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Towards 2050 – The Challenge for Tall Buildings
展望2050——超高层建筑的挑战


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Abstract

The continuing increase in urbanization creates significant challenges for our cities and the tall buildings within them. This includes the demand for space, consideration of the environmental constraints and societal expectations. The paper considers present trends and looks at how this is impacting the thinking of high-rise design. It projects forward to 2050 and looks at a futurists view and the need for tall buildings to become more than shells to create spaces, but the need for them to function as an integral part of the urban ecosystem. The paper concludes with an overview of a concept design for a 150 story in which many of the principals and drivers for design have been incorporated.

Keywords: 2050, Future, High-Rise, Modular, Environment, Timber

摘要

持续增长的城市居民对我们的城市和城市中的建筑带来了巨大的挑战。这包括对空间需求，对环境问题和人口扩张问题的担忧。本篇论文探讨了城市人口的增加对高层建筑设计的理念产生影响及目前的趋势和表现。本文同时对未来的建筑形式进行了探讨和推测，未来的高层建筑将不单单是创造居住空间的外壳，同时将会成为城市生态系统不可或缺的一部分。文章中对一栋150层建筑的整体设计概念进行了介绍，在这座建筑中我们应用和吸收了很多可行的新设计理念。

关键词: 2050，未来，高层建筑，模块化，环境，木材

Introduction

It is an incredible fact that by 2050 the human population will have reached 9 billion people, 75% of whom will be living in cities (Hargrave 2013). When faced with these statistics, the well-known migration into the cities of China comes to mind. However, whilst there is obviously a significant differentiator in terms of scale, the demands for city growth are, to different degrees, global.

This migration has resulted from a number of factors spanning the fabric of social needs and economical drivers. It is evident that this increase in migration is occurring in an 'ecological age' – basically a time where society is mindful of the resource constraints of our planet, and the need to address (change) the ways of the past. By 2050, there will be a majority of people that will have experienced their whole life in the digital, and the environmentally conscious, age. It is fair to say that the expectations of the populous at that time will be extensive. It is therefore incumbent on the designers, developers and contractors of this age to be mindful of these expectations and the challenges it presents.

This paper is to be read in conjunction with the presentation material, which will give a graphical insight to the challenges and the 'stepping stones' that are being taken to address. It also, in a semi-provocative way,

概述

令人震惊的是，到2050年世界人口将达到90亿，75%的人类将会生活在城市 (引自Hargrave 2013) 。基于以上的人口增长数据，首先想到的就是众所周知的中国城市化移民。从很多角度来看，城市增长需求是全球化的，但是就不同尺度而言又存在很明显的差异。

这样的移民是基于各种因素的影响，涉及社会组织需要和经济形式的驱使。已经被证实，这种增长的移民趋势正发生在"生态时期"，这个时期人们开始关注地球的能源紧缺问题，人们需要反省过去的生活方式。到2050年，地球上大多数人都会经历数字化和拥有环境意识的年代。很公平的说，到那时，地球上人口的密度会相当的高。因此，为满足极具膨胀的人口需要，对那时的设计者、开发商和承包商来说，将面对的是一种相对于当今来说更大的挑战和责任。

这篇文章应与相关的演示材料一起阅读，在相关的演示材料中，将用图表展示挑战并为后人解决相关问题提供的"垫脚石"。同时，也为人们描绘了未来世界的景象，为未来的研究和发展趋势提供方向和范围。

现如今的趋势指标

如下提出个一些参考指标，或者可以叫他们"垫脚石"，让我们了解一下当我们进入

present the picture of what the future may hold and the extent to which this will be a way finder for future research and development trends.

2050年的生态时期，一切是如何变化发展的。

Current Trend Indicators

Below are defined some indicators, or as they could be referred, 'stepping stones,' into how things are likely to develop in the ecological age as we move to 2050.

Certain cities have the luxury of being able to develop organically and in a controlled way. Many do not. The CBD areas in these cities are in high demand and space is confined. Whilst the concept of modifying existing buildings to accommodate increased accommodation is not new, it is evident that in certain parts of the world, the demand for prime inner city space is pushing to unprecedented levels the demand (and viability) for modification.

In Sydney, not one of the usually recognized global city migration centres, there is presently underway a project to extend an existing 25 story building to a 68 story building. This is compelling proposition. Why should a building of stature, that has served its owners well for 30 years, be demolished and rebuilt to become a 'greater icon'? In this instance, there was an advantage in retaining the 'old' and allowing the new to literally 'embrace'. The solution was to develop a form of tower that matched well with the existing from a planning perspective, a structural form that integrates and strengthens the existing and which achieves the new heights (Figure 1). In the spirit of stepping stones to 2050, these can be seen as significant because:

- There is an evident benefit in recycling on a macro-scale materials, via a whole building re-use. Demolition in crowded CBD's does present challenges which can be avoided.
- It is a very evident example of retention of materials to be seen by all, including passers-by.
- It elevates challenges to the construction industry, and will demand a different skill set and approach.
- It exemplifies the need for an 'adaptability culture' in the buildings that we develop.

Taking the last point, the project in question presents significant challenges in terms of building intervention, construction methodologies, planning and structural design. If the original designers of the building had known that such a dramatic extension of the building would take place within the design life of the building, the building potentially could have been designed differently. This does not necessarily need to be at extra cost, but merely a consideration of how the building might be more easily adapted. For example:

- Knock out provisions around cores that enable them to be 'expanded'
- Consideration as to where the additional structure could be provided around the perimeter and making sure there is a strategy for access to place additional foundations.
- What could the extended form look like, when considering the design of the original smaller form.

It is more about envisioning. It reinforces the need for a design mentality that is geared around adaptability, modular approach and one which recognizes the known horizon of technology and accommodates.

The materials we use in buildings, particularly high-rise construction, have changed little in the past 60 years. It is refreshing that there is

部分城市可以以有机理和可控制的方式来发展。但大多数的城市则不能。这些城市中心区域的需求很大，但又受空间的限制。同时，改进现有的建筑用以容纳更多的人群，这种概念已经被提出好多年。有证据显示，在全球的部分区域，对城市内部空间的需要已经达到前所未有的程度，亟需进一步对改进的可行性进行研究。

悉尼，一个全球推崇的移民城市，正在把现有的25层建筑增高到68层。这个提议非常引人注目。为什么我们非要拆除一栋承载30年回忆的老建筑，来重建一栋更高的建筑? 在这个案例中，采取保留老建筑，并让新建筑包围在老建筑之外的设想会带来极大的好处。这样的解决方案，不仅能满足在规划角度上建立一个与现有建筑相匹配的高楼，同时这种建筑形式既能支撑现有建筑、保持现有结构的完成性同时，又能支撑起新建的高层建筑 (如图1)。基于通向2050年的"垫脚石"的精神，这样的建筑形式可谓意义重大，因为:

- 除了重新利用整个老建筑相对于宏观角度上回收利用材料所带给我们的好处外，它很好的避免了在拥挤的CBD区域拆除建筑所带来的挑战。
- 这是一个很好的保留老建筑供大家观赏的案例。
- 它对建筑业提出了更高的挑战，并会需求开发出一种不同的方法来和技能。
- 它例证了我们在进行发展中应考虑到建筑物在"适应性文化"方面的需要。

就最后一点，这个工程将会面临建筑方的干预，施工方法，规划和结构设计等方面的巨大挑战。如若老建筑的设计者能够了解到在建筑的使用年限内将会发生如此戏剧性的扩展改建，那么这栋建筑很可能会以不同的方式进行设计。这样并不一定需要更多的花销，但是如果在设计中已经考虑了这种扩建，可能会使改建更容易，比如:

- 调整和淘汰临近核心筒周围的构件，这样就更能满足后期的改建需求。
- 预先考虑后加建筑的添加地点，并在策略上保证建筑周围有空间来进行施工后建建筑物的基础。

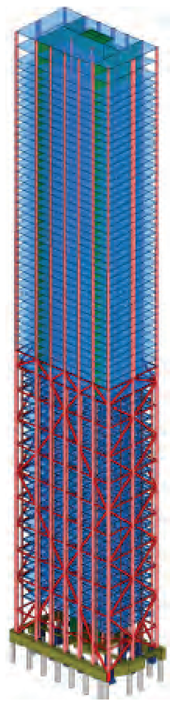

Figure 1. Extension of existing tower (25 to 68 storys) (Source Arup)
图 1. 现存塔楼延伸加建 (25到68层) (来源: 奥雅纳)

now considerable activity in the use of timber intensive methods of construction for high-rise. The Life Cycle Tower concept for an open plan 20 story timber hybrid structure (Figure 2 and 3) in one of several proposals worldwide that have raised the bar in terms of what can be achieved. The smaller scale projects that have been constructed to date, notably the 8 story prototype life cycle tower in Austria and the 10 story all timber Forte tower in Melbourne have demonstrated the potential of lightweight accurately machined timber elements to enable incredibly fast and high quality construction. In addition to the benefits of speed, and prefabrication, a key has been the potential to produce CO_2 neutral buildings from an embodied energy perspective. Timber is also a material that is light and therefore lends itself to use in seismic zones where large mass is detrimental to the performance of the buildings.

In the 'stepping stone' approach to achieving goals, it is believed that timber represents a significant step forward and one that will be fully capitalized upon in meeting the future demands of modularization and adaptability. It is agreed that there are some hurdles to be faced; these are centered around people's potentially negative perception of timber as a reliable material, and their perceptions regarding its vulnerability in fire. It is believed however, that in certain situations, and in geographies where timber use in smaller scale dwellings is more commonplace, the potential negative perceptions will be overcome – particularly by a generation of people that will embrace the long term benefits of timber as a sustainable material.

Cities currently hold 60% of the world's population, but are responsible for 80% of the emissions. It is widely recognized that buildings represent the vast majority of emissions and energy usage in cities. It is encouraging, however, to note that strides are being made to address this issue. These are considered stepping stones to achieving the goal and are imperative to getting where we need to be. The various statutory bodies in parts of the world are indeed implementing targets that push in the right direction. However the pace at which this 'push' from statutory bodies is being implemented is no doubt impeded by many competing factors – not least the financial considerations of development and the resistance to change.

What is clear is that whilst new technologies are being developed, to be truly successful, there is a fully holistic approach that needs to be adopted - one which will challenge our approach to design.

Figure 2. Life Cycle timber tower.
图 2. 可循环木材塔

- 当考虑原来小建筑的设计时，能预先考虑到后期扩建的形式。

它更多的是对未来的展望，是对提升契合适应性和模块化方法的设计思维的需要，它揭示了对众所周知的技术和包容的认知。

建筑材料，特别是用于高层建筑的材料，在近60年间几乎完全没有变化。令人耳目一新的是，木材深加工方法在高层施工领域有了重要的发展。利用全球计划之一的"可循环利用的建筑"概念所建造的20层开敞布置的木质混合结构 (图2及图3) 将我们现有的技术提高到一个新的高度。一些已建的较小规模实验性项目，如奥地利的8层可循环利用的建筑原型和墨尔本10层的全木质Forte塔向我们展示了一个可能性——轻质精细制造的木质构件能够使得施工变得难以想象的快捷和高质。除了速度及预制的优势外，一个重要的因素是，从能源的角度来看，实现了将建设不产生二氧化碳的建筑的可能性付诸实现。木材是一种轻质材料，这一特点使得木材可用于地震区，因为在地震区庞大的质量将使得建筑物在地震中的性能变差。

从"垫脚石"项目能达到目标来看，木材被认为是发展进程中的重要一步，并能够完全满足未来对建筑模块化及适应性的要求。但是仍然还是有些问题是需要解决的，这些问题主要集中在人们对于木质材料作为一种可靠材料有潜在的负面印象，以及木材的抗火性非常差。但是在特定情况和地域条件下，采用木材作为结构材料的小规模公寓非常常见，特别是了解到木材作为一种长期可持续性材料具有独特优势的下一代人，对木材潜在的负面看法将会慢慢地改变，

如今，世界上60%的人口生活在城市中，但是却排放出占全世界80%的废弃物。到达2050年之后，情况将会变得更加严重。非常明显，建筑物产生了城市中大部分的废弃物及能量消耗。这一点已经被广泛证实。但是，令人鼓舞的是我们正在不断进步。这些都是我们在为达到目标的垫脚石项目中必需要做的事情。世界上一些法定机构确实在力争实现这个目标，并正在向正确的方向前行。但是这些法定机构正在实行的这种努力毫无疑问地受到各种复杂的因素制约，尤其是发展所需的财力及对改变所产生的抵制。

显而易见的是新的技术正在被开发，若要真正实现，需要采用充分和全面的方法，这将会对我们的设计理念带来新的挑战。

2050年会是什么样子?

从以上章节我们介绍了一些"垫脚石"的项目中我们应该思考未来的目标，去除现在的束缚，来思考未来将会变成怎么样。下述大部分内容由奥雅纳开发和创造团队提出，这个团队专注于突破现有视野，利用现有准则挑战自我并开发出未来的发展趋势。图4以图解的形式展现出这些想法的部分精华，并有意以这样包罗万象的形式来标明这些问题的解决思路。

Figure 3. Office floor for Lifecycle Tower
图 3. 可循环塔的办公层

So What Could 2050 Look Like?

Whilst the above introduces some of the 'stepping stones', it is appropriate to consider the goal of the future and, removing many present constraints, think about what that future might look like. Much of below has been developed by Arup Foresight and Innovation, a group of individuals who specifically look over the horizon and challenge us on present norms that exist at the present and develop visions for the future. Figure 4 shows a diagrammatic distillation of this thinking. It is intentionally all-encompassing in its form to flag some of these issues.

A key driver here is that it recognizes that in 2050, there will be generation of adults that have lived all their lives engaging with smart devices and materials. They will have experienced technology breakthroughs that redefine how human beings interact – not only with each other but with their surrounding environment. There will be an expectation for an environment that invites adaptation with ease, a place where hard infrastructure, communication and social interaction are seamlessly intertwined, and one in which buildings are used 24 hours a day. The overriding goal is that in 2050 buildings function as part of an urban ecosystem while actively contributing to the unique needs of the individual user. By producing energy, food, clean air and water, they transition from being considered passive shells to becoming adaptive and responsive organisms – effectively living and breathing structures.

Some of the specifics proposed are as follows:

- Incorporation of vertical farms
- Lightweight modules that are interchangeable to reflect the changing demands of usage and hence are continually adaptable.
- Smart infrastructure grid which collect data on its occupants and informs and responds accordingly.
- Algae façades to produce bio fuels.
- Nano treatments applied to the envelop that are able to neutralise airborne pollutants and capture CO_2.
- Water extraction from humid air
- Fully robotic maintenance
- Encouraging ecological interaction

Whilst large scale implementation of some of these aspects may be a little out of reach of present thinking, it is evident that drivers, ecological and societal will force the issue and influence the priorities.

Putting This Thinking Into Practice – Study of a 150 Story Building

Above has looked at some of the immediate trends in addressing urbanization, as well as leaping forward to look at what the futurist's view of the building in 2050 might encompass.

Arup paired with Kiss + Cathcart architects to look at the design of a 150 story building that recognizes these goals and ideals, to explore if it is possible to design a 150 story building that produces all its own energy, and treats and reuses its water and waste. The geometry, structure, construction methods and materials, building systems, and energy consumption and production were all analyzed taking into account foreseeable improvements in technology by 2050 (Figure 5).

Geometry – The general layout and geometry of the building lends itself to a low energy use building. The shape of the building is determined by our requirement that the building have thin floor plates (max. 15 meter), as a key objective is to create a building that

Figure 4. A vision for 2050
图4. 2050年愿景

一个主要驱动力是，在2050年，有一代人将会与智能设备及材料生活在一起。他们将会体验到科技突破所带来的对人类互动的重新定义——不单单是人与人之间的，还包括人与环境的交流。那将是一个安逸的环境，一个将建筑，交流和社会活动融合在一起的地方，一个建筑物每天持续被使用24小时的地方。最重要的目的是在2050年，建筑功能将成为城市生态系统的一部分，并主动向住户提供特定的服务。生成能源，食物，清洁的空气及水，建筑物将从被动体转变为有适应性和互动性的有机体——一个真实地活着的、会呼吸的结构体。

一些设想如下:

- 垂直农场;
- 可根据不同需求进行替换的轻质模块，从而使建筑物拥有更强的适应性;
- 可收集住户相应的数据并根据收集的数据对用户进行反馈的智能网络架构;
- 能提供生物燃料的藻类幕墙;
- 能够净化空气中的污染物，吸收二氧化碳的采用纳米材料涂层的外立面;
- 从潮湿的空气中提取水;
- 全智能维护;
- 支持鸟类，植物及昆虫之间的互动。

在大体量的建筑物中应用上述设想也许会超出我们现在的理解，显而易见，生态及社会发展的驱动力将推动上述应用并提升其重要性。

将思考转化为实践 ——对一栋150层高层建筑的研究

以上审视了一些目前解决城市化问题的趋势，也展望了在未来学家眼中2050年的建筑的走向。

Arup奥雅纳和Kiss+Cathcart建筑师事务所一同探索并设计了一栋能同时拥有这些目标和理念的150层高层建筑，旨在尝试一种可能性，该可能性是指对于一栋150层高的建筑是否可以自生能源，处理并循环利用水资源和垃圾。建筑几何、结构、施工方法乃至建材、建筑系统和能量消耗产出都将被一一分析并且考虑了2050年可预见的技术改进 (如图5) 。

can provide for human physiological and metabolic needs, including daylight penetration and views to the outside from all interior spaces. Additionally, the strategy of using thin plans increases the ratio of façade to floor space, which generates higher yields from the solar façades.

Structure – Usually a high façade to floor area ratio raises the embodied energy, operational energy, and construction cost of a building. To address these concerns, several methods of modular construction were analyzed to see what might be possible by the year 2050. The modules themselves incorporate timber construction in a way which meets fire code, with the overall objective of making the building lighter, possessing less embodied energy, and in a way which allows for easy replacement of modules to make the building use flexible as the needs of occupant change.

Movement Through the Building – A challenge of high-rise buildings is the movement of occupants throughout the building. Providing enough elevators for 150 stories generally requires a bulky core, which is in conflict with the long thin layout of this building. The latest technology indicates that double stacking elevators, with carbon fiber rope, would lower the weight of the elevators, require less elevator banks, and drastically reduce the elevator energy consumption. The long thin layout allows for more access to egress stairs, which is often a challenge of high-rise buildings.

Operational Energy – With regards to the operational energy consumption of the building, the research has focused on:

- The effects of improvements in the performance of the envelope on the total energy consumption, with consideration for the modular construction and improved infiltration rates;
- The effects of glazing ratio of the façade on the energy consumption for HVAC and lighting respectively;
- Increased performance of all energy consuming systems based on trend lines from the last 20 years and looking ahead. This includes lighting technologies, HVAC equipment, and water recycling systems.

Analysis of the above has been done through a model that has been developed in-house by Arup. The final energy model resulted in a total energy demand of 36.4 kWh/m^2/year for a New York climate. Figure 6 shows how this compares with the normal condition for a building in 2013.

Energy Production – This building allows for the consideration of building integrated photovoltaics (BIPV) on a large scale. Besides research into new PV technologies, the geometry of the building was formed to allow for maximum exposure to sunlight. Solar studies of the building and its surroundings, in a dense urban context, have given a realistic perspective on the amount of shading on the façades. An overall façade coverage of 60% solar systems, adjusted for latitude, weather, shading and B.O.S. losses, proved an affective output of 60.5 kWh/m^2 of floor area per year (Figure 7).

Embodied Energy – The embodied energy of building materials is relatively increasing in importance with the reduction of operational energy, to be neutral a building must expect to obtain energy 'payback.' Especially for a high-rise, embodied energy is very high due to the demands on the structure. Data derived from NREL studies and an internal Arup database was used to calculate an overall energy balance of the building materials. Given the high surplus on energy production, the tower is able to regenerate the amount of energy it took to build it within a reasonable timeframe. The desired payback was met by the building becoming neutral before any replacement of modular systems would be needed.

建筑形体—建筑的平面布置和建筑物的几何形状自然而然地影响着建筑物的低能耗。建筑的形状由我们的需求所决定，该需求使得建筑物具有轻薄的楼板 (最大处为15米)。我们的主要目标是创造一个能满足人类生理和代谢需求的建筑，其中包括有充够的阳光照入，从内部空间任何位置都能欣赏外部风景。另外，使用轻薄型楼板的策略增加了幕墙与楼板面积的比例，从而能使楼面获得更大的光照面积。

建筑结构—较高的幕墙与楼面面积比会提升隐性能耗，运营能耗以及建筑物的建造费用。为解决这些问题，我们分析了模块化施工的几种方法，并期望至2050年该方法能成为一种可能。建筑物各个模块采用能满足防火需求的木结构建造，从而使得建筑物更加轻盈，内嵌能耗更低。建筑物各模块易于更换，从而建筑物的适用性更强，能满足使用者改变功能的需求。

建筑物内部交通—高层建筑的一大挑战在于使用者在建筑物内的交通。为一栋150层高的建筑提供足够的电梯势必需要一个非常巨大的核心筒，这点将与建筑物瘦长型平面布置相抵触。最新的电梯技术表明采用碳纤维拉绳的双层轿厢电梯能有效减少电梯重量，降低对电梯井数量的要求，并且在很大程度上减少电梯能耗。另外，瘦长型平面需要设置更多的通道以到达疏散楼梯，这也是高层建筑设计中的一个挑战。

运营能耗—就建筑物的运营能耗方面，研究主要集中在以下几点:

- 在考虑模块化施工和提高渗入率的前提下，优化建筑外维护结构对建筑总能耗的影响;
- 幕墙的窗墙比对于建筑空调和照明能耗的影响
- 基于过去20年和将来的新趋势优化总能耗系统。这包括照明技术，暖通设备和水循环系统。

以上的分析工作基于由奥雅纳自主开发的一个模型。最终的能耗模型表明若假设该建筑在纽约，则每年的能耗需求为每平米每年36.4 千瓦时。图6比较了该模型与2013年的一栋普通建筑物。

能量生成—该建筑物的设计允许在大尺度上考虑建筑集成光伏技术 (光伏建筑一体化)。除了研究新的光伏技术，建筑物的几何形状旨在获得最大限度的光照。在高密度城市区域内对建筑及其周边环境的日照分析，真实地反映了建筑立面上的阴影投影范围。

Figure 5. The 2050 tower (Source Kiss + Cathcart Architects)
图 5. 2050塔（来源: Kiss+Cathcart 建筑事务所）

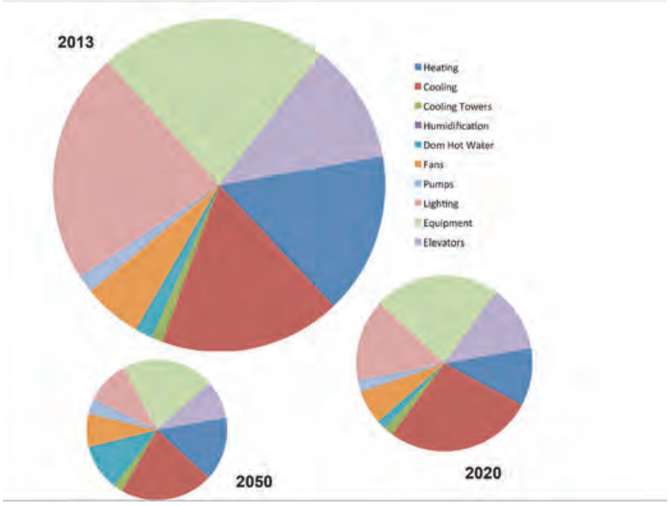

Figure 6. Operational Energy usages to scale (Source Arup)
图 6. 运营能量使用比例图 (来源: 奥雅纳)

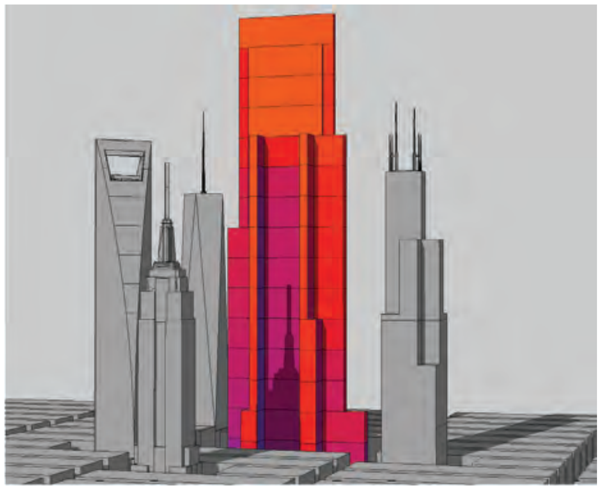

Figure 7. PV analysis with shading from surrounding buildings (Source Arup)
图7. 结合周围建筑的投影进行的PV分析(来源: 奥雅纳)

Water - The water balance scenarios considered that by 2050, availability of municipal water may be scarce and the impact on infrastructure of a 150 story tower may not be able to be accommodated. With recent technological progress in the reuse of gray and black water the strategy for minimizing the need of fresh water from the grid has been solidified. With regards to the water demand beyond what is available from rainwater and recycling, it is assumed that potable water will be generated through desalination of ocean water and the energy needed for this process is accounted for in the energy balance.

Waste - The issue of waste has been addressed both with regards to the building and its inhabitants. The embodied energy includes the waste processes associated with the end of life of building components and as such the energy of the full life cycle of the building has been accounted for. As for the biological waste generated by the occupants, a study was conducted into the waste to energy strategies that are currently available. For the 2050 tower a waste process based on incineration is found to be most applicable for the scale of the building. With this process the 2,500 tons of waste per year can be utilized to generate 2.8 kWh/m^2/year.

When combined, the operational energy, embodied energy, construction methods, and new technologies all point to the possibility of a totally self-sufficient tower by the year 2050.

Conclusion

This paper has presented some of the challenges facing the increased migration to our cities in terms of space demands and environmental considerations and what this means for the design of high-rise towers. It has conveyed some present trends and steps that are evolving as well as looking at what the tall building of 2050 might comprise. A specific study performed on a 150 story building indicates that tall buildings may indeed be an answer to the urban population challenges in the year 2050, and when combined, the operational energy, embodied energy, construction methods, and new technologies all point to the possibility of a totally self-sufficient tower. The studies are on-going on many fronts and will continue to refine our thinking and potential application of these principles.

太阳能系统的覆盖率为60%的幕墙，按照纬度、天气、阴影和系统平衡损失调整后，将提供每年每平米60.5千瓦时的有效能量输出 (如图7) 。

隐性能量—建材的隐性能耗与减少建筑物的运营能耗正逐步受到重视，建筑物对于能量也讲求投资回报。特别对于一栋高层建筑，由于对建筑结构的高要求，隐性能耗是十分可观的。利用国家再生能源实验室以及奥雅纳内部数据库中的研究数据来计算建筑材料总的能耗平衡。如果建筑物自身的能量生产盈余很高，那么建筑物就能在合理的时间内生成与建造该建筑物所消耗能量的同等能量。在替换模块系统以前，需要通过建筑物自身能量平衡来得到期待的投资回报。

水—水平衡策略表明，至2050年，市政用水可能告急，很有可能无法满足一栋150层高层建筑的需求。随着近期循环利用中水和废水的相关科技进步，确立了建筑物对市政用水的依赖逐步减弱的大体策略。当用水需求超过收集雨水和循环用水的量时，则需通过海水淡化来生成饮用水，而该过程中所需能量将被考虑进能量平衡。

垃圾—这里的垃圾被定义为建筑垃圾与居住垃圾。隐性能耗包括建筑物构件在到达使用寿命时的废弃处理的能耗与在建筑物整个生命周期内所需考虑的能耗。对于由居住者产生的生物垃圾，已进行了一项将垃圾转换为能量的研究。对于2050年的高层建筑，基于焚烧的垃圾处理被认为是最适合该建筑物尺度的方式。在该过程中，每年2500吨的垃圾可生成每年每平米2.8千瓦时的能量。

当把运营能耗、隐性能耗、建筑方法、以及新技术的应用结合起来时，至2050年我们完全有可能创造一栋自给自足的高层建筑。

结论

本文就空间需求、环境考虑以及对高层建筑设计意义几方面阐述了一些移民加剧的城市所面临的挑战。本文在阐述了当前的新趋势和新进展的同时，展望了2050年超高层建筑的发展方向。 对于一栋150层超高层建筑的研究表明，超高层建筑将是解决2050年城市人口问题的答案。当把运营能耗、隐性能耗、建筑方法、以及新技术的应用结合起来时，我们完全有可能创造一栋自给自足的超高层建筑。这项研究正在各领域前沿展开，并将继续对我们的思想和潜在的应用原则产生深远影响。

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