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Building Services and Achieving Sustainable Vertical Urbanization
建筑机电系统与实现可持续竖向城市化发展

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Abstract

This paper examines how the essential MEP/FP systems are adapted into sustainable solutions in vertical urbanization and how this is achieved whilst meeting the challenges of modern day architecture and structural engineering as well as the occupants that have aspirations to improved levels of comfort and safety. The application of current technology including the use of BIM and its benefits in the construction process in terms of both financial performance and energy consumption is considered. It considers related and associate components of the building, brought together with the MEP systems in terms of interaction and interface to create integrated solutions. Case studies are presented giving examples of the coordinated sustainable approach as well as compliance with current code. In conclusion this paper lists a number of key directions that can be adopted in selection of sustainable environments and how they may enhance a buildings life span and operational efficiency.

Keywords: Sustainable solutions; integrated answers; case studies, performance, energy consumption

摘要

这篇论文阐述了机电设备系统是如何在面临现代建筑、结构工程以及居住者对更高的建筑环境舒适度与安全性等要求挑战下，适应于可持续的竖向城市化发展。本论文考虑了当前运用的主要技术BIM，及其为施工过程的成本控制和建筑能耗控制提供的有利条件。本论文着眼于楼宇中的所有相关设备和部件，结合与机电系统的相互作用与界面影响，以给出一体化的解决方案。案例分析中给出了在符合当前规范要求前提下，实现可持续建筑设计目标的项目案例。在总结部分，文章汇总了一系列重要方法指导，可应用于可持续发展环境中，并指出如何凭借这些方法延长建筑使用寿命，提高建筑系统的运行效率。

关键词: 可持续解决方案，一体化的解决方案，案例分析，建筑系统性能，建筑能耗

Introduction

The introduction of vertical urbanization with its increased density of population per square kilometer of ground surface area has a significant impact upon the primary engineering networks and building services that are required to support such developments. Whilst urban planners promote vertical living releases areas at ground level for green area and recreation use, within the area of the high-rise development there remains a significant concentration of services that have to be accommodated. The network of transportation that brings the people in close contact with the development in many cases to a point where there is little exposure to the external environment is generating larger areas of space that require to be treated with services provisions to maintain acceptable internal conditions. This may be seen to create a heavy burden on the services designer however it should be considered as an incentive to introduce energy efficient solutions that are sustainable and adaptable.

引言

随着纵向城市化发展及由此带来的单位平方公里土地人口密度增加，极大地影响了基础工程网络和支持这一发展趋势的楼宇设施。随着城市规划师们极力推进垂直人居生活环境，以提供更多地面环境作为绿化和休闲空间，在高层建筑开发区域内，需容纳大量高度集中的服务设施。随着高层建筑的发展，人居服务产业不得不做出相应的调整，以适应这一变化。交通网络规划让人们更趋于近距离接触开发的项目，人们往往汇集到一个点，使得人们很少接触外界环境，因而更多室内区域需要借助服务设施来提供良好的室内生活条件。这似乎为建筑机电设计师造成了大量的工作，但也应借此机会鼓励实现可持续能源效率解决方案。

运用可持续设计，结合智能先进的施工技术，以减少能源消耗和运行费用，已成为国际和国内开发项目的首要事务。这篇文章提供了当前运用这类实践的项目案例，以阐明这样的解决方案如何应用于越来越多的垂直城市。原来被认为不适用于中国

The application of sustainable design with smarter and enhanced construction for both international and local developments with reduced energy and operational costs is a national priority and this paper provides examples of current projects where such practice is being adopted and how these solutions can be adopted into the increasing vertical cities being developed. Design solutions that were considered not feasible in China are now being adopted and whilst there remains large sectors of the built environment that follows traditional solutions the more ambitious clients that recognise the benefits of investing in the building stock to improve performance is growing. From the construction perspective, contractors with a desire to improve and follow the new trends are actively developing their business around such models and growing their teams to react to the new quality, efficient design and construction and will learn quickly from the consultants who are developing highly efficient strategies and quality buildings.

End User Requirements

Urbanization and the provision of facilities that can accommodate and sustain a healthy environment for those people who live and work in these developments must be the prime consideration during the design process if such developments are to be sustainable We must consider longer life cycles for such developments that have significant investment cost.

In many cases the design solutions are driven around a known set of parameters that are documented in such advisory or mandatory standards as ASHRAE or CIBSE or GB / local China Code. This information is essential to be read digested and understood however whilst embodying this in our designs there is a need to question such solutions in the real application of the specific project for which we are designing. As an example the perception of how we work and how we behave in the office environment are often different in reality to what we perceive (see Figure 1) is an example of working pattern as understood by the individual and as measured in reality. This difference affects the way we create the comfortable environment for the occupants. There is a considered opinion that requires face to face communication and therefore the building design has to embrace such a culture that allows that to be encouraged. The building services engineer has to adopt such activities when considering the working environment in terms of temperature, humidity, ventilation and air movement.

In today's modern office designed for the new generation the provision of sport and food related activities have to be integrated with the normal working environment. The provision of physical activities rooms, showers, kitchens and breakout areas with different requirements have to be accommodated. Working hours are seen to be extended and operating times have moved to more flexible working. The ability to time schedule, plus using real time activity sensors and a system of engineering that acknowledges such activities is essential.

Considering the architectural vision and wish for developers to have individuality in their property the variety of building envelopes requires careful consideration (see Figure 2) and with a variety of envelope solutions the interior space systems have to be smart in adopting solutions that can respond to the envelope and external conditions. Glare, thermal performance, radiant effect, impact on the air conditioning. vary in terms of exposure and as such the envelope design has to adopt appropriate protection. Annual energy costs need

的设计方案现在已经得以改进实现，尽管仍有很大一部分设计者运用传统设计方式，越来越多的客户开始意识到投资提高建筑环境性能的益处。从施工角度看，承包商愿意跟从这一新发展趋势的，会主动围绕这个方案模式发展他们的业务，培养他们的团队响应高质量、高能效的设计和施工，并且更快地从那些设计绿色节能建筑的顾问公司学习。

终端用户要求:

城市化和能提供能并维持一个健康的人居生活工作环境的系统设施是设计的首要考虑因素，对于耗费大量资金的项目，我们需为其实现更长的建筑生命周期。

在许多设计案例中，设计方案都根据设计标准和规范制定，这些标准和规范包括ASHRAE, CIBSE, GB (中国国标) 。消化和理解这些标准和规范十分重要，然而当我们把这些标准和规范结合在我们的设计中时，有必要质疑，这样的设计要求是否在我们设计的特定项目中切实可行。比如，我们在办公室的实际工作和行为总是与我们在设计中的假设是不一样的。以图01工作模式 (来源: AECOM 职场管理) 为例，个人理解的工作模式和实际测得的工作模式是不同的。这种不同往往会影响我们如何为住户设计舒适的室内环境。 有一种观点建议让设计师和住户面对面的交流，设计因而接受这种文化并奉行。楼宇机电工程师在设计考虑工作环境的温度、湿度、通风和空气流动时，需要进行这样的实践。

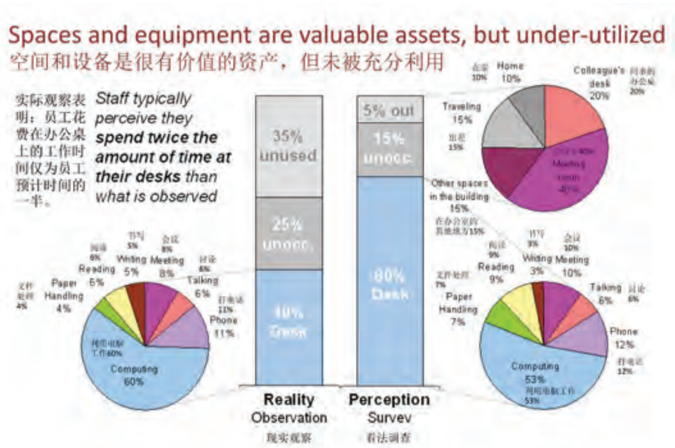

Figure 1. Working Patterns (Source: AECOM Workplace Management)
图1.工作模式 (来源: AECOM 工作场所管理)

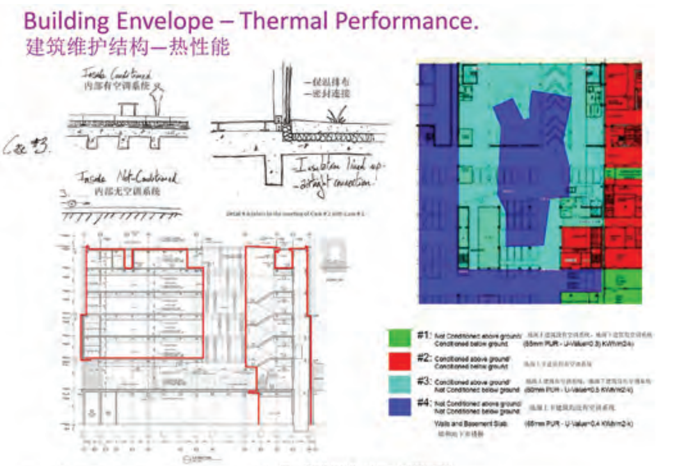

Figure 2. Building Envelope (Source: Campus Project Shanghai)
图2. 建筑围护结构 (来源: 上海某园区项目)

to be considered (see Figure 3). Considering vertical urbanization the provision of suitable vertical transportation is essential to meet end user need in terms of delivering the service capacity and speed and as part of the construction and cost considerations utilizing the efficiencies of spatial requirements. Advanced technology that can examine these against a known set of design parameters is essential and providing appropriate advice is important (see Figure 4) is an example that shows the base design and two optimized solution with the appropriate saving in space, cost and energy consumption.

From a building owner / operator perspective the development has to achieve financial control within a planned budget as well as the aspirations of the visual impact and operation with installations that are effective, efficient, maintainable and sustainable.

Design Coordination

The ability to communicate within the Client / design team remains a key component to achieving success for these new designs with strong sustainable features. The desire to have the best and most individual designs that merge overseas designers requiring local knowledge and code interpretation to ensure the design is progressed through a route that will not only be distinctive and innovative but also approved through the China codes. This is particularly relevant in terms of life safety systems where the need to balance local code with international insurance requirements such as NFPA or FM and sustainability solutions which may be commonplace outside China but are viewed with caution within China. The procurement of certified products and client's wishes to retain the production of such materials in China must be considered.

The application of BIM technology as a design supporting tool is providing added value in tall building design creating economy of space and improved constructability (see Figure 5).

BIM as a catalyst for more harmonious working between the designers – the common platform of BIM requires that the design team shares and works together to achieve the end design. This provides a composite solution.

BIM as a design tool and provider of enhanced coordination: – the ability to use the model to visualize relationships of services and installation sequencing is now adopted to create improved coordination before construction begins.

BIM as a provider of improved understanding: – the ability to understand the design to allow detailed cost to be prepared and major equipment options to be identified. The requirement to retain choice in major material selection and the later transfer of the selected material into the model allows the design to be firmed into a constructible solution.

BIM as a provider of improved quality of construction – the transfer of the model into the construction stage and ongoing development enables faster and clearer understanding as installation drawings are prepared. The ability to address contractor queries and requests for information can be readily responded to with the model. 90% of the Requests for information relate to coordination can be responded within 3 days (see Figure 6).

BIM as a process for enhanced information to manage and operate the building with sustainable solutions and energy saving benefits: – the

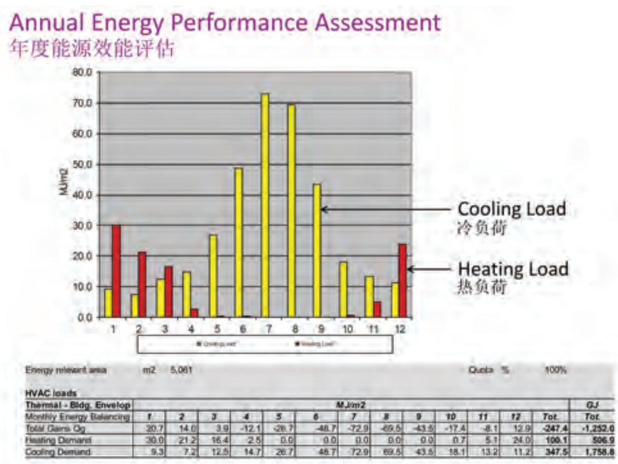

Figure 3. Life Cycle Energy Performance (Source: Campus Project Shanghai)
图3. 生命周期能源效能评估 (来源: 上海某园区项目)

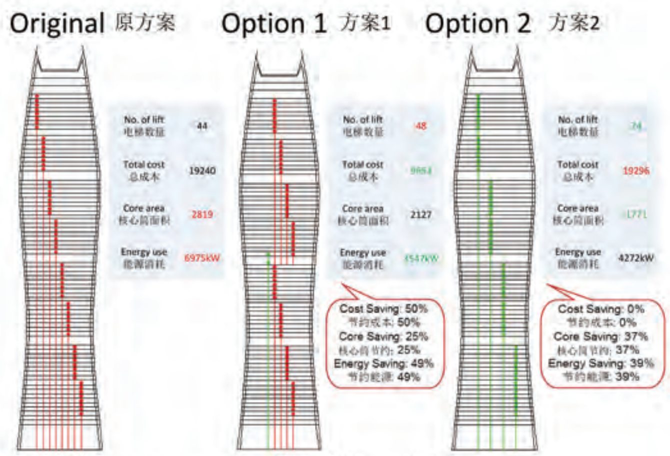

Figure 4. Vertical Transportation. (Source: AECOM VT Team)
图4. 垂直运输 (来源: AECOM 竖向交通团队)

Figure 5. BIM Model v Construction. (Source: AECOM BIM Team)
图5. BIM 模型 VS现场施工 (来源: AECOM BIM团队)

在当今为新生代设计的现代化办公楼中，运动设施和食物相关的活动须考虑成为工作环境的一部分。设计需考虑提供各类健身房、淋浴间、厨房和休息区。因工作时间延长，办公室营运时间向更具弹性的方向发展。营运时间的规划功能系统，加上实时人员活动感应装置的运用，以及满足这些活动的智能化系统，对办公楼宇是非常必要的。

考虑到建筑的视觉效果和开发商对其物业独特性的期望，变化多样的建筑围护系统需要在设计中给予精心考虑。参考图02 建筑围护结构 (来源: 上海园区项目)，相应于多样的外墙设计方案，内部空间系统设计中须采用相适应的方案，以响应外墙设计和外部环境条件。不同的外墙系统具有不同玻璃透光率、隔热性能、

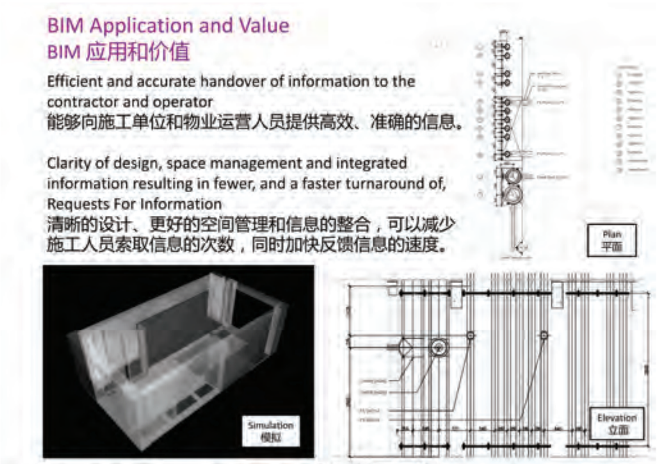

Figure 6. BIM Detailing. (Source: AECOM BIM Team)
图6. BIM 详细介绍 (来源: AECOM BIM团队)

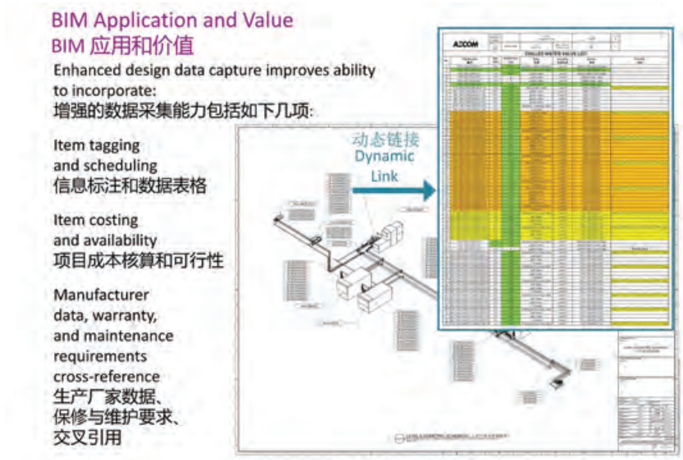

Figure 7. BIM Transfer to Maintenance Schedule. (Source: AECOM BIM Team)
图7. BIM 模型至维保计划 (来源: AECOM BIM团队)

output from the BIM model converts readily into itemized schedule's and visual images to allow improved tracking of the building maintenance. (see Figure 7).

All of these activities have an increasing role in the tall building design solution.

Project Experience

The following projects consider the above issues as we seek to improve the performance of the building stock, produce energy efficient solutions and reduce carbon footprint in tall building design.

Project Example 01 - Research and Development Campus

The development encompassed four office buildings and two laboratory buildings plus a cafeteria building. A combined basement accommodates a variety of facilities including an animal center, energy center, car park, plant rooms including a bomb shelter.

This is a multidisciplinary project that includes structural, MEP, landscape engineering, façade review, architectural lighting, interior design, and BIM to varying degrees. "Green" technical solutions were incorporated such as Variable Air Volume (VAV), chilled ceilings, chilled beams, displacement ventilation / below floor air conditioning, fresh air and exhaust air volume CO_2 control, rainwater treatment and recycling, solar water heating. BIM modeling was carried out to demonstrate the design's maintainability and accessibility, fully modeled in 5 No. Building's. Design deliverables were required to meet high international standards including bilingual (Chinese and English) documentation and be fully code compliant. These principles apply to all multi story developments.

The initial requirement for the design was to address the building envelope. If low energy consumption was to be achieved a high quality, high performing envelope was essential both in terms of U value thermal transmittance and air leakage. Shanghai has a very wide band of external environmental conditions with periods of very low humidity and equally very high humidity applying radiant cooling installations required control of fresh air and the operating temperature of the ceilings and chilled beams. Natural smoke ventilation and stair pressurization were desirable strategies and simplified the design from a safety perspective in some buildings. A column free environment with a full height triple glazed façade required the application of CFD modeling to ensure the application of internal blinds was fully

辐射效应，会对空调系统产生不同的影响，因此外墙结构设计也需要采取合适的保护措施。年运行能耗成本需在设计中予以考虑，参见图03 生命周期能源效能评估 (来源: 上海园区项目) 。考虑到纵向城市化发展，设计选用适合的竖向交通设施十分重要，以满足用户在垂直运输设备容量、运行速率、空间利用效率等方面的要求，并兼顾施工和投资费用等因素。须运用先进技术，基于特定的参数进行设计验证，从而提供合理的建议，这两点至关重要。以图04 垂直运输 (引自: AECOM 竖向交通团队) 为例， 对比了传统设计和2个优化设计，体现了空间、成本、能耗上的优势。

从业主和营运商的角度来看，楼宇的建设需将资金控制在预算范围内，同时需满足视觉效果，以及整个建筑楼宇系统稳定、高效、易维护、可持续的运行。

设计协调

业主与设计团队之间的交流沟通是决定可持续设计项目能否顺利完成的关键因素。在做这种特殊的，有海外设计师的项目时，需要结合中国当地知识和规范，以使我们的设计不仅仅具有独特性和创新性，同时也符合中国的规范。 特别是消防安全系统设计，我们不仅要满足当地规范的要求，也要满足国际保险规定，比如NFPA或者FM， 以及一些可持续的设计方案，这些措施在国外相当普遍，但在国内的应用被十分慎重对待。设计必需考虑这些经国际安全认证的材料设备在中国的采购问题，以及客户希望在中国国内对这些产品进行维保的需求。

BIM技术作为设计辅助工具的运用，为高层建筑设计提供了附加价值，它创造出更经济的空间利用率，并且提高了施工效率。 参见图05 BIM 模型VS现场施工 (来源: AECOM BIM团队)

BIM作为设计师之间的协调媒介: 它提供了一个方便的平台，要求设计团队分享和协作，以完成最终设计。它提供了多专业综合的设计解决方案。

BIM作为设计工具: 增强了设计协调工作，使设备的相互关系和施工顺序可视化，令施工开始前的设计协调工作得到有效增强。

BIM作为增强理解的工具: 对设计的深入理解，帮助完成详细的造价和主要设备选型。BIM保留主要材料的可选性需求，以及后期将材料选型信息输入模型，使设计更有效地融入施工方案。

BIM作为提高施工质量的工具: 模型转换进入施工阶段，以及后续进一步深化完善，在深化施工图设计阶段使得深化设计人员能更

integrated with the perimeter air return system, glare and daylight calculations and the application of lighting control to create an environmentally acceptable working space adjacent the perimeter wall. To comply with environmental discharge requirements and dispersion of contaminated kitchen air exhaust plus fume cupboard exhaust site wide CFD site modeling was adopted to reduce any opportunity for re-entrainment of this contaminated air. Some buildings focused heavily on building orientation and solutions that used heavy weight structure to mitigate thermal transfer whilst others adopted a transparent solution for visual effect, external shading with perimeter balconies was adopted on one building and a move away from a typical curtain wall solution to a window wall application on another, however the environment systems had to retain on a building by building basis the high performance requirements. Such variety and yet demanding visual and performing characteristics to be achieved has stretched the technology commitment and innovation (see Table 1).

Building envelope U-value and shading coefficient **建筑围护结构的U值和遮阳系数**	**U-value w/m².k** U值w/m².k	**Shading Coefficient** 遮阳系数		
Eternal Wall (Including opaque curtain wall) **永久性墙体 (包括不透明幕墙)**	0.55			
Roof 屋顶	0.7			
Floor 地板	1.5			
Partition 隔断	1.5			
Window 窗口	1.8	0.4		
Conditioned Area M² **空调覆盖面积 (m²)**	Cooling Load kW 冷负荷 (千瓦)	Cooling Index Watts / m² 冷却指数 (瓦/平方米)	Heating Load kW 热负荷 (千瓦)	Heating Index Watts / m² 供暖指数 (瓦/平方米)
4,838	875.6	181	403.8	83

Table 1. U values and Energy Performance (Source: Campus Development Shanghai)
表格1. U值与能耗 (来源: 上海研发园区项目)

Project Example 02 – Demonstration Building Tianjin

This 10-story commercial building in Tianjin incorporates the multiple functions of office, retail, exhibition and restaurant, with the development objective of being a demonstrative green building in the Tianjin Economic- Technological Development Area (TEDA). Four green building credentials were targeted: China Green Building (3-star), USA LEED (Gold), European BREEAM (Very Good) and Japanese CASBEE (Grade S). Green techniques adopted in this project include:

- Passive design for all-year natural ventilation;
- Double glazed (low-e) ventilated façade on the southern elevation and double-pane low-e façade on the northern elevation to achieve optimal building envelope performance;
- High efficiency and low carbon emission MEP system and equipment utilizing under floor air distribution.
- Other conservation measures include ground source heat pumps and SCBH15 high performance transformers;
- Recycled grey water use for irrigation, car washing and toilet flushing.
- Water conservation sanitary ware
- Vertical and horizontal daylight tubes to basement / exhibition floors to reduce artificial lighting.
- High efficiency lighting adopted for typical floors with auto-occupancy and light level sensors.
- Renewable energy sources including PV panels on the roof

快更清楚地理解设计图纸。运用BIM能够跟踪承包商提出的技术疑问，承包商要求补充的信息可以通过模型直接给出答复。90%关于协调的解决方案可以在3天内给出。参见图06 BIM 详细介绍 (来源: AECOM BIM团队)

BIM作为一种信息的强化处理工具，可以借助以管理楼宇系统，并使楼宇系统在可持续及节能模式下运行: BIM模型的输出可以很方便地转化成带编号的设备列表和可视化图像，协助改善楼宇设备的运行维护工作。参见图07: BIM模型至维保计划 (来源: AECOM BIM团队)

所有以上提到的技术在高层建筑设计中正在发挥越来越大的作用。

项目经验

以下项目在设计中考虑运用了以上各点，改善提升了建筑的性能，提供高效节能的系统方案，减少高层建筑的碳足迹。

项目案例01 - 某研发园区

该项目包含了4幢办公楼和2幢实验室楼，以及一幢餐厅。一个大型地下室连接各地上建筑，地下室包含不同功能区域: 动物研究中心，能源中心，停车库，以及设备用房和人防区域。

这个项目涉及结构、机电、景观、幕墙设计审核、建筑灯光设计、室内设计和BIM等多个专业。 运用了各类"绿色"技术方案: 包括VAV (Variable Air Volume, 可变空气流量) 空调系统，冷吊顶，冷梁，置换通风/地板送风空调系统，新/排风CO2浓度控制，雨水回收和处理，太阳能热水系统等。其中BIM模型用以验证设计的可实施性和可维护性，总计建立了5幢建筑的完整BIM模型。 设计成果交付要求满足高水平的国际标准，包含中英双语设计文件交付，并且需完全满足规范要求。这些原则用于项目内所有多层建筑设计。

设计的首要任务是解决建筑外墙系统。 要实现绿色节能目标，高质量、高性能的建筑外墙系统是关键因素，它包含外墙系统的传热系数和建筑的气密性水平。上海地区的气候条件在不同的季节相差很大，一年中有湿度很低的时间段，同样也有湿度很高的时间段，令冷吊顶和冷梁等辐射供冷系统安装时，需要控制新风量和辐射供冷系统运行温度。考虑火灾安全问题，我们设计了自然排烟和楼梯间加压送风等简单易行的策略。CFD模型对拥有三层玻璃幕墙、无柱的内部空间进行模拟，以确保室内百叶与外围回风系统完全结合，透光、自然光模拟计算集合智能照明控制系统，在外周边临近幕墙区域创造出一个良好的工作环境。为满足排风和厨房油烟的环保排放要求，项目进行了场地CFD模拟，以有效阻止二次夹带污染。一部分建筑着重运用建筑朝向和重型结构方案降低外墙结构传热，另一部分建筑则采用透明幕墙以满足视觉效果; 其中一幢设计了外遮阳系统结合周边退台设计，另一幢建筑从标准幕墙改为釉质玻璃墙。然而，需根据每栋建筑各自对高性能的要求设计合适的环境系统。 这些多样的建筑外观和高水准的建筑性能要求，提升了对技术投入和创新的要求。参见表格01: U值与能耗 (来源: 上海研发园区项目)

项目案例02: 低碳示范建筑- 天津

这栋位于天津的10层高商业建筑功能复杂，包括办公、零售商业、展厅和餐厅，该建筑在设计初期就设定为天津经济技术开发区 (TEDA) 的绿色示范性建筑。本项目要求获得四项绿色建筑证书: 中国绿色建筑三星，美国LEED金奖，英国BREEAM (Very Good 优秀奖) 和日本CASBEE (S级) 。因此诸多绿色科技被设计引进这个项目:

and southern vertical wall, energy regeneration lifts, and solar hot water system;

- Recyclable steelwork for structural perimeter columns, recycled aggregate concrete (RAC) for basement floors;
- Other recyclable non-structural and architectural materials were widely used from local sources.

The design achieved 50-60 KWh/m^2/y energy saving and 45-55 Kg/m^2/y carbon reduction in comparison with the benchmark specified in the national Public Building Energy Saving standard, i.e. 30-35% energy and carbon reduction, respectively. The design of this project has successfully achieved the targeted grades of green building credentials (see Figure 8 and Table2).

Project Example 03 – A High-Rise Development In Shanghai

Located at levels 60 and 61 of the Shanghai World Financial Centre these two levels of fitting out required the engineering designs to cater in addition to the pure office function services for a full restaurant kitchen, dining and lounge facilities, gymnasium with full shower and locker room capability, server rooms, meeting / training rooms, games area all compressed into 5,000 square meters. The project achieved a LEED CI - Gold certificate.

The sustainable solutions working within the existing building construction were focused on indoor air quality and achieved by increased fresh air rates 30% higher than ASHRAE90.1-2007, enhanced filtration to standard MERV13 (American Standards) or F7 (European Standards) the recirculated and fresh air, indoor CO2 monitoring of the main meeting rooms and individual office, material selection with reduced VOC emissions. Energy saving was implemented by the use of LED lighting and enhanced control systems that introduced 29.22% energy saving compared to ASHRAE90.1-2007 whilst the use of the "Energy Star" rated equipment, a requirement of LEED shows beneficial reduced energy consumption based upon the clients monitoring since occupation.

Working within the constraints of the existing base build MEP systems modifications were completed and approved by the Client and the base build owner and created a new benchmark for future office developments that the Client intends to carry out. The project embodies sustainable design solutions in terms of adaptability for the future, variable environmental conditions to suit the end user activities, life safety system to FM standard as well as local code.

This project is an example of the importance of fully understanding the client's operational needs and designing accordingly, providing a user friendly, adaptive and flexible working environment, essential to drive the effective and efficient performance of the users.

Project Example 04 – A High-Rise Development in Shanghai

This 24 Story Grade A office development included a number of floors dedicated for Trading use and in the podium, retail and restaurant facilities with 3 levels of basement. The building achieved LEED NC Gold and Hong Kong BEAM certification. At completion the LEED commissioning for Energy related systems including HVAC, Lighting, and Daylight control, domestic hot water and renewable energy systems. HKBEAM was completed.

From the initial concept design the project considered the feasibility of incorporating sustainable solutions and in doing so the vertical

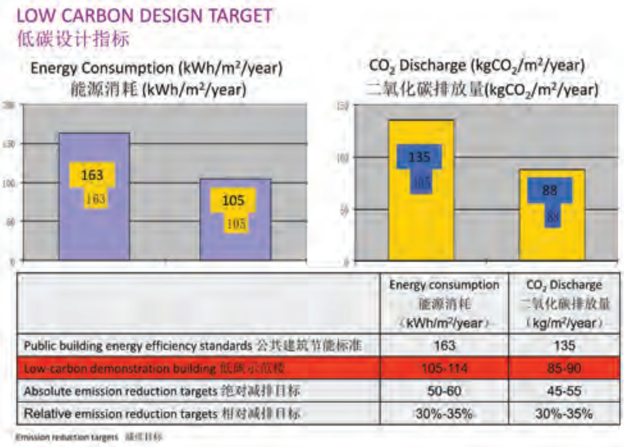

Figure 8. TEDA Low Carbon. (Source: AECOM MEP Team)
图8 天津经济技术开发区 (TEDA) 低碳项目 (来源: AECOM 机电团队)

Performance Savings 节能性能	% Energy Saving 节能 %	% Carbon Saving 节碳 %	CO2 Discharge Reduction CO2 排放量削减
Fresh Air Volume Control by Request 可按需求改变新鲜空气供应量	9.57	7.4	94
Original Design 原创设计	8.57	5.2	65.9
Ground Source Heat Pump 地源热泵	8.48	5.1	64.4
Dehumidify by Li-Br + heat Recovery 锂-溴除湿 + 热能重复利用	4.13	3.6	45.8
PV Panels 光伏电池板	2.33	2.9	37
Horizontal Daylight Tubes 卧式日光通道	2.31	2.8	35.1
Lift Energy Re-generation 电梯电能再生	1.16	1.4	17.6
Solar Hot Water 太阳能热水	0.62	0.7	9.4
Underfloor Air Conditioning 地板空调	0.61	0.7	9.2
IPM Motor IPM马达	0.29	0.3	4.3
Vertical Daylight Tube 垂直日光隧道	0.19	0.2	2.8
Green Roof 屋顶绿化	0.15	0.2	2.5
Wind Power 风力	0.01	0.15	1.9
Double Façade 双层幕墙	0.05	0	0.2
Building Type 建筑类型	Energy Consumption in KwHrs / square metre / year 能源消耗 (千瓦时/平方米/年)	CO2 Discharge in Kg CO2 per sq metre CO2排放 (千克CO2/平方米)	
1980 Reference Building 1980年代大厦作参考	321	211	
Building Based on GB Energy Saving Code 2005 GB建筑节能标准2005	160	106	
LEED based Building LEED标准建筑	145	101	
Demonstration Building 示范建筑	99	73	

Table 2. TEDA Energy and CO2 Comparison (Source: AECOM MEP Team)
表格2天津经济技术开发区 (TEDA) 能耗和二氧化碳排放比较 (来源: AECOM机电团队)

story height was set. The building utilized a composite structure with concrete core and structural steel frame. The structural steel frame allowed larger penetrations for the appropriate distribution of services and the improved ability to use the ceiling void as a return air plenum as well as access for services into and out of the core. The layout grid was adopted to cater for the open plan office with single occupancy or multiple occupancy solution with internal escape corridor around the core. The building envelope was considered for enhanced performance and associated equipment selection and performance control (see Table 3 and 4).

BIM modelling including architecture, structure and MEP was adopted for partial areas including all basement and lower podium floors, major plant rooms and typical floors. At completion as fitted drawings will be recreated into the BIM model for use by the owner for building management.

This building considered both user requirements and adaptability, adopted a process of design coordination across the design team through the adoption of BIM, applied standards that were measurable in terms of energy saving which should allow for extended building life and good working conditions all of which will contribute to the commercial success of the project.

Conclusion

There is undoubtedly a requirement by local and international developers to address the question of sustainable design and we see this in many areas of our business and more frequently. Equally there is an increasing requirement for designers to have a wider understanding of how such measures may be implemented into designs with surety of performance and cost efficiency. A disciplined process of examination is required at the early stages of the design with a better and more closely controlled concept design report. Key parameters that meet the cost objectives must be set down and as we introduce the sustainable design and the Building Services Engineers must play a greater role in supporting this part of the process. The decision to implement BIM shall be established be it fully or partially implemented.

New technology to assist in the design process is essential we will see an increasing use of CFD modelling, building performance models and life cycle costing. Considering the technical innovation that may be adopted in engineering design solutions with embedded sustainability the following factors must be considered in sustainable vertical urbanization:

- A greater focus on end user requirements and methods of operation.
- Consider what the design requirements are today and the wider implications of adaptability in the future.
- A greater need to consider construction techniques to allow spatial accommodation for engineering systems equally whilst BIM does refine the design to create efficient use of space it equally reduces the building tolerance that can be accepted in construction.

Note: The views expressed in this manuscript are those of the author and do not necessarily represent the views of AECOM.

- 全年自然通风
- 南立面为双层玻璃Low-E通风幕墙，北立面为双层Low-E幕墙，以优化外墙系统性能
- 高效、低碳节能的机电系统设备采用地板送风系统
- 其它节能措施包括地源热泵和SCBH15 高效变压器
- 中水回收处理用以灌溉，洗车和厕所冲洗
- 节水型卫生器具
- 垂直和水平自然光通道用于地下室和展厅层，以减少人工照明量
- 结合红外线人员感应装置和照度传感器的高效智能照明系统
- 可再生能源，包括南立面和屋顶的太阳能光伏发电 (PV板) 系统，可再生能源电梯，太阳能热水系统
- 再生结构材料包含: 周边结构钢柱和地下室再生石粒混凝土 (RAC)
- 来源于当地的其它再生非结构性材料和建筑材料，广泛应用于本项目

本项目设计与国家公共建筑节能设计要求的标准比，成功达到节省能源50-60千瓦/平米/年 和 减少碳排放45-55千克/平米/年的， 年能耗和碳排放量各减少30-35%。 这幢建筑的设计成功获得了上述四个绿色建筑认证证书。参见图08 TEDA 低碳项目 (来源: AECOM 机电团队) ; 表格02- TEDA 能耗和二氧化碳排放比较 (来源: AECOM机电团队)

项目案例03- 一上海某高层建筑

本项目为上海环球金融中心60-61楼的室内装修项目，除办公功能外，还拥有餐厅和厨房、休息区设施、带淋浴室和更衣间的健身房、服务器机房、会议室和培训室、游戏区，总面积5000平方米。本项目成功荣获LEED CI金奖。

这个在已建成的超高层建筑内进行的可持续设计方案， 着重于提高室内空气品质，包含提高新风量，令新风量比ASHRAE90.1-2007更高出30%; 回风和新风的过滤等级达到MERV13(美国ASHRAE标准)和F7 (欧洲标准) ; 会议室和独立办公室采用CO2的实时监测; 材料选取上减少VOC排放量; 通过 LED照明和智能照明控制系统的运用，比ASHRAE90.1-2007标准更节能 29.22%; 并根据LEED要求采用"节能之星"等级的灯具，自客户入驻后的监测显示了节能方面的收益。

虽然受到大厦原有机电系统的限制，装修改造工程依然顺利完成并收到客户和大厦业主的肯定，同时为客户今后开展同类型办公室装修改造工程建立了一套新的建造标准。这个项目结合对未来的适应性、满足不同区域人员活动要求的环境条件，将FM要求的防火安全要求和当地规范合理地融入了可持续设计方案。

这个项目是一个很好的范例，体现了对业主营运需求的深入、准确的了解，并在设计上对这些要求进行响应，提供了一个友好的、具有可适应性、灵活性的工作环境，对于用户实现高效能运营具有十分重要的作用。

项目案例04 –上海某高层建筑

本项目是一幢24层的甲级办公楼，包括一部分楼层作为交易楼层，裙房为零售和餐饮，另有3层地下室。这幢建筑成功取得LEED NC 金奖和香港HK BEAM认证。在完工时，确保获得LEED认证的内容包含暖通空调系统，照明和日光控制系统，生活热水系统和可再生能源系统。香港HK BEAM认证工作已经完成。

在最初的概念设计阶段，项目就考虑了诸多可持续绿色设计的可

The highlighted energy saving measures are summarized below 主要节能措施详见下表	
Category **类别**	Energy Saving Measures 节能措施
Envelope Design **围护结构设计**	External wall with low K-value 低K值传热系统外墙 Low E glazing with low shading coefficient Low-E低遮阳系数玻璃
Lighting Design **灯光设计**	Use of high efficient T5 Fluor scent lamp in office area 办公区域采用高能效的T5 日光灯 Day light Control in the parameter zone for all office floors 所有办公楼层外围采用日光感应控制
Air Side Equipment **空气设备**	Demand control ventilation 通风量按需控制 70% Energy Recovery wheel 转轮能源回收效率为70% Air handling unit installed with high efficiency fan 高效节能风机
Water Side Equipment **水处理设备**	High COP chiller 高能效制冷机 High efficiency water pump 高能效水泵

Table 3. 688 Energy saving techniques (Source: AECOM Energy Comparison Report)
表格3 688 节能技术 (来源: AECOM 能耗比较报告)

Category **类别**	Design Case Consumption (kWh) 现有建筑能耗 (kWh)	Baseline 1 (Boiler System) Consumption (kWh) 基准模型 1能耗 (锅炉系统) (kWh)	Baseline2 (Heat Pump System) Consumption (kWh) 基准模型2 能耗 (风冷热泵系统) (kWh)
Lights **灯光**	1,407,423	2,049,337	2,049,337
Equipment **设备**	2,088,138	2,088,138	2,088,138
Lift **电梯**	1,492,171	1,492,171	1,492,171
Heating **采暖**	433,754	170,560 kWh (Electricity Consumption) (耗电量) 10,604therm* (Natural GasConsumption) (天然气量)	265,813
Cooling **制冷**	1,012,125	1,402,791	1,402,650
Heat Reject **热损耗**	23,391	30,854	30,852
Pumps **水泵**	636,459	991,740	990,318
HVAC Fans风机	924,480	827,881	828,016
HVAC Independent Fan **空调独立风机**	1,182,844	1,477,765	1,477,765
Exterior Lighting **室外灯光**	255,132	255,132	255,132
Total **总计**	9,455,917	11,097,067	10,880,192

*1 therm is equivalent to 29.3kWh 1 therm=29.3kWh
*一个热当量相当于29.3千瓦小时，1therm = 29.3kWh
Energy Reduction of Design Case compared with Baseline 1 =14.79%
设计的建筑比基准模型1节能14.79%

Energy Reduction of Design Case compared with Baseline 2 =13.09%
设计的建筑比基准模型2节能=13.09%

Table 4. 688 Energy consumption comparisons (Source: AECOM Energy Comparison Report)
表格4: 688能耗比较 (来源: AECOM 能耗比较报告)

实施性，并据此确定了楼层层高。这幢建筑结构采用了混凝土核心筒和钢结构框架混合系统。钢结构框架上允许较大尺寸机电管线开洞，提高了吊顶上方空间作为回风静压箱的利用效率，并方便机电管线进出核心筒。平面布置为开放式办公平面，能满足单个租户和多个租户等多种类型租户要求，中间的逃生走廊围绕核心筒布置。建筑的外墙设计考虑了性能的提高和相应的设备选型及性能控制。表格03:688 节能技术 (来源: AECOM 能耗比较报告)；表格04: 688能耗比较 (来源: AECOM 能耗比较报告)

建筑、结构和机电专业利用BIM建立了部分区域的模型，包括地下室和裙楼低层，主要设备房和标准层。在完工阶段，装修竣工图将被导入模型，为业主的运营管理提供帮助。

这个建筑设计同时考虑了用户的要求和可适应性，运用BIM在设计过程中采用跨专业的协调，运用可测量的节能设计延长建筑的生命周期和提供优良的工作环境，从而提高了项目的商业价值。

总结:

毫无疑问，许多国内和国际的开发商要求融可持续设计在于其开发项目中，我们在项目的不同领域中看见这些要求，并且今后这些项目也会越来越多。同时，设计师们也开始思考怎样让这些可持续方案融入到设计中，并且保证建筑环境的舒适性，以及成本的控制。在项目的最初阶段，应采用更规范的研究程序，从而提供更好、更严谨的概念设计方案。满足成本控制要求的主要指标必须锁定，当我们开展可持续设计时，机电工程师应发挥较大的作用以支持可持续设计的过程。首先应确立应用BIM技术的决定，无论全部还是部分使用BIM技术。

新的技术用以辅助设计过程是十分必要的，我们会看到更多的CFD模拟应用，建筑能耗模型和建筑生命周期内的成本控制。考虑到工程设计在可持续设计中可能采用的技术创新措施，在竖向可持续都市化中应考虑以下因素:

- 更多地关注住户的需求和运行方式
- 考虑现时的设计要求和未来的可适应性
- BIM技术确实可优化设计，创造更有效的空间使用，但它同时也降低了施工可接受的楼宇设计余地; 在设计中应更好地考虑施工技术，以便为工程系统预留足够的空间。

注意: 文章中提到的观点仅代表作者个人，并不代表AECOM