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Author: LiJun Cao, Environmental Market Solutions, Inc.

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Sustainability Strategy
可持续性策略

LiJun Cao, *Environmental Market Solutions, Inc.* | **曹丽君,** *君凯环境管理咨询 (上海) 有限公司*
HaiTao Li, *Zhongnan Group* | **李海涛,** *中南建设控股集团*

This chapter explores methodologies and approaches for achieving sustainable design for megatall buildings, through the review of various sustainable design elements that will be implemented in the Suzhou Zhongnan Center. Based on the stipulations of LEED CS 2009, the design team established targets for reducing energy demand, which will be achieved through elements such as ice storage, optimization of façades and fenestration, and targeted distribution of the HVAC systems and chiller plants. In addition, greywater and rainwater recycling programs are pursued.

本节通过分析苏州中南中心中应用的各种可持续设计元素，探讨了实现超高层建筑可持续设计的方法论和途径。 根据LEED CS 2009中的要求，设计团队将降低能源需求作为目标，并将通过冰蓄冷，外墙和开窗方式，以及合理分布HVAC系统与冷却塔的方式来实现此目标。另外，团队还将进行灰水及雨水回收利用的项目。

Energy Design

Energy-saving design is always at the core of a green-building concept. Particularly for megatall buildings, energy savings involve the extensive investments made in lighting, ventilation, cooling and heating systems. The starting point for reducing energy consumption is to optimize performance of the building envelope. The optimized building envelope had been achieved by a comparative study of the typical floor's energy consumption, then reviewing various options.

Demand Reduction

Based on the requirement of LEED CS 2009, the design team established the following targets.

- The energy consumption of MEP systems should be decreased by 20% in comparison with the latest Chinese energy code.
- The annual energy cost of the building should be decreased by 16% compared with ASHRAE 90.1-2007.

In an attempt to achieve the established energy-saving targets, the impact on building HVAC load and operating cost, building-envelope measurements, such as fenestration U-value, opaque wall U-value, and glass shading coefficient (SC) were studied. As shown in computer energy models, better façade insulation will reduce the HVAC load and related operational cost at a slightly higher initial cost. With the comprehensive consideration of initial cost, operational cost, energy savings, and building shape etc, the façade parameters outlined in Table 2.1 were finalized.

Heating and Cooling Sources

The height of the HVAC-serviced area in this project is 598 meters. If only one centralized water cooled chiller were used, then at least four heat exchangers would be needed to avoid over-pressurizing the water system. Each heat exchanger will lead to a 1°C temperature difference Therefore, in order to maintain the temperature of the highest point at 7°C, to achieve dehumidification, the output water temperature of the chiller should be set at 3 °C. This will result in significant reduction of efficiency of the chiller and cause huge energy loss. As a result, a separate chiller plant room was proposed for the hotel area.

能源设计

节能永远是绿色建筑的核心理念，超高层建筑也不例外，需要提供照明，通风，制冷，供暖，设备等大量消耗能源的系统。减少能源需求的起点是优化建筑的维护结构参数。项目团队通过对标准层能耗模拟的方式寻求最佳的维护结构设计。

减少需求

根据LEED《能源与环境设计先锋奖》以及《绿色超高层建筑评价技术细则》的相关要求，项目团队制定以下目标

- 与最新中国能源标准相比，全年累计空调采暖和制冷负荷降低3%
- 与最新中国能源标准相比，全年暖通空调系统节能率20%
- 与ASHRAE 90.1-2007标准相比，全年能耗运行费用节省16%

依据建筑可能达到的保温性能，分别研究了透明幕墙的保温性能设计，不透明幕墙的保温设计，玻璃的遮阳系数对于建筑能耗和运行费用的影响; 计算机全年动态研究结果表明，在工程范围内，研究的三个指标随着保温性能的改善呈单项变化。综合考虑造价等因素，本项目拟采用以下保温性能作为设计依据 (见表2.1) 。

冷热源绿色设计

本项目空调区域的高度为598米，如果只是

Considering the division of property ownership and the measurement of needs, the offices at the lower levels of the tower and podium space are provided with their own dedicated water-cooled chiller plant rooms. Megatall buildings have a very high air-conditioning demand at peak times. In order to balance cooling and heating demands, an ice storage system was proposed. Although the ice storage system will do little to reduce energy consumption, it will balance the electricity demand between daytime and nighttime, which will contribute to the preservation of the city's energy infrastructure and protect the environment, which had been encouraged by local policies.

The peak cooling load for a typical summer day is 72,510 TRH (excluding the apartments). The ice storage system's anticipated capacity required is 21,760 TRH, which is 30% of the daily peak cooling load. Since most of the cooling requirement for the hotel will occur during the night, the ice storage system will be mainly used for the offices and podium at the bottom of the tower (see Figures 2.14 and 2.15 and Table 2.2).

In order to avoid consuming additional electricity and/or gas, all of the HVAC heating load and domestic hot water load will come from civil waste steam.

Renewable Energy
Using solar energy was a major goal of the project.

The tower's roof is not flat, so 1,500 square meters of solar panels were placed on the roof of the podium. The annual energy generated is expected to be 261,450 kWh, which will be used for powering the service equipment in the podium such as fans, cooling tower, etc.

Water Design

Because of its lakeside setting, it is commonly though that Suzhou has a very rich water resource. In fact, much of Suzhou's water

Types 类型	Assembly Fenestration U-value 透明部分综合传热系数	Opaque wall U-value 不透明部分综合传热系数	Glass SC 玻璃遮阳系数
Performance Data 参数要求	< 2.0 w/m²/k	< 0.6 w/m²/k	< 0.3

Table 2.1. The consideration of energy-saving targets in the façade
表2.1. 对于节能目标的考虑

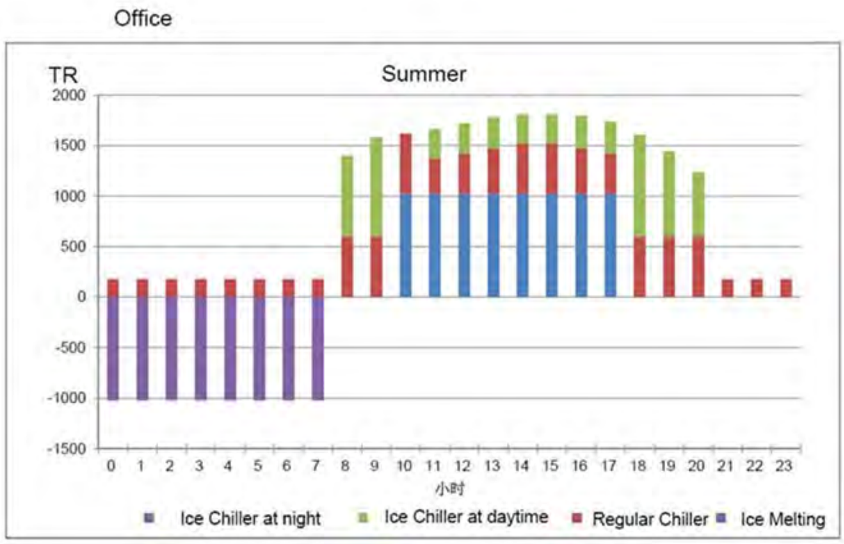

Figure 2.14. Office Ice Storage
图2.14.办公部分冰蓄冷示意图

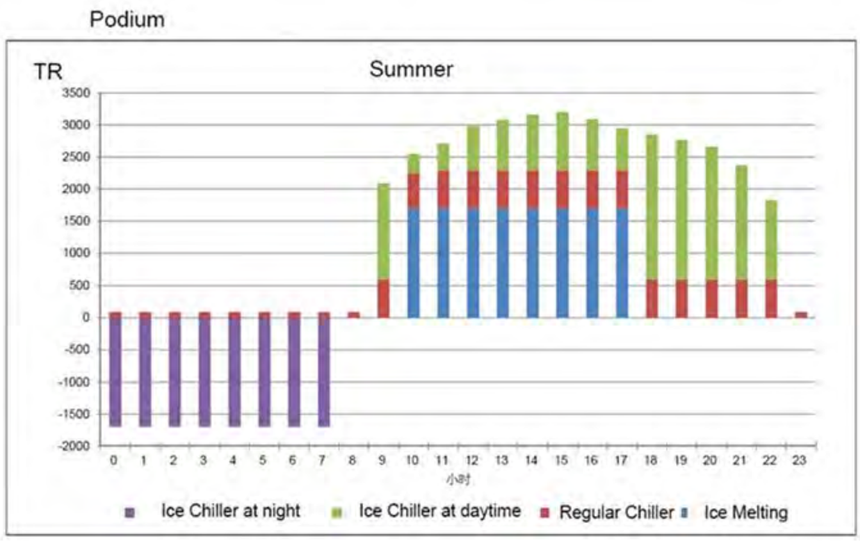

Figure 2.15. Podium Ice Storage
图2.15. 商业部分冰蓄冷示意图

	Office 办公			Podium 裙楼		
Performance Data 参数要求	Peak-time chiller electricity Demand 冷机峰值用电需求	HVAC Summer Operation Cost 空调夏季运行费用	Chiller Plant Equipment additional Cost 制冷机房设备追加投资	Peak-time cooling electricity Demand 冷机峰值用电需求	HVAC Summer Operation Cost 空调夏季运行费用	Chiller Plant Equipment Cost 制冷机房设备追加投资
Regular System 常规系统	1086 kw	1,978,000 RMB	0	2100 kw	2,678,000	0
Ice Storage System 冰蓄冷系统	448 kw	1,006,000 RMB	6,000,000 RMB	1087 kw	1,508,000	7,000,000 RMB

Table 2.2. Cooling demand at office and podium levels
表2.2. 办公区及裙房层的制冷需求

comes from other cities and runs through Suzhou. The total water resource for the city is 10 billion cubic meters, or less than 2,000 cubic meters per capita. Seventy percent of its water is sourced from other provinces and cities, and the other 30% is from local rainwater. Therefore, if a drought occurs in the upstream area, Suzhou will have a lack of water. In addition, pollution of surface water means just under 50% of the water can be used for industrial and domestic purposes.

Huge water demand will not only increase the operating costs and life-cycle costs of the building, but would also add pressure to municipal water supply and treatment facilities. On the contrary, buildings that use water efficiently can reduce maintenance costs, produce less sewage, lower sewage treatment costs and reduce the initial investment for the city water supply system.

Therefore, water conservation is taken as an important design objective.

Reducing Water Demand
Water-saving products will be introduced to all water consuming points in the building. The preliminary design and benchmark comparison are listed in Table 2.3.

Design for Greywater
Megatall buildings use and discharge a significant amount of water daily. Due to the large number of apartments in this project, the water resources consumption is even more significant. However, the large amount of greywater brings more opportunities for water saving in this project through greywater reuse.

设计一个集中冷站，那么需要四个板换作为压力分割，否则整个系统的压力将超过常规设备的承受能力。每个板式换热器基本会带来1度的温度差，为了保证最高处的温度在7度左右用于除湿，那么冷冻机房的出水温度需要设计为3度，这个会严重降低冷机的运行效率，能源损失较为严重。所以酒店部分会单独设计一个冷冻机房。

考虑到产权分割和计量需求，位于建筑相对较低位置的塔楼办公和裙房将分别采用集各自的冷站提供空调冷源。超高层建筑的空调峰值需求较大，为了平衡建筑的一天负荷情况，削峰填谷，本项目采用了冰蓄冷系统。蓄冷技术虽然从能源转换和利用本身来讲并不节约，但是其对于昼夜电力峰谷差异的调节具有积极的作用，能够满足城市能源结构调整和环境保护的宏观要求，具有一定的政策性鼓励意义。

本项目在夏季设计日空调的冷负荷 (公寓部分除外) 为72,510冷吨时，预计采用的冰蓄冷容量为21,760冷吨时，比例为30%。由于酒店的大部分冷负荷均出现在夜间，因此本项目的冰蓄冷系统服务于位于建筑底部的办公和裙房商场部分 (见图2.14、2.15及表2.2) 。

整个建筑的空调热源和集中热水热源全部采用市政余热，避免消耗额外的电力或者燃气。

可再生能源利用
项目的主要目标为高效的使用太阳能。

本项目塔楼无屋顶，因此布置了1,500平方米的太阳能发电板在裙房屋顶，年发电量预计261,450 kwh，这些电会用于裙房屋顶的机电设备运转例如风机，冷却塔等。

水资源设计

苏州地区水多是一个表面现象，实际情况是过境水多，本地产水少。苏州全市水资源总量为100亿立方米，人均占有量不足2,000立方米。且70%来自其他省市的过境水，通过苏州本地降雨形成的水约为30%，如果上游地区干旱，那么苏州将会缺水; 另外地表水污染情况较为严重，能够用于生产和生活的水不到50%。

建筑水资源的大量消耗会严重增加建筑的使用成本和全生命周期成本，同时也会增加市政管网的投资和压力。建筑的节约用水能够降低运行费用，降低污水排放，减少污水处理成本，同时降低自来水系统的一次投资。

本项目将节约用水作为一个重要的设计任务。

减少需求
所有部位的用水器具采用节水性的产品，初步的设计参数和基准如下表2.3所示。

再生水设计

Sanitary 类型	Water Closet 大便器	Urinal 小便器	Lavatory Faucet 卫生间洗手龙头	Shower 洗澡龙头	Kitchen Sink 茶水间厨房龙头
Office/Retail/Hotel Public Space **办公/商业/酒店公共区域**					
Proposed 设计参数	3/6 L	1.9 L	3.8 L	7.6 L	9.4 L
Benchmark 基准参数	6 L	3.8 L	3.8 L	9.4 L	9.4 L
Unit 单位	Per flush 每冲	Per flush 每冲	Per minute 每分钟	Per minute 每分钟	Per minute 每分钟
Apartment 公寓					
Proposed 设计参数	3/6L	N/A	3.8L	9.5L	8.4L
Benchmark 基准参数	6 L	N/A	8.4L	9.5L	8.4L
Unit 单位	Per flush 每冲	Per flush 每冲	Per minute 每分钟	Per minute 每分钟	Per minute 每分钟
Hotel Guest Room **酒店客房**					
Proposed 设计参数	3/6L	N/A	3.8L	12 L	N/A
Benchmark 基准参数	6 L	N/A	8.4L	9.5L	N/A
Unit 单位	Per flush 每冲	N/A	Per minute 每分钟	Per minute 每分钟	N/A

Table 2.3. Preliminary design and benchmarks for water consumption levels
表2.3. 初步设计及基准用水量水平

Renewable Sources of Water
The project will collect the high-grade greywater from the hotel, apartment and small office / home office (SOHO) functions (see Table 2.4).

Due to the strong wind force at the top of the building, rainwater is very difficult to collect. Also because of the small surface area, roof and façade rainwater collection systems were not considered.

Due to the daylight demand at the basement level, a sunken plaza was designed. Rainwater from the north of the plaza is collected in the rainwater pond, and then treated by a mechanical filter to reach the standard of recycled water, and then finally mixed into the clean water reservoirs for re-use. However, the volume is minimal, and thus it is not normally considered in non-traditional water reuse calculations.

Design for Reclaimed Water Treatment Process and System
The greywater treatment system is designed to process 295 m^3 /day at an average rate of about 24 m^3/hour, running 12 hours a day. Considering the running efficiency, 205 m^3/day of greywater can be treated. Therefore 74,825 m^3 of greywater can be treated each year.

The Scope of Reclaimed Water Re-use

- Landscape irrigation: about 134 m^3 per year
- Road flushing: about 23,618 m^3 per year
- Garage flushing: about 3,429 m^3 per year
- Fountains: about 413 m^3 per year
- Office and retail toilet flushing: about 48,062 m^3 per year
- From the above, the calculated yearly water demand is about 75,656 m^3, which can be matched by the greywater system.

超高层建筑的日用水量和排水量均非常大，针对本项目的大量公寓，水资源的消耗更甚。同时，大量优质杂排水也为本项目带来了更多的节水机会。为了更好地节约用水，本项目设计了中水回收处理和回用系统。

再生水的来源
本项目拟回收酒店、公寓、公寓式办公的优质杂排水 (见表2.4) 。

超高层建筑由于在高处风力较大，雨水很难汇流被收集，同时也因为超高层建筑的占地面积较小，因此本项目未考虑屋顶和立面的雨水收集系统。

由于采光需要，本项目设计了下沉式广场。收集北侧下沉广场的雨水，经过初期弃流，收集到雨水池，经过机械过滤等工艺处理到回用水的相应标准，混入中水清水池回用。由于其水量较小，在非传统水源的回用比例计算过程中不予考虑。

再生水的处理工艺和系统设计
整个中水处理系统的规模按照295m^3/天，设计平均处理速度为24m^3/h，每天的运行时间为12小时，考虑到运行效率，本项目的日产水量按照205m^3/天进行计算，全年产水量为74825立方米。

再生水回用范围

- 绿化灌溉，约134m^3/年。
- 道路浇沙，约23,618m^3/年。
- 地库冲洗，约3,429m^3/年。
- 景观补水，约413m^3/年。
- 办公及商业厕所冲洗，约48,062m^3/年。
- 上述部位的年需水量约为75,656m^3，和中水处理系统匹配。

非传统水源利用比例
整个项目的年用水量约为73,2513m^3，(包含冷却塔补水、景观用水、道路冲洗用水、洗车用水) 本项目非传统水源的利用比例为 74,825 / 732,513 = 10.21%。

地下室采光

Item 序号	Place 部位	Number 使用数量	Discharge Standard 原水排水量标准	Discharge Coefficient 排水量系数	Day 用水天数	Water volume per day 平均日原水量	Water volume per year 全年原水量
1	Guest Room 酒店客房	567 Bed/床	220L/D/B床	0.58	365	71.9	26225
2	Hotel staff 酒店员工	281 People/人	70L/D/D天	0.58	365	11.3	4135
3	Tour 会所观光	8 People/人	800L/D/D天	0.58	365	3.7	1346
4	Apartment 公寓	1778 People/人	140 L/D/P人	0.55	365	137.6	50207
5	SOHO office 公寓办公	574 People/人	240 L/D/P人	0.31	264	42.2	11129
6	Office 办公	3383 People/人	25L/D/P人	0.31	264	25.9	6832
						292.6	99874

Table 2.4. Estimated water consumption
表2.4. 预计用水量

Proportion of Non-Traditional Water Use

The total water consumption of this building (including cooling tower make-up, landscape use, road cleaning, car washing, indoor water, etc.) is about 732,513 m^3 per year. This makes the non-traditional water ratio 74,825 / 732,513, or 10.21%.

Basement Lighting

Eighty percent of the information that people get from the outside world comes from natural light and optical radiation. Natural light has a positive effect a person's motivation and mood.

Providing daylight to the underground space is not only beneficial to energy savings, but also improves conditions for occupants. Due to the enclosure of underground space, natural light can increase the natural communication between indoor and outdoor spaces, and reduce psychological ill effects. Natural lighting can also work as a reliable source of basement emergency lighting in the daytime.

The introduction of three sunken plazas let daylight into the basement space, which covers up to 22% of the area of basement level 1.

Site Wind Environment Design

According to relevant studies, in order to avoid unpleasant incidents, such as strong wind at the pedestrian level, which may drive objects into the façade or inhibit walking, the wind speed should be less than 5m/s within the pedestrian zone around the building, and particularly between the ground and 1.5 meters above grade to ensure comfort while conducting normal activities. Besides, poor ventilation will severely hinder the flow of wind, which may even create stagnant pockets and vortices in some places. These phenomena are not conducive to the dissipation of outdoor heat and pollutants, so they should be avoided as much as possible.

The design of this project resulted from seeking the best solution for the outdoor wind environment. Simulation results showed that under the dominant wind direction, the wind speed is less than 5m/s within the zone of 1.5 meter high above the ground in the pedestrian

人从外界获得的信息约有80%都来自光和光辐射引起的人的视觉。自然光对人的灵敏度、活力指数和心情有正面作用。

地下空间的天然采光不仅有利于照明节能，而且充足的天然光还有利于改善地下空间卫生环境。由于地下空间的封闭性，天然采光可以增加室内外的自然信息交流，减少人们的压抑心理等; 同时，天然采光也可以作为日间地下空间应急照明的可靠光源。

本项目准备设计三个下沉式广场，有效地下室采光面积达到地下室一层面积的22%。

场地风环境设计

为避免建筑单体设计和群体布局不当，而有可能导致行人举步维艰或强风卷刮物体撞碎玻璃等事故，相关研究表明，建筑物周围人行区1.5m高处风速宜低于5m/s，以保证人们在室外的正常活动。此外通风不畅还会严重地阻碍风的流动，在某些区域形成无风区和涡旋区，不利于室外散热和污染物消散，因此应尽量避免。

本项目通过有效的体型设计，最大限度的改善室外的风环境。根据如下模拟结果显示: 各季节主导风向下，建筑室外人行区在距离地面1.5米高度处的风速小于5.0m/s，室外风速放大系数小于2，建筑周围人行区

Figure 2.16. Public plaza below the mall will attract and entertain visitors from near and far (Source: Gensler)
图2.16. 购物中心下方的公共广场将吸引远近的游客前来休闲娱乐 (来源: Gensler)

area around the building. Also, the outdoor wind velocity amplification coefficient is less than 2 and the wind environment is within the range of comfort requirements. According to the simulation analysis of the outdoor wind environment, the project meets both the new and old editions of the GB/T50378 green building evaluation standard, as well standards for high-rise green buildings.

风环境在舒适度要求的范围之内; 根据室外风环境的模拟分析，本项目满足GB/T50378《绿色建筑评价标准》新旧版和《绿色超高层建筑评价技术细则》的要求。

Conclusion

In recent years, scholarship and technology around green buildings have developed rapidly. High-rise green buildings have their own distinctive features. Through the study on this project, the following green building elements are identified as crucial for megatall buildings:

- Water resource saving
- HVAC cooling sources

Combined with other green building design concepts, this project aims to achieve LEED CS 2009 Gold certification and CHINA Green Label Three Stars.

结语

关于绿色建筑的话题和技术近些年发展迅速，超高层建筑有着其自身鲜明的特点。通过本项目的研究，以下绿色建筑元素对于超高层建筑更有意义。

- 节约水资源
- 空调冷源

配合其他绿色建筑的设计理念，本项目的绿色建筑目标为国际上通用LEED CS 2009黄金级和中国绿色建筑标准三星级。

References (参考书目):

GB50378 **Green Building Evaluation Standard**

Super High-rise Green Building Evaluation Details

LEED Core & Shell 2009