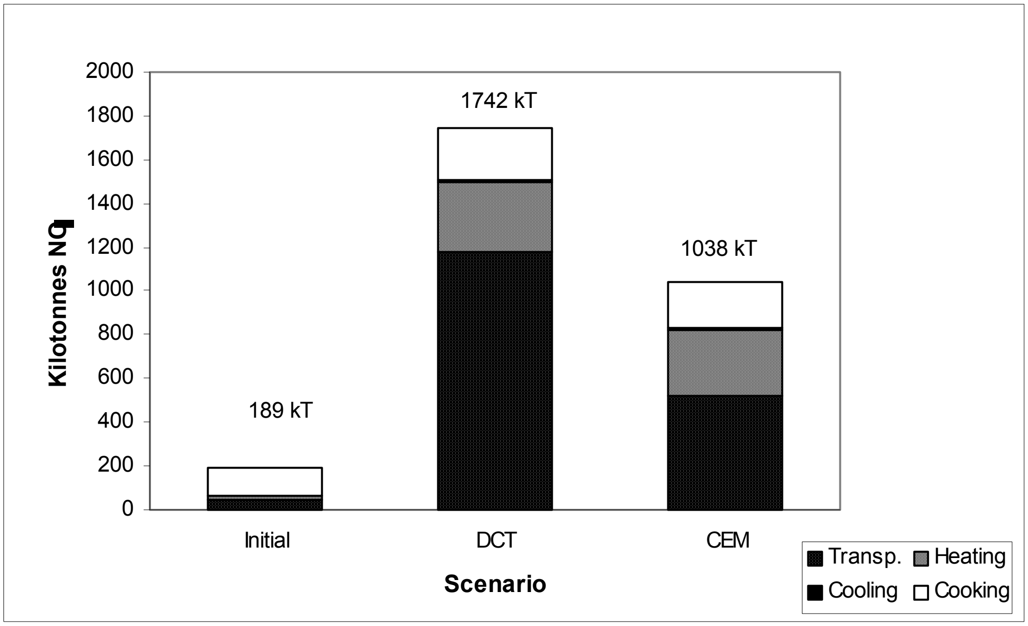

Figure 2.6 Total Annual Particulate Emissions for the Initial Period and Future Scenarios.

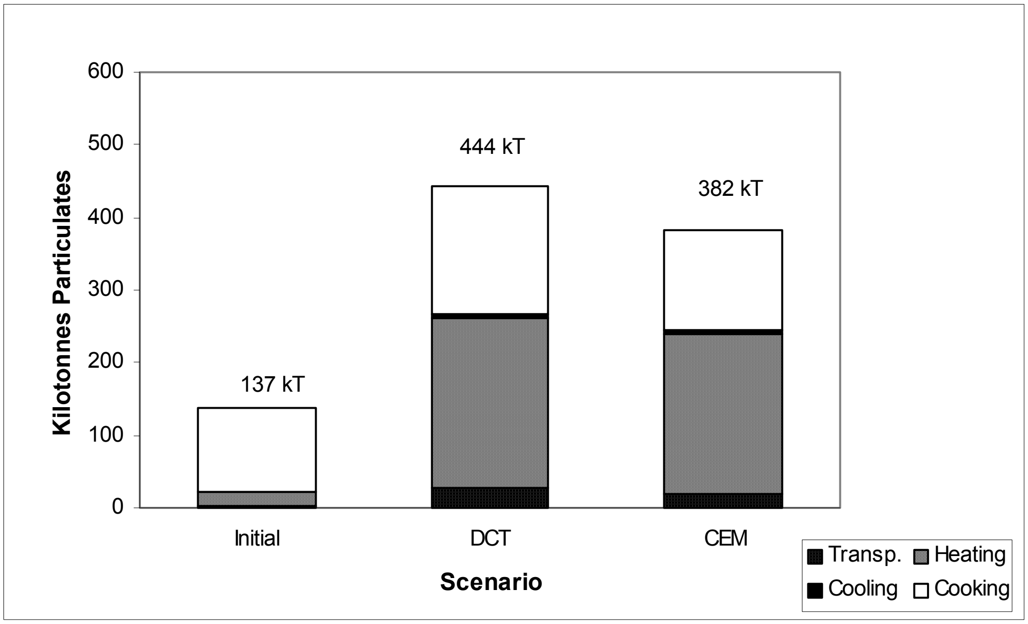

Figure 2.7 Total Annual Energy Consumption for the Initial Period and Future Scenarios.

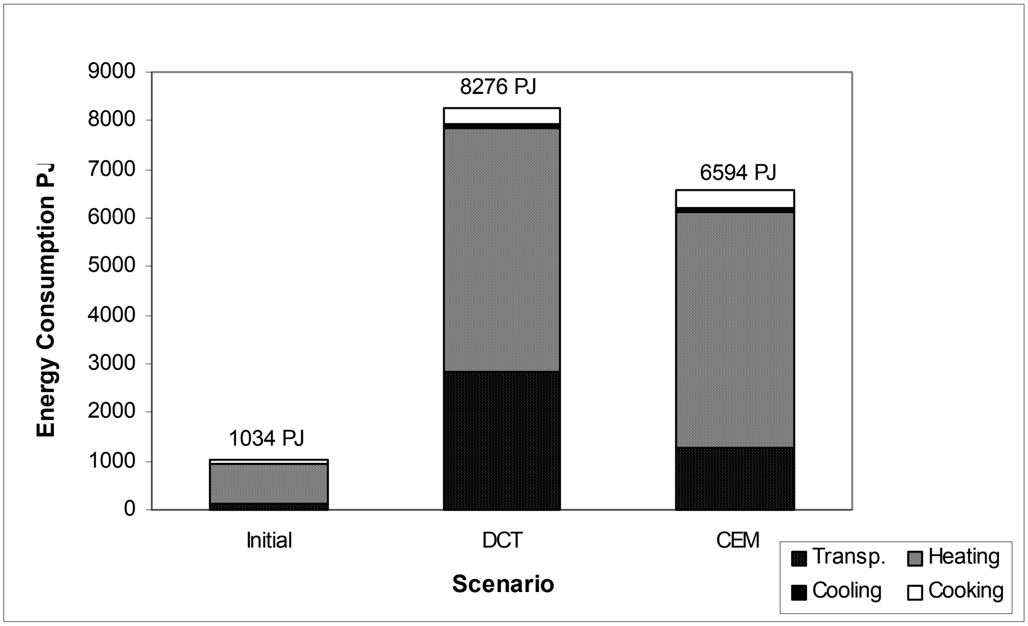

Table 2.10 Differences in Total Emissions between the CEM and the DCT Scenarios

Emission	Savings between CEM and DCT Scenarios
CO_2	14.4%
SO_2	9.7%
NO_X	40.4%
Particulates	14.0%

2.4 Discussion

Interpretation of the Results

The CO_2 savings of 14.4% between the CEM and the DCT future scenarios fall in a similar range to those found in Failing's (1995) study for British Columbia which found that CEM measures would save approximately 17%.[32] It is worth noting that CEM measures have an equally significant effect on particulate emissions (14.0% savings), a major health concern, and an even stronger effect on NO_x emissions (40.4% savings). SO_2 emissions are relatively less affected (9.7% savings). The effects of

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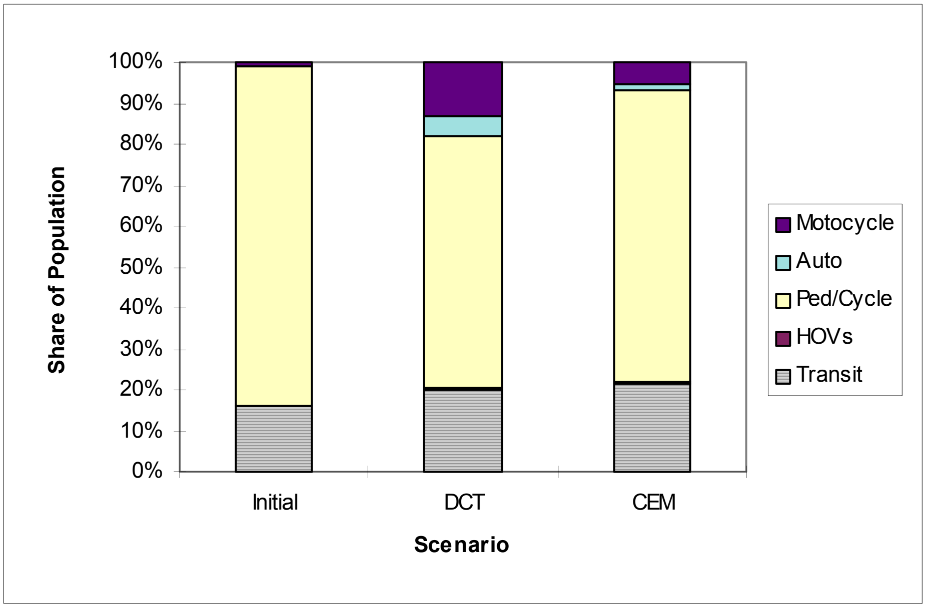
[32] This study's methodology is similar.

CEM in this modelling exercise are midterm. Given the even longer lifespan of infrastructure, the environmental benefits from the CEM measures will continue into the long term.

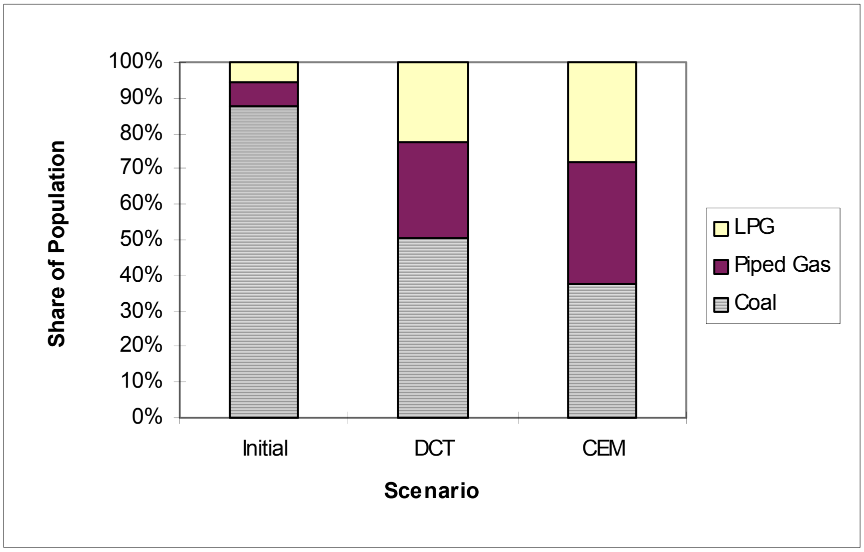
As can be seen in Figures 2.3 - 2.6, transportation is a major future source of NO_x emissions, but a relatively smaller portion of the other emission types. The modelling results show that transportation emissions are strongly affected by CEM initiatives. The mode share evolution that leads to these savings is depicted graphically in Figure 2.8. The key difference between the DCT and CEM scenarios is the reduction, through land use planning and transportation management, in the share of the urban population that has adopted motorcycles and automobiles as their travel mode. The land use relationships that influenced this modal evolution are indicated in Figure 2.1 and 2.2 in Section 2.2.3 'Initial and Future Distribution of Population between Development Classes.' This finding underlines the importance of shaping the growth of motorization. Urban form, which is currently built, will have major impacts on local air quality and acid rain formation 20 years down the road.

Figure 2.8 Transportation Modal Shares (All Zones and Development Classes Included)



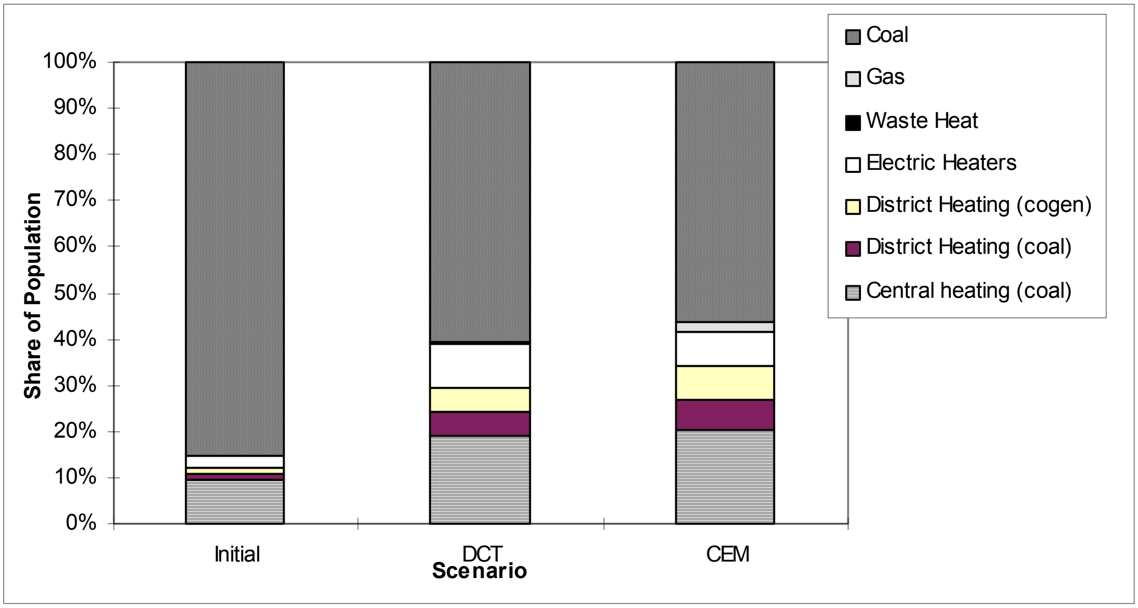
CO_2 and particulate emission reductions result from savings in each end use. CO_2 emission reductions are balanced between all end uses, although, as can be seen in Figure 2.4, heating contributes the most overall because of the larger size of this end use. Reductions in particulate emissions in cooking contribute the most to total particulate reductions. Coal burning is displaced quite strongly by LPG and piped gas (see Figure 2.9).

Figure 2.9 Cooking Technology Shares (All Zones and Development Classes Included)



Heating is the end use that is the least affected by the CEM measures evaluated in the model. This can be seen in Figures 2.3 - 2.6 by the small differences in emissions for this end use between the future scenarios. The breakdown of heating technology shares in Figure 2.10 reveals that the share of coal-based central and stove heating is not very different between the DCT and CEM scenarios, although the share of these technologies is substantially reduced compared with the initial technology share distribution in 1991. The DCT scenario is already achieving many 'CEM' technology penetration aims. New building stock in the DCT scenario is already multi-storey for which central heating is the standard technology. The Chinese government already has strong goals for district heating and the multi-family residential development that occurs in China is favourable to district heating (particularly compared to building trends in North America). The CEM scenario only increases this slightly. Technology share differences that are more apparent between the scenarios in Figure 2.10 are the greater portion of cogenerated heating and the smaller share of electric heating in the CEM scenario. The latter has little effect on particulate emissions, because particulate removal in electricity generation is reasonably high, even though energy efficiency levels are relatively low for that end use. The other emissions are cut because of efficiency differences. It would be useful as a follow-up to this model to explore how site specific design and penetration of passive and active solar heating may reduce heating-related emissions.

Figure 2.10 Heating Technology Shares (All Zones and Development Classes Included)



Cooling does not figure strongly in the future scenarios for China as a whole. This end use accounts for a very small percentage of all emissions in the results presented in Figures 2.3 - 2.6. Although cooling in Zone 5 makes up close to one quarter of the per capita annual energy use that heating does in Zone 1, the Non-Heating Zone (Zones 5 and 6) make up a much smaller portion of the total urban population (See Figure 2.12). The effects of CEM on cooling should not be overlooked since all emissions besides CO_2 affect the local region foremost. The portion of these emissions from cooling in the Zones 5 and 6 are significant. Cooling comprises approximately a third of SO_2 emissions in these Zones (5 and 6); the CEM scenario reduces these emissions by 16 percent. This occurs even with a very small introduction of district cooling in the CEM scenario (see Figure 2.11).

The discussion of cooling raises the issue of how zones contribute differently to total emissions. This is depicted for climate differences in Figure 2.12. The model reflects the significant growth of energy in the ‘Transition Zone’ (Zones 3 and 4) due to the relaxation of heating controls, demand for cooling and income growth. The relative share of emissions to population grows 27% in this zone, while growing only 6% in the non-heating zone and shrinking 13% in the Central Heating Zone. Nevertheless, the Central Heating Zone still makes up more than half of total emissions in the future.

Figure 2.11 Cooling Technology Shares (All Zones and Development Classes Included)

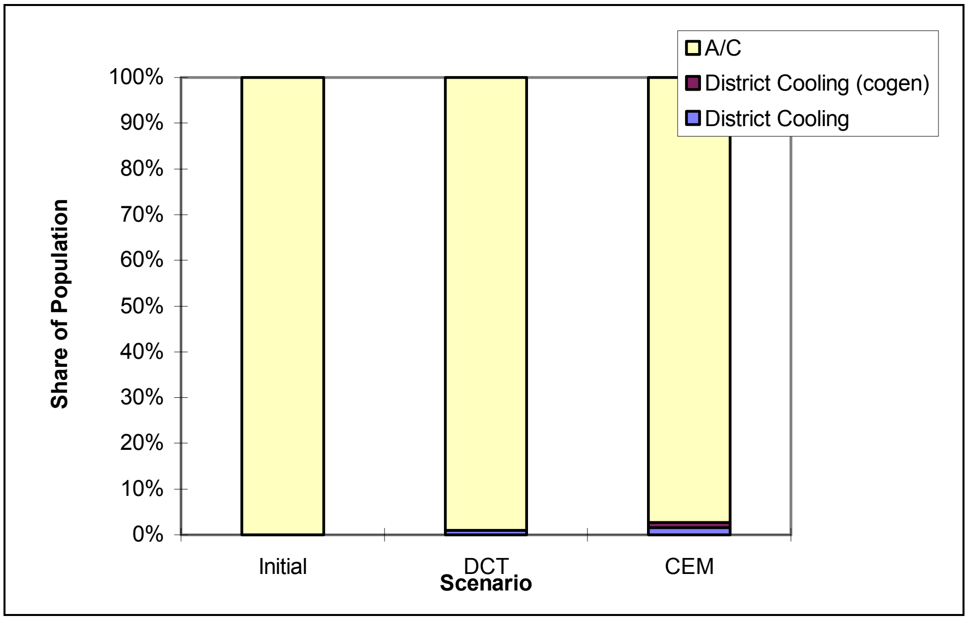
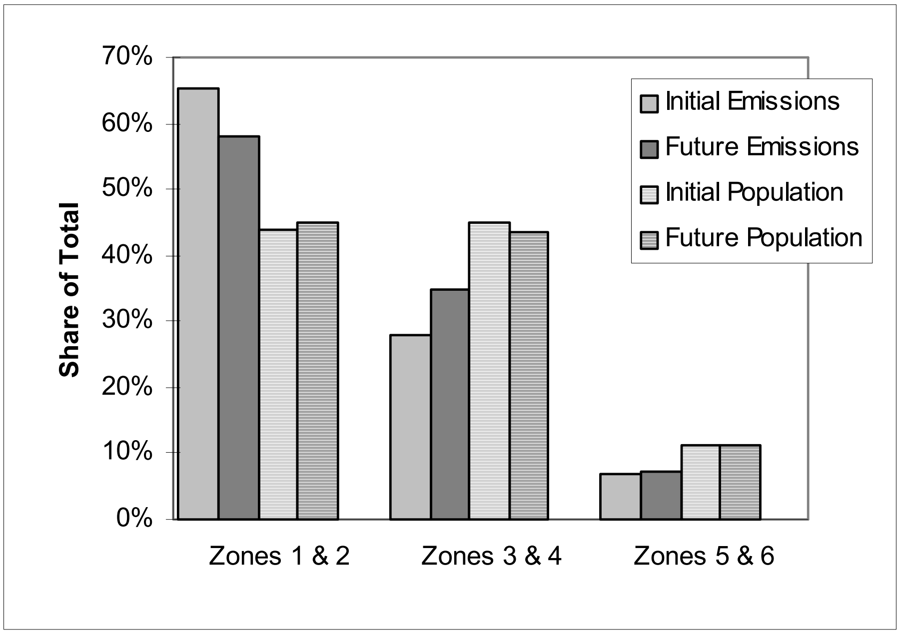


Figure 2.12 Shares of Population and Total Emissions by Zones (Distinguished by Climate)



Model Limitations/ Uncertainty

Model Structure

The model results must be interpreted with an understanding that they do not predict the future, but are instead a quantitative exploration of two hypothetical scenarios of future urban form and energy growth.

The model is grounded in data and observable trends; however, the model has simplified many of the complexities found in the actual system. The key instances include:

- Assuming no energy consumption for cooling in the Central Heating Zone and no energy consumption for heating in the Non-Heating Zone.
- Assuming that the comfort level of different development classes (i.e. low storey compared to high storey) is identical and that the average per capita living space is the same across all development classes.[33]
- Not taking into account many of the behavioral aspects of energy use. For example, in centrally heated apartments, inhabitants will often open windows to control the heat in their apartments because they have no control over the temperature setting.
- Limiting the consideration of new end uses -- i.e. hot water heating (which would increase the heating load).
- Simplifying urban form in a limited number of fixed development classes which may not represent all Chinese communities.
- Limiting the potential for changes in development class mix, because changes in mix from the redevelopment of existing development is not considered.
- Limiting future changes in coal mix, technological end use efficiency and emission control.

The last point can be explored in the model by manipulating certain parameters in order to discover how strategies such as coal washing and technological demand side management may curb emissions alone or in conjunction with CEM strategies. The future coal mix was altered to show a switch from 93% unwashed anthracite/ 1% washed anthracite to 94% washed anthracite, and to show a switch from 29% briquetted/ 71% non-briquetted to 100% briquetted coal. The resulting effect on heating and cooking emissions are shown in Figure 2.14. CO_2, and NO_x emissions are affected only slightly by these measures and are not illustrated. Briquetting has a major effect on both SO_2 and particulate emissions, while washing has some effect on SO_2 emissions and decreases particulate emissions only slightly. Briquetting and washing decreases SO_2 emissions for heating and cooking more than the CEM measures modelled, although the CEM measures affect a broader array of emissions and end uses. Coal washing

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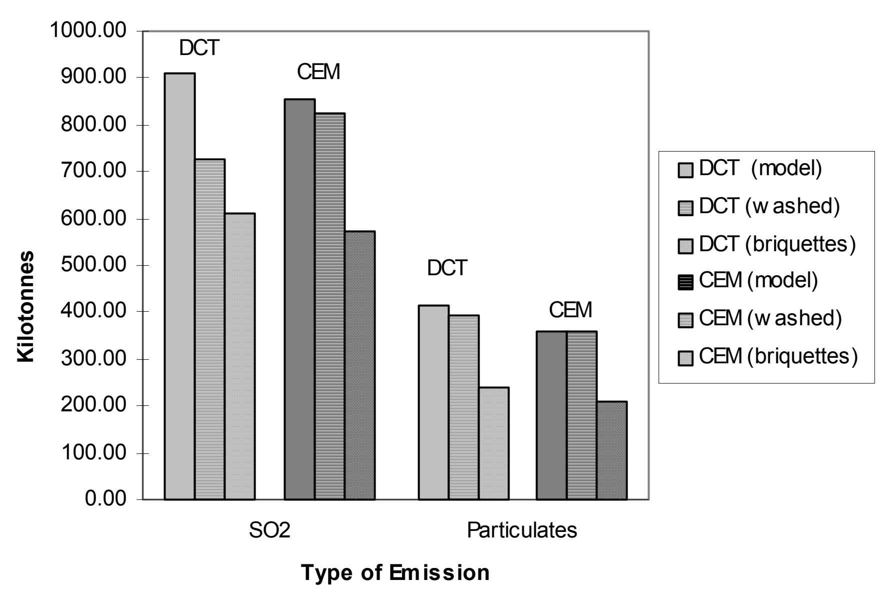
[33] The reality is more complex. For example, apartments generally have more living space, and therefore have a higher energy heating/cooling requirement. This is interesting considering the reverse is true in North America and Europe.

and briquetting complement the CEM strategies to reduce SO_2 cooking and heating emissions further. However, coal washing in conjunction with CEM strategies does not decrease particulate emissions any further. This suggests that if the only objective of policy is to reduce particulate emissions from cooking and heating end uses, a choice must be made between coal washing and the CEM strategies contemplated in this modelling exercise. Both reduce particulate emissions in cooking and heating to a similar degree. However, CEM strategies do reduce particulate emissions in additional end uses (transportation and cooling) which will have a greater overall impact in improving local air quality.

While evaluating technological demand side management (DSM) measures is beyond the scope of this paper, future efficiency differences in a number of technologies were evaluated to gain a sense of how these developments would affect future savings. This was carried out by improving the efficiency of some technologies relative to others in the same end use. I assumed that the efficiencies of the following technologies improved 25% relative to the others within their respective end uses: automobiles, coal stoves, room air conditioners. The efficiency of electricity was also assumed to increase by 25%. The resulting change in emissions is relatively small. The differences in emissions between the CEM and DCT scenarios are reduced by 2.35 % for CO_2, 2.88% for NO_x , 1.04% for SO_2, and 0.57% for particulates.

Figure 2.14 The Effects of Coal Briquetting and Coal Washing on Future CO_2 & SO_2 Emissions from Cooking & Heating.



Data

In addition to these simplifications, uncertainty is also present in the model due to data limitations. This manifests in different ways. First, some values are problematic. For example, it is rarely explicit when a study describes a value that relates to urban area (i.e. total urban energy consumption), what definition of urban is described by this value -- towns, cities, counties, agricultural, non-agricultural. Second, in some instances data is derived from a site specific Chinese study or a study from another country because of a lack of available Chinese national data. In some cases, the analysis is performed using 'educated' assumptions (quantitative interpretation of qualitative trends) rather than on hard data. Furthermore, there are some parameters over which there is a range of speculation (motorization growth rate, population growth rate), and others where there are divergent study results (effects of urban form on transportation). Given these model limitations, it is therefore important to consider the range around values used in the model. These are shown in Table 2.11. Certain parameters are also explored in more detail.

Table 2.11 Uncertainty Ranges in Model Parameters

Parameter	Value(s) in Model	Estimated Range(s)
Future penetration of district heating	DCT 20% CEM 23%	10 - 25%. 12 - 33%
Motor vehicle growth rate (DCT)	14%	7 - 19%
Reduction in motor vehicle growth rate (CEM)	34%	25 - 50%
Future share of electric heating in Zones 3 & 4 (by development class)	20% (L1 & 2) 18% (M1 & 2) 10% (H1 & 2)	10 - 40% 10 - 40% 10 - 40%
Future share of central heating in Zones 3 & 4 (by development class)	5% (M1 & 2) 10% (H1 & 2)	0 -10% 1 - 20%
Future district cooling penetration (DCT) (by development class)	1 - 2%(M1 & 2) 2 - 3 % (H1 & 2)	0 - 4% 0 - 5%
Increase in gas penetration in CEM relative to DCT (annual growth rate)	1%	0.5 - 1%
Future public transportation modal share	22% (DCT Zones 1,3,5) 23% (CEM Zones 1,3,5) 17% (DCT Zones 1,3,5) 19% (CEM Zones 1,3,5)	19 - 24% 20 - 26% 15 - 19% 16 - 21%
Annual growth in cooling demand	12% (Zone 3) 10% (Zone 4) 14% (Zone 5) 12% (Zone 6)	9 - 18% 7 - 16% 11 - 20% 9 - 18%
Future annual 'passenger km traveled' (PKT)	6661	5000 - 8000
Energy efficiency of urban transport (GJ/PKT)	0.0034 (auto) 0.001125 (motorcycle) 0.00021 (bus) 0.0012 (HOV)	0.0015 - 0.0039 0.0008 - 0.00145 0.00018 - 0.00024 0.0010 - 0.002
Transportation 'class multipliers'	1.27 (L1) 2.0 (L2) 1.1 (M1) 1.83 (M2) 1 (H1) 1.73 (H2)	1 - 1.6 1.5 - 2.5 1 - 1.4 1.4 - 2.3 1 1.3 - 2.2
Heating and cooling 'class multipliers'	1.34 (L1 & L2) 1.00 (M1 & M2) .98 (H1 & H2)	1.2 -1.5 1 1 - .75
Future heating demand (GJ/capita/year)	4.8 (Zone 1) 4.0 (Zone 2) 2.2 (Zone 3) 1.1 (Zone 4)	4 - 5.5 3 - 4.5 1.5 - 2.5 0.5 - 1.5
Annual growth in housing stock	1.9%	1 - 3%
Particulate emission control in electricity generation (elec.), district heating (dh) and central heating (ch)	95% (elec.) 85% (dh) 30% (ch)	85 - 98% 70 - 90% 20 - 40%

Table 2.11 Uncertainty Ranges in Model Parameters (continued)

Parameter	Value(s) in Model	Estimated Range(s)
% of existing development assumed mixed	95% (1-3 stories) 70% (4 - 10 stories) 20% (11+)	85 - 100% 60 - 90% 10 - 40%
% of new development (DCT) assumed mixed	15% (1-3 stories) 55% (4 - 10 stories) 15% (11+)	5 - 50% 40 - 75% 5 - 20%
Initial distribution of building types, Archetype I (Zones 2, 4, 6)	62% (1-3 stories) 35% (4-10 stories) 3 % (11 stories)	49 - 79% 20 - 45% 1 - 6%
Initial distribution of building types, Archetype II (Zones 2, 4, 6)	83% (1-3 stories) 17% (4-10 stories) 0 % (11 stories)	75 - 92% 8 - 25% 0 - 1%
Type of new building, Archetype I (Zones 2, 4, 6)	1% (1-3 stories) 76% (4-10 stories) 23 % (11 stories)	0.5 - 2% 72 - 83% 16 - 28%
Type of new building, Archetype II (Zones 2, 4, 6)	3% (1-3 stories) 88% (4-10 stories) 9% (11 stories)	2 - 4% 85 - 90% 5 -12%

Sensitivity of Transportation Parameters

In exploring the sensitivity of the parameters, it was found that model results are very sensitive to transportation parameters and in particular, the projection of motor vehicle penetration. Figure 2.14 demonstrates how varying motorization growth rates affect the model results. The arrow indicates the annual automobile and motorcycle growth rate projected in the model. The range for the growth rate that is expected varies from a low of about 7% based on an elasticity of 1.09 and an excepted GDP growth rate of 6%, to a high of about 19% based on an elasticity of 1.95 and an expected GDP growth rate of 9%.[34] Uncertainty is due to economic, political, cultural and geographical factors. NO_x emissions are strongly affected by differences in this parameter, because they are the principle emissions from transportation energy use. Similarly CO_2 is sensitive because a significant portion of savings between the DCT and CEM scenarios in Figure 2.3 occurs from transportation. SO_2 and particulate savings are not particularly affected because they are not strongly linked to transportation. This sensitivity suggests that the CEM strategies will be more effective the more Chinese cities resemble North American ones in their dependence on motorized transportation.

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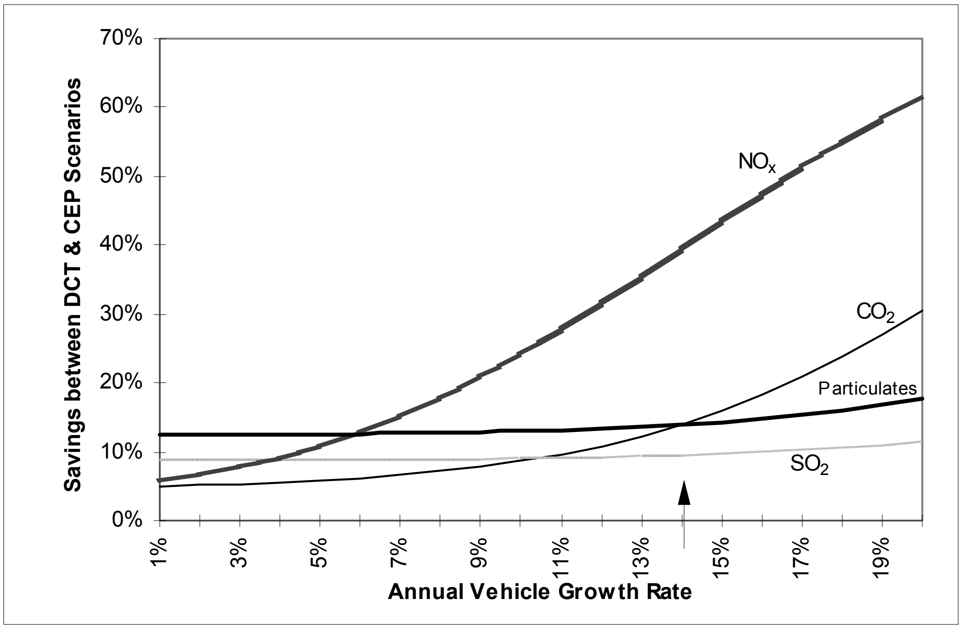
[34] The upper and lower elasticity values are taken from a table of income elasticities of motor vehicle ownership in Stares & Liu Zhi (1996).

Other transportation parameters that show strong sensitivity when both the upper and lower end of the estimated ranges are tested are:

- The energy efficiency of urban transportation.
- The reduction in the motor vehicle growth rate through transportation management in the CEM scenario.
- Transportation class multipliers.

Figure 2.14 Sensitivity of Motor Vehicle Ownership on the Savings between the DCT and CEM Scenarios.



Energy Consumption Multipliers

The variation in estimated transportation and building energy savings in CEM studies is explored in more detail. In general, there is some consensus in the literature on direction of the effects, but differences as to the degree. Sources of uncertainty in empirical studies include the large number of variables influencing energy use, and the difficulty in isolating the effects of built form. (socioeconomic factors, climate, behavioral variables etc.). Uncertainty also results from how accurately these mainly Western experiences can be related to China. This aspect is investigated further in the model by exploring how much differing estimations of the effect of urban form on passenger km traveled and in building energy would affect the model results. It was found that the model is reasonably sensitive.

Testing the range between the lowest and highest values in the transportation class multipliers in Table 2.11, affects the percentage change in total emissions savings between the DCT and CEM scenarios by 24% for CO_2, 4% for SO_2, 13% for NO_x and 3% for particulate emissions. The effect is less strong for heating and cooling multipliers. Testing the range between the lowest and highest values in the transportation class multipliers in Table 2.11, affects the percentage change in total emissions savings between the DCT and CEM scenarios by 24% for CO_2, 4% for SO_2, 13% for NO_x and 3% for particulate emissions.

Future Directions:

The results of this modelling exercise broadly suggest that CEM strategies may bring about significant reductions in emissions. However, because of its limited scope and data, this exercise provides a foundation for future exploration and refinement, rather than a solid solution. Directions for future study might include:

- Applying the model's method on a smaller scale and with more specific data -- for instance, by looking at one province or urban area.
- Developing China-specific studies from which to base land use interactions rather than apply numbers from out of country studies. This is particularly important given that the North American context is considerably different. A lot of CEM studies look at effects on VMT.
- Altering the model to address other CEM strategies, such as facilitating renewable energy penetration.
- Calculating detailed costs estimates of reducing emissions through CEM measures and comparing these costs to alternative measures (such as coal washing).

Chapter 3

Implementing CEM in China

While the previous chapter has established the potential benefits of applying a CEM approach in Chinese urban areas, the important aspect of how CEM may be realized remains unanswered. Does China have the planning tools and institutions to effectively control urban growth and energy infrastructure development, as well as industrial, commercial and residential siting? What aspects of current institutions are amenable to CEM? What kind of policy tools would be most suitable in realizing the CEM strategies outlined in Chapter 1? Addressing these questions not only involves analyzing the component parts of CEM -- land use planning, site and building design, energy supply and delivery systems, and transportation management -- but also how institutions and policy tools can implement CEM holistically. The implementation of CEM objectives necessarily requires an institutional structure capable of using a systems perspective which can achieve diverse social, economic and ecological objectives.

This Chapter examines some of the key institutional and policy implementation issues involved in land use planning, site and building design, alternative energy and supply, and transportation management. The following framework is used:

- The main objectives for CEM implementation are set out.
- Current institutions and practices are analyzed in terms of how they meet these objectives.[1]
- Specific implementation recommendations that stem from this analysis are forwarded.

Discussion of these issue areas will give some insight into the overall nature of Chinese institutional structures. In addition, the ability to adopt a systems perspective and to integrate energy and urban planning policy at a state and local level is explored further to capture what cannot be touched upon by investigating the facets of CEM separately.

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[1] Institutions and policies are changing rapidly in China. Thus the names and descriptions of institutions may change very quickly from what is described here.

3.1 Land Use Planning

3.1.1 Institutional Objectives

- The ability to influence urban development including urban growth; industrial, commercial and residential siting; and infrastructure development.
- The ability to carry out integrative and holistic planning.

3.1.2 Analysis of Current Practices

The Existing Land Use Planning Process

Urban planning practices find their routes in the recent past. The *City Planning Act* was implemented in 1990 and applies to all development and construction activities within municipal government planning areas. The dominant means of control of urban form is through the use of 'master plans', a practice which has only been in place since 1984. Master plans are strategic 20 year plans for urban construction and development which define a city's identity and its future direction and scale of development. Future general land use patterns and major infrastructure distributions are outlined including roads and energy provision. Plans may include urban environmental protection. Measures and procedures for plan implementation are also developed, including guidelines and schedules of development projects. A diagram showing the organization of government institutions relating to urban planning and land administration is shown in Figure 3.1. The master plan is developed at the municipal government level by the City Planning Bureau, a branch of the Municipal Construction Commission which mirrors the Ministry of Construction (MoC) at the local level. The City Planning Bureau follows guidelines which are developed by the MoC in its Department of Urban Planning. Once developed, the plan is submitted for approval to the central state government.[2] When approved the plan becomes a statutory document -- all development is to coincide with this plan. More detailed area plans are drawn up on the basis of the master plan, though these plans are not subject to overview or approval at a higher level.

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[2] First it is approved by the municipal People's Congress. It is then submitted for approval by the next higher level of government--in practice by the Urban Planning Bureau of that level. (Hok-Lin Leung, 1993). For the centrally directed administered cities, provincial capitals, and large cities greater than 1 million, the plan is submitted to the State Council for ratification (Li Xiaojiang & Yu Li, 1996).

Development proceeds as follows: Investments proposed by licensed enterprises and nonprofit institutions are submitted to the local Planning Commission, another branch of the municipal government which shadows the State Planning Commission (SPC). Once approved, plans are passed on to the City Planning Bureau for decisions on a site which have to be consistent with the master plan. Thereafter, the site plan is followed by the issuance of various permits. If new rural land is required for development, approvals and permits are also sought from the local bureau of 'State Land Administration' (SLA) which has the responsibility of monitoring and controlling land use. Residential development is guided in a similar fashion. Real Estate Development Companies (REDCs) -- authorized in 1984 to introduce 'commercial' transactions in real estate -- are controlled by the municipal Construction Commission so that residential development is controlled in accordance with the plan.[3]

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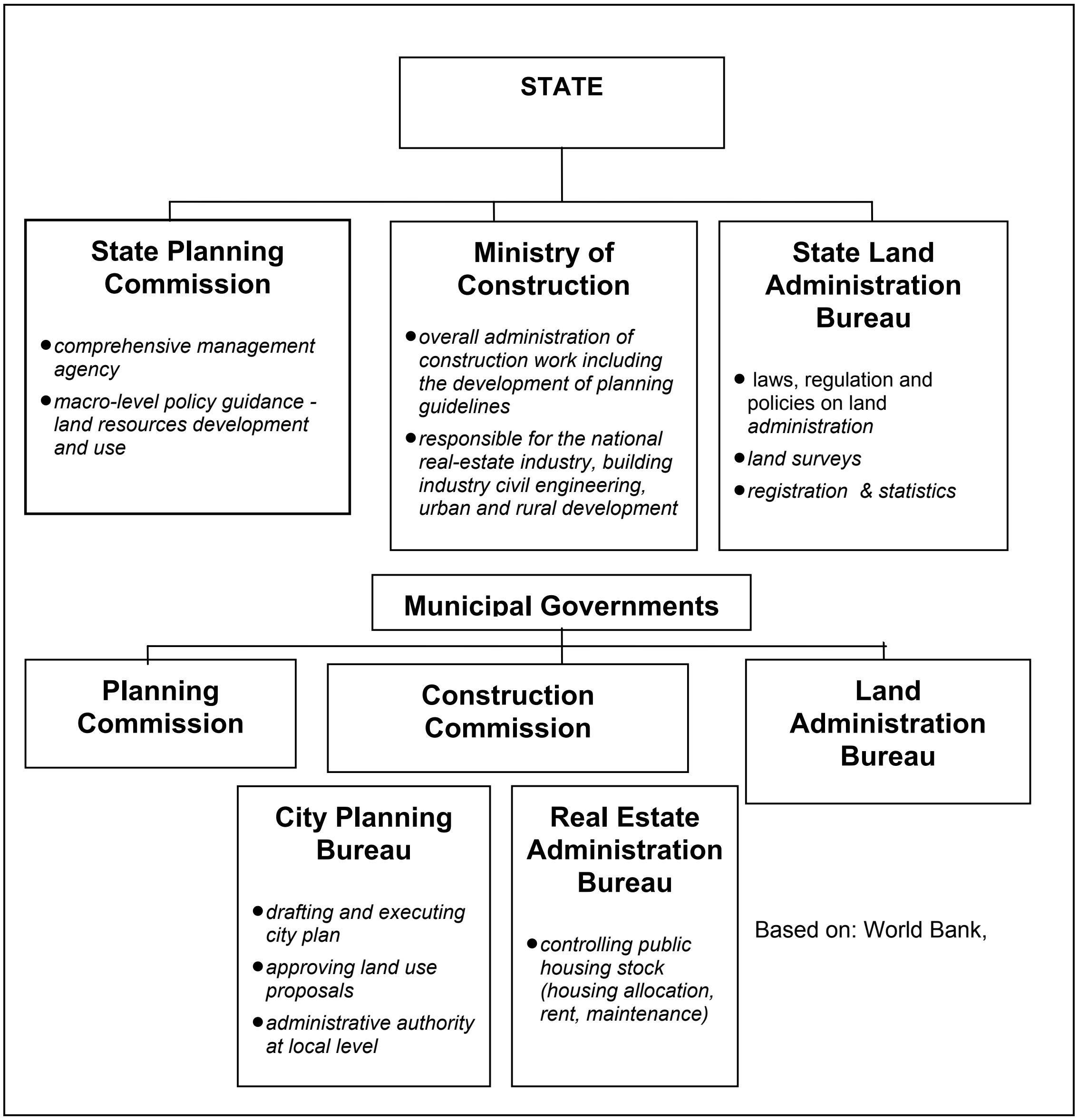
[3] 40-80 percent of all new housing units completed are sold under "regulated" market conditions by REDCs.

Figure 3.1. Organization of Significant Government Institutions that Relate to Urban Planning and Land Administration



Based on: World Bank,

Analysis of the Process

The urban planning process has the appearance of a very structured and comprehensive framework suited to the integration of CEM objectives into urban form development. However, in the description of urban land form in Chapter 1, it was mentioned that new development is frequently disjointed and poorly planned, while inner-city development is scattered and unconnected, all of which would suggest that actual development differs from the planning process outlined above. Numerous aspects contribute to the unfolding of urban development which has definite implications for the ability to promote sustainable energy principles within urban form.

Project Coordination

One source of piecemeal redevelopment is the different timing of construction as financial resources become available. There is a lack of coordination and connection between new projects. Housing projects are generally restricted to the tier of buildings which exist along the street. Thus the manner in which the construction project affects the spatial patterns of the whole neighborhood is not taken into account, confounding problems of traffic flow and creating poorly unified land use (Zhou Yiming & Xiong Yichang, 1989). Buildings are constructed along the property line, leaving no land for other uses, such as parking spaces for bicycles and basic activity space. The average width of the planned area is between 20 and 30 meters. Coordination of development projects and infrastructure is particularly problematic in new development zones. Often, these zones are too large to be adequately serviced by infrastructure, and development fails to materialize. Density control is nonexistent and building code enforcement minimal (Hok-Lin Leung, 1994).

Plan Enforcement

A priority for local government is often to accelerate economic development and short-term growth, and development control may be relaxed in order to increase the attractiveness of particular sites for development (Gar-on Yeh & Fulong Wu, 1995). A reliable framework for the protection of planners against arbitrary decisions and executive interference is absent. According to Hok Lin Leung (1989), changes and revisions are made without the consent of the approving authority. It is not uncommon for planning decisions to be overturned by the mayor or ‘the powers that be’ without reference to the master plan. This is despite the stipulation in the *Urban Planning Regulations* of 1984 that no change is allowed in the master plan once it has been approved. A significant factor cited for the lack of enforcement is that the rights and responsibilities of the actors involved in plan making, implementation and urban development are not clearly spelled out or enforceable (Hok Lin Leung, 1994). This is made worse by the lack of planning and municipal legislation that planners can refer to, or enforce decisions with. A shortage of planners in many cities further aggravates this situation (Zhao Shixiu, 1992).

Plan inflexibility

Ad-hoc approval of spot development also causes infrastructure requirements to be different than as proposed in master plans. The cumulative effects of district-level permits for land development are usually not monitored and reflected in revised macro-spatial infrastructure plans. Trunk infrastructure dictated by the plan, such as road, gas and electricity provision, may proceed without responding to the reality of development. For example, in Tianjin, the urban population has been growing and is largely contained within 9 or 10 km from the centre, an area which is poorly serviced by infrastructure. However, based on a 1980 master plan, the local government went ahead and built a 100 km long Third Ring Road, 11 to 12 km from the city centre, which has since been grossly underutilized. The Plan does not prevent adjustments to changes in small area development, which is facilitated by the district plans developed by lower-level authorities, but it directs long term investment in trunk infrastructure away from those areas. CEM necessitates having a planning process that is much more dynamic and adaptive and whose principles are explicit and realistic. Many cities are now revising their master plans, but the process for state approval is lengthy. Additionally, they still do not incorporate feedback based on systematic monitoring of small-area demographic and economic indicators (World Bank, 1993a).

Development Control

The mechanism for development control varies somewhat, but so far most cities have developed zoning ordinances (Hok-Lin Leung, 1994). Hong Kong development has unfolded through the British system of development permits. The key differences are that the zoning ordinance approach relies on predetermined designation of all lands for specific uses and building parameters, while the development permit approach treats each development proposal according to its merit, although a city-wide master plan gives some guidance. Both approaches have certain challenges in being adopted by China. The ‘zoning ordinances’ approach requires a precise legal procedure to ensure due process in amendment and is based on the primacy of private ownership. Currently land use zoning rules are overly general, and there is no clear understanding about the legal holder of property rights to a certain piece of land (Gar-On Yeh & Fulong Wu, 1995). The development permit approach is based on state functionaries willing and able to articulate the public good, and thus raises issues of corruption and waste (Hok-Lin Leung, 1991). While a permit system may be superior for implementing CEM objectives in terms allowing more flexibility to allow for mixed land use and building types, both approaches are capable of accommodating CEM objectives. Zoning should not be overly restrictive in specifying land uses.

Peri-urban Areas

In addition to the challenges mentioned above, a significant obstacle to comprehensive urban planning and the adoption of CEM principles within the present planning system, is the large proportion of urban development which is not even covered by the urban planning framework. Development in peri-urban areas and the suburban fringe, which is experiencing the fastest rate of economic growth in China, is not subject to any comprehensive planning procedures, and is a major source of urban sprawl.[4] According to a World Bank study, satellite imagery indicates that a vast amount of peri-urban development has emerged in the last decade, often equal in scale to the officially requisitioned land meant to follow the master plan guidelines governing the growth of the city (World Bank, 1993a). A city planning bureau usually does not have sufficient personnel to enforce the city plan over the whole city-region. The practice is for the city planning bureau to make the master plan for the city-region and enforce it within the urban core (or "city proper"), and for the district/county planning bureaus to enforce the plan at the district/county level. The city government is reluctant to intervene in the suburban districts and rural counties for fear of antagonizing the traditionally powerful peasantry (Hok Lin Leung, 1993). Coordination of development within the region is also challenging, particularly in terms of locating development zones and growth within the region. According to Hok-Lin Leung (1994), "every administration, provincial as well as municipal, has bypassed central government to create their own 'development zones' and embarked on an orgy of development and competition, each setting up its own tax policies, subsidy schemes and land policies."

Institutional Coordination

Urban planning agencies face considerable challenges in managing city construction projects. The organization and management of construction enterprises suffer from a lack of communication between building departments and local authorities and between the different enterprises themselves. The structure of economic management and development has caused economic activities in a spatial unit to be compartmentalized according to structure of the bureaucracies involved. Often, the social and

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[4] Commercial housing tends to cluster in the urban fringe because of the relative ease in consolidating land. Redevelopment of old areas with dense populations is more costly because of the necessity to relocate the original residents and complications in negotiations for land (Gar-on Yeh & Fulong Wu, 1995).

economic development program in a city is developed by the planning committee while the urban plan is drawn up by the construction committee, quite independently of each other. A decision in 1986 to place the Urban Planning Bureau at the state level under the joint leadership of both the State Planning Commission and the Ministry of Construction represents an attempt to improve the linkage between economic planning and urban planning (Hok Lin Leung, 1993).

Market Reform

The introduction of market values into land use is a major component of how urban development is unfolding. The role of city planning is increasingly seen to be one of developing and administering the city in order to provide better conditions for investment, living and working, and less the direct involvement in the organization and management of production. The market development of land use values is in a state of transition. In 1988, the Constitution and the Land Administration Law formally recognized the right to transfer state-owned land to users who would pay for the rights to use such land, becoming leaseholders. Real estate development companies (REDCs) can transfer serviced land, housing and related facilities on a for-profit basis. Ownership rights still reside with the state; thus land cannot be bought and sold, but development rights and use rights can. The price of land is determined by compensation to land owners which is set by planning, rather than the marketplace. Land use taxes were introduced to provide incentives to return underutilized land to city authorities, and to encourage spatial restructuring. However, these taxes lacked a coordinated intergovernmental strategy to create real land markets based on explicit prices, and were not widely successful. One reason given was that land was sold at too low a price (People Republic of China Yearbook, 1995). Furthermore, land is often developed on the periphery of urban areas because acquisition of land for leasing or the development of commercial housing in the city center involves much time-consuming bargaining. Urban planning practices are slow to reconcile with market changes, especially now that industries and enterprises have more discretion in choosing their location than before (Gar-on Yeh & Fulong Wu, 1995). Zhao Shixiu (1992), Director of the Urban Planning Department (MoC) states that “the existing urban planning administration is the continuance of the system under the old planned economy with complicated operation processes and low efficiency.”

3.1.3 Recommendations

A. A revised master planning concept, which still involves coordination between the state and municipal levels of government, would be important in bringing together energy policy and urban planning policy. However, it could be reformed so that it can be better integrated into actual municipal planning and development processes. This would involve changing its frequency, flexibility and its content. For example, removal of the requirement of State Council approval would discourage static plans. Nevertheless the state level role in setting objectives to be incorporated into the urban planning process would be valuable.

B. In order to implement plans comprehensively within the broader urban area, master plans could be developed and implemented within a regional context. Alternatively, municipal control could be effectively extended over peri-urban areas. Either of these options would require changes to the legislative framework.

C. The incorporation of adaptive management principles into urban planning would be helpful in coordinating land use development. A mechanism could be created that allows actual development to be ‘fed back’ into the plan including the nature, location, and phasing of infrastructure investments, and the requirement for new planning to be done to reflect these changes. Hong Kong and Singapore, for example, have flexible macro structure plans that allow for such feedback (World Bank, 1993a).

D. Any level of land use plans should optimally be developed through an iterative and comprehensive process which involves a detailed examination of the existing city. For example, an approach would be to develop alternative scenarios of expected expansion and redevelopment with associated basic infrastructure networks and other facilities needed to support related urban configuration of the city. Scenarios could then be judged by multiple criteria, and the associated energy implications and environmental effects determined.

E. It is critical that urban planning recognize the linkages between comprehensively developed housing projects where work units purchase housing for their workers, and the location of the workplace, since that link is no longer directly made as part of economic development. It is also important to ensure housing development is adequately coordinated with industrial development either through on-site housing by company or close-by under municipal control.

F. In order to reduce arbitrary planning decisions, a stronger legal framework could be applied to planning practices. For example, information about a land development proposal as well as the decisions and their justifications could be well advertised (Hok-Lin Leung, 1994). In addition, the better enforcement of existing laws and regulations would allow land use plans to be more effectively implemented.

G. CEM land use objectives need to be encouraged through policy instruments that are appropriate to the government's evolving role towards the emergent market economy. Instruments include regulatory (legal) mechanisms and market incentives. Their relevance in implementing CEM objectives is discussed below:

- The further development of consistent legal mechanisms for development control would allow developers and third parties to gain a clearer understanding of property rights to a certain piece of land, and for the state to have greater control over development. This could be accomplished through both zoning and development permit approaches. CEM objectives could then be implemented through conditions attached to those rights. For example, favorable heat source areas could require special development standards for future uses in order to locate heat intensive uses close to heat sources wherever practical.

- Market mechanisms could implement CEM objectives through the use of the price system. For instance,
    - Developers could be offered bonuses to accomplish goals set out in the master plan. This might include: maintaining and encouraging significant densities in areas targeted for mass transit facilities; encouraging housing development corporations to provide certain kinds of on-site services such as grocery stores, daycare centres and clinics.
    - A taxation structure could be established which taxes land heavily relative to buildings and makes it expensive to leave land vacant, thus discouraging urban sprawl.

H. An effective coordination mechanism between departments would be helpful for planning and managing infrastructure projects and for regulating development. Inconsistencies or conflicts that might arise could be managed by clear rules that are developed jointly by the departments involved.

3.2 Energy Supply and Delivery Systems

3.2.1 Objectives

- The ability to identify energy efficient and alternative supply investment opportunities appropriate to local conditions and that make sense from an economic, social and environmental perspective.
- The ability to encourage the efficient development of these opportunities.

3.2.2 Analysis of Current Practices

Many Chinese national energy policy goals are in keeping with the CEM strategies -- for example, China has stated policies of encouraging cogeneration, district heating systems and clean coal technology such as coal cleaning and coal gasification. The government's goal for cogeneration in district heating and cooling is a coverage of 15% of residential floor space by 2000 (Fuqiang Yang, 1996). It is useful to examine Chinese institutional, financing and regulatory measures, to see whether they are effective in achieving policy goals, particularly in the context of China's evolution towards a more market-based economic system.

The Existing Energy Planning Process

A diagram showing the organization of key state level and local institutions relating to energy supply and delivery process is shown in Figure 3.2.[5] Energy supply is managed through separate ministries -- the Ministry of Power Industry (MOPI), The Ministry of Petroleum Industry, and the Ministry of Coal Industry. Each ministry coordinates with state commissions and administers energy prices, approves new energy projects and controls the operation of existing entities.[6] Government funds for energy development now go through several large state corporations servings as developers, such as the State Energy Investment Corporation and the recently formed State Power Corporation. Currently, policies and regulations on renewable energy are primarily administered by the Ministries of Power, Water

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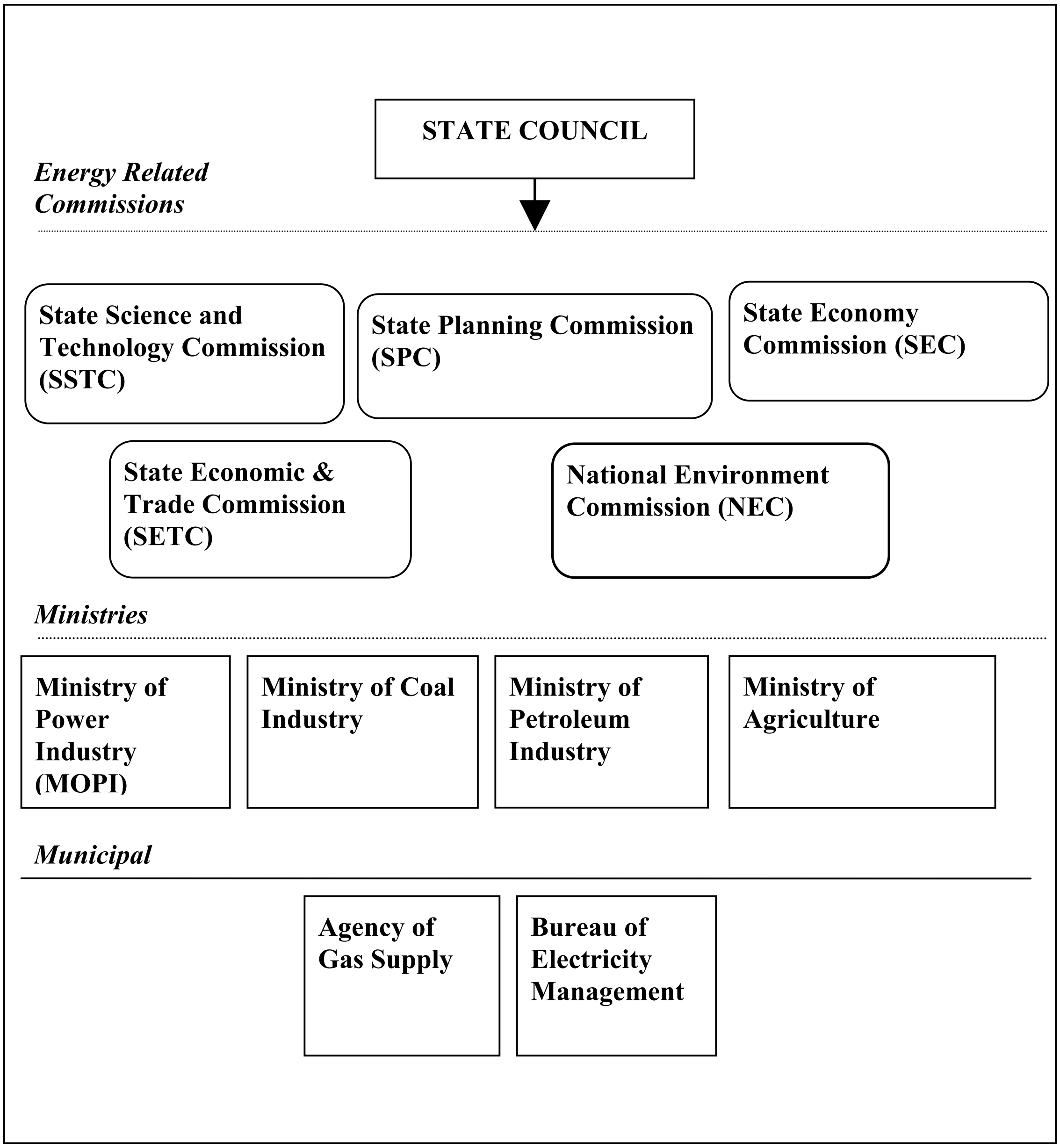
[5] This diagram describes institutions as they are known to exist in 1996.

[6] Commissions have an integrative, coordinating role and are at a higher bureaucratic level than ministries. Commissions involved in energy planning include the State Planning Commission (SPC), the State Economy Commission (SEC), the National Environment Commission (NEC), and the State Science and Technology Commission (SSTC). The SPC is responsible for setting the direction of energy conservation capital construction investments, planning national key capital construction projects, approving large and medium scale projects. The State Economic and Trade Commission (SETC) sets and implements technological renovation demonstration projects in energy conservation, rational resources utilization, rural energy, and 'new' energy.

Resources and Agriculture. The State Science and Technology Commission (SSTC) and MOPI provide technical support where possible. Ministries have concentrated on national strategies and policies, while delegating responsibility for project development and regulation to various provincial bureaus (Jaccard & Hao Liu, 1994). The structure at the provincial and lower governments levels in energy supply is similar to those at the central government level. Municipal structures include an Agency of Gas Supply and a Bureau of Electricity Management (Yichun Xie and Costa, 1993). The process for urban power supply is quite centralized. Cities submit applications for electricity demand to provincial power companies, which produce general supply-and-demand balances for their regions and submit their electricity production and consumption plans to MOPI. MOPI issues an annual electricity production consumption plan for the country. To get their quota of electricity in the upcoming year, enterprises and electricity management bureaus tend to specify in their plans power consumption much greater than what they really needed (Ming Yang, 1996).

Figure 3.2 Organization of Significant Government Institutions Related to Energy Supply and Delivery Systems



Analysis of the Process

Project Evaluation

CEM strategies require the flexibility to comprehensively evaluate supply measures, which is a challenge in the existing institutional arrangement. Different ministries have different processes and guidelines to assess projects; there is no single intra-ministry process regarding project assessment. The government is constrained in its ability to coordinate policies across subsectors (Fuqiang Yang et al., 1996). The SPC is one of the key places for coordinating each sector's development policies. However, as the SPC also functions as a funding allocation agency, each ministry seeks to protect its own interests during the negotiation process. Success is measured by the degree to which each ministry is able to secure investment capital for sector projects. The discrete planning and project review guidelines in each sector make project assessment at the SPC level very difficult. For example, project-evaluation procedures for cogeneration pre-feasibility and feasibility studies, approvals, and financing are inconsistent (Fuqiang Yang, et.al., 1996).

Project Financing

The Chinese government now has much less direct control over the type of projects that are funded. For example, the share of central government direct investments and loans in total cogeneration investment has declined annually since 1980. Overall, central and local governments share less than 50% of the total current cogeneration investment and will share even less in the future. Multiple channels of investment have become increasingly crucial. Since the mid-1980s, the most significant increases in financial resources for power development have come from fundraising.[7] After 1987, local administrations gained more power over financial decisions and project selection and could ratify energy sector projects costing up to 50 million yuan. They are allowed to examine and approve fuel-fired power plans with capacities of up to 800 MW and hydropower stations with capacities of up to 100 MW. The contribution by local governments to total investment in power plants increased from 1% in 1983 to 17% in 1990 (Fuqiang Yang et.al 1994).[8] Alternative energy delivery systems such as cogeneration projects have become "local" projects which have to meet local economic conditions and customer requirements. According to Fuqiang Yang et.al. (1996), local administrations are often more enthusiastic about cogeneration development and more flexible in their policies concerning cogeneration development.

Financial incentives have been a particularly important tool in promulgating efficient and renewable supply goals. One means has been through the use of preferential interest rates for energy conservation project loans. Rates on capital construction loans are 30% below rates for commercial loans, and rates on technological renovation project loans are 50% below. National energy conservation capital

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[7] Fundraising refers to local government capital, internal enterprise funds, collective savings, union funds, private savings, and stocks and bonds.

[8] Before the reforms, local administrations were required to transfer a major part of their revenues to the central government. In 1980 a new treasury reform policy required local administrations to establish quota contracts with the central government. Local administrations shared more financial power and were able to invest more in local projects.

construction loans are managed by the SPC's China Energy Conservation Investment Corporation (CECIC) and administered by the Construction Bank of China, while technological renovation loans are overseen by the SETC's Resources Conservation and Comprehensive Utilization Department and are administered by the Industrial and Commercial Bank of China. Preferential loan rates (50% below commercial rates) have also existed for rural and renewable demonstration projects. These have been overseen by SETC's Resources Conservation and Comprehensive Utilization Department and are administered by the Industrial and Commercial Bank of China and the Agricultural Bank of China (Wang Qingyi et.al., 1995). Relatively favorable tax treatment of cogeneration projects has occurred, because policies have allowed local flexibility in determining a project's final tax rate (Fuqiang Yang et. al, 1996).

Unfortunately, investment in more efficient supply technologies is facing new challenges. Under the pressure of severe electricity shortages, more central government investments are expected to be allocated into conventional electric power rather than large-sized cogeneration (Fuqiang Yang et.al., 1996). Preferential rates are diminishing as a tool as financial institutions and practices are redefined. According to Wang Qingyi et.al. (1995), about half of national energy conservation capital construction loans receive no break on interest rates. Banks in coastal areas do not issue preferential rate energy conservation loans, and as the other specialized banks have commercialized, they have become less willing to take on these preferential rate loans. Tax incentives have also diminished. Since 1993, a 13 per cent value added tax has been added to any operation that changes energy from one form to another, including heat, steam, and cooling, which has affected cogeneration profitability.[9]

On the other hand, the transition to a market-based economy is also creating incentives to diversify supply and to switch to more efficient supply technologies. For example, low coal prices in the past have limited the development of new energy because of the greater relative cost of developing and importing new energy resources and higher energy efficiency technologies. In 1993, planned coal prices began to be freed up; by 1994 all but 100 Mt (10%) of coal output was no longer subject to mandatory price controls (Wang Qingyi et.al. 1995). In 1994, the dual-tack price system for crude oil and oil products was abolished and national unified pricing was implemented. A new electricity pricing scheme was also adopted by six grids, under which the price of electricity from new power plans would be set to recover cost plus return. Overall the freeing of coal prices represents a significant breakthrough in energy price reform. However, progress in reforming prices is still slow in a number of areas. First, problems in promoting gaseous fuels have resulted from heavy price

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[9] The 13 per cent rate is lower than the 17 per cent rate for the rest of industry.

subsidies to residential gas users. Low prices act to defer capital investment. Second, electricity prices could be priced to better recover costs and provide returns on investment determined by project loan rates. Relatively higher rates for out-of-plan electricity gives collective-owned generators a short-term perspective and encourages construction of small, inefficient units. Lastly, current energy pricing relating to cogenerated heat and power is not market based. It is not uncommon for the prices that heat producers receive to be lower than their costs. Heat prices have not caught up with increases in fuel and other material prices over the last decade, because prices are held artificially low to meet basic human needs and to avoid adding fuel to an inflation problem (Fuqiang Yang et.al., 1996). Cogeneration projects face difficulties in meeting the economic criteria for loan approval, because they are often unable to meet a set internal rate of return, due to low regulated prices. Overall, pricing should be efficient, equitable and meet social goals.

Administration of Existing Supply

While the development of new supply is important, the ability to administer existing supply systems is also critical to sustainable urban energy practices. Many challenges are faced in the administration of central heating at the local level. Central heating management is complicated by the existing housing-management systems. Communication is problematic between work units and cogeneration stations which usually have their own respective reporting central administrations, and have little involvement with local governments. Promoting energy efficiency of the operating central heating system, which often relies solely on administrative orders of local governments, is difficult (Feng Liu, 1993). Residential space heating is also not metered. Since residents do not pay much for heating services, there is little incentive for them to conserve (Feng Liu, 1993).

3.2.3 Recommendations

A. Sustainable energy supply could be encouraged by the adoption of consistent and transparent project evaluation procedures across government ministries and by evaluating options within an integrated resource planning framework. In considering projects, it is important that the benefits and costs of all available supply and demand-side alternatives and their respective impact on the local environment are thoroughly studied.

B. Greater coordination of policies and investment across energy subsectors is very important to implementing CEM objectives. This could be accomplished through the addition of integrative mechanisms or through institutional restructuring. For example:

- Provincial and local energy bureaus could be created that combine existing separate bureaus. For example, at the city level, the Agency for Gas Supply and the Bureau of Electricity Management could be combined; and at the provincial level, coal and electricity bureaus could be combined.

- Coordinating bodies free from the competitive dynamics that often characterize interagency communication could be introduced within the bureaucratic structure. Possibilities include the establishment of a separate body underneath the State Council that will unify energy conservation policy research, formulation, and coordination (Wang Qingyi et. al., 1995).

C. The closer coordination of municipal-level energy supply agencies with urban planning bureaus and commissions would help integrate urban planning with energy supply and industrial location decisions. For example, in order to promote larger scale district energy systems which encompass more than one project, a district energy zone could be created which includes those neighborhoods considered for ultimate inclusion in a district energy system. Special measures for density, diversity, rate of growth and site standards for this zone could be applied.

D. It is important that financial incentives, which have been used in the past to encourage efficient and renewable energy supply, reflect the significant changes to energy development and financing. This could include:

- Encouraging commercial banks to offer preferential interest rates for energy efficient and alternative energy technology investment.
- Reinstituting the tax exemption for delivered heat.
- Adjusting the tax treatment of energy equipment expenditures to recognize that most renewable resource have no fuel costs to be deducted from revenues for tax purposes (Byrne et.al., 1996).
- Using financial incentives to encourage technical upgrade investments as an effective way to solve capital constraint problems. For example, investing in bottom-cycle cogeneration from existing power stations is less capital intense than new cogeneration development.

E. Continued price reform in electricity, natural gas and ‘heat’ markets would encourage the diversification of energy supply. For example, higher natural gas prices would attract more supplies to the residential sector and make some gasification projects affordable. Cogenerated district energy projects would also benefit from pricing mechanisms that reflect the costs and benefits of cogeneration as accurately as possible. This could be aided by the negotiation of price and purchase contracts for cogenerated energy through an intermediary. For example, in Jiangsu Province the local governments are involved in negotiating electric rates between the cogeneration producer and utility, with positive results (Fuqiang Yang et. al, 1996).

F. More incentive to conserve residential heating energy could be introduced at the household level, by reforming the present residential heat-charge system so that end users are more directly tied to the heat supply. For example, heat meters for each apartment with centralized heating systems could be introduced. In addition, central and local governments could allocate funds for local housing bureaus to conduct routine inspection and maintenance of the central heating systems, in order to improve the overall functioning of residential heat supply (Feng Liu, 1993).

G. International cooperation in energy technology development and transfer could be intensified so that the use of new energy-efficient and alternative energy technologies is accelerated. Trade barriers for imported equipment and products could be removed, arrangements for domestic industries to manufacture foreign designs under license encouraged, and foreign exchange loans made available to purchase imported equipment if it is more efficient and cost effective than domestic equipment.

3.3 Site and Building Design

3.3.1 Objectives

- The ability to effectively influence the development of energy efficient building structures appropriate to local conditions.

3.3.2 Analysis of Current Practices

Standards

A major component of China's policy to encourage energy efficient building is through the "Energy-Efficient Design Standards for Residential Buildings -- Heated Buildings" ('the Standard') which has been in place since 1986. The Standard is a generalized statement of energy efficiency standards; it is up to local government agencies to use the Standard as a basis to develop detailed rules and regulations suited to local construction practices and climate conditions. Currently, there is only a single standard which covers heated residential buildings. The overall goals of this regulation are to first reduce the space heating fuel intensity (coal consumption per season per square meter of floor space) of new buildings to a level 30% less than its 1981 value by 2000, and secondly to further reduce the space-heating energy intensity of new buildings to a level 30% less than its 1990 value by 2000. The total reduction is 50% (Lang Siwei, et.al. 1992).

So far, the first-period goal has not met expectations. The actual implementation of the Standard has been realized to a great extent only in a few cities such as Beijing, where since 1991 all new civil buildings must be designed in accordance to the local rules and regulations of the Standard (Lang Siwei, et.al. 1992). In many smaller urban areas where air pollution control is not as stringent as in large cities and in cities with easy access to coal, there is not as much spending on energy-efficient buildings (Feng Liu, 1993). Poor implementation can be attributed to a range of factors. Supervision and enforcement mechanism for the Standard have not been developed. Scientific and research efforts, as well as the present infrastructure of the construction industry have not been sufficient to meet the technology needs for the construction of energy efficient buildings (Feng Liu, 1993; Lang Siwei et.al., 1992). Furthermore, the pressure of housing demand and the shortage of capital also give excuses to the local governments and the construction industry to resist the Standards, because the incremental capital cost of conservation measures could be used to put up more apartments. Developers get no direct benefit at all from energy efficient buildings. Property owners such as work units, they are usually swamped with demands for a quantity of apartments rather than for the quality of apartments (Feng Liu, 1993). Additional funds for improving thermal performance are also usually not made available.

Housing Ownership

The structure of the housing market and ownership complicates efforts to promote energy efficiency in building design. Ownership rights and housing tenure in China are divided into three components: land rights or land tenure (ownership of land), building tenure (ownership of buildings), and land use rights or living rights which entitle holders to ownership and title of occupancy of the space. All land rights are owned by the state, while building rights and living rights may be held by the danwei (work unit), the state or individuals. The majority of post-1949 housing is controlled and allocated by work units (Morris, 1994). Individual efforts to improve energy efficiency through such measures as retrofitting insulation and windows are difficult. Maintenance of the exterior and structure of housing is the responsibility of the government, while interior upgrading, non-structural repairs and improvements are the responsibility of dwellers. However, a number of factors make government repairs and upgrading inaccessible to dwellers. All requests for repairs are reviewed by official jurisdictions and requests which do not fit official programs are often deemed unnecessary. The length of time for the process to be completed is also lengthy (Morris, 1994).[10] Low rents have restricted the amount of money available for public investment in housing. For example, in 1990, average rents for urban residents in Shanghai covered only one quarter of maintenance costs, and were not sufficient to cover the additional costs of management, administration and household depreciation (Morris, 1994).

However, housing policy reforms have been initiated to convert the welfare housing system in China into a self financing business whereby the existing housing investment system is to evolve into a three-way partnership where the financial burden of housing is shared by the state, enterprises and the private sector. A leasehold system is being established in which the state still owns land, but the use of land is transferable. Components of housing reform include rent increases to eventually reflect the full market cost of housing production, privatization of existing housing including the ability of dwellers to purchase apartments, and the commercialization of new housing. Individual housing purchasing is minimal; however, a growing trend has been the purchase of open-market housing by work units who then distribute it to their staff, with the latter sometime being required to pay a certain part of the overall expense (Gar-on Yeh & Fulong Wu 1995). The capital needed for urban construction is more dependent on the income from land transfer, commercial housing and commercial urban facilities (Zhao Shixiu, 1992). Relatively little currently exists in the way of market incentives to encourage energy efficient building practices, and current building is not effectively incorporating energy conservation. According to Yu Joe Huang (1989), the development of a real-estate market has created strong disincentives against energy conservation by loosening government control and by rewarding those who build as quickly and cheaply as possible.

3.3.3 Recommendations

A. The Standard would be more effective if enforcement mechanisms are more thoroughly adopted. For example, each local government could establish an inspection and enforcement body for residential building codes. Violations of building codes could be clearly linked to economic or legal responsibilities. In addition, the development of energy efficiency standards for buildings in

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[10] This article refers to Lilong housing in Shanghai.

the Non Heating and Transition Zone areas would help limit the expanding demand for energy for heating and air conditioning in these zones.

B. The current development of a leasehold land system rather than a system based on private land ownership is favourable for the implementation CEM site and building objectives because the state can specify terms of the land lease. Terms could stipulate development requirements favorable to CEM objectives, such as building restrictions and design, height, arrangement of structures and permitted land use. Existing building approval processes could also be expanded to include consideration of the use of microclimate, landscaping, and location of paved surfaces.

C. The penetration of alternative energy efficient design, building materials and techniques would be assisted by increased support by the local and central governments for building sciences and technology research and development. It is particularly important that the development and introduction of new building materials and products that fit local conditions be stimulated. Support could also be given to the production and marketing of energy-efficient building materials.

D. Programs to encourage energy efficiency in building design need to take advantage of changes to ownership and financing structures. Possible strategies could include:

- Lending terms from financial institutions that recognize the lower operating costs of energy efficient homes.
- Financing mechanisms for preferred technologies for work units and individuals.
- A retrofit marketing and financing strategy which targets buildings at the time of privatization.
- Energy audits to identify opportunities for site and building efficiency improvements including air tightness, insulation, and the efficiency of heating and cooling systems.
- Having the central government match local development funds for efficiency measures in residential buildings.
- Residential and commercial demand-side management could be instituted by utilities in conjunction with integrated resource planning (least-cost planning) requirements.

3.4 Transportation Management

3.4.1 Objectives

- The ability to actively manage motorized transportation through a holistic planning process which fully considers all alternatives including demand management.
- The ability to influence the location of workers relative to the work place.

3.4.2 Analysis of Current Practices

Motorization

The growth of motorized traffic in Chinese urban areas has been dealt with through a mix of transportation planning and management efforts, as well as through some measures directed specifically at controlling motorization. For example, quotas, parking and garaging requirements have been implemented in some Chinese cities to control the number of motorcycles, taxis and enterprise-owned vehicles. However, according to Stares and Liu Zhi (1996), measures applied to date in China appear ad-hoc, are implemented as problems arise without analysis of needs and benefits of each vehicle class, and carry little restrictions on car usage. The tax system is currently favourable to automobile growth. Fuel taxes are very low in China compared to most other countries in the world. China imposes relatively high taxes on imported vehicles to restrain the volume of imports, but quite low taxes on domestically manufactured vehicles in order to encourage local industry. There is strong pressure from the vehicle manufacturers in China to maintain this system into the future (Stares & Liu Zhi, 1996). The central government has also decided to adopt a motor vehicle industry development policy whose central focus is the formation of a domestic market to ensure economies of scale for the domestic industry.[11]

Transportation Planning

Faced with considerable pressures of motorization and population growth, cities are active in transportation planning although this is made difficult by fragmented responsibilities for municipal transport. Specific engineering and technical means have been emphasized in domestic traffic

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[11] The policy aims to encourage private car ownership, and calls for the elimination of government controls on vehicle purchases, for car prices to be determined by the market, and for taxes on cars to be reduced (Stares and Liu Zhi, 1996).

research. Ring-road construction is usually seen as an important part of the overall traffic management scheme -- construction of inner, middle and outer rings to accommodate different traffic flows. Chinese master plans frequently have major outlines for urban road networks which, according to Stares and Liu Zhi, go well beyond the scale of expressway construction in existing developed motorized cities across the world (Stares & Liu Zhi, 1996).[12] Because traffic congestion constrains vehicle trips in the most heavily congested cities, the result of greater roadway capacity is likely to be more traffic (Sathaye et.al.,1994).[13]

Mass Transit

China's technological policies worked out by the State Scientific and Technological Commission have underlined the importance of developing public transport. Nevertheless, Allport (1996) suggests that many Chinese cities face a dangerous vacuum in mass transit development, created by planning for something that will not be built for many years, while ignoring here-and-now mass transit problems. Some larger urban areas have drawn up major plans for underground metro development which are quite ambitious, capital intensive and time-consuming. The total planned network of just Beijing, Tianjin, Shanghai, Guangzhou, Jinan and Chengdu is two to three times the entire metro network which exists in Asia today. Despite the potential contribution they make to improving traffic conditions and urban efficiency, rail systems require heavy levels of initial investment, high continued subsidies and lack the route flexibility of bus and paratransit systems. In addition, studies from both Manila and Hong Kong indicate that rail systems may tempt bus users, but do not necessarily lure passengers away from cars or other private modes (Sathaye et.al., 1994).

In his investigation of the mass transit planning process, Allport (1996) identifies a number of limitations. He suggests that the process is often technically oriented, and narrow in institutional terms. Objectives for the metro as part of the transport system are not explicitly set. For example, it is not clear what transport policy assumptions are set, e.g. the future role of the car, vehicle restraint policy, etc. Nor is it clear how demand forecasts are prepared such as how they are influenced by socio-economic changes occurring from fares. Plans are also not constrained by available funding.

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[12] It is not uncommon to see plans for motor networks of high performance urban expressways comprising two to four ring roads, several other radial routes extended to the planned new development areas, and networks of expressways criss-crossing the central areas within the planned Inner Ring, all superimposed on the existing urban area street network.

[13] The following rationale is given: If the volume of the road network is increased, congestion may initially decline. Existing personal vehicle users can travel faster and are able to make more trips, increasing traffic volume. It also means that the difference in travel time between public and private transportation increases, making personal vehicles more attractive and inducing new travel demand.

Rather, funding is seen as a 'problem to be solved' once the plan is determined. Cost estimates often build in assumptions set by the state which may not reflect actual local conditions. Lower-cost alternatives to the metro are not frequently evaluated. Justification depends on comparison with the do-nothing situation. For example, medium-capacity systems and elevated metro systems are not considered for construction through the centres of most cities, even though many cities in developing countries have built elevated LRT systems through their centres because they were affordable at their stage of development. Another important concern of mass transit planning is that bicycle-bus integration does not appear to be fully recognized.[14]

Public transport services are underpriced, which burdens the road system with excess traffic, and produces financial deficits to be made up from general revenues (Stares & Liu Zhi, 1996). The constant adjustment of commodity prices increases the cost of public transport, making it difficult for these enterprises to adopt new equipment and techniques. Instead, they can often only manage to maintain their position (Xu Xunchu, 1990).[15] Currently, no substantial state funds are available for metro investment. Recent experience suggests that the municipalities are usually unable to invest substantial resources in metros and that development will be constrained to those larger, wealthier cities where large real estate profits can contribute to funding (Allport, 1996). However, reforms have opened up funding sources for new capital investment so that now funding sources can include direct investment, loans or grants from the government, collection of investment from enterprises, or joint venture projects (Yu Qingkang and Shi Young, 1988). The state can also offer preferential treatment to encourage development, for example, by allowing municipalities to borrow foreign funds at low rates, by allowing land development and by allowing municipalities to issue bonds to finance such projects.

Land Use

As mentioned in Section 1.2, transportation demand is strongly linked to work proximity. China is unique compared to other countries in the role of the work unit in securing housing for its employees. However, this role has undergone significant changes in the past decades, so that work units no longer determine directly where their staff and workers live, but instead purchase housing for workers in comprehensively developed housing projects which are developed by the municipality's development companies (Gar-on Yeh & Fulong Wu, 1995). The focus is turning to municipal control over business

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[14] Past planning has seen terminal bus stops put midway between subway stops, about ten minutes of walking distance away (Xu Xunchu, 1990).

siting. The discussion and recommendations in Section 3.1 are equally applicable to this section on transportation management.

3.4.3 Recommendations

A. China currently has a window of opportunity to establish effective transportation policies before motorization is too far advanced. The development of inter-agency teams at the municipal level would allow more comprehensive and holistic planning that includes consideration of demand-side management and land use planning, as well as traffic management and engineering traffic solutions. It is important that transportation planning develop a wide range of possible strategies that are evaluated using multiple criteria to determine the most suitable strategy. In terms of mass transit, both metro and lower-cost options should be evaluated.

B. The government is in a position to be proactive in practicing land use and transport planning on a scale not normally possible, because of the government's ownership of land, which provides the ability to control development and to ensure the land can be secured to implement transport projects (Allport, 1996). This is different from other developing countries. Land use planning could be much more closely coordinated with transportation planning. The recommendations in Section 3.1, which relate to urban planning, are applicable here.

C. The maintenance of public funding for mass transportation is important for the continued improvement of transit systems. However, funding relationships could be altered to allow the system to become more self-sufficient. For example, Sit (1995) suggests that more needs to be done in the way of bus company exemption from taxes, supply of cheap fuel, and increased investment from the government to modernize and increase the fleet.

D. Public transportation planning for both the short and long term would allow public transportation improvements to be achieved while pursuing longer term options. For example, Allport (1996) suggests that both a long term (15 years) transport strategy, and shorter term action plans (5 years) could be formulated which are fundable. Less expensive means of public transportation development could be explored that can be upgraded as funds permit. For instance support could

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[15] In 1990, transportation costs were only 0.9% of living expenses in Tianjin (Xu Xunchu, 1990).

be given to the improvement of ground public transport which could lead into the development express buses, busways and light rail transit.

E. It is critical that urban planning recognize the relationships between comprehensively developed housing projects, where work units purchase housing for their workers, and the location of the workplace since that link is no longer directly made as part of economic development. Approaches that could be taken might include encouraging development companies to coordinate with work units that have a demand for housing at the initial development stages of their projects, including siting decisions. Or, if projects are already being established, preferential treatment could be given to work unit housing demands that are in closest proximity to the development.

F. Work unit employee transportation programs could be encouraged, such as subsidizing transit passes, developing HOVs (as motorization develops), and providing bicycle facilities. This is already informally a part of many enterprises, but explicit policies should be made to encourage environmentally friendly transportation. Currently, most non-freight motor vehicle traffic occurs between enterprises. Travel by non-motorized modes could also be encouraged by limiting motor vehicle parking.

G. Comprehensive measures to control vehicle ownership and use could be further developed at the appropriate government level. This might include:

- Raising fuel and vehicle taxes, and using the funds to invest in public transportation.
- Establishing tolls at peak hours on key bridges and connector routes.
- Continuing the use of vehicle quotas.
- Restricting vehicle ownership to those who have off-street parking places (widespread practice in urban Japan).
- Employing area-wide bans to prevent certain types of vehicles entering the city centre during daytime hours.
- Employing a system of odd-even number plates which restrict selected vehicle operation based on the date and the number of the plate.

- Instituting parking controls.

- Instituting area pricing such as supplementary licenses, tolled cordons and electronic road pricing.

3.5 Integrating CEM Objectives

In the recommendations in Sections 3.1-3.4, the importance of integrating energy and urban planning policy at a state and local level, and adopting a systems perspective has been brought up frequently. These objectives are explored further in this section.

Interagency Cooperation

Institutions involved in the urban planning and energy planning are broadly linked at a state level. Commissions integrate policies which involve various facets of the economy, while ministries manage specific aspects of the economy. Commissions are at a higher bureaucratic level than ministries. However, the State Planning Commission's (SPC) role as an integrative mechanism for coordinating ministry policies to achieve stated policy objectives is challenging, because functional ministries and territorial governments compete for power and funding. Furthermore, a study of the Chinese bureaucratic system suggests that integrative policy making -- that which involves more than one functional ministry at more than one level -- is made difficult by the functioning of China's unitary system, whereby both lines of authority are to share power cooperatively according to a system of dual rule (Lieberthal and Oksenberg, 1988). However, there is often either rule by one or the other depending on the relative power of each in the issue at hand. Economic planning still often dominates policy making, a holdover of the 'lack of non-productive' investment mentality. This prioritization, and the very rapid pace at which new industrial investment is established, allows economic development without full rationalization of how its development will fit into existing or future community structure and infrastructure patterns. The legal system does not function in a fashion that enables it to adjudicate key issues and establish stable precedents. The implications of this bureaucratic structure on the prospects of successfully implementing CEM are significant, given that planning initiatives rely upon a holistic and integrative approach. For example, the CEM strategy of coordinating industrial energy with residential siting could be problematic to implement given the communication that would be necessitated between financial, construction, energy and industrial vertical ministries.

Local Government

The level of responsibility for energy and urban planning at the municipal level is generally favourable to CEM implementation. As seen in the Section 3.1, city agencies have a greater role than any other level of government in guiding urban land development. This control is even more pronounced now that greater powers of approval have been invested at the lower levels of government with regards to energy investment projects. Local actors also have much more latitude in initiating industrial projects and allocating increased proportions of national investment. Direct municipal investment and building have shifted to the regulation and control of both private and state development. Municipalities are in a good position to use their close relationship with foreign investment to access 'state of the art' technologies.[16] Comprehensive planning, which includes industrial sites and environmental protection, is also increasingly being undertaken by local government (Hok Lin Leung, 1993). However, local government processes face some challenges in being able to implement CEM strategies. First, public involvement in both urban and energy planning is limited -- residents should be allowed to become more involved in guiding the development of urban plans and exploring how CEM strategies might improve their immediate circumstances. The level of organization that presently exists at the neighbourhood level, in the form of neighbourhood and residents committees, is quite strong. Environmental programs are part of their jurisdiction. However, these committees have had little control over land use in their areas, especially vacant land which may exist. Second, municipal structures face many of the same coordination problems as the state level. The local level of planning coordination can be further confounded by prominence of vertical power structures, which are outside of the control of the local level of government.[17]

Bureaucracy

A basic goal of China's urban economic reforms has been to break the administrative lines of authority that bind China's economy, and to permit the growth of horizontal economic ties, which is potentially more conducive to cooperative government policy. However, the fundamental structure of the Chinese bureaucratic system that was established in the 1950's still continues to exert tremendous influence on the policy process. Lieberthal (1992) suggests that the reforms flattened China's bureaucratic hierarchy and increased the importance of non-bureaucratic sectors without changing the fundamental nature of relationships which rely upon informal criteria, such as personal connections and bargaining.

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[16] Some cities, including Shanghai, have even been looking into foreign investment in the development of municipal infrastructure systems.

[17] Large developers, who often have the backing of state ministries, generally 'call the shots' (Hok Lin Leung, 1993).

Procedures for a system of democratic and scientific policy making have yet to be established. Admittedly, the combination of the rapid development of non-governmental efforts, the commercialization of many governmental activities, continued bureaucratic power to intervene in the market, and confusion over norms, does makes it more challenging for clear CEM initiatives to be taken. However, authorities and resources have been redistributed to some extent, and in some sectors and areas, markets are quite strong. An emerging market system has the potential to loosen the bureaucratic holds that have been responsible for poor land use and disjointed planning. Past examples of sprawling land use have been attributed to a disregard for the inherent value of the land. A World Bank (1993a) report on land use reform suggests that further marketization of land use values will lead to more dense suburban development, but that the emergence of the market economy will loosen the control exercised by urban and economic planners over the location of economic investment. The successful implementation of CEM is dependent on how it can fit into the continuing evolution of a market economy as well as the new political economy relationships that will develop.

Future cooperation

The future implementation of CEM relies on how development brought on by these changes can be managed, and whether an urban planning system can be maintained and strengthened in the changing times. The emergent nature of the market system is favourable to incorporating, from the start, tools and processes that can implement CEM objectives, such as regulation, market incentives, education/information and targeted public investment. This could allow the development of a more sustainable capitalism before systems become entrenched. Adjustments need to be made to existing policies that are favourable to CEM in order for them to reflect the market-oriented reforms. For example, Integrated Resource Planning (IRP) could be incorporated into energy planning so that gains from CEM through the urban planning process can be linked to other measures to improve energy efficiency. The Ministry of Construction and the respective energy ministries could also develop guidelines and energy-related goals that it feels could be fulfilled at the municipal level. These guidelines could then be included as part of the guidelines given by the MoC for the master plan. Legal boundaries are just now being developed, which could be shaped to strongly support CEM and other environmental aims. Already, some laws are providing a context for new planning approaches such as CEM. An Air Pollution Prevention and Control Law was passed which limits the mining of low quality coal, establishes acid-rain control areas and popularizes technologies for coal cleaning and the separation and briquetting of coal (Xie Zhenhua, 1996).

Conclusion

The way urban form unfolds will orient energy patterns far into the future -- longer than the life of any one automobile, boiler or air conditioner. Once the asphalt hardens, certain paths become less possible. Walking to work may cease to be a travel option; a district energy option may not be pursued because it is not economical. It is thus critical to shape urban form and infrastructure patterns so that the most sustainable energy paths can be followed. CEM should be an important component of a sustainable energy strategy in China, and needs to complement conventional energy analyses. This paper has sought to provide a thought-provoking analysis by highlighting what CEM might look like in China, and ways that it could be fitted into that country's current urban and energy planning practices. Some effort was also made to quantify the environmental benefits from adopting a CEM approach in order to provide a basis for informing Chinese decision-makers of the importance and relevance of this type of approach .

As shown throughout this paper, there are significant differences between a North American application of CEM and a Chinese application, both in terms of its benefits, specific strategies, and institutional dimensions. Reductions in local air emissions is a particularly strong rationale for applying CEM in China where the direct local environmental effects of residential energy consumption are felt much more than in North America. In many ways, China is well suited to adopting this perspective, particularly in its current position in being able to shape market forces before practices become entrenched. The ability for land control is much stronger given China's more 'conditionally-structured' property rights. Other advantages include the closer ties that currently exist in China between work and residence location due to the continuing organizational role of the work unit. The work unit is also critically placed to implement transportation strategies. China already approaches many energy issues with a CEM angle, for instance through its strong focus on district energy and renewable energy development. Furthermore, the municipality is already part of the institutional structure that oversees energy provision, which can complement its role as urban planner. Nevertheless, to adopt CEM, some key challenges need to be overcome. Economic opportunities are short-term and immediate and difficult to reconcile with longer-term, sustainability concerns. And even when policy and legislation are formulated, they need to be supported and enforced, and different government agencies and levels of government coordinated, so that what unfolds is indeed guided by policy objectives.

In implementing CEM, a gradual approach is needed. For example, a beginning point would be to gain a better understanding of how urban form and urban energy supply are currently being developed, and to understand what guides decision making. Rationales need to be more transparent and traceable. At the same time, actions to implement measures do not need to wait until after large amounts of information and studies have been carried out. A key CEM strategy is the encouragement of mixed land use development, and this can be integrated into current neighbourhood design practices. Additionally, neighbourhood and building designs do not need to wait until alternative energy supply technologies are available before manipulating design to accommodate them. For example, dwellings can be fitted with systems that are amenable to future hookups with district heating and cooling, and choices about roof angles and neighbourhood siting can be made to maximize the later adoption of solar hot water heating and/or photovoltaics.

A very important consideration in pursuing CEM strategies is cost, and particularly cost in relation to alternative strategies that would also reduce greenhouse gas and local air emissions. Though costs are not explicitly measured in this study, some speculations are offered. Costs are likely to be relatively low per tonne of CO_2, NO_x, SO_2 or particulates reduced. This statement is based on cost estimation included in Lee Failing's (1995) study which found that reductions through CEM measures in British Columbia can provide net benefits. Cost estimations included a savings in the cost of providing and servicing infrastructure. I would speculate that costs would be somewhat higher in China because the larger cost savings in Failing's study come from changes in urban form from single detached housing to multi-family housing, a change that is not applicable to China. Nevertheless there would still likely be many instances where moving to a more coordinated, mixed land use will lead to total cost reductions in providing infrastructure and will lower total energy costs because of efficiency improvements. Cost evaluation would also be affected by issues such as prices (i.e. the price of coal; whether steam/heat prices are reformed), and from who's perspective cost is evaluated (i.e. social or private). Furthermore, CEM strategies will most likely lead to favourable non-cost benefits such as a relatively greater employment effect from pursuing locally based energy projects compared to megaprojects, as well as reducing the loss of agricultural land to urban sprawl.

This paper can be viewed as a 'departure point' for exploring the relevance of CEM to China. It is hoped that many of the issues raised in this paper will be taken up in greater detail in future research. In conducting this study, it was found that there are many areas in which the knowledge base can be improved in order to have a clearer understanding of the potential effects of CEM on energy-related air emissions. These aspects are presented in Table 4.1 and based on parameters in the modelling exercise that were shown to cause the savings between the DCT and CEM scenario to be the most sensitive. They are presented from the strongest to the weakest. In addition to the informational needs outlined in Table 4.1, future CEM research directions are also be suggested. China has been treated in my research as a homogenous entity, overlooking the unique variations in urban planning and development experiences of different urban centres. A study exploring the detailed application of CEM to a specific urban community would be an important 'next step' in investigating this issue, both in terms of quantitative analysis and in terms of the social, political and implementation issues.

Table 4.1 Suggested Research Questions

Rank	Aspect	Suggested Research Questions
1.	Level of motorization	What level of motorization ownership can be expected in the future? At what point will the growth rate slow because of limited road capacity? When will this occur? How will the growth in motor ownership affect mode shares?
2.	Urban gas penetration	What conditions can maximize penetration of urban gas?
3.	Urban transportation efficiency	What are the characteristics of Chinese urban travel?
4.	Urban form and transportation	How does urban form affect travel demand and mode choices in a Chinese context (for example, where travel is less home-work based)?
5.	Travel demand	How much will travel demand characteristics change in the near future?
6.	Heating demand	How much will heating demand grow, particularly given the strong demand growth in the Transitional Heating Zone?
7.	Housing stock growth	What is the future projection of housing stock? Is it expected differ from the present growth rate?
8.	District heating penetration	Will the expansion of the district heating system be able to meet government projections? How does urban form affect the economics of district heating in China specifically?
9.	Cooling demand	How much will heating demand grow, particularly given the strong demand growth in the Transitional Heating Zone?
10.	Particulate emission control technologies	To what extent are there effective particulate emissions control technologies in electric generation, district heating and central heating? How will this change in the future?

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