

# Sustainable City Planning and Building Design: Case Study

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**ABSTRACT:** There has been more than 150 years in the history of Western industrial civilization. The industrial civilization had long depended on carbon based technology. Building industry is a major area to have most of the energy drain. The sprawling cities, typical 20th century's practices have the major blames on producing waste gases that are affecting our environment. The carbon based global economy dominates our daily life. The already oversized Ecological Footprint for most of developed countries, plus continuing using the non-renewable energy resource based technology, not only pay a heavy price on our environment and could lead to global ecological collapse. Taking China as an example, China has strived for their modern image for the past decade. People want to copy western living styles, for instance, wider roads; garden houses, landscaping villages and high rises blocks in order to catch up with the modern living in the West. Copying the West despite great climatic difference, not only destroy the harmony between the culture and the nature, at the same time overuse the energy resources, in consequence self-destruct the environment. Destruction of huge parts of agricultural land in China in the past two decades and contamination of farm lands by all kinds of industrial waste are results from boom of manufacturing industry. China has paid high prices on the environment in exchange to the fast economic development. Air and water quality are poor, water shortages had already challenged the 1.3 billion people in China. This paper bases on proposals to Ningbo, a city along China's east coast in Zhejiang Province among only in academic circle, not yet being discussed among officials, on how successfully utilizing renewable resources in city's strategic planning and in the building design. This requires knowledge on waste treatment and on balancing resource management. At the same time, it takes into consideration of cultural, traditional factors in Ningbo. How vernacular forms of building design or urban pattern could find their perfect fits with China's rapid economic development will also be discussed in this paper.

Keywords: sustainable city, eco village and eco building

## 1. INTRODUCTION

Sprawling cities become 20<sup>th</sup> Century's common practices, unprecedented the city perimeter makes the towns often blur from one to the other, linked by highways and local roads. The freeway has come to rule the landscape. The cities hence invest hugely in infrastructure [9]. The challenges of the 21st century of growing urbanisation are management of resource, to achieve renewable energy based society, densification and dealing with pollution. The issues surrounding the future role of energy extend far beyond technologies, affecting all human activities, including our economic, our mobility, and the stability of our society. Our energy use impacts the environment in ways that may be irreversible- especially as the human footprints on the planet expands due to population increases [1].

China's economic development is happening so fast that it suffers what the west suffered over the past 150 years. The accelerated growth, especially in the urban area neglects traditional Chinese urban forms by largely copying the western urban patterns. Ecological concept of building design has lost to market economy. Copying the western built form

despite great climatic differences between China and the west not only destroys the harmony between the culture and the nature, as well increases the energy demand. In recent years, energy saving has become the central government's major concern. By legislation carbon free developments have been realised lately. Preservation of the integrity, stability, and the beauty of the biotic nature in China are coming to be the future built environment.

At the same time, vernacular forms of building design or urban pattern would find their perfect fits with China's rapid economic development. How can those vernacular forms of building design or urban pattern play major roles for the rapid urbanisation in terms of saving energy? The design approaches to ways of how the development could blend into the nature by using the local material, not only aiming at the natural appearance and for their locality, at the same time it aims for energy goal.

To all architects challenges are to manage zero impact to our living environment, as well as to achieve aesthetic goal. Since carbon is a new indicator for designer to achieve energy efficiency, manage carbon should start at early stages of design process.

The following discussion bases on studies of Ningbo, a city along China's east coast in Zhejiang Province on how to use renewable resources at city's strategic planning and in building design. Taking cultural, traditional factors and using vernacular building design or urban planning is very important, in comparison to high technologies on renewable energy. Those vernacular forms should perfectly fit into China's rapid economic development; verse vice copying western living styles despite great climatic difference should be re-evaluated on its suitability to local climate.



**Figure 1:** Model of Future Development of Ningbo

## 2. URBAN AND BUILDING DEVELOPMENT

### 2.1 Geography and Cultural Information

Ningbo (literally "Tranquil Waves") is a coastal city in the Zhejiang province of China. It lies in the south of the populous Yangtze River delta and is bounded on the east by the East China Sea. Today the city has a population of 5.43 million. It covers an area of 9,365 square kilometers including the urban area of 1,033 square kilometers. To the west of Ningbo are mountains. Between these mountains and the sea is a fat plain with a dense network of waterways. Off its coast there are beautiful islands. Ningbo has a subtropical monsoon climate with an annual average temperature of 16.1C. Annual rainfall averages 1,350 millimeters. It has about 240 frost-free days. Ningbo is located at east longitude from 120°55' to 122°16' and north latitude 28°51' to 30°33'.

Of a typical subtropical monsoon climate, Ningbo features mild temperature with moderate humidity and distinctive seasons, and it is an ideal resort to enjoy both natural and cultural endowment. A tranquil coastal city, Ningbo's 500-km coastline forms a scenic seascape.

Ningbo is a famous historic city also with rich cultural heritage. It is the birthplace of the "Neolithic Hemudu Culture" dating back more than 7,000 years. The Tianyi Tower in Ningbo is preserved as repository of ancient manuscripts, training center for archivists and center for study and research. The perfectly protected wooden architecture - Baoguo Temple built since Song Dynasty and the two-thousand-years-old historic town - Cicheng Town,

The Coast Defence Relics Site is a key unit for national cultural relic's preservation. The Chiang Kai-shek's Former Residences at Fenghua is a national key unit for cultural relic's preservation of the State Council of China. Yueyao (Porcelain Kilns of the Kingdom Yue) Ruins at Shanglin Lake The Tuoshan Dam, at the foot of Tuoshan Mountain of Yinjiang Town, Yinzhou District, is listed as one of the four largest irrigation projects of ancient China (the other three are: the Zhengguo Canal, the Lingqu Canal, and the Dujiang Dam) and now it is a key national project for cultural relics preservation. Situated under the Luhua Peak in Taibai Mountains, Asoka Temple is 19 kilometers to the east of Ningbo and is one of the "China Five Buddhist Mountains". The temple was built in 282 AC, so it is over 1700 years old. Tiantong Temple, 25 km to the east of Ningbo, is the No. 2 Mountain among the five Chinese Zen Buddhist School Mountains. Xuedou Mountains has been called "The First Mountain in Siming Mountains". It is said that Emperor Ren Zong in Song Dynasty once dreamed of visiting the mountain. So it is also named "Dreamed Mountain". In South Song Dynasty, the Xuedou Temple of Maitreya's bodhimandala was one of the ten ancient temples of Chan Buddhism in China, named it one of the five Buddhist Mountains in China. Xikou Xuedou Mountains Scenic Area is a major state-level tourist attraction and has become forest Park of state-level. Dongqian Lake Scenery Area is a provincial scenic-historic preservation area

### 2.2 Famous Port City

Ningbo is a famous port city; Ningbo Port is not only a deep-water port in the Chinese Mainland, boasting one of China's four international deep-water ports. In 2004, the throughput of the port amounted to 226 million tons, maintaining its status as No.2 among coastal ports of the Chinese Mainland, and becoming one of the top 5 ports in the world. It handled 4,005 million TEU containers in 2004, ranking 4th among coastal ports of the Chinese Mainland, and becoming one of the top 20 TEU container ports in the world with a highest growth rate among coastal ports of the Chinese Mainland for 6 successive years [4].

### 2.3 Recent Development

Ningbo, no exceptionally follows most of other Chinese city development patterns. Typical 20th century's sprawling pattern was read as copying to the West. New town centres are shooting up in those older townships, the towns become blur from one to the other, linked by highways and local roads. New town movement or city movement in China are assembling to the new town movement since the 60s. Milton Keynes, designated as a new town on 23 January 1967, is the largest new town in England.

Ningbo's Inner City has grown from an area less than 30 square kilometers in early 80s to over 200 square kilometers in 2005, at a speed of almost ten times to the original size of inner city in 25 years. It left very few memorable historical heritage of inner city to its new visitors. Those townships blur one to the other were oddly and poorly built buildings.

### 3. CIRCULAR MECHANISM MODEL

Circular mechanism model had been within Chinese culture since the ancient time. Chinese had long practiced "cradle to cradle design theory" [5].

The City movement in China are defiantly followers to Ebenezer Howard's urban model of "Garden City" movement. "Garden City" movement was the major urban model in the West since the turn of the 20th century. It originally was to satisfy people's demand for a decentralized society. His idea of a city in a garden was a decentralized plan of moving people from an overcrowded city centre to a low density, moderate-sized, self-contained urban community [9]. The Garden City Movement gradually became a city planning movement. The concept of the green belt was not the farm belt; instead it was a green park-land suitable for picnics. Howard's Garden City aimed to be socially, economically, as well as ecologically sustainable. It gradually lost its commitment to social change, because the physical concept of a city in the garden is more interesting to his followers. [6]

Cities sprawled out into the country threaten our rural land. A large number of people in a small area have to have their needs supplied from outside, for instance, food and water. The farm belt keeps the city supplied with all the food it needs. For cities to become sustainable everything should be recycled, in return, the city gives back its human and organic kitchen waste to sustain the soil of the farmland. This green belt idea is ruined by the sprawling of urban structures and also changes the dynamics of rural-urban relations, converting peasant to urban citizen [9]. In Chinese situation, it would rely on more balance between rural and urban population. Cities sprawling out into the countryside destroy the circular mechanism theory. It is common knowledge that human survives depend on nature's balance.

### 4. SUSTAINABLE TOWN PLANNING

#### 4.1 Planning Strategy in General

Sustainable urban forms or 'compact cities' are intensifying cities. The more compact cities are the more travel distances being reduced, thus fuel emissions are lessened, rural is saved from development, local facilities are supported and local areas become more vital. The inner city of Ningbo has grown a lot since the 80's at its size, as well as its population. The population has grown from 300,000 to 1,700,000 and from less than 30 square kilometers to more than 200 square kilometers in less than 25 years. In early 80's a density of more than 100 people/hectare, but now there is only less than 85 people/hectare from last year's survey.

There are a lot of newcomers migrate from rural area to city. In Zhejiang province, especially Ningbo area is prosperous than a lot of other areas in China. The newcomers can not afford to live inside the city. Those temporary homes, squatter settlements, are usually found without most basic services, like sewage, roads, water, electricity or even power in near by townships. Although the inner belts of the

cities have not yet been abandoned but temporary homes, squatter settlements are everywhere. There are huge demands for people to achieve comfort and at the same time to achieve energy efficient of the built environment, social as well environmental.

De-zoning is a new urban target for reducing commuting distances in cities. It means creating cities with districts accommodating both homes and work places [6]. This idea of planning cities is with greater density, an urban layout with greater proximity between homes, schools, shops, and places of entertainment and pleasure. IT technology make possible for home working. Flexibility of working at home or outside of the home allows planners to achieve their new planning strategic [7].

The mixed-use concept provides jobs opportunities for local residents. Facilities within walking distance are to reduce the need for travelling. Alternative transport systems are minibus service to the nearest public transport stations.

Car uses should be discouraged. Reorganization of city layouts, with greater proximity between home, work, and shop is necessary. Cars and roads are invented to shorten distance, but congestion on the city streets due to automobile becomes a common problem in Chinese cities and in the other part of the world.

If shrinking car use is the most important goal of a compact city, public transportation thus becomes an important solution. Pedestrians of Garden City who could walk across the city within fifteen minutes or less or bicyclists and residence used the railway system around the city would still be a good model for a sustainable city. Encouraging walking, cycling and using public transportation of Garden City model is still the main emphasis of energy conservation and environmental protection. Density of 150 people/hectare is the new target of densification to new urban development. Neighbourhoods of 7,500 would be considered efficient. It could support the local facilities with at least 87% of the people living close enough at 500m or 5 minutes walk from them

#### 4.1.1 Transportation

A green transport strategy sets a target of reducing the residential fossil fuel car mileage by 50% compared with an equivalent conventional village. The idea is to use photovoltaic to displace fossil fuel in transport. The photovoltaic could produce energy for transport. The living and working arrangements will also reduce the need for transport. Bicycling, walking or hydrogen car would be the future renewable solutions for the area. How to save the energy as well as to protect the environment should be addressed here. The present density of inner city of Ningbo at 100 people/hectare or 85 people/hectare may not achieve the above mentioned goal and density 150 people/hectare is desirable in Ningbo.

#### 4.1.2 Energy

Target at 95% energy supplied to Ningbo coming from renewable sources is still a wishful thinking, not yet in action. The Government had just legislated how

building industry should apply renewable energy technologies in June 1<sup>st</sup> 2006. Developing renewable energy technologies, like solar energy, wind, hydro and ground heat power and energy-efficient appliances have a long term mean to reduce energy consumption. The combined heat and power CHP plant, using tree surgery waste, will provide most of the electricity and hot water. The wood-gas generated from the tree waste is used to power the engine that generates the electricity. The waste heat from the engine is piped to the dwellings to heat water. Excess electricity will be traded back to the national grid. Solar energy can be used to power cars at the same time to power houses.

Ningbo has a power utility plant with biomass combustion system to provide 200,000 to 300,000 people at 25 MW electric. It suffers not enough fuel biomass sources to feed the plant for the electricity. A lot of fuel material, for example rice husks, wood chips, cardboard or bark and sawdust have some other uses in China, not yet be considered as waste. The only waste, for example, municipal biomass waste or construction site waste need to be collected better to be send to the power plant site. This paper has not found out why feeding the only one biomass utility plant in a city with a population of 5.43 million would have problem.

#### 4.2 Physical Planning

Planning cities within greater density, an urban layout with greater proximity between homes, schools, shops, and places of entertainment and pleasure is not difficult to achieve. It is because Chinese had long practiced the denser and mix-used theories in their town planning history. Density of 150 people/ hectare is the new target of densification to new urban development. Neighbourhoods of 7,500 would be considered efficient. It could support the local facilities with at least 87% of the people living close enough at 500m or 5 minutes walk from them.

What transportation systems Ningbo inherited would affect its economic, its air quality and the surrounding environment. Car and freeway had been 20th Century's creations in the West. Car and freeway suppose to create speed for the city. Sprawling city has directly related to car uses. How could the Chinese city pursue its normal daily activities without the car and the freeway? Should Chinese stop copying the West, finding different patterns to suit themselves? Technology of car design would be improved to minimize CO<sub>2</sub> admission. Thus less CO<sub>2</sub> is released to the atmosphere, hence less contribution to the global warming. Planting trees, farming and landscaping in the urban area or in suburb countryside would all help absorbing CO<sub>2</sub> released from the combustion of fossil oil. The road design above the ground and under the ground would help less use of the actual land.

Combined Heat and Power Station (CHP), a system with efficient burners, is suitable for compact cities with high population density. The photovoltaic panel can be used to shade the roofs of the building to produce energy for the use in the neighbourhood. The living and working arrangements will also reduce the need for transport. Every dwelling has been

designed for bicycle storage. Neighbourhoods of 7,500 connect with each other by bicycle and public transportation routes. Subways and light-rail systems can free a lot of valuable ground surface. Tram and train are still the most sustainable vehicles in the modern time. Villages, townships and homes, schools, shops, and places of entertainment and pleasure are going to be built along the transportation routes.

The great concerns for the Western countries now are how to shrink the footprint of the cities. It hesitates to use green land for new developments. Many developed countries have restricted such practices. There are reasons for it, for example to preserve the agricultural land and to protect the integrity of the nature of the wilderness. In China there are 1.3 billions people. Such a big population has to be supported by their own agriculture and to survive with healthy forest to absorb CO<sub>2</sub> from the people or from the fossil oil using. Live in harmony with its nature almost is the 1<sup>st</sup> priority in the country. What happen to this entire people when large scale of wilderness or agricultural land is rehabilitated by people, from animal or flora's habitat to human's habitat. There are complications about transferable disease from animal to human. A lot of problems can start with careless developments. Hygiene or healthy problems should be well taking care of prior any land being granted to develop.

Ningbo does not want to see nature reserves, ecological zones and sustainable agriculture disappearing fast. Pre-end the possible voids for possible building zones to their best purpose of specific requirements and limitations, for example, parkways, parks and fields of fire are mapped out to. The visibility from roads in the area, not being cut off from the environment by acoustic baffles should be taking into consideration. The nature and the physical structure, like highways and railway lines should be opened up to each other for the purpose of balance in harmony.

## 5. ECO-VILLAGE AND ECO-BUILDING DESIGN

Building design and plan layout should be environmentally well considered. Details like maximizing day lighting and orientation to maximize the south expose of building facades are considered for both energy and economical importance. Hygienic living condition starts with providing adequate light. The minimum day-lighting obtained from a building area should be regulated. Sun light, light, shape and orientation of the house relate to human healthy. Dutch by-laws required that every living room should receive a minimum of three hours of direct sunlight on its facade every day. This regulation influences the potential density. The architects suggest a maximum density in housing with a floor area ratio of 3 to 4 which is three to four times denser than the current Western European density [9]. The building's heavy concrete structure absorbs heat from the sun to prevent overheating in the summer and stores the sun's warmth in the winter. Heating requirements for

a Ningbo homes is around 10% of that for a typical home of the same size. The combined heating and electricity bill will be around 1/3 of that for a conventional electricity bill of a property. In winter, heat is retained in the dwellings by high levels of insulation. The dwellings are super-insulated with 300mm thermal insulation. Combination of passive solar gain and heat from lighting and cooking will keep the dwelling warm in winter. Natural ventilation system is to use stack ventilation with heat recovery. In summer, the conservatories will convert into open verandas by opening the windows. Night cooling will remove the heat stored in the building fabric. The design means that domestic energy consumption will be about one-tenth that a standard suburban house [9]. Investigating person-environment relationship is essential for architects who design houses. Bioclimatology of the area affects attitude towards design of buildings [8].

Facade design, triple glazing using and window size design contribute to energy saving and to aesthetic appearances of the building. Using recycle or environmentally friendly building materials and paints from floor up to ceiling of the building would benefit sustaining our planet.

The ideal sustainable building or township don't rely on the national grid, but produce enough renewable energy sources from hydraulic, wind, solar and ground heat energy power. A district of 7,500 populations and an individual house would have enough electricity for themselves. The net-electricity generated from renewable energy design will be sold to the national grid. Treatment of sewage water is another important issue in the building and urban design. Surface and sewage water could be naturally purified by plants, for example, reef bed is a good way treating surface water, grey water. Rain water could be collected for flushing toilet or for other non-drinking purposes.

## 6. VERNACULAR ARCHITECTURE VALUE

Zhejiang's vernacular architecture highlights distinctive regional and ethnic characteristics. Their adaptation to local terrains, diversity in forms, functional use and aesthetic value make them a cherished legacy of China's ancient architecture. Traditional Chinese architecture embeds with a kind of natural science combined of Geography, Meteorology, Landscaping, Ecology and Urbanism. Since the ancient time Chinese emphasis "sphere and man are always together", respect nature, living in harmony with the nature. In Chinese thousands year's history, natural wood is used as the main building material for dwelling and for government building or Palace in ancient Chinese architecture. Timber frame buildings are so characteristic, becoming main stream of Chinese architecture. The wooden crafts on the building are delicate. They appear to be harmony side by side with white walls and grey tiles. The images of the natural wood craft or the timber structure blend in with the natural surrounding, with gardens, wooden furniture perfectly.

Zhejiang has a lot of water features, running stream or river, arching bridges and many rain days. People and alleys and their busy activities are typical scenery in eastern coastal town like Ningbo.

The folk dwellings in Zhejiang features water alley, stone paving, pitching roof, white wall and grey tile reflect the best solutions of using the local sources for building material. Vernacular forms would have aesthetic appearance and at the same time they would be the most economic building solutions for the area. How cities, towns and buildings are designed ecologically appropriate, one has to learn from their own local historical choices of architectural and urban built forms.

## 7. REGENERATION OF THE HISTORICAL CITY OF NINGBO

Ningbo had a long history as described previously. How to re-captures the city's old cultural glory and its historical value? Monumental regulations in Ningbo should limit the demand for modern programmes, generating tower block invisible from the street behind the historical facades should be taken into consideration towards an urban renaissance. The recent massiveness and higher densities in the city leads to the question of whether the existing lighting and air quality regulations should change.

Special regeneration scheme and remove green-field land for housing require regeneration programmes to make easier for regeneration bodies to endow cash and assets to local developer. Establish housing regeneration companies to undertake regeneration in areas where there is badly deteriorated and vacant stock. Appoint special local authority area regeneration committees in urban priority areas, to enhance the quality and speed of decision-making. Produce detailed planning policy guidance to support the drive for an urban renaissance. Steer development towards more effective use of urban land and buildings accessible by sustainable forms of transport; encourage the use of sub-regional plans to set overall requirements for providing housing on brown-field land and in recycled buildings [6].

## 8. HOW TO DEAL WITH SOURCES OF POLLUTION IN NINGBO?

Sustainable urban design includes: cutting down pollution, noise level and heat island effect. Black water and grey water can be recycled. Rainwater can be collected and to be used for domestic purposes. Recycling includes household waste and industrial waste, for example, bulky construction materials, all structural steel of a demolished building can be reclaimed from a demolished building site. A new construction can always use reclaimed materials from near by demolishing site. This is a way indirectly to reduce the amount of waste going to the landfill. The site waste can be separated into different skips for recycling. When recycling facilities for household waste is well

designed, household waste for landfill will cut down to 20% for an average household.

## 9. ENERGY MANAGEMENT IS CRUCIAL

The present cities depend on non-renewable resources. The combustion of non-renewable resources produces waste gases that affect the environment. The fuel consumption patterns of our modern cities cause Acid rain-damaged forest and global warming. The energy that flows through city today is much greater than which flows through natural, rural villages and a smaller footprint city.

New approach to urban energy management is crucial. First of all, energy consumption has to be reduced. A study shows that one hundred people using a bus need only 40 square metres of road space. In contrast, the same number of people in cars needs some 2000 square metres. Yet cars have not solved people's travel problems, with traffic jams as a style of every day living. Denser land use and better public transport are solutions with great expectations of improving the energy problem. Secondly, energy consumption can be reduced by improving energy supply systems, for example, by using combined heat and power stations, a system with efficient burners suitable for compact districts with high population density. Thirdly, renewable energy technologies, like solar energy, wind power and energy-efficient product have been invented, not only to release less carbon dioxide to the air but also to cut down the amount of energy costs to the cities [6].

Cutting down on water consumption is another sustainable issue of the development in the city. Each building is designed to collect enough rainwater from its roof to meet its water needs; a water meter is displayed in the kitchen to remind residents of their water consumption and the amount of rainwater being collected into large tanks sitting at the foundations. Hopefully, Ningbo residents are targeting to use 54% of the water of a conventional house.

## 10. CONCLUSION

The above discussions are based on a list of wishful agendas for the Ningbo city officials to look at. The list is proposed un-officially among small group of academic and developer's circle. The reaction and impression from all kinds of meetings are:

- 1) Developer would not apply renewable technologies unless the government's regulation said so. The economic profit would be affected and capital would increase due to apply renewable technologies to their development projects.
- 2) Small numbers of government officials and academic know the detail of renewable technologies well.
- 3) People tend to learn more and more about sustainability concepts, but haven't yet relate the topic to their daily life and realized how hard it is to apply it in everyday life and unfortunate a lot of behaviours people conduct there are selfish and harmful to the environment.

In the 21st century, the accurate view of the environmentalism would be a scientific and humanist discussion. Air and water pollution and city "environment" appear in front of architecture, economic, psychology, law, planning. Sustainability is "not only environmental criteria, but also issues of social equity and choice, both now and in the future".

Densification, concentration of resources and dealing with pollution are challenges of the growing urbanisation. Choices in favour of sustainability are often costlier and more difficult to implement because of the application of new techniques and materials. Extra efforts, flexibility in management, clear rules, and a good control system are needed. This will pay off in the long run [6].

To avoid experiencing large-scale ecosystem collapse in China, Chinese should learn from their ancestor's application on circular mechanism theory. The valuable traditional construction methods in city, like Ningbo, in province, like in Zhejiang, and to learn from intelligent green and energy efficient building & technologies and products from the West. It is dangerous only practice the models from the West.

Expertise in intelligent and sustainable/green buildings and capability to deliver energy efficient building design, urban master-planning and transport infrastructure in China is greatly needed.

Ningbo, as one of the leading cities in China should promote sustainability at all level including to their key political and economic decision makers.

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