China's urban energy:
status, trends and community energy planning

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Urbanization of China in future two decades

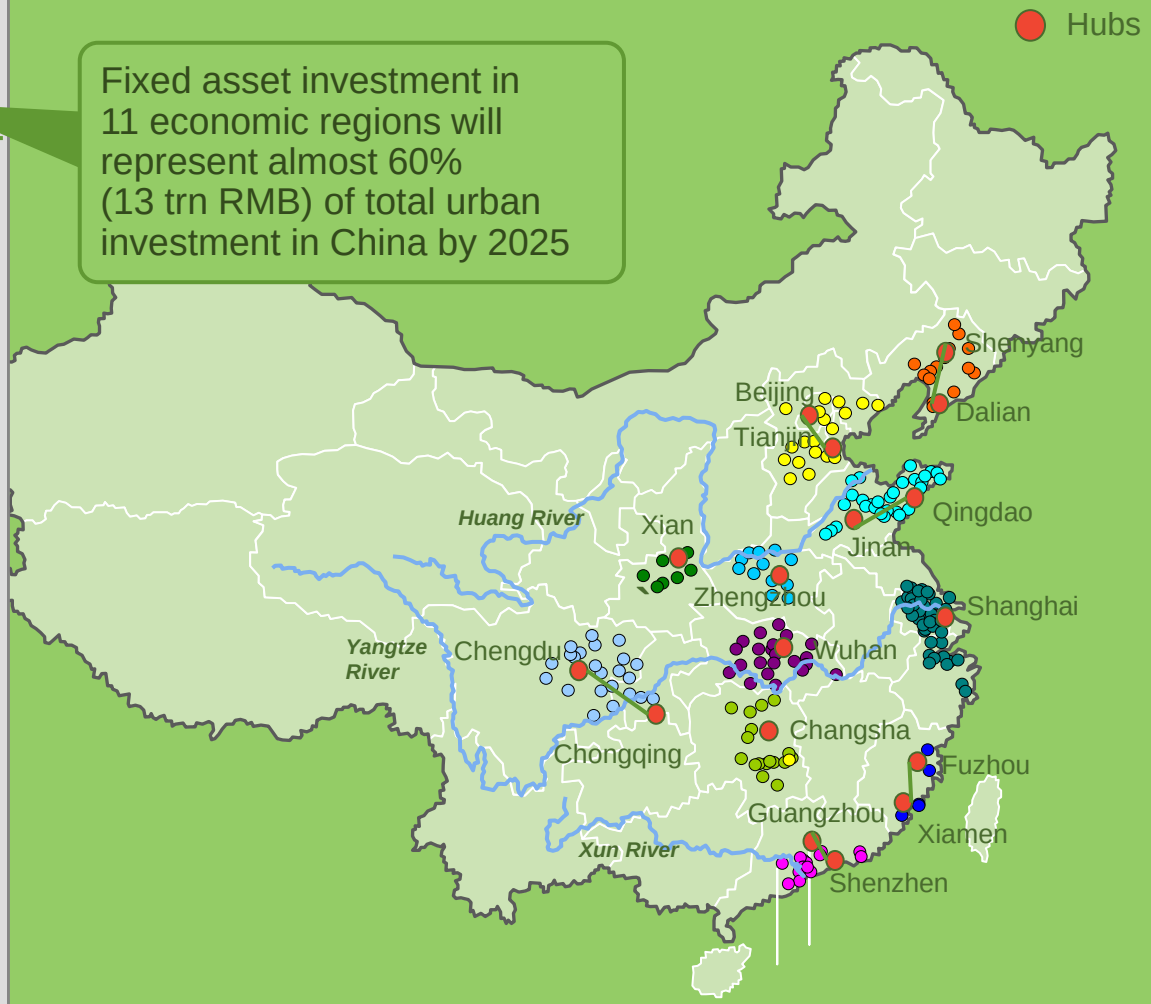
McKinsey Global Institute analysis

超过整个美国的人口（3.5亿）将从农村移居到城市	More than **350 million people** will move from rural to urban, over the population of entire United States
将有200个城市人口超百万	More than **200 cities** with population over one million; in Europe today there are only 35 cities of that size
将建设50000栋摩天大楼，相当于10个纽约	There will be up to **50,000 new skyscrapers**, the equivalent of buildings in ten New York cities
新建170个快速交通系统	Up to **170 new mass transit systems**; in Europe today there are about 70
到2025年，三分之二的中国人生活在城市，成为10亿城市	**… that's nearly 1 billion people**

11 city agglomerations with population over 60 million

Regional hubs	Number of cities in the region
Beijing / Tianjin	28
Shenyang / Dalian	22
Qingdao / Jinan	35
Xian	8
Zhengzhou	23
Shanghai	58
Chengdu / Chongqing	31
Wuhan	27
Changsha	20
Xiamen / Fuzhou	14
Guangzhou / Shenzhen	23

Fixed asset investment in 11 economic regions will represent almost 60% (13 trn RMB) of total urban investment in China by 2025



Source: McKinsey Global Institute analysis

A phase of build up cities

- Till 2020, the key transition period to the development of urbanization in China.
- Rapid population gathered to the cities brings huge investment and consumption demand on the environment, social security, infrastructure, and public services facilities.
  - New construction of industry park, business district, inhabit community and small town.
  - Retrofit of old cities.
  - Renew of transport facilities
  - Livelihood facility projects, such as health care, sports and fitness, and leisure entertainments

Characteristics of China's urbanization (1)

- Huge population.
- Land shortage.
- The heavy chemical industry and real estate are the main in the investment structure.
- The low-end manufacture is the main in the industrial structure.
- Export-oriented trade structure.
- The services economy is weak due to weak consuming.
- Real Estate is "kidnapping" the economy.
- Dual social structure.
- Lower level of urban management.

Characteristics of China's urbanization (2)

- New industry park or new settlements filled the gape in the city group, to form de facto super mega cities even with 100million population.
- Unreasonable land use to sprawl urban. Per capita land use in urban is 133m^2/p, far higher than the developed countries (per capita 82.4m^2) and developing countries (per capita 83.3m^2).
- Fragile ecological environment and infrastructure, vulnerable to the impact of natural disasters caused by climate change.
- Huge demand on energy and environment, social security, infrastructure, and public services facilities.
- Transition to the modern service industry based on the imperfect industrialization.
- Central government guides the transformation towards people-oriented and sustainable development strategies based on scientific development and harmonious approaches.

Energy characteristics of Chinese cities

- The main sector of energy consumption in almost all cities is manufacture industry.
- The high carbon endowments of energy structure with coal as the main resource
- A car-oriented planning concepts caused huge increasing in traffic energy consumptions;
- General level of building energy consumption is not so higher, but there are coexistences of
  - low energy consuming and poor environmental quality;
  - energy waste and energy poverty;
  - waste big and saving small.
- Huge demand of urban life energy in the future.

Trends of urban energy consumption

- In the industrial parks with modern manufacturing, the process energy consumption translated into the energy for built environment protection. To improve indoor environmental quality can increase the added-value of products, reducing energy intensity.
- Service industry park and business district are modern service-oriented. The indoor environment is a key factor in the safe operating (such as the data center), and also a key factor for improving the working efficiency of white-collar workers.
- The mode of global division of labor and intensive production has improved the efficiency of resource allocation, transferring the processing energy to logistic and traffic energy consumption.
- With the increase in disposable income and a sound social security system, residents' energy consumption for basic necessities, so-called "urban life energy" will be gradually increased.

Estimating development of residential & public buildings in Chinese cities & towns

Urbanization ratio	50%	60%
Total population of cities & towns /million	670	840
Per capita floor area of residential buildings /m2	30	35
Total floor area of residential buildings /billion m2	20	29.4
Per capita floor area of public buildings /m2	10	11.5
Total floor area of pulic buildings /billion m2	6.7	9.6
Total floor area of civil buildings in cities & towns /billion m2	26.7	39.0

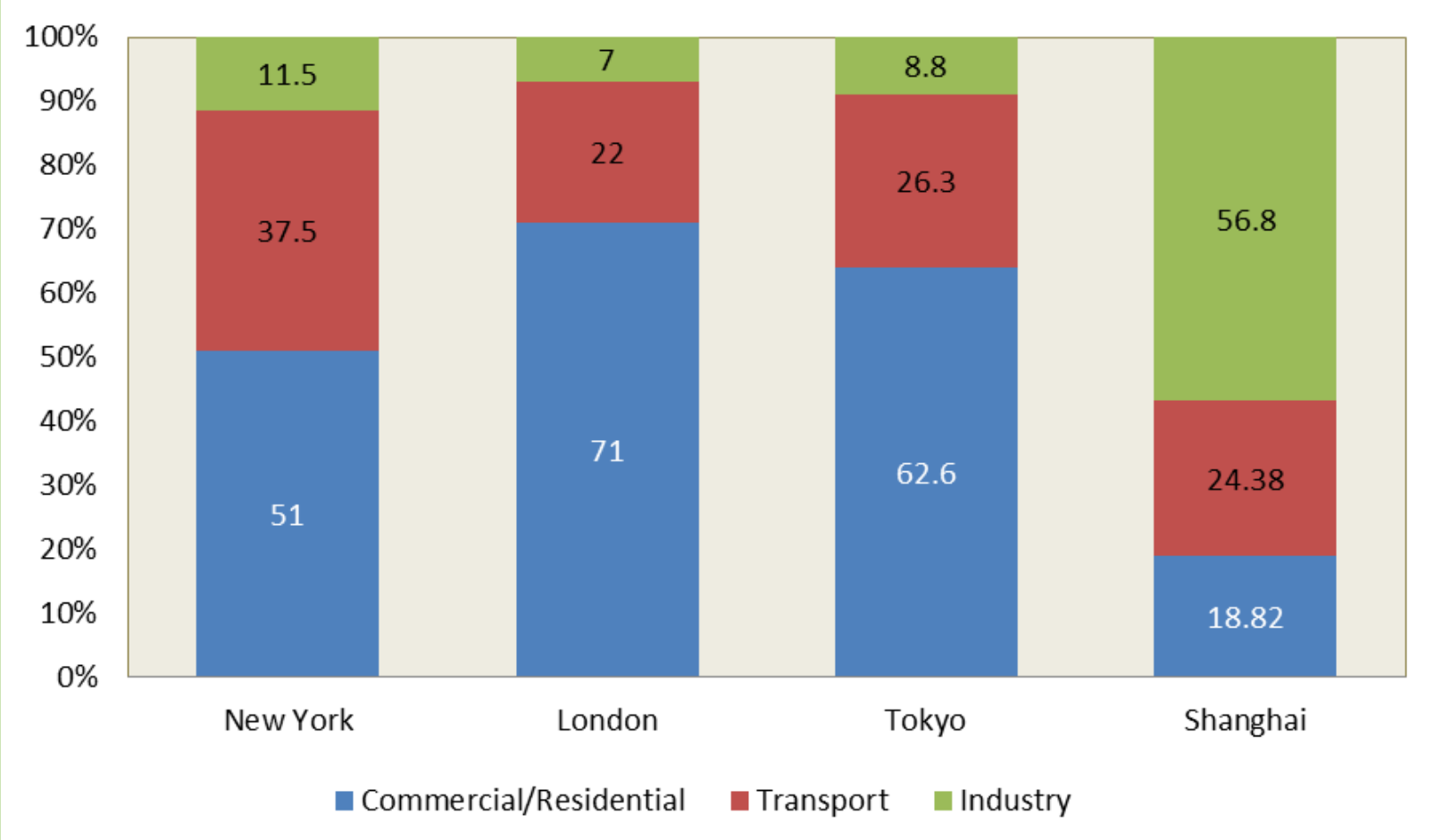
On building energy

- From a macroeconomic perspective, the greater the proportion of building energy consumption in total, the more reasonable and healthy of the economic development.
- Increase of building energy proportion in total is inevitable, but also an important symbol of economic structural adjustment and living standard improvement.
- The aim of building energy efficiency
  - Don’ t suppress reasonable energy needs in civil buildings
  - Decrease energy intensity in process of building usage
  - Increase building energy efficiency
  - Solve the gap of wealth in building energy usage
  - Increase renewable energy usage
  - Implement scientific building energy management
  - Create better built environment
- Truly reflects the "people-oriented" thinking of the scientific concept of development.

Energy consumption proportion of various sectors (%)

Country	Proportion			Primary, secondary and tertiary industries in GDP			Urbanization rate
	Industry	Building	Transportation	Agriculture	Industry	Services	
US（2007）	32.2	39.5	28.3	1	22	77	81
EU（2006）	27.5	41.1	31.4	5.0	24.9	70.1	80
Japan（2007）	45.6	31.2	23.2	1	31	68	80
China（2007）	58.3	24.5	17.2	11.3	48.6	40.1	45

Proportion of carbon emission in four mega-cities （%）



Energy consumptions in different types of building are different in nature

Manufacture
- Create GDP
- Value added built environment

Services industry
- Create GDP
- Energy efficiency improvement
- More services with less energy

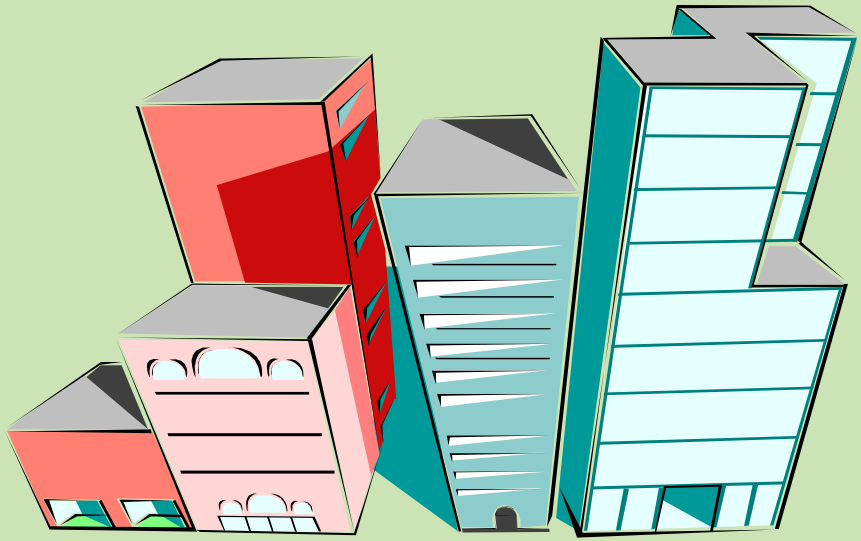
Utility
- Create GDP
- Energy efficiency improvement
- More services with less energy

Public services
- Expenditure
- Service efficiency improvement
- Reduce consumption

Livelihood
- Expenditure
- Promote the rational consumption
- Curb extravagant consumption
- People-oriented
- Meet basic human needs

Segmentation of energy consumption

- 三大领域是产业、交通和建筑。Three major sectors are industry, transportation and building.
- 两大部分是生产性能耗和碳排放以及消费性能耗和碳排放。Two major parts are productive and consumable energy consumption and carbon emission.



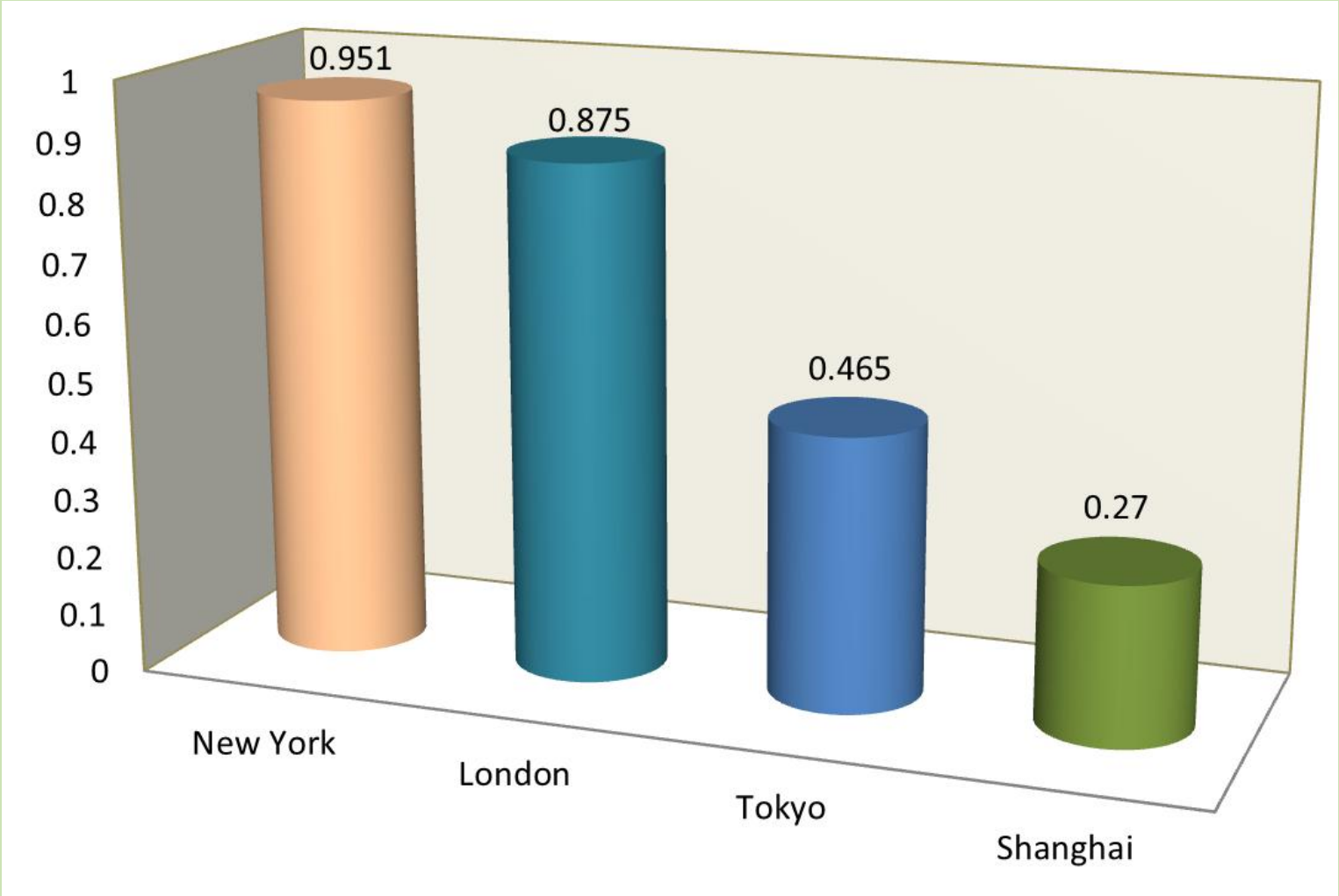
Productive energy consumption & carbon emission

- 体现在单位GDP能耗和单位GDP碳排放中。Reflected in the per unit GDP energy consumption and carbon emissions.
- 工业建筑、商用建筑、部分公用事业（如航站、车站、医院）的公共建筑，以及物流交通的能耗。Industrial, commercial and public utilities buildings, and logistic transportations are included.

Consumable energy consumption and carbon emission

- Public welfare and services buildings
- Government administrative office buildings
- Public traffic
- Urban life energy, in which residential building and private vehicle are included.
- Consumable energy consumption does not create value.
- It can be defined as energy consumption of urban life.

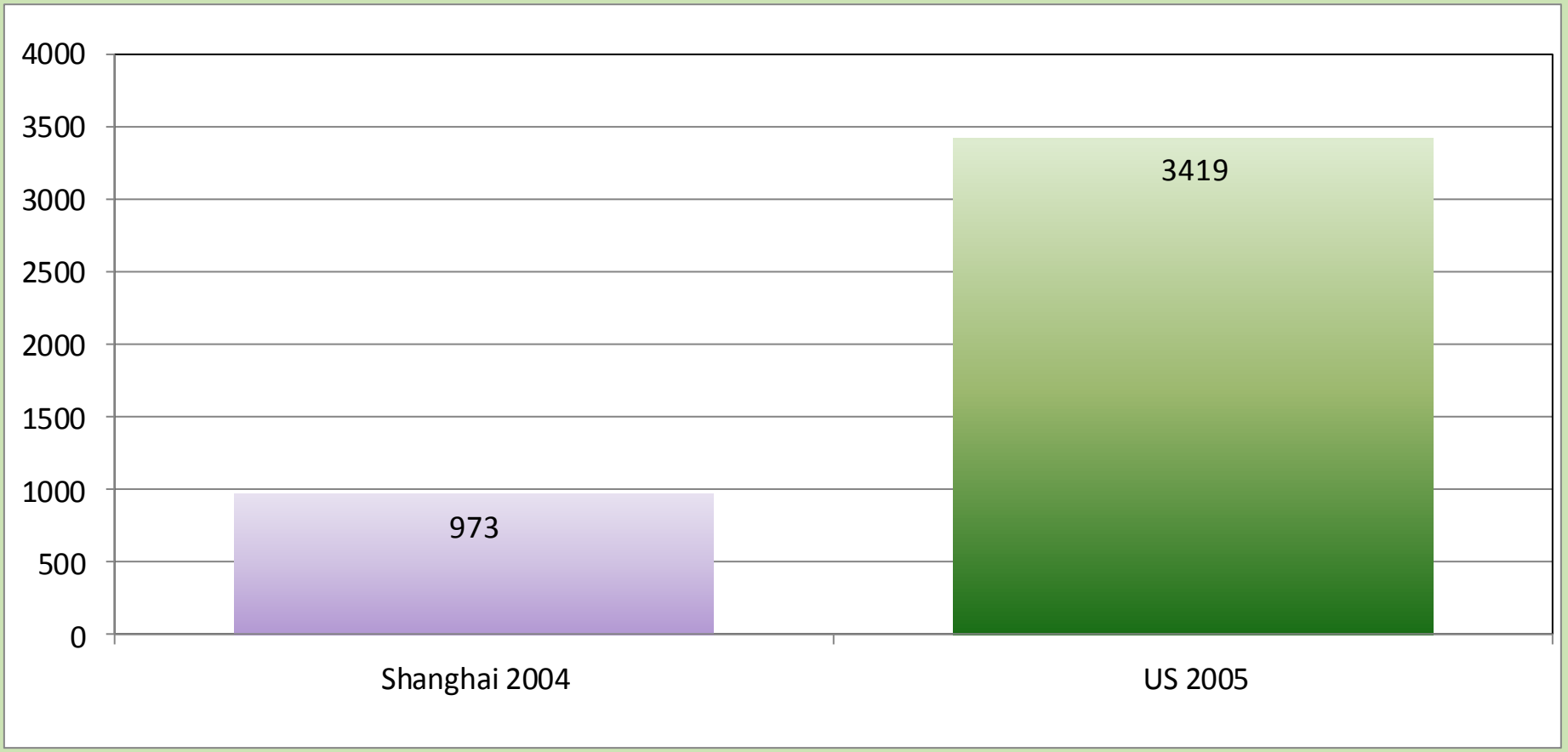
Per capita residential energy consumption in four cities （toe）



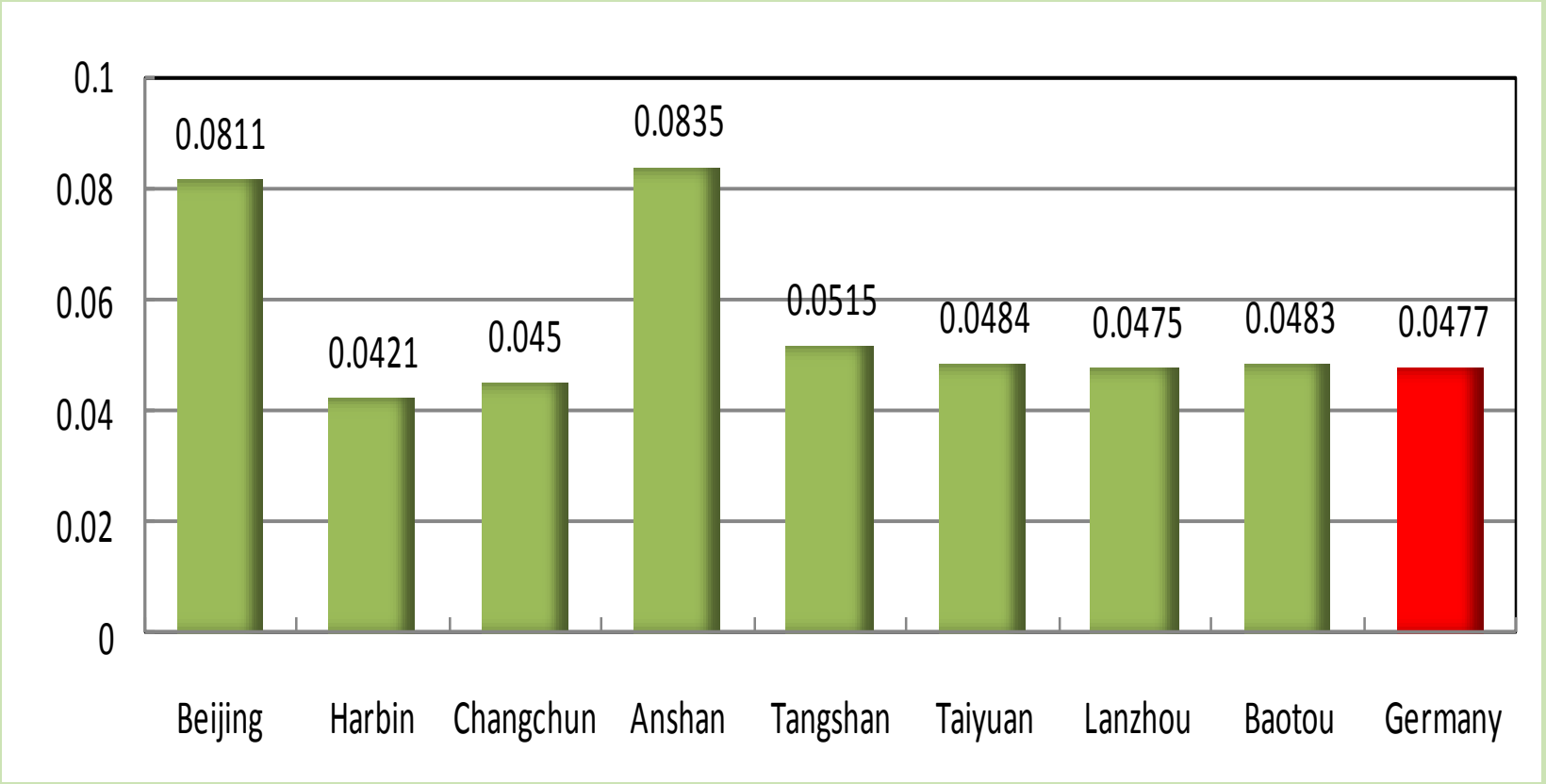
Comparison of heating and cooling demand

City	Latitude	HDD	Mean Temp. Jan.	Mean Temp. July
柏林 Berlin	52	2540	-0.4 ° C	17.9 ° C
汉堡 Hamburg	53～55	3073	0.5° C	16.8° C
纽伦堡 Nürnberg	49～51	3010	-0.8° C	18.3° C
慕尼黑 Munich	47～49	3061	-2.2° C	17.3° C
纽约 New York	40.77	2614	0° C	24° C
西雅图 Seattle	47.53	2471	5° C	19° C
罗马Rome	42	1570	1.9° C(Min)	31.2° C(Max)
伦敦 London	51	2558	4° C	17° C
温哥华 Vancouver	49.18	2820	3° C	17° C
哈尔滨 Harbin	45	5032	-19.2° C	22.8° C
北京 Beijing	40	2699	-4.3° C	25.9° C
东京Tokyo	35.7	1579	5.2° C	25.2° C
旧金山San Francisco	37.6	1675	9° C	17° C
亚特兰大Atlanta	33.7	1662	5.0° C	26.0° C
洛杉矶Los Angeles	34	1274	14.6° C	23.5° C
达维斯Davis	38.7	1527	7.3° C	24.0° C
休斯顿 Huston	29.7	1371	10° C	28° C
上海 Shanghai	31	1691	3.7° C	27.8° C
南京 Nanjing	32	1967	3.0° C	28.0° C
杭州 Hangzhou	30.2	1647	4.0° C	28.6° C

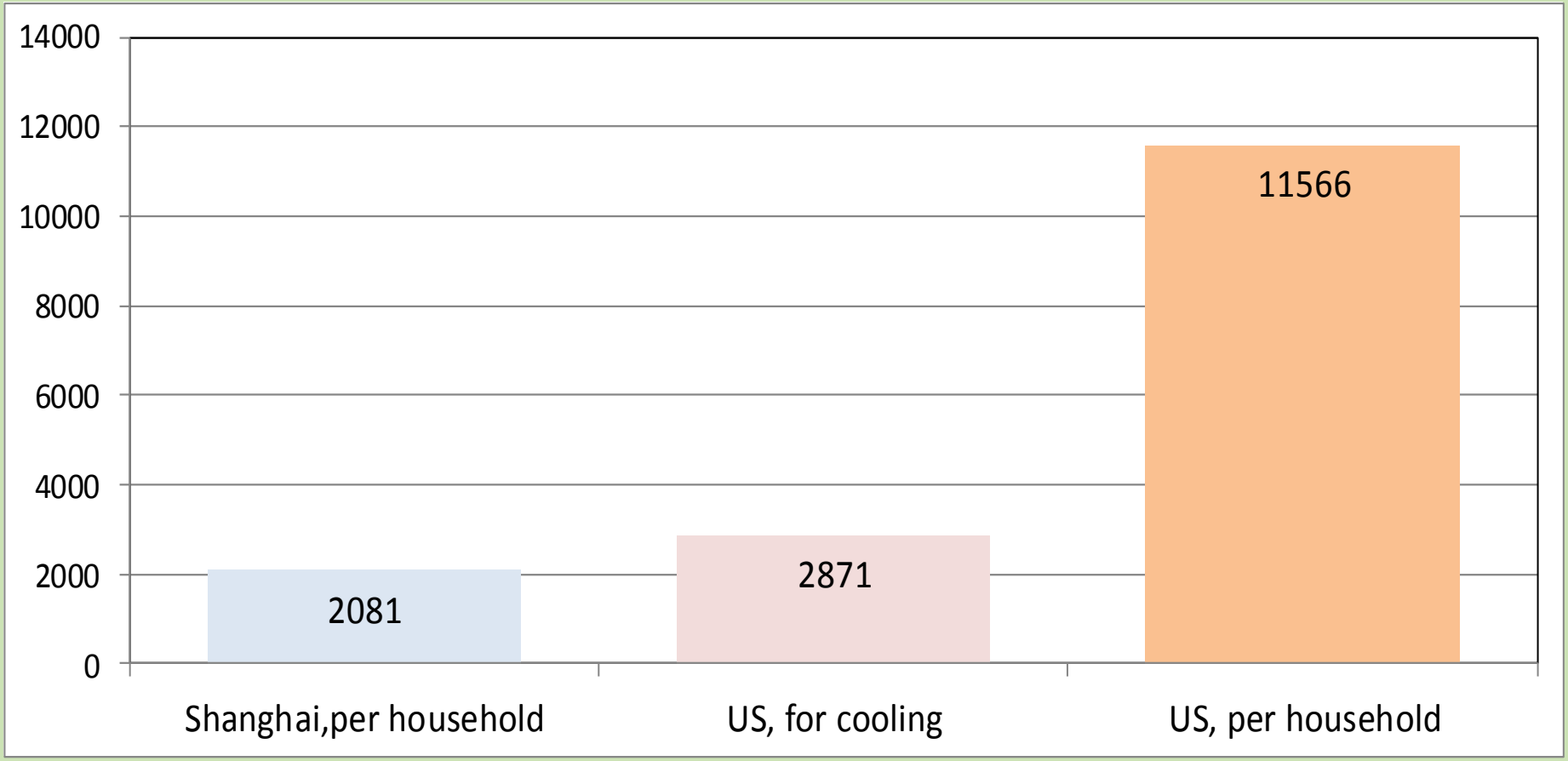
The mean value of energy consumption per household was less than one-third of the average of US (kgce)



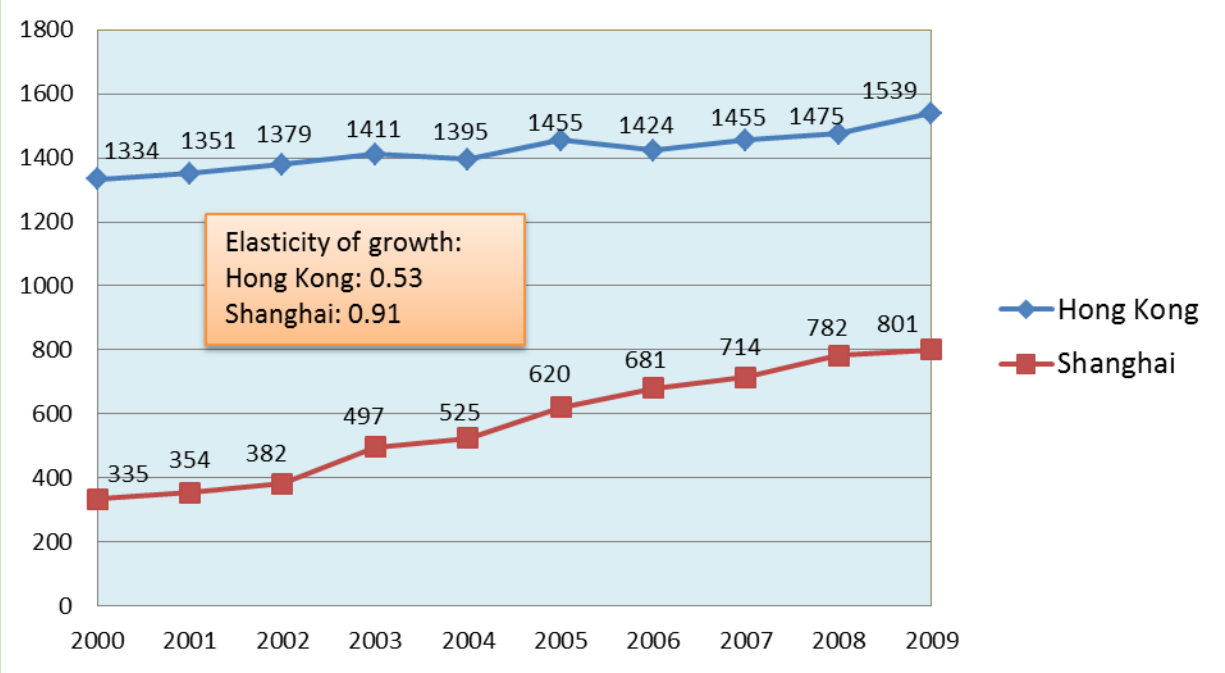
Comparing of per sq.m and per HDD energy consumption for heating (kWh/ m² HDD)



Annual per household electricity consumption in Shanghai is not as much as electricity consumption for cooling only in US household, and less than one-third of the average in US.

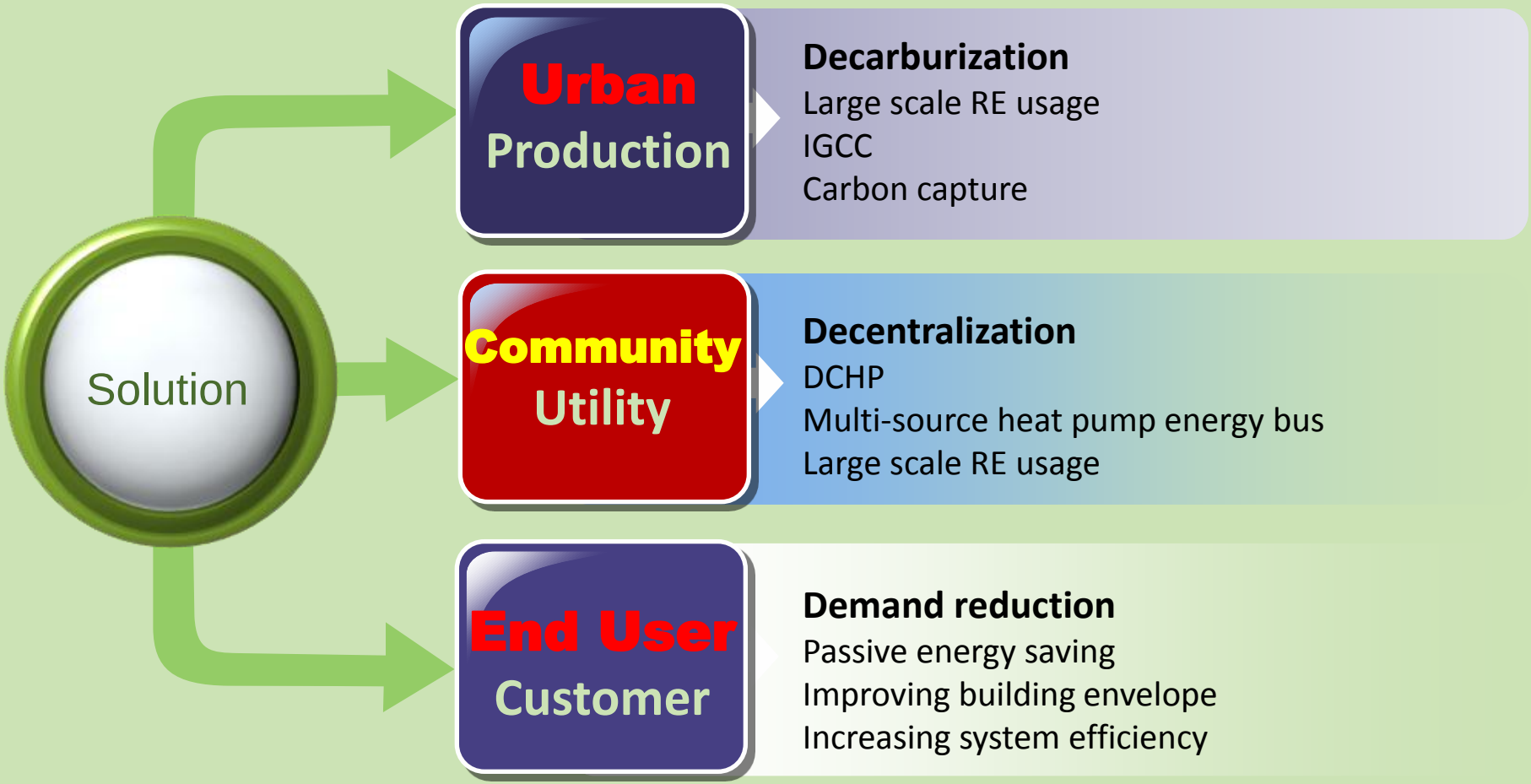


The growth trend of residential energy consumption is rigid

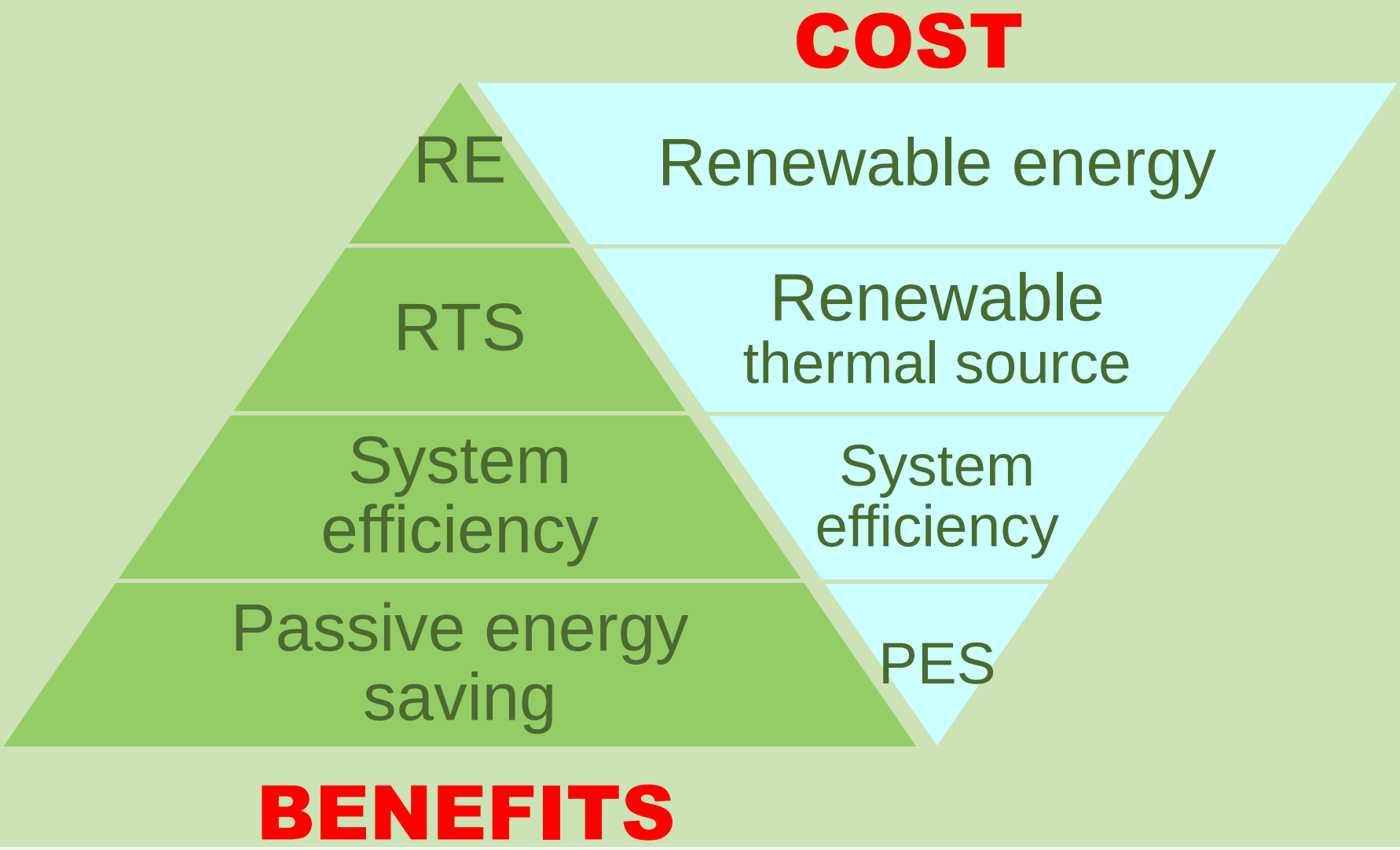


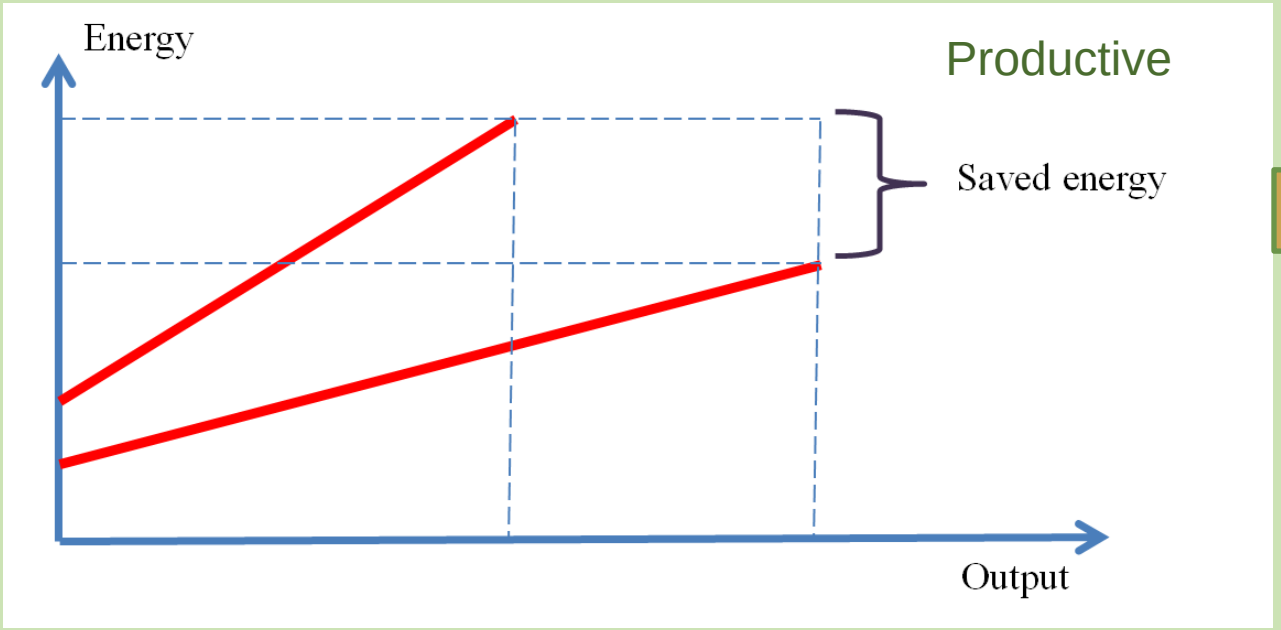
- 这一趋势不以采取什么样的节能措施或什么样的行政限制措施为转移。The trend is independent to taking what energy saving measurements or what administrative restrictions.
- 我们所能做的是尽量降低住宅能源消费弹性系数。We can do is to try to reduce the elasticity of residential energy consumption.
- 随着经济增长，住宅能耗的增长会达到相对稳定。With economic growth, the growth of residential energy consumption will reach a relatively stable.

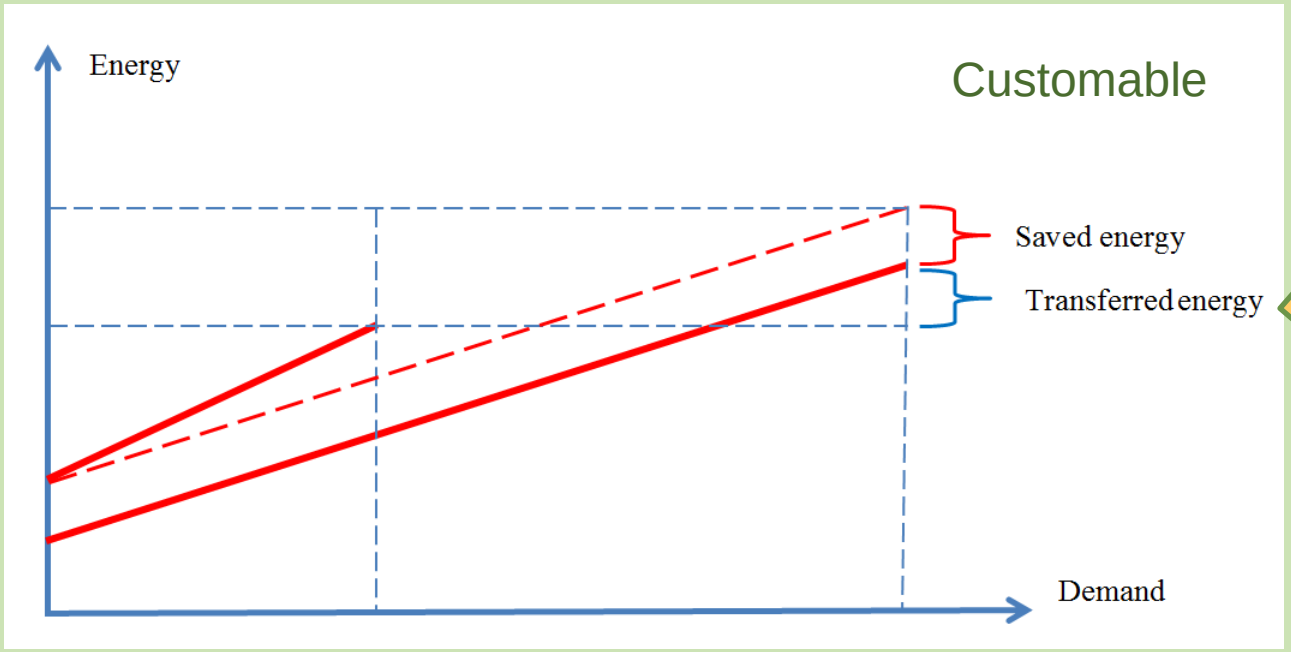
Solutions on three level



Input & production





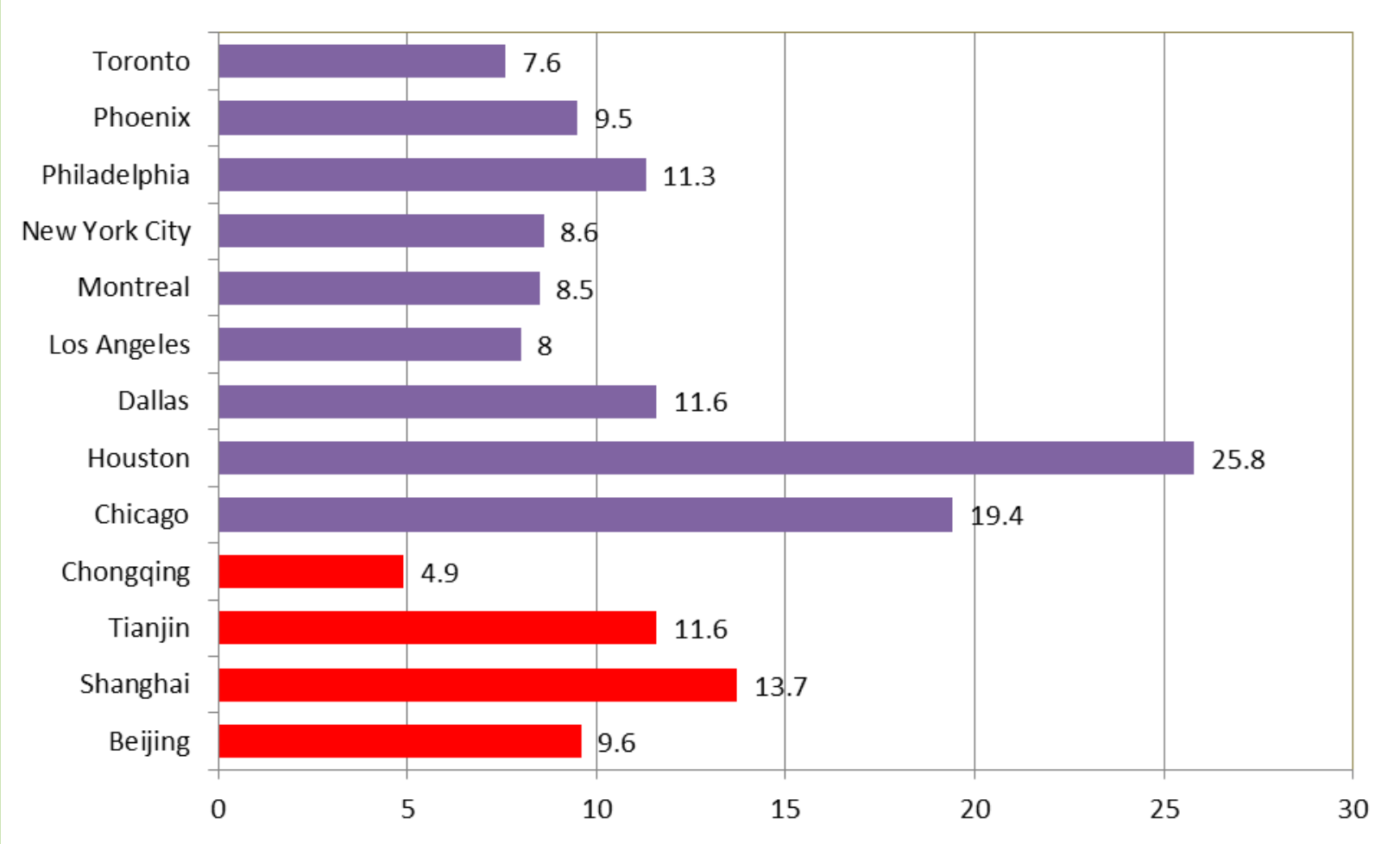


Zero growth scenario

Energy consumption & carbon emission in major Chinese cities

城市City	单位GDP能耗（吨标准煤/万元） Per GDP (10,000yuan) energy consumption (tce)	人均碳排放（吨CO2/人） Per capita CO2 emission (tCO2/p)
北京Beijing	0.67	9.6
长沙Changsha	0.943	8.1
成都Chengdu	0.936	7.0
大连Dalian	0.92	12.4
福州Fuzhou	0.71	5.6
广州Guangzhou	0.713	12.6
贵阳Guiyang	1.94	9.5
哈尔滨Harbin	1.386	8.6
呼和浩特Hohhot	1.75	18.3
济南Jinan	1.18	12.5
南昌Nanchang	0.955	6.8
南京Nanjing	1.253	13.9
南宁Nanning	0.873	9.0
宁波Ningbo	0.87	10.8
青岛Qingdao	0.87	10.9
上海Shanghai	0.833	13.7
深圳Shenzhen	0.56	11.1
石家庄Shijiazhuang	1.73	10.7
太原Taiyuan	2.44	19.7
唐山Tangshan	2.777	26.1
天津Tianjin	1.02	11.6
无锡Wuxi	0.848	16.1
西安Xian	0.934	5.4
西宁Xining	3.859	15.3
厦门Xiamen	0.616	9.0
重庆Chongqing	1.333	4.9
珠海Zhuhai	0.623	9.6

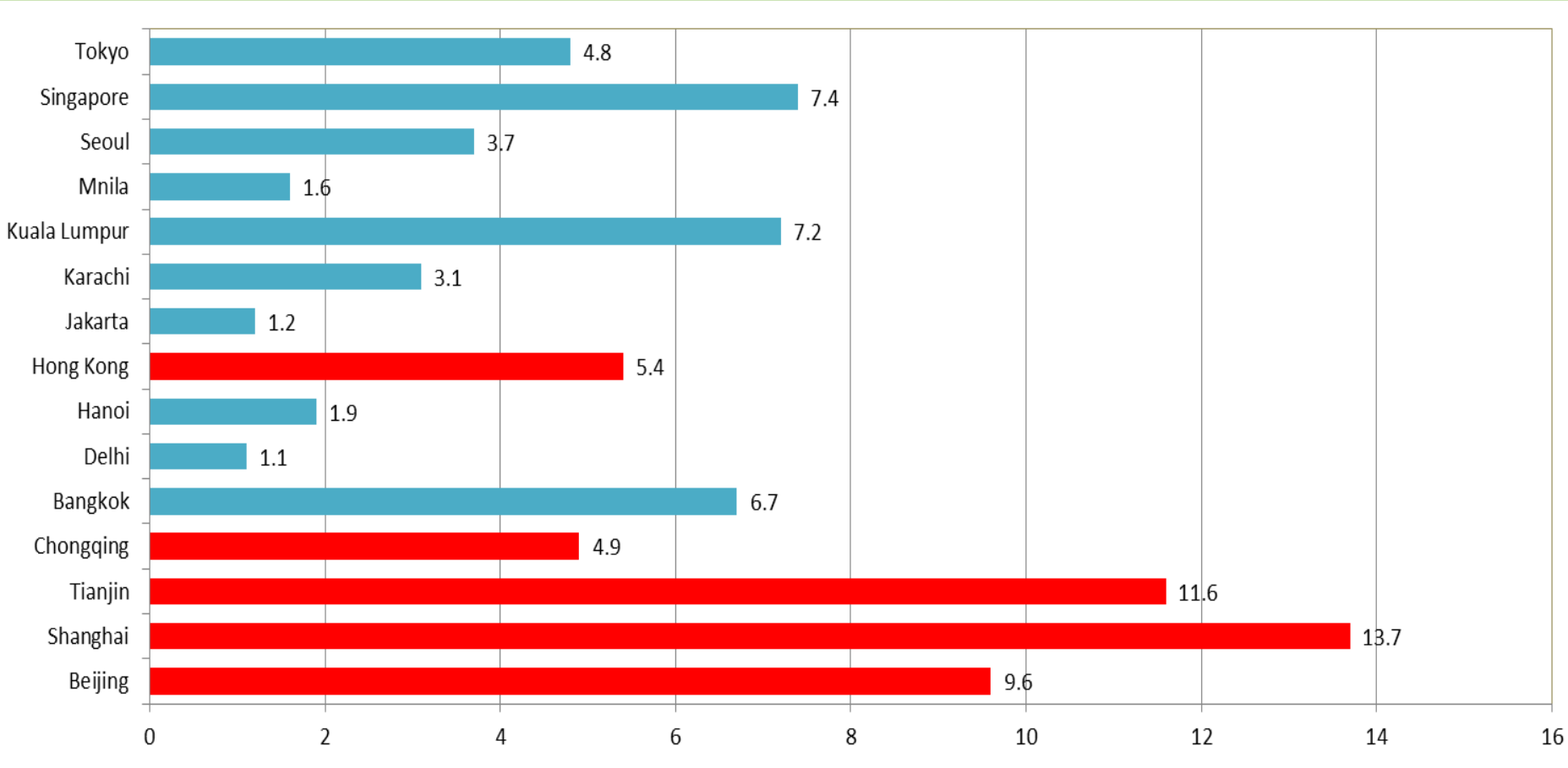
Comparing of per capita carbon emission in megacities of China & North America



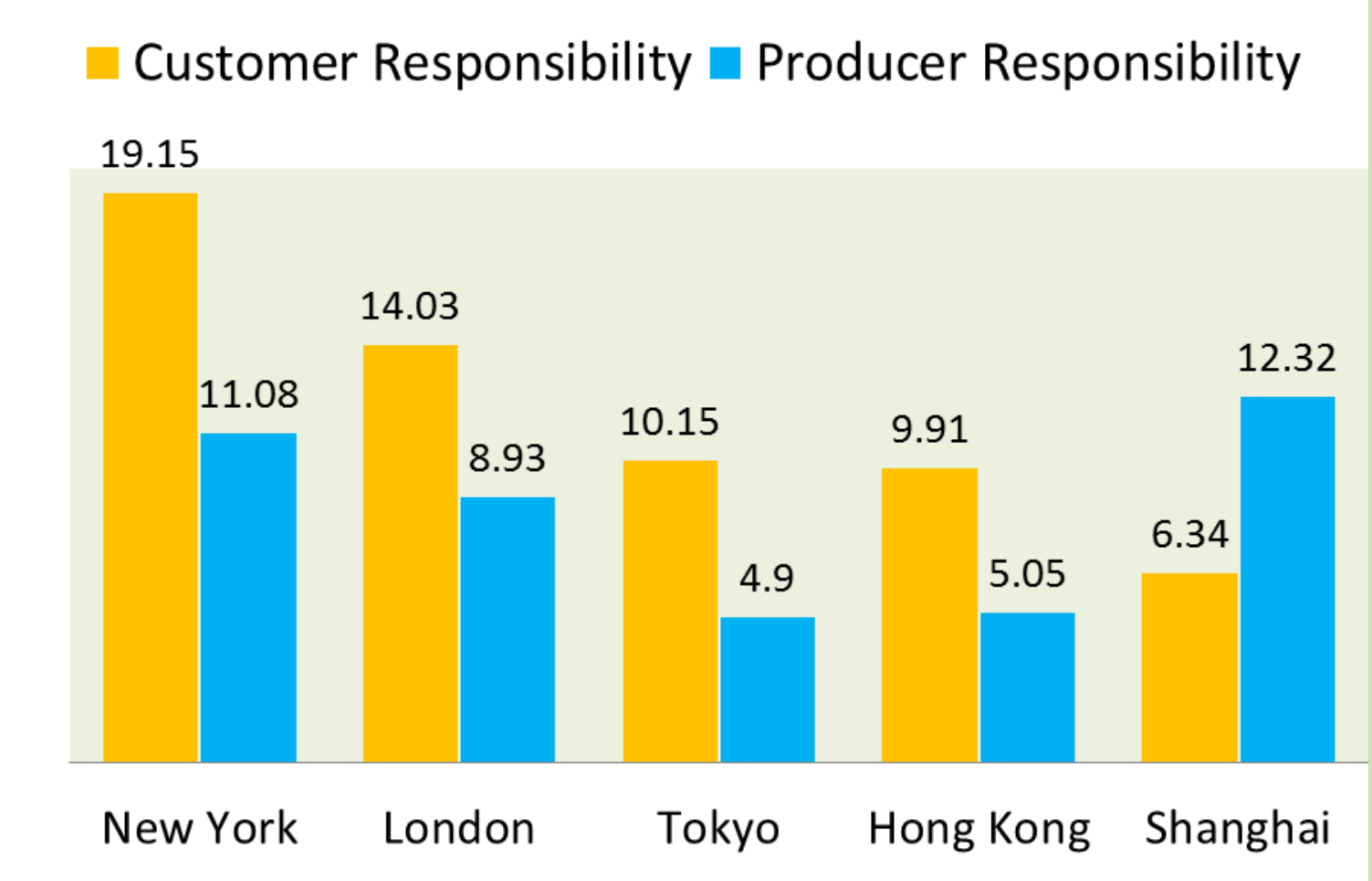
Comparing between Shanghai and European megacities with population over 3million

城市 City	人口 Population (million)	人均GDP Per capita GDP (PPP Euro)	人均能耗 Per capita energy con. (tce/a)	人均CO2排放量 Per capita CO2 emission (t/a)
柏林Berlin	3.4	21561	2.66	6.57
伊斯坦布尔 Istanbul	12.6	14615	1.24	3.25
伦敦 London	7.6	44890	2.67	5.84
马德里Madrid	6.1	25012	2.75	4.08
巴黎Paris	11.7	34941	3.30	5.04
罗马Rome	4.0	27910	2.89	3.50
上海 Shanghai	19.21（2009）	16258	5.41	13.7

Comparing with Asian megacities



Per capita carbon emission based on customer responsibility and producer responsibility (2007)



Carbon calculation based on principle of producer responsibility

- $CEP = \frac{GDP}{P} \times \frac{E}{GDP} \times \frac{CEE}{E} = \frac{CEE}{P}$
  - CEP: per capita CO2 emission; tCO2/p
  - GDP: gross domestic production; RMB
  - P: population
  - E: total energy consumption
  - CEE: per unit energy CO2 emission
- CEP of Shanghai is the highest due to heavy industry structure, lower production efficiency and coal-dominated energy structure.

Carbon calculation based on principle of customer responsibility

- $CEP = \frac{CI+CS-CO}{P}$
  - CEP: per capita CO2 emission; tCO2/p
  - CI: embedded carbon input;
  - CS: local carbon emission;
  - CO: embedded carbon output.
- CEP of New York is the highest due to highest expenditure and imports of low-end products with higher embedded carbon.

The urban form of Chinese low carbon cities should be the compact city with three “H”

High density

High plot ratio

High rise

6 aspects of low-carbon city

气候变化与能源
Climate change & energy

城市规划
Urban planning

水与环境
Water & environment

绿色建筑
Green building

交通
Transportation

景观与碳汇
Landscape & carbon sink

Challenges for community energy planning

- Fast urbanization process with huge immigration
- Old & backward infrastructure
- Fragile ecological environment
- Frequent extreme weather disasters due to climate change
- It is impossible the proportion of renewable energy can rapidly increase in short-term
- Uncertainty of occupancy rates and thermal load
- Huge potential of energy demand
- Coordination with master planning and other special planning

生产性能耗计算公式
Computational formula of productive energy consumption

$$E = \sum_{i=1}^{n} （PGDP_i \times P_i） \times EI$$

- 式中，
  - *E*: 城区总生产性能耗水平，吨标煤（tce）；
  - Gross productive energy consumption level in the district;
  - *n*: 新城区重点发展的产业数；
  - Number of prioritized industry in the district;
  - $PGDP_i$: 第*i*个产业的人均产值，万元；
  - Per capita production value in number i industry;
  - P_i: 第*i*个产业的预期就业人数；
  - Predicted quantity of employment in number i industry
  - *EI*: 预测万元GDP能耗强度指标
  - Predicted energy intensity index of unit GDP.

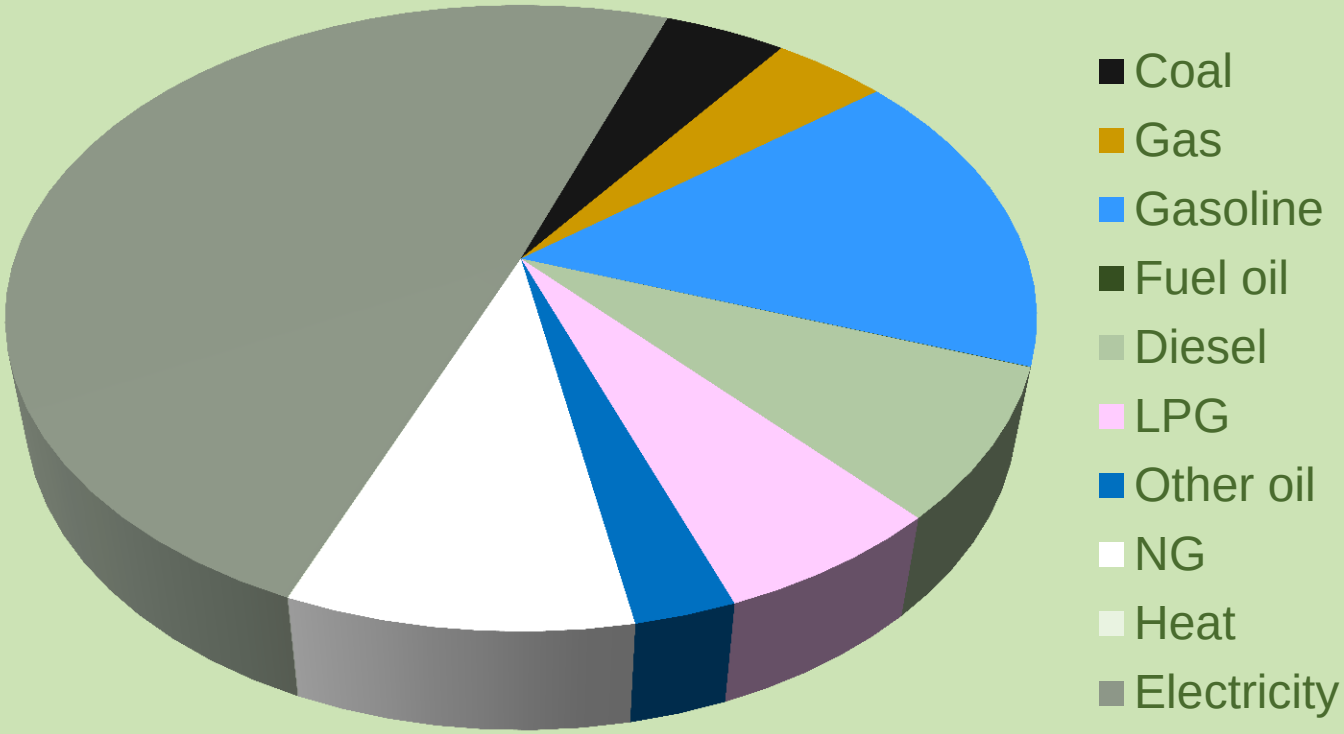
To set goal for productive energy consumption in the community

- Reflected in the per unit GDP energy consumption and carbon emissions.
- Focus on fostering and developing industries of energy saving & environment protection, new generation of information technology, biotechnology, high-end equipment manufacturing, new energy, new materials, and new-energy green autos industries.
- Productive energy consumption:
  - Adjustment of industrial structure
  - Prior to services and high value-added industries
  - Cascade energy usage, depending the community as a whole
  - Energy recovery and recycle
  - To improve the processing efficiency
- **Per unit GDP energy consumption level is Y% of the local level over the same period.**

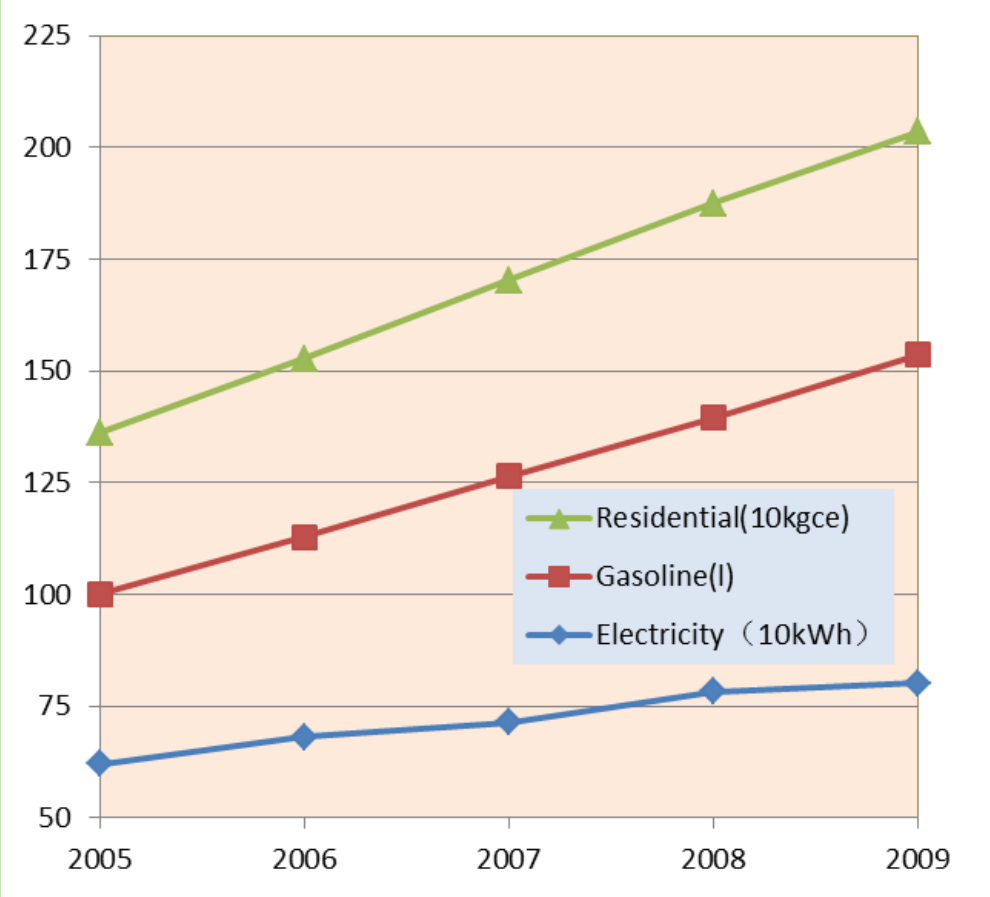
The goal of building energy consumption of public agencies

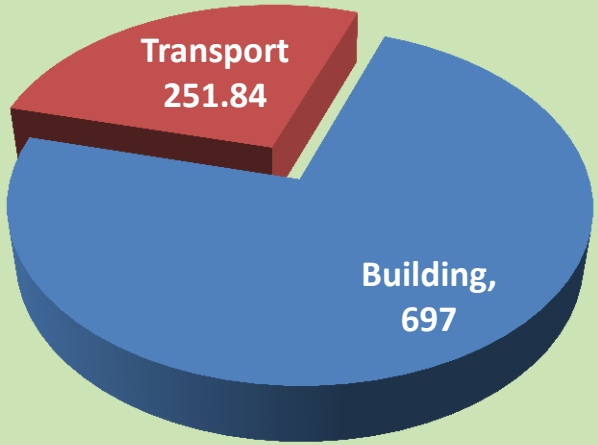
- 在基准线基础上再降低若干百分点。A number of percentage points could be reduced on the basis of the baseline.
- 在当地公共建筑能耗监控系统检测得到的能耗值的下四分位数基础上，再降低若干百分点。To reduce a number of percentage points based on the lower quartile of data got from local public building energy monitoring system.

Shanghai: Urban life energy structure 2009



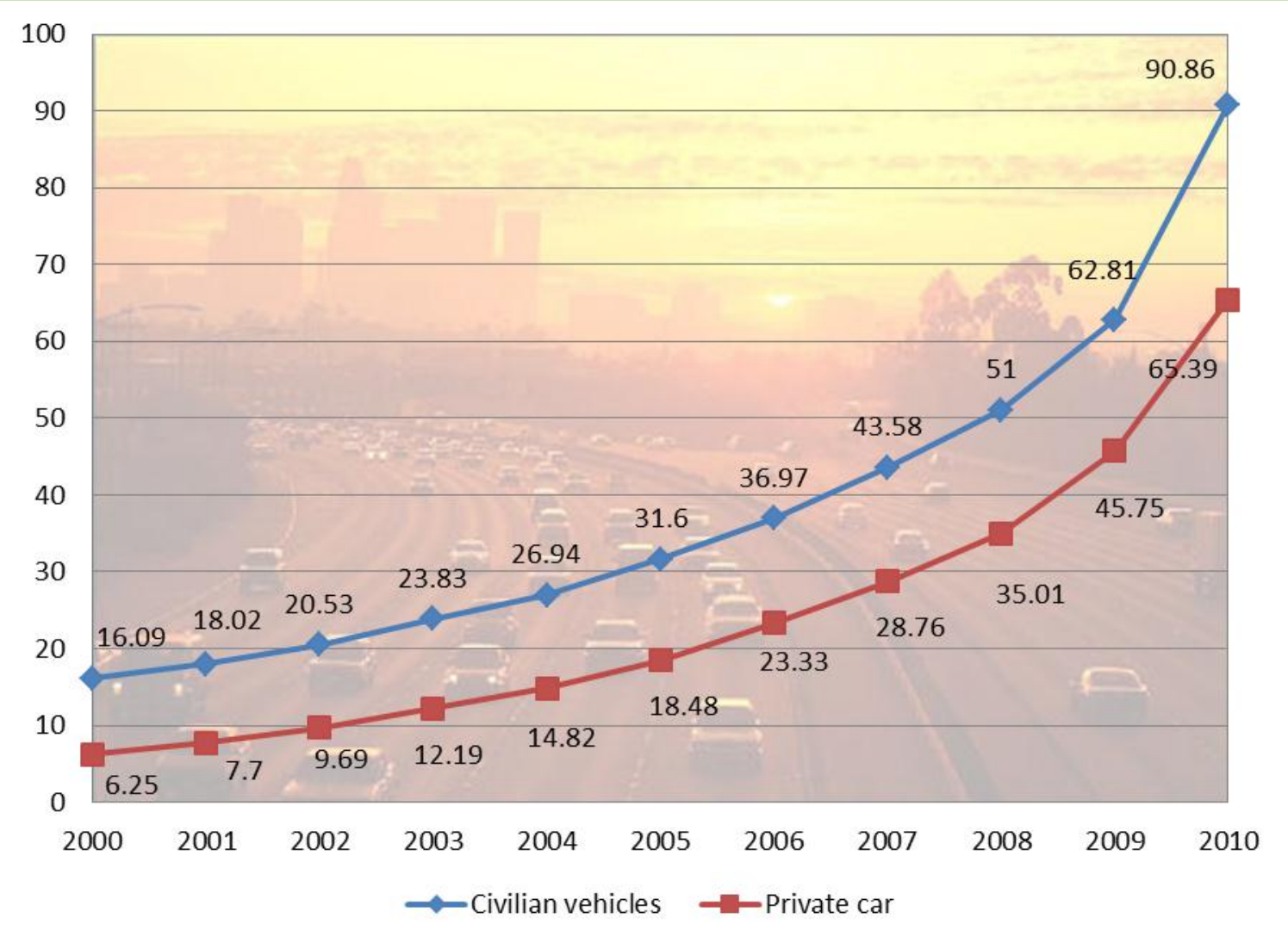
Growth & shares (2009) of residential urban life energy in Shanghai





The growth of transport energy is faster than building

China vehicles possessing



Per 100 residences private car ownership

城市 City	每百户私人汽车拥有量（辆） Per 100 households private car (units)	每百人私人汽车拥有量（辆） Per 100 capita private car (units)
北京 Beijing	30	12.24
上海 Shanghai	17	6.83
东莞 Dongguan	68	30.5
深圳 Shenzhen	30	14.22
天津 Tianjin	16.1	5.75
成都 Chengdu	18.1	6.65
佛山 Foshan	54	18.95
温州 Wenzhou	33.3	12.06
武汉 Wuhan	7.6	2.73

Spending time for the growth of private car ownership in Beijing

- 0-1million, 48years
- 1-2million, 6.5years
- 2-3million, 3years+9months
- 3-4million, 7months

- On BAU scenario the traffic energy demand would increase rapidly and exceed building energy soon.
- The worry is recent sales of large cars increased rapidly.
- Should to reexamine the policies on developing of China's automobile industry

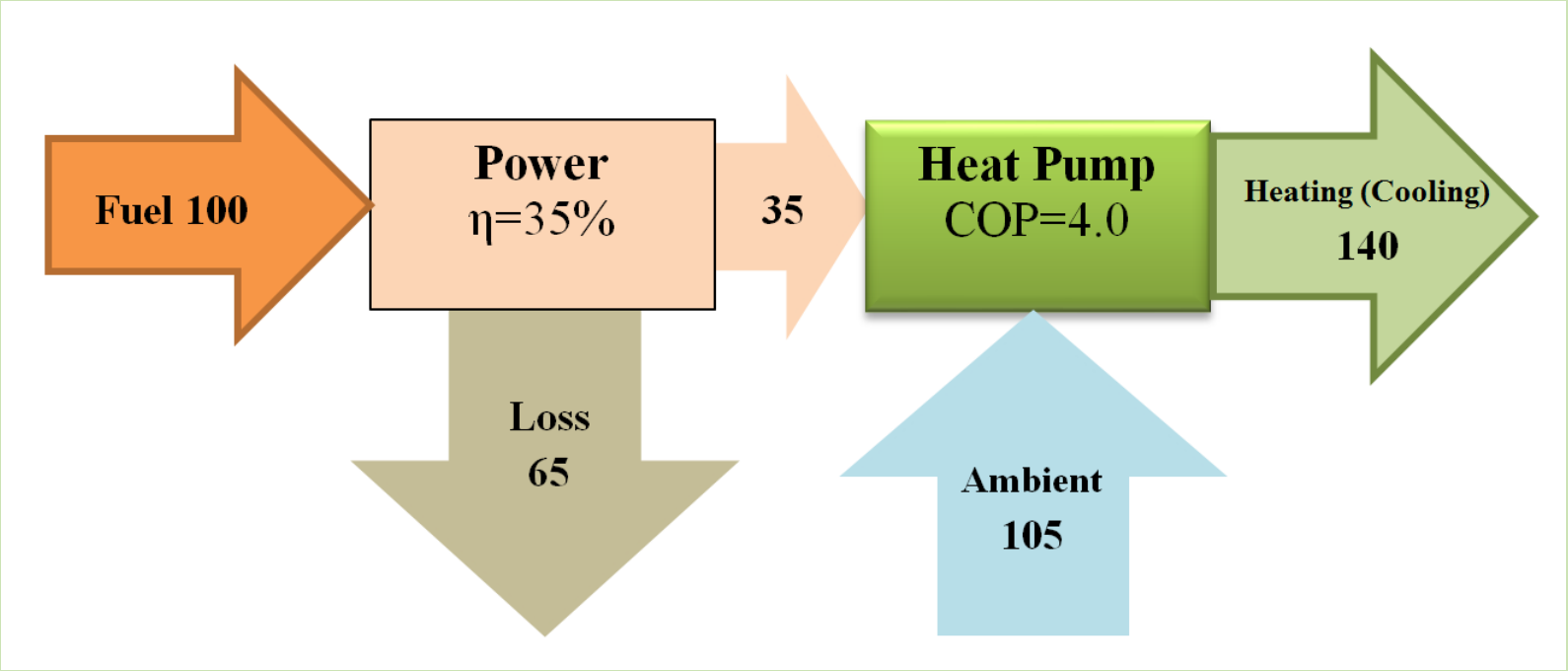
To reduce energy consumption of transport

- 紧凑型城市和混合社区 Compact city & complex community
- 提高公交出行比例、减少私人轿车使用To increase the proportion of bus travel, reduce private car use
- 降低私人轿车拥有量Reduce private car ownership
- 鼓励小排量汽车Encourage small cars
- 鼓励混合动力或电动汽车Encourage hybrid or electric vehicles
- 增加万人公交车拥有量和地铁里程To increase the quantity of public traffic & the mileage of metro
- 更加舒适和便捷的快速公共交通More comfortable and convenient MRT

How much renewable energy has been used by heat pump?

- 低品位的“未利用”能源是一种可再生热源 The low-grade untapped energy is an renewable thermal source.
- 主要是指那些与环境温度相近且无法直接利用的热能。It mainly refers to the heat that is close to ambient temperature and can not be directly used.
- 广泛存在于土壤、水、空气、工业废热和污水之中 Widely consists in soil, water, air, industrial waste heat and sewage.
- 热泵使用少量的高位能，把不能直接利用的低位热能转换为可以利用的高位热能。 Heat pump converted low-grade heat that is impossible to use it directly to high-grade available heat by using small amount of high-grade energy.

The energy flow chart of heat pump system



The ratio of renewable energy usage is :

$$\frac{140-100}{140}\times 100\% = 28.6\%$$

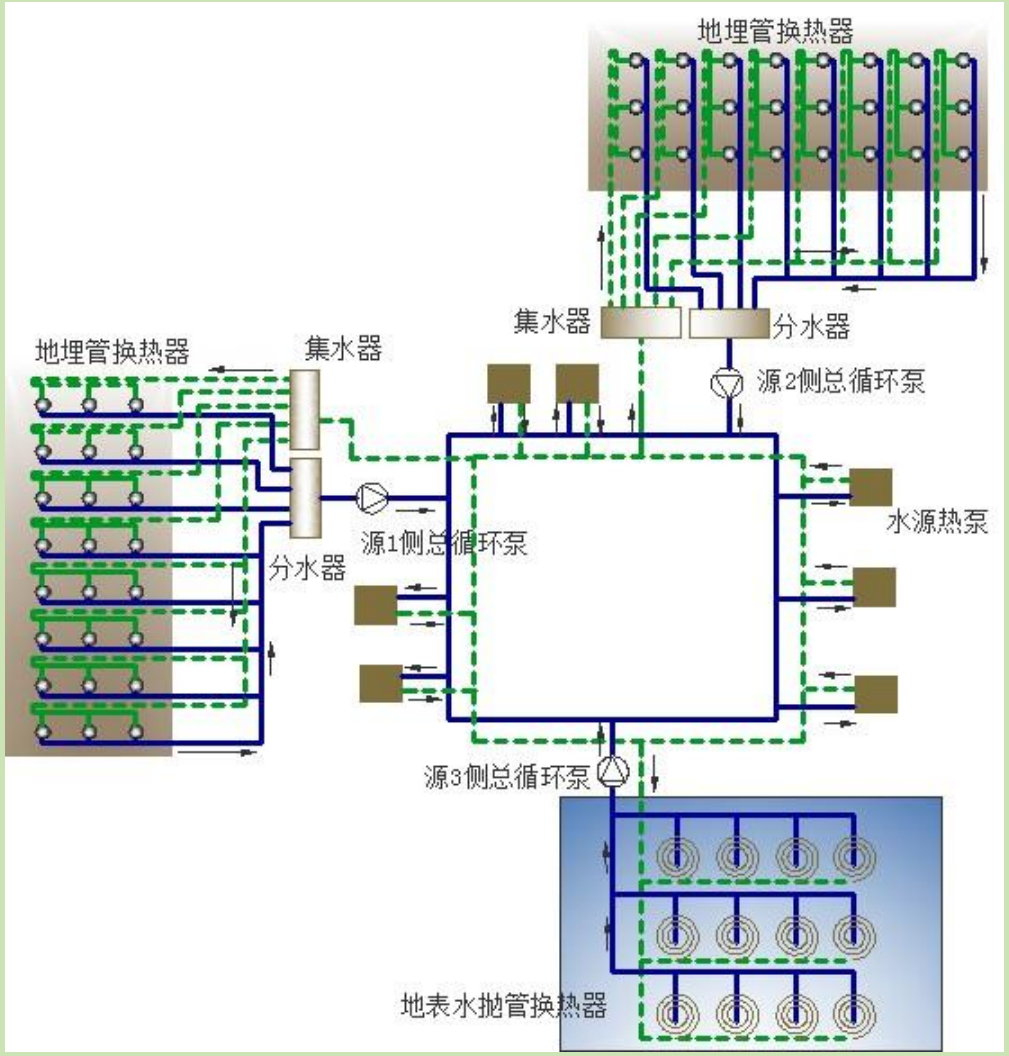
Energy bus would become infrastructure of future low-carbon eco-cities

- In computer science, the “bus” is a computer's internal structure, which is a public channel for transmitting information by the CPU, memory, input and output devices etc. The computer's various components are connected through the bus. The external devices are also through the corresponding interface circuit connected with the bus.
- The so-called "Energy Bus" is a infrastructure pipeline network through which the water from coupled heat exchanger (with multi low-energy sources such as ground soil, surface water or solar water heater) as the heat-source/heat-sink was fed to the terminal users. On the terminal, the water from energy-bus is regarded as heat-source/heat-sink of the water-source heat pump.
- M (resources) to N (water source heat pumps)
- Heat pump technology is the key technology of community energy system

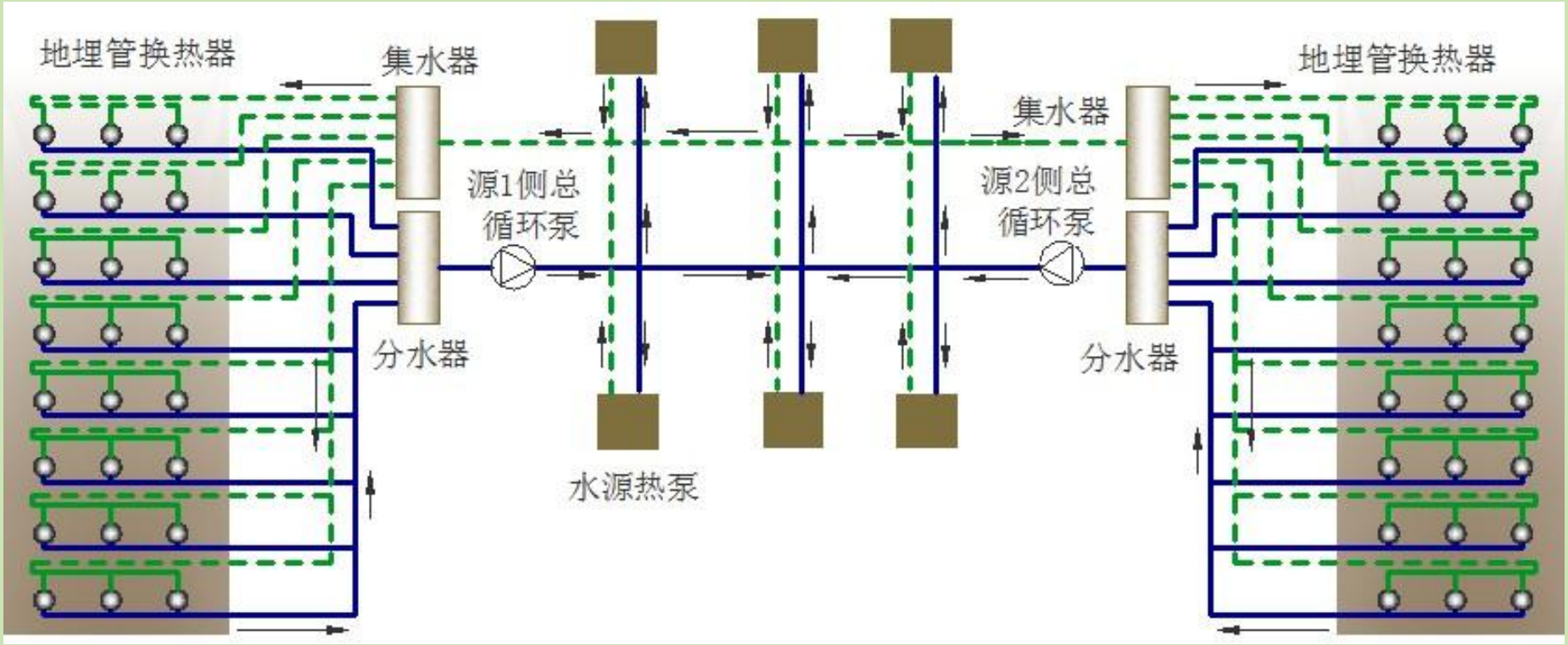
低碳生态城区能源规划的任务
Tasks of low-carbon eco-community energy planning

- 如何集成应用低密度的可再生能源 How to integrate the application of low-density renewable energy sources.
- 如何集成应用低品位的未利用能源 How to integrate the application of low-grade and untapped energy.
- 如何将无碳的虚拟能源（即用户端的节能）作为替代资源 How to use the carbon-free virtual energy (i.e. the client's energy saving) as an alternative energy resource.
- 如何集成低碳的分布式能源 How to integrate the low-carbon distributed energy.
- 如何实现碳能源资源的梯级利用、循环利用和回收利用 How to achieve cascade usage, recycling and recovering of high-carbon energy.
- 如何利用负荷参差率和同时系数降低负荷 How to use irregular ratio and diversity factor of thermal load to decrease the load.
- 如何实现城区能源投资的多元化、能源管理的市场化，以及清洁发展机制How to achieve diversified invest of community energy system, marketization of energy management and clean developing mechanism.

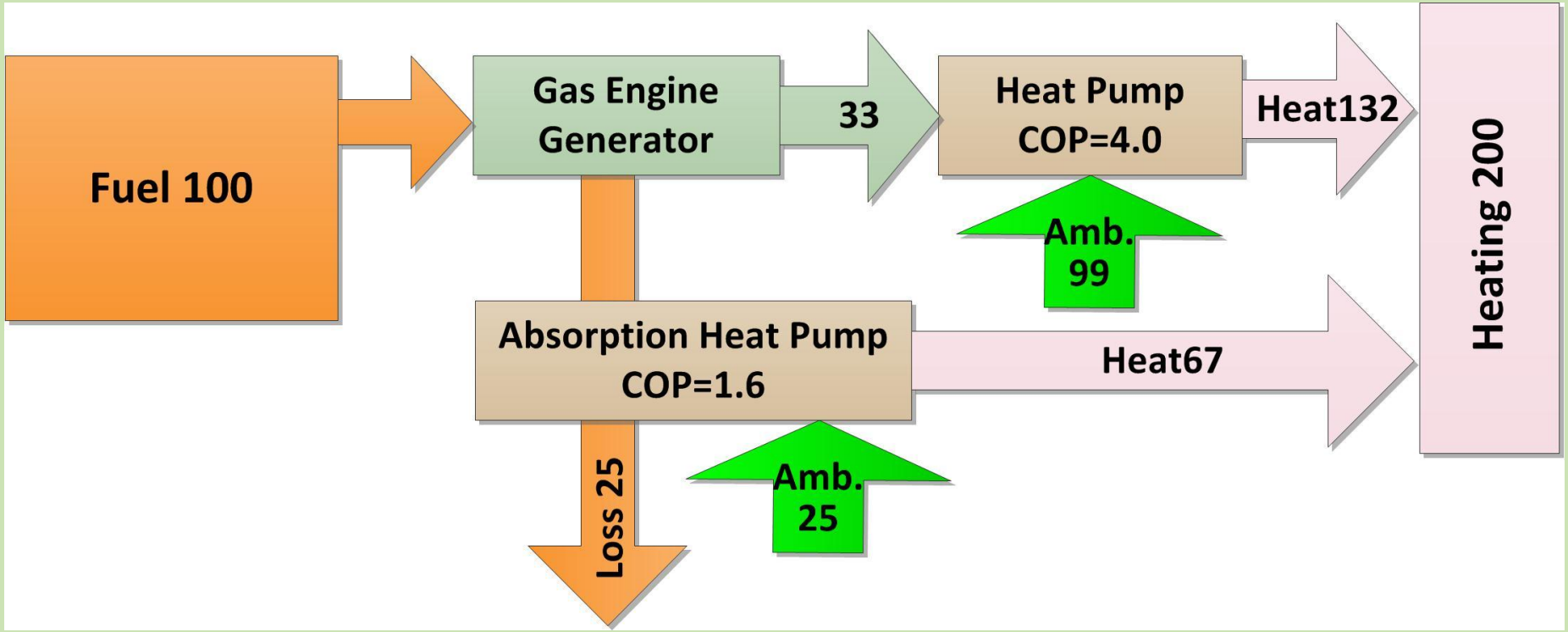
Multisource Circle Type Energy Bus System



Multisource Rami form Energy Bus System



Highest efficiency: cogeneration + heat pump



Thank You