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A Sustainable Solution For Urbanization In China

中国城市化可持续解决方案

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Christopher Drew是公司的可持续设计总监，为AS+GG的各个项目做出贡献。在2009年加入AS+GG之前，他在马斯达尔城担任可持续部门经理，该项目位于阿联酋阿布扎比附近，是一个低碳项目。

Dennis Rehill has extensive experience in the design of supertall projects around the world.. Recently he led design efforts on Dusseldorf's GreenQ and Vantone Great City master plans.

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Adrian Smith has been a practicing architect for over 40 years. His body of work includes landmark structures like the Jin Mao Tower in Shanghai, China and the Burj Khalifa in Dubai, United Arab Emirates. Adrian's design approach considers each project holistically.

Adrian Smith是一位从业40多年的建筑师。他的工作范围主要包括地标式构筑物，如中国上海的金茂大厦和阿联酋迪拜的哈利法塔。Adrian的设计手法以纵观全局见长，他在每个项目中的设计都从整体考虑入手。

Abstract

This paper presents a design solution for a new high density vertical City in China for 100,000 residents sharing a live-work environment. The built up area is 1.3 km^2. The philosophy for the City has been to provide a highly walkable development located within a managed natural environment that is affordable to young professional Chinese and is suitable for multi-generational living. Significant savings in potable water and electriCity demand as well as waste diversion from landfill have been achieved. The urbanized area contains more than 30% green space and provides educational and medical care facilities. It has a strong economic model and has been developed to comply with over 50 Key Performance Indicators that cover environmental, social, and economic aspects of the overall community development.

Keywords: Density, Vertical City, Infrastructure, Integration, Sustainability

摘要

本文提出了一种中国新建高密度垂直城市的设计方案，在这座垂直城市中，将有10万名居民共享同一个生活和工作环境。建成面积达1.3平方公里。该城的设计理念是在一个井然有序的自然环境中提供一个可以高度步行的空间，既让中国的年轻人士负担得起，又适合几代同堂，共享天伦之乐。 项目在直饮水、电子城需求以及垃圾填埋场的废品分流等方面均取得了显著的节能成效。 城市化区域包含超过30%的绿地，提供了教育和医护设施。在发挥重大的经济模范作用的同时，项目开发还符合50多项主要性能指标，涵盖整体社区开发的环境、社会、经济等多个方面。

关键词：密度、垂直城市、基础设施、整合和可持续性

Introduction

At the beginning of 2012, the global population stood at over 7 billion people, with more than half of all people on the planet living in urban areas. The United Nations estimates, using a medium growth rate, that this will increase to over 8 billion by 2025 and to almost 9.5 billion by 2050. This will be accompanied by an increase in overall average population density from 51 people per sq. km in 2010 to 59 in 2025 and 68 in 2050 (United Nations, 2010). Not only will the global population be increasing, but cities will also be expanding at an exponential rate; the World Bank estimates that between 2007 and 2025, the annual urban population increase in developing regions is expected to be 53 million (United Nations, 2009). Often, people move to the Cities simply for the economic benefits and career opportunities. Furthermore, cities tend to have a greater range of education facilities for parents to choose from for their children as well as better healthcare and social facilities. There are, however, significant negative environmental effects associated with urbanization. The result of this trend is urban sprawl, the outward expansion of metropolitan areas. Urban sprawl has and will continue to put economic, social, and environmental constraints on our

简介

2012年初，世界人口超出了70亿，一半以上的人口居住在城市区域。联合国预计，按此增长速度，到2025年世界人口将增长到超过80亿，到2050年将接近95亿。与此同时，平均人口密度也将从2010年的51人每平方米增长到2025年的59人每平米，2050年将增长到68人每平米（联合国2010报告）。不仅全球人口在不断增长，城市规模也将迅速扩展。世界银行预计从2007到2025年间，发展中国家地区的城市人口每年将增加5300万（联合国2009报告）。通常，人们移居城市是为了寻求经济利益及工作机会。此外，城市还提供了更大选择范围的教育设施，及更好的医疗及公共设施。该趋势的结果是导致城市蔓延、大都市扩张。因此，城市化给城市环境带来了巨大的负面影响。城市的不断扩张已造成并将继续带来经济、社会及环境方面的制约。随着城市扩张问题的不断深入研究，当今的社会不得不重新审视城市设计及建造方法。

中国的经济增长速度史无前例，同时严峻地考验着发展所依赖的各类自然资源。现如今中国已跃居世界第二大经济大国，同时也成了最大的碳排放国家（CDIAC,2008）。城市不断地扩张以容纳不断增长的人口，因此，不得不占用农田以进行各类项目开发。不断增长的人口导致对食物需求

society. As the issue of sprawl is researched and addressed, our society has been forced to reexamine the way we design and build cities.

China has been experiencing economic growth at an unprecedented rate, which has put a strain on the natural resources needed sustain their development. As China has become the second largest economy in the world, it has also become the largest carbon emitter (CDIAC, 2008). Their cities are expanding outwards to accommodate an increased population, but consequently there is a loss of farmland to developments. Further compounding this problem is the growing demand for food to accommodate a growing population with an increasing standard of living. This example is just one of many problems that so clearly illustrates how intertwined these issues are between economic, social, and environmental consequences. No one issue is isolated; these systems are all interrelated. China's rapid population and economic growth have provided a clear example of the challenges associated with urban sprawl.

As a result of this, China's society is facing a multitude of issues, specifically how to address and manage the foreseeable population growth and its associated environmental and societal consequences. By 2025 China is expected to have 221 cities with more than 1 million people in them (McKinsey Global Institute, 2009). Today, China stands on the precipice of addressing this urbanization. They are faced with the opportunity to redefine how to design and build cities. In this project we propose a high density vertical City that presents a solution to the challenges created by urban sprawl. Rethinking cities as vertical from establishment allows for an economical, functional, and environmentally beneficial solution to addressing urban sprawl. In particular, we focus on climate and energy, place and community, sustainable transportation, natural resources, ecology and the natural environment, food production, business and economics and sustainable architecture.

The Great City Concept

In order to address the issues above while at the same time ensuring a financially viable business model, a design brief was prepared that included the following requirements:

- 100 hectares built-up area and 200 hectares buffer zone
- 100,000 residents
- Live/work mixed-use environment
- Affordable to the emergent middle class
- Healthcare industry as an economic driver
- Phaseable and replicable

The location of the proposed development is approximately 25 km south of Chengdu City Centre in an area of farmland that is zoned for mixed-use development as part of a regional masterplan for Chengdu (see Figure 1).

Design Principles

Having been provided with a design brief, the design team went on to develop a series of design principles, which encapsulated the clients' needs as well as what was considered to be of importance in order to realize the construction of the project:

- Create a vertically-integrated, three dimensional City that utilizes land efficiently.

的日益增长，及不断提高的生活标准使得该难题更加复杂。从经济、社会及环境影响之间的错综复杂的问题可见一斑。没有任何一个问题是孤立存在的，这些系统相互关联。中国快速增长的人口与经济给城市扩张带来了挑战。

因此，中国面临的问题是多方面的，特别是如何解决并管理好可预见的人口增长及与其相关的环境及社会问题。到2025年，中国预计将有221个城市的人口超过100万（麦肯锡全球研究所，2009）。如今，中国亟需解决城市化问题，并有机会重新定义如何设计与建造城市。在本项目中，我们提出了高密度垂直城市的概念，以迎接由于城市扩张带来的挑战。将城市重新构思为垂直模式，从经济、功能及环境方面解决了城市扩张所带来的问题。特别是，我们非常关注气候与能源、场地与社区、可持续交通、自然资源、生态、自然环境、食品生产、商业与经济及可持续的建筑。

立体城市概念

为了解决以上问题，同时确保经济上可行的商业模式，编制了包括以下要求的设计任务书：

- 100公顷建筑面积及200公顷缓冲区
- 10万居民
- 生活/工作综合环境
- 中产阶级负担得起
- 带动经济的医疗保健产业
- 可分期开发及可复制

拟开发项目位于成都市以南的农田区，离成都市区大约25公里，该综合开发项目作为成都市区域总体规划的一部分（见图1）。

设计原则

在设计任务书的基础上，设计团队制定出一系列即可满足业主需求又可实现项目建造的设计原则：

- 打造垂直结合型、高效利用土地的三维立体城市
- 建立牢固的经济基础
- 容纳多代人口，并确保各年龄及各收入群体的住房及工作

Figure 1. Location of GREAT City. (Source:AS+GG)
图1. 立体城市位置（出自：AS+GG）

- Create a strong economic foundation.
- Accommodate a multi-generational population ensuring housing and jobs for all age and income groups.
- Realize a walkable community that encourages pedestrian activity and minimizes automobile dependence.
- Design a visually attractive, unique and distinctive City.
- Incorporate food production and agriculture as a foundation of economic and social well-being.
- Achieve affordable urban development as a viable economic model.
- Create a sustainable community with the lowest-possible environmental impact.

From these principles, a series of Key Performance Indicators (KPIs), based on eight themes from the BREEAM Communities rating system was developed. The Key Performance Indicators, of which there were a total of 53, ranged from environmental targets, such as retaining and managing 100% of stormwater from a 1 in 100 year storm event on site, to social targets, such as providing 10% affordable housing and 10% social housing.

The Masterplan

The supertall towers within the City will help create a unique City image and establish a new landmark for the region. With a series of closely-connected high-rise towers, the City will benefit from sustainable vertical transportation and short, walkable distances. This will also preserve larger amounts of land for conservation and buffer areas surrounding the City.

The first stages of conceptual masterplan design, which took place before a site for the development had been confirmed, involved producing simple massing models to illustrate the effect of density – how best to fit 6 million square meters of floor area onto 1 square kilometer while retaining a logical road layout. The purpose of doing this was to test the various layout options for the City and to understand the relationships between building density, height, green space, and road dimensions. It was also during this stage that some of the key principles, such as parcelization and walkability were tested.

Once a site had been confirmed, several site visits were undertaken to familiarize the design team with the site. A GIS database was developed using CAD data, field data and satellite image analysis. ArcGIS Spatial Analyst was used in order to produce a digital terrain model of the site that would ultimately inform many of the decisions regarding access roads, green space, stormwater management and building typology. The site is effectively located along two intersecting ridges (see Figure 2) that run North-South and East-West. The valleys between the ridges were immediately identified as areas that should be developed for stormwater management, recreation, fish farming and as areas where bamboo 'reed beds' could be constructed for final treatment of waste water.

The evolution and implementation of the principles of concept design followed a simple route (see Figure 3):

- Preserve the valleys
- Define a clear City identity comprised of 5 districts
- Create internal and external open space systems
- Implement a legible road network

- 实现步行社区，鼓励徒步活动并尽量减少对汽车的依赖
- 设计与众不同、引人注目的立体城市
- 将食品加工及农业作为经济与社会福祉的基石
- 打造可负担的、经济模式可行的城市项目
- 建立可持续发展社区，并尽量减小对环境的影响

本着以上设计原则，基于BREEAM社区评级系统的8大主题，制定了一系列关键性能指标（KPIs）。主要性能指标共有53项，包括从诸如储存并管理场地百年一遇暴雨雨水的环境目标，到提供10%经济适用房及10%社会住房的社会目标。

总体规划

立体城市内的超高塔楼将有助于创建独特的城市形象，并形成该区域新的地标。立体城市有一系列紧密相连的高层塔楼，并能从可持续垂直交通和较短的人行道受益。这也将保护立体城市周围大量的保留地和缓冲区。

在开发基地确认前，进行概念性总体规划设计的第一阶段， 这包括制作模型，突出密度效果-在确保合理道路布置的同时，如何将六百万平米的建筑面积集中于一百万平米上。这样做的目的是对立体城市各种布局进行测试，并了解建筑密度、高度、绿地和道路尺寸的关系。也是在这一阶段，测试了分区和可步行性等主要原则。

一旦基地确认下来， 设计团队需进行多次实地考察以便熟悉基地。利用CAD资料、现场资料和卫星图像分析资料开发GIS数据库。采用ArcGIS空间分析扩展模块来生成基地数字地形模型（最终将告知通道、绿地、雨水管理和建筑类型决策）。该基地沿着两个南北向和东西向的交叉山脊。山脊间的山谷确认为雨水管理、休闲、养鱼和竹子和芦苇床区域，也可用作废水最后处理区域。

按照简单步骤（见图3），发展和实施概念设计原则。

- 保护山谷
- 确定明确的立体城市（含5个区域）形象
- 创建室内外开敞空间系统
- 实现清晰的道路网络

Figure 2. Digital Terrain Model of the site showing intersecting ridges (Source:AS+GG)
图2. 显示场地交叉山脊的数字地形模型（出自：AS+GG）

Figure 3. The development concept for GREAT City (Source:AS+GG)
图3. 立体城市的开发理念（出自：AS+GG）

- Define buildable development parcels
- Establish a comprehensive green network

During this evolution, the relationship between different programmatic uses, building heights and City identity was established, resulting in the production of a parcelization plan, a building height plan and a program plan (see Figure 4).

Environmental Response

To meet the KPIs that had been developed for energy: a reduction in building energy demand of 30% against Chinese Building code and maintaining a peak demand of less than a 10% increase against baseload necessitated that climatic response was considered at every stage of the design.

Chengdu has a humid subtropical climate and is largely mild and humid. Being situated at the western edge of the Sichuan basin, Chengdu is therefore sheltered from northwest winds from Siberia in winter by the Qinling Mountains to the north. Snow is rare but there are a few periods of frost each winter and for several months there is a need to provide heating to the buildings with January average temperatures of approximately 6°C. The summer is hot and humid, but not to the extent of the 'three furnaces' cities of Wuhan, Nanjing and Chongqing in the lower Yangtze basin. July and August average temperatures are approximately 25°C with afternoon highs sometimes reaching 33°C. Rainfall is common all year round but peaks in July and August. Cloud cover is almost constant, with Chengdu recording one of the lowest direct sunshine totals in China and most days during the winter months being overcast and cloudy. Spring tends to be sunnier and warmer than autumn. Winds are moderate to low annually and generally come from the North East, providing some opportunities for natural ventilation especially at higher levels.

The main design considerations in response to location and climate were to:

- Maximize daylight available to residential, hospital and offices, response to low daylight (see Figure 5).
- Maximize daylight available to the street (response to low daylight).
- Minimize wind obstructions to pedestrian areas – streets, plazas and courtyards .

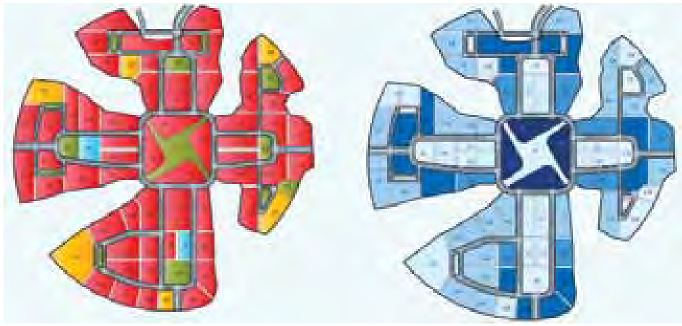

Figure 4. Parcelization and Building Height Plan (Source:AS+GG)
图4. 分区和建筑高度平面图（出自：AS+GG）

- 明确可建造开发地块
- 创建综合绿地网络

在该过程中，建立不同功能、建筑高度和立体城市形象的关系，生成分区平面图、建筑高度平面图和用地业态分布图（见图4）。

环境响应

为满足能源开发的关键性能指标要求：考虑在设计的每个阶段，将中国规范要求的建筑能源需量降低30%， 并通过气候响应策略，将高峰能源需求增长速度维持在低于基础负荷10%增长水平。

成都属亚热带湿润气候区，主要为温和、潮湿天气。成都位于四川盆地西部边缘， 其北边的秦岭山阻挡冬季从西伯利亚吹来的西北风。这里很少下雪， 不过冬季有一段霜冻期， 且有几个月需要给建筑供暖（其中一月的平均气温约在6摄氏度）。夏季炎热和潮湿， 但不及三大“火炉”城市-武汉、南京和重庆。七、八月份的平均气温约为25摄氏度，其中午后温度有时高达33摄氏度。常年有雨，不过在七、八月份的雨量最大。云量几乎不变，成都是中国获取最低直接日照总量的城市之一， 其中冬季绝大部分时间都处于阴天和多云的天气。春季比秋季更加晴朗和温和。每年有适量的东北风吹来，为自然通风（特别是在高区）提供机会 。

根据项目地理位置和当地气候条件，设计应：

- 考虑到较低的日照量，最大化住宅、医院和办公建筑的可用日照（见图5）
- 最大化街道可用日照（考虑到较低的日照量）

Figure 5. Map showing sunlight hours on winter solstice, viewed from southwest (Source:AS+GG)
图5. 西南侧冬至日照时数（出自：AS+GG）

- Minimize wind obstructions to adjacent residential towers to promote natural ventilation (reduce energy demands).
- Minimize potential for urban heat island in summer through integrating landscaping and green roofs (also serves to improve microclimate and air quality).
- Maximize environmental quality in winter with landscaping and trees to block winter winds and increase the ambient temperature of the City.

This was achieved through the following design interventions:

- All units should have some east, west or south exposure throughout the City as to promote good availability of natural light to all residents.
- Daylight available to buildings is optimized at -10 degree rotation from north-south. Atmospheric conditions attenuate daylight in late afternoon, the rotation balances daylight between Eastern and Western façades. Staggering and spacing buildings is essential to promote daylight to all buildings throughout the district, because of the amount of diffuse light availability.
- The ideal typology is a linear through unit where all units are dual aspect with decentralized cores, however these units are limited to 132 meters height. The other major typology is a double loaded corridor central core building rotated with eastern and western facing units.
- Courtyards - height should be limited at the east and western exposures to allow a greater amount of light and should be located south of towers and other high obstructions.
- Driving the natural landscape amenity through the City, reducing density in select areas and increasing the porosity of the architecture would help better promote calm breezes throughout the City, important for human comfort during the humid summer months (see Figure 6). The optimal building design for daylight, a dual aspect offset core building, is also ideal for natural ventilation.
- Large-scale, high density office buildings and manufacturing districts located up-wind to the majority of the residential buildings greatly limit natural wind flow throughout the City and could also adversely affect residential air quality. Courtyard buildings are optimized to promote breezes through lower sides in the predominant wind direction that will maximize air movement. This also maximizes daylighting to the courtyards.
- Buildings should maximize the use of landscaping on the roof and throughout the façade to reduce urban heat island effect and promote slightly warmer temperatures in winter. Tallest buildings should be located to the North of the City or directly south of uninhabited space such as valleys, parks, streets or infrastructure buildings to prevent shadow and keep the City more pleasant in winter months.

An Overview of the City as envisioned, including all of the design interventions is illustrated below (see Figure 7).

Building Energy Performance

Preliminary energy modeling for the various building sectors was undertaken using Integrated Environmental Solutions Virtual Environment. Prototypes for each building were created using area schedules developed during masterplanning as well as templates

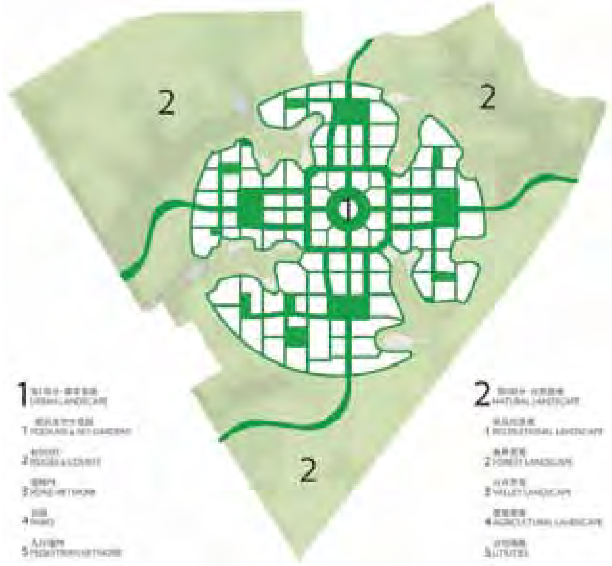

Figure 6. Natural areas penetrating into the City (Source:AS+GG)
图6. 城市自然区（出自：AS+GG）

- 最小化街道，广场和庭院等行人区的风阻
- 最小化相邻住宅塔楼的风阻以促进自然通风（降低能耗）
- 通过绿化景观和绿色屋顶最小化城市热岛效应（同时有助于改善小气候和空气质量）
- 通过绿化景观和树木使城市冬季环境质量达到最佳，阻挡冬风并提高城市的环境温度。

采用下列设计策略实现上述设计目标：

- 城市所有住宅单元设置东西或南立面，以便提高自然光利用率。
- 南北偏10度时建筑可用日照为最优。傍晚时大气条件会削弱日照，这样一个旋转角度可平衡东西立面日照。考虑到漫射光的可用量，建筑的交错布局和间距非常重要，可提高区域内所有建筑的日照量。
- 理想类型为线形布局，所有单元采用分散式核心筒，双向布局，但限高132米。其它主要类型为内廊式中央核心筒式建筑，沿朝东朝西建筑单元旋转。
- 庭院---限制东西立面高度，以便扩大采光，同时庭院应位于塔楼或其他高障碍物的南侧。
- 促进城市内自然景观设施的建设，降低区域密度增加建筑孔隙率，以便在整个城市中形成微风循环系统，可在潮湿的夏季提高人体舒适度（见图6）。 最优采光设计方案，即双向分散核心筒式建筑同时也是实现自然通风的最佳方案。
- 大规模高密度办公楼和制造业区位于大部分住宅建筑的上风向，在限制整个城市的风流量同时也可能影响住宅区的空气质量。充分利用庭院建筑以便在盛行风向下风区形成微风系统，最大化空气流通。同时最大化庭院的采光。
- 建筑应充分利用屋顶景观和立面景观，减少城市热岛效应，提高城市的冬季气温。最高建筑应位于城市北侧或山谷、公园、街道或基础设施建筑等非居住区的南侧，以减少建筑阴影，确保城市在冬季更舒适宜居。

根据项目定位，以下概述了立体城市设计，包括所有的设计策略（见图7）。

for construction, HVAC, lighting, equipment loads, and occupancy schedules based on building type and function as well as on Chinese Code. The energy simulated in each building was then extrapolated, based on kWh/m^2 to the entire program area for each building type. This established a building energy consumption baseline for the City of Chengdu.

The City was then modeled for high energy performance using strategies such as enhancing the building envelope, radiant cooling, HVAC optimization, heat recovery, high efficiency lighting, natural daylight availability and enhancement, and intelligent building management systems. The result of these strategies was a City that would require slightly over 30% less energy than the Chinese Code baseline design. The baseline office demand was 220kWh/m^2; when enhanced energy efficiency strategies were included in the model, the number was reduced to 123kWh/m^2, a 44% reduction. The baseline residential demand was 303kWh/m^2; when enhanced energy efficiency strategies were included in the model, the number was reduced to 235kWh/m^2. Of the total energy demand, 38% is associated with heating and a mere 6% associated with cooling. It is anticipated that with further study, significant changes to these numbers could be made through adjusting the environmental temperature control set-points to levels that are more appropriate to the Chengdu residents' lifestyle expectations.

Site-Wide Infrastructure

Progress towards a low carbon City requires that three key elements be addressed:

- Energy and water demand reduction.
- Local scale renewable energy production.
- Decarbonized infrastructure.

These must be combined in a way that delivers the low/zero carbon objectives at minimum cost when considered over an agreed lifecycle. The optimum combination varies for each location and further detailed assessment of the site will be required to carry out this optimization process. The aim of the process in GREAT City was to engineer an integrated combination of technologies that best served to optimize resource efficiency and functionality.

The proposed utility infrastructure incorporates best practice in sustainable infrastructure design for energy, water, and solid waste management, thus enabling the City to become one of the most energy, water and waste efficient developments of its kind and it is expected that many of the approaches adopted for GREAT City will become normal practice on future developments.

It was agreed between consultants and client very early on in the design process that only proven technologies and systems would be proposed in order that the GREAT City infrastructure would be as reliable as that of any other development with more traditional infrastructure but would use only 41% of the energy and 42% of the water when compared to a traditional City. It will produce only 60% of the normal CO_2 emissions. The way that solid waste will be managed on-site means that some waste will be converted to energy and that 89% will be reused rather than sending to landfill.

To achieve these goals the power provided to the plots parcels will be supplied through a combination of the external electriCity grid, from Combined Heat and Power (CHP) plants distributed around GREAT City in "energy hubs" and from an onsite waste to energy plant.

Figure 7. View of GREAT City (Source:AS+GG)
图7. 立体城市（出自：AS+GG）

建筑能效

通过使用整体环境解决方案虚拟环境，对各个建筑区进行了初步能源建模。根据总体规划确定的面积表，建筑、暖通、采光和设备负荷模板以及基于建筑类型、功能和中国法规编制的建筑使用表，建立各建筑原型。然后以千瓦时为单位，将建筑模拟能耗类推至每种建筑类型的整个功能区。

通过改善建筑围护结构，辐射制冷，暖通设计，热回收，高效采光，自然光利用率并采用智能建筑管理系统，立体城市成为了高能效的典范。通过使用上述策略，立体城市所需能源比中国法规中的基线设计所需能源低30%多。办公能耗基线为220千瓦时，将上述提高能效的策略应用于模型后，能耗降至123千瓦时，减少44%。住宅能耗基线为303千瓦时，将上述提高能效的策略应用于模型后，能耗降至235千瓦时，总能源需求中，38%为制热需求，6%为制冷需求。随着研究的进一步深入，通过调整环境温度设定值至更符合成都居民生活预期的水平，可进一步大幅度降低能耗。

场地基础设施

在立体城市低碳设计中，应体现三种主要元素：

- 能源及水需求量减少；
- 局部范围可再生能源的产生；
- 减碳基础设施。

当考虑采用统一的生命周期时，上述元素设计须通过最低的成本实现低/零碳目标。对于不同的位置，最佳组合方式也不同，因此为便于优化需要对场地进行进一步详细评估。而工程师的任务则为将优化资源效率和功能的技术整合进立体城市的设计中。

由于基础设施的可持续设计采用了能源、水和固体废物管理方面的最佳做法，因此立体城市将成为该类项目中能源、水和固体废物利用最高效的项目之一，预计其采用的多个设计手法将成为未来项目的常用做法。 业主和顾问在设计阶段早期已确定只使用成熟的技术和系统，确保立体城市的基础设施与其他开发项目的传统基础设施一样具有可靠性，立体城市的能耗和水耗只占传统城市的41%和42%，其二氧化碳排放量只为正常建筑排放量的60%。通过现场处理固体废物，89%的废物可被转换成能源重新利用。

为实现上述目标，应结合分布于立体城市“能源枢纽”位置的热电联产厂（CHP）及现场废弃物能源再生厂的外部电网，为地块供电。

Waste water will be collected and treated on-site and reused for toilet flushing, road cleaning and irrigation, greatly reducing the wastage of potable water. To achieve this objective, an onsite waste water treatment plant was proposed. Treated waste water would be discharged to the valleys for further treatment using bamboo reed beds (see Figure 8).

Waste heat from the waste-to-energy plant and from the CHP plants will be used as a source of direct heating or diverted to absorption chillers (converting heat to cooling) to provide a very efficient source of cooling to some buildings. Underground Thermal Energy Storage (UTES) was proposed to further increase the efficiency of the cooling and heating for the site.

The main plant for the onsite utility systems is located in an Ecopark complex to the north-west corner of GREAT City. This area houses the following equipment:

- Wastewater Treatment Plant (WWTP).
- Combined Heat and Power (CHP) plant for the production of energy from solid waste, waste water treatment sludge (residual waste from waste water treatment) and natural gas.
- A vacuum solid waste collection system main station where waste is collected from across the site.
- Anaerobic digesters for biogas and compost production from sewage, green, and food waste.
- A materials recovery facility where solid waste is segregated for further use.
- Hazardous waste storage.

The Ecopark will be provided as a fully functioning facility supporting the GREAT City and will also provide an educational and promotional function allowing the City to advertise its sustainable design achievements.

Figure 8. Topography and stormwater surface flow (Source:AS+GG)
图8. 地形和雨水地表径流图（出自：AS+GG）

Figure 9. Performance of GREAT City compared against a code compliant baseline (Source:AS+GG)
图9. 立体城市性能与合规底线比对（出自：AS+GG）

Key Statistics

Various parameters regarding the program and performance of the City were calculated and compared against a Chinese code compliant design baseline. These key statistics are presented in Table 1 & Figure 9.

Conclusion

GREAT City is a compact suburb of Chengdu with its own identity as a stand-alone City. It will be home to over 100,000 people in a live/work environment. It has been designed to be environmentally, socially and economically sustainability, using 48% less energy, and 58% less water than a conventional development of similar population. It will also produce 89% less landfill waste and generate 60% less carbon dioxide.

	Great City 立体城市	Traditional City 传统城市	Net Change 净改变
Green Area And Public Parks In Urbanized Area 绿化面积+都市化范围内的公园	31%	20%	55% Increase 55% 增加
Total Public Open Space In Project Area 项目范围内的公共开敞空间总面积	81%	40%	103% Increase 103% 增加
Areas Of Roads Devoted To Pedestrian Or Bike 专门用于行人或自行车的道路面积	50%	20%	150% Increase 150% 增加
Urbanized Land For 100,000 People (Sq. Km.) 为1万人口所用的都市化土地面积（平方公里）	1	7	7 Times Less Land Needed 7 所需土地减少倍数
Residential Water Consumption (m^3/day) 每个居民的用水量（立方米/日）	9,050	19,720	54% Reduction 54% 减少
Residential Potable Water Demand (m^3/day) 每个居民的饮用水量（立方米/日）	7,100	19,720	64% Reduction 64% 减少
Non-Potable Water Demand Met On-Site (m^3/day) 每个居民的非饮用水量（立方米/日）	1,950	0	100% (Non-potable water needs met) （非饮用水量相同）
Waste To Landfill (tons/year) 填埋的废弃物（吨/ 年）	6,780	108,100	94% Reduction 94% 减少
City Energy Use (kWh) 能耗量（千瓦/小时）	595,030,000	1,142,900,000	48% Reduction 48% 减少
City Gas Consumption (kWh) 燃气耗量（千瓦/小时）	635,280,000	813,567,000	22% Reduction 22% 减少
Carbon Dioxide Emissions (tons/ year/100,000 people) 二氧化碳排放量（吨/ 年）	310,000	1,010,000	69% Reduction 69% 减少
Urbanized Area Devoted To Vehicular Roadways 都市范围内专门用于机动车的道路	12%	20%	40% Reduction 40% 减少
Urbanized Area Devoted To Pedestrian Use 都市范围内行人专用区	44%	30%	47% Increase 47% 增加
Percentage of People Fed With Site-Grown Food 现场出产的食物可供养人数	10%	0	10% Increase 10% 增加

Table 1. Key Statistics for GREAT City (Source:AS+GG)
表1.立体城市主要统计资料（出自：AS+GG）

现场收集并处理废水，并将其用于冲厕、道路保洁和灌溉，以大大减少饮用水的浪费。建议在现场修建一座废水处理厂以实现这一目标。将处理后的废水排放至山谷，通过竹子和芦苇床对废水做进一步净化（见图8）。

废弃物能源再生厂和热电联产厂（CHP）产生的废热可直接作为供热源或传送至冷却装置（转热为冷），为一些建筑提供有效制冷源。建议采用地下热能存储（UTES）进一步提高场地供冷和供热效率。

现场动力系统主厂房位于立体城市西北角的生态园，设有以下设施：

- 污水处理厂（WWTP）。
- 热电联产厂（CHP）使用固体废物、污水处理沉淀物（污水处理后的残留废物）及天然气生产能源。
- 真空固体废物收集系统主站，收集场地各处的废物。
- 在厌氧消化池中利用污水和食物渣滓生产生物气和混合肥料。
- 采用材料回收设施隔离并进一步利用固体废物。
- 危险废物贮存。

生态园是立体城市的功能配套设施，兼具教育和宣传功能，使立体城市能宣传其可持续设计成果。

主要统计资料

按照中国规范的设计底线计算并比对立体城市业态及性能的各种参数。表1和图9中注明了立体城市的主要统计资料。

结论

立体城市位于成都郊区，是一座具有独特标识的独立城市。十万人将同时入住立体城市生活和工作。立体城市的设计具有环保性及社会和经济可持续性，比容纳同样人口的传统开发项目减少了48%的能耗、58%水耗、89%的垃圾填埋及60%二氧化碳的排放量。

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