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The Payoff for Investing in the Human Experience

用户体验的投资回报

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In this chapter, Shanghai Tower is introduced along side The Tower at PNC Plaza, to posit that economic propositions for double-façade design solutions must go beyond energy considerations and incorporate the value of human experience. The design performance of glass double skin façades has been well-researched, yet there is a lively debate among practitioners and academics about their actual benefits. Many projects claim to achieve high levels of energy efficiency through the use of double façade technology. The counter-argument highlights instances where actual performance did not achieve what was anticipated in the design, and asserts that any operational energy savings are offset by the increased embodied energy of double façades over single façades. This presentation will use case study comparisons to evaluate the role user experience can play in the "return on investment," (ROI) of double façade design.

本文通过对上海中心和PNC广场塔楼的案例研究，提出双层外立面的设计方案不能仅考虑节能，还应包含用户体验的价值。有关双层玻璃外立面的设计性能已有较为深入的研究。但当前业内人士和学者对于双层外立面的实际效益仍存在激烈争论。众多项目声称通过运用双层外立面技术取得了高效节能的效果。而持相反观点的人则指出，实际性能并未达到设计预期，并认为运营中节约的能源都由于采用双层而非单层外立面导致的隐含能量增量而抵消。本文将采用案例对比研究的方法，评估用户体验对于双层外立面设计投资回报率 (ROI) 的作用。

Introduction

Shanghai Tower and The Tower at PNC Plaza share an aspiration to set new benchmarks in sustainable design, and both use a unique double-façade approach as a key strategy to achieve that goal (see Figure 3.27, 3.28). Building façades are a key driver of building energy performance as they mediate the outdoor elements to provide a comfortable interior.[1] While façades are typically designed as a thin layer separating man from nature, double façade design offers unique opportunities to improve building energy efficiency and to provide users with a sense of control over their environment. This is achieved by affording the opportunity to engage with the building by literally opening a window and because double façades with large enough cavities provide a spatial experience of the boundary that separates man from nature.

Vertical Cities as Urban Habitat: The Future of Dense Urban Areas

Often tall buildings are looked upon as iconic landmarks, a view that encourages an external view only, which tends to privilege form-making and façade treatment over the user experience from the inside. As cities increase in density and buildings become taller, the urban habitat must be a built environment that provides experiences that transcend merely being sustainable and livable, to become enjoyable and even exhilarating. Tall buildings that are stacked layer upon layer of floors, with little consideration of the experiential qualities beyond the view out from a high vantage point, do not provide users with an experience that sustains them. Two statistics make the case for the imperative for sustainable high-rise building in dense urban cores: there will be a 69% increase in urban population by 2050, and 67% of all people, or roughly 6.2 billion of the earth's projected population of 9.5 billion people, will live in cities in 2050.[2] Shanghai Tower and the Tower at PNC Plaza are examples of how high-rise design can incorporate double-façades to address this challenge. Both provide a counterpoint to the typical high-rise design, by providing vertically integrated spaces within the layer of the double façade. This provides users with a greater sense of connection to the outdoors and nature, as well as providing a spatial three-dimensional experience of the tower.

简介

上海中心和PNC广场塔楼项目都致力于打造可持续设计的新标杆，二者都采用了独特的双层外立面技术作为实现该目标的关键策略 (见图3.27, 3.28) 。建筑外立面是建筑物能源需求的重要因素，因为外立面通过缓解室外环境的影响来创造舒适的室内环境[1]。一般情况下，外立面是将人同自然环境隔开的薄层，而双层外立面则具有独特的优势，能够提高建筑物节能效果，并为用户带来环境控制感。这种控制感通过在建筑物上开窗的方式得以实现，而内外双层外立面之间空间足够宽敞，提供了人与自然分界处的空间体验。

1. The calculation of building loads is a complex analysis that varies by building type and use. As stated in ASHRAE, "Heat flow through the building envelope is mainly associated with the energy performance of buildings. However, other aspects are equally important. Interior surface temperature serves not only as an indicator for hygienic conditions in the building (e.g. conditions preventing surface condensation or mold growth), it can also be a major factor for thermal comfort." American Society of Heating, Refrigeration, and Air-Conditioning Engineers (2009), ASHRAE Handbook—Fundamentals, Atlanta: ASHRAE, pp. 25
1.摘自《ASHRAE 手册-基础》亚特兰大ASHRAE，第25页， 美国暖通空调工程师协会出 (2009) 。
2. United Nations, Department of Economic and Social Affairs, Population Division (2011), "World Urbanization Prospects, the 2011 Revision Highlights." New York: United Nations, pp. 70. Available: http://esa.un.org/unup/pdf/WUP2011_Highlights.pdf [June 1, 2014].
2.摘自《世界城市化展望2011年修订要点》第70页。纽约联合国经济及社会事务部人口分署出。 (2011) 。

Figure 3.27. The Tower at PNC Plaza (Source: Gensler)
图3.27.PNC广场塔楼 (来源: Gensler)

Figure 3.28. Shanghai Tower (Source: Gensler)
图3.28.上海中心大厦 (来源: Gensler)

The Case for ROI Measured in Terms of User Experience

The usual measurement for return on investment, or ROI, is calculated by the formula:

Return on Investment (%) = (gain from investment – cost of investment) / cost of investment [3]

In the case of evaluating alternative proposals for building projects, the typical inputs for this calculation are operating expenses and capital expenses. In Double Skin Façades, Oesterle, Lieb, Lutz, and Heusler make the case that this relatively simple formula can be expanded to include as many variables as appropriate, including, for instance, an evaluation of interest and amortization based on the timing of when costs are accrued. The authors further elaborate that specific to double façades, the cost-benefit trade-offs of the whole building, and not just individual systems, must be taken into account, where for example a more expensive façade can provide reduced costs of air conditioning and lighting.[4] This approach for calculating ROI is logical because it takes advantage of readily quantifiable and available information. And it is useful for choosing among alternatives to maximize the

通过垂直城市打造城市生境: 高密度城区的未来

一般情况下，高层建筑物被看作地标建筑，在这种观点的鼓励下，设计仅注重外观，侧重于外形设计和外立面处理，而非用户在建筑物内的体验。随着城市密度加大，建筑物高度增加，城市生境提供的建筑环境应该超越可持续和宜居层面，成为一种令人愉悦甚至欣喜的体验。高层建筑物由楼层叠加而成，除高处俯瞰的视野外，很少考虑体验性，未能为用户提供在大楼内始终愉悦的持续体验。以下两组数据说明，在高密度城中心建造可持续的高层建筑势在必行: 到2050年，城市人口将增加69%，全球67%的人，相当于预计95亿地球总人口中的62亿，将在城市居住[2]。上海中心和PNC广场塔楼为高层建筑如何利用双层外立面解决这个挑战起到了示范作用。两者都打破了典型的高层设计，在双层外立面之间提供了一体化的竖向空间。这加强了用户同室外环境和大自然的联系，同时为大厦打造了三维空间体验。

用户体验与投资回报率分析

投资回报率 (ROI) 通常采用以下公式计算:

投资回报率 (%) = (投资回报-投资成本) /投资成本[3]

在评估建筑项目的数个可选方案时，上述计算公式一般采用运营费用和资本费用。在《双层外立面》一文中，Oesterle，Lieb，Lutz 和Heusler提出，上述公式过于简单，可适当增加各种变量进行补充，例如，应计的成本利息和分期偿还。该文进一步阐明，对于双层外立面，须考虑整栋建筑的成本-收益权衡，而非单单立面系统，必须考虑，例如，较昂贵的外立面可以减少空调和照明的支出[4]。这种ROI的计算方式合乎逻辑，因为充分利用了量化信息和可用信息。在选择最大化资产价值的方案时也非常适用。但这种方法倾向于忽略一些更难以用经济成本衡量的价值，而这些价值对于最大化出租率和入住率有着直接影响。并且这种方法忽略了一项任何建筑项目最重要的推动因素也是大部分公司最重要的投资: 人力资本。

3. Investopedia, "Return on Investment." Available: http://www.investopedia.com/terms/r/returnoninvestment.asp [June 1, 2014].
3.摘自《投资百科》之"投资回报"

4. Huesler, W., Lieb, R.D., Martin, L., and Oesterle, E. (2001), Double-Skin Façades: Integrated Planning. New York and London: Prestel Verlag.
4.摘自《双层外墙》 - 整体规划，Huesler, W., Lieb, R.D., Martin, L., 及 Oesterle, E. (2001)著。纽约和伦敦普雷斯特出版社。

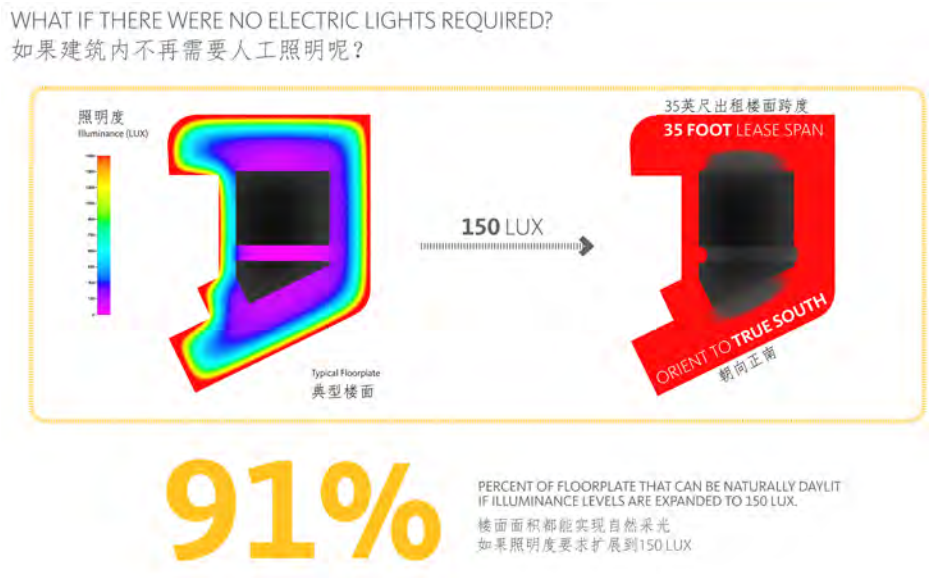

Figure 3.29. Daylight evaluation for The Tower at PNC Plaza (Source: Gensler)
图3.29. PNC广场塔楼自然采光评估 (来源: Gensler)

value of an asset. But in doing so, this approach tends to overlook values that are more difficult to measure in economic costs, values that have a direct impact on maximizing lease rates and maximizing occupancy rates. And it overlooks one of the most fundamental drivers of any building project, and the most significant investment most companies make: human capital.

Expanding the ROI equation to factor in human capital, then, significantly changes the result. Research conducted by the University of San Diego Burnham-Moores Center for Real Estate and CBRE indicates that sustainably designed buildings reduce sick time by 2-5 days annually and increase productivity by 4.8%.[5] In the case of a Delos® Well™ certified office, the ROI is projected at 360% over 3 years, with a 13% increase in employee productivity and a $4-8k benefit per employee per year.[6]

Design Process: Reinventing the Chassis of a High-Rise at PNC Tower

The process of designing the Tower at PNC Plaza opened new lines of inquiry into the debate around the efficacy of double façade design. The aspiration for the project, established at the outset, is to be "the world's greenest high-rise".[7] The immediate question this aspiration begs is what does that mean, and how is it measured? The answer the team developed, that to be the world's greenest high-rise entails a balance of energy responsiveness, workplace innovation, and community enhancement, provided criteria that guided decision making for the project (see Figure 3.29). These criteria were reflected in the words of PNC Chairman and then-CEO, James Rohr, who said, "The Tower at PNC Plaza is an exclamation point on our investment in downtown Pittsburgh, and it reflects our commitment to community, competitiveness and innovation, as well as to the comfort and productivity of our employees." What these criteria also afforded was the opportunity to redefine the terms of the debate about the performance of double façades.

The notion of the high performance building was thus conceived not as a tradeoff between user experience versus comfort to gain efficiency, but rather as a platform to enhance user experience, improve the community, and achieve efficiency. User experience and behavior inform the building design and the increasing integration of technology into the architecture of the built environment.

Design Process: Reinventing the Chassis of a High-Rise at Shanghai Tower

The process of the design for Shanghai Tower illustrates a potential for double façades beyond concerns with energy performance alone. The design aspiration for Shanghai Tower was to build an icon of modern China that would be a landmark on the Shanghai skyline. "This tower is symbolic of a nation whose future is filled with limitless opportunities," said Mr. Qingwei Kong, President of the Shanghai Tower Construction & Development Co., Ltd. The desire for a unique, expressive form that would fulfill that mandate had to overcome the relentless inertia of gravity and extreme wind loads caused by typhoons. The twisting, tapering form of the building,

在ROI的计算公式中纳入人力资本因素从很大程度上改变了计算结果。圣地亚哥大学Burnham-Moores地产中心及CBRE进行的研究表明，可持续建筑每年可减少2-5天的生病时间，并能够提高4.8%的生产率。[5]以Gensler设计的、位于洛杉矶CBRE集团并获得Delos® Well™认证的办公项目为例，三年的投资回报率达到360%，员工生产率增加13%，平均每位员工每年福利为4000-8000美元。[6]

设计过程: 重塑PNC高层塔楼的"基座"

PNC广场塔楼的设计过程为有关双层外立面设计效用的争论开启了新的思路。项目目标最初定位为"世界上最绿色的高层建筑"[7]。但这个目标带来的直接疑问是: 这是什么意思，如何衡量这个目标? 团队给出的答案是，世界最绿色的高层建筑意味着在节能响应、办公场所创新、社区提升之间取得平衡，这为设计决策提供了标准 (见图3.29) 。PNC主席和执行总裁James Rohr先生的一段话也反应了上述标准，"PNC广场塔楼是我们在匹兹堡城中心投资项目的标杆，反应了我们对于社区、竞争力和创新，以及对员工舒适度和生产率所作出的努力。"这些标准同时也为重新界定双层外立面性能的争议话题提供了可能。

因而高性能建筑不是以用户体验和舒适性之间相互妥协为代价提高效率，而是作为提升用户体验、促进社区发展和提高效率的平台。用户体验和行为启发了建筑设计，并推动技术融入到建成环境的建筑中。

5. Miller, N. and Pogue, D. (2009), "Do Green Buildings Make Dollars and Sense?" San Diego: University of San Diego and Los Angeles: CBRE. Available: http://catcher.sandiego.edu/items/business/Do_Green_Buildings_Make_Dollars_and_Sense_draft_Nov_6_2009.pdf [June 1, 2014].
5. 摘自《绿色建筑的钱途与前途？》，Miller, N. 及 Pogue, D著. (2009),圣地亚哥及洛杉矶大学CBRE出, 美国圣地亚哥。

6. Workplace Evolutionaries (2014),"WELL-Certified Workplaces." Houston: International Facilities Management Association. Available: http://cdn.ifma.org/crec/webinars/ifma-webinar_wellness-jan-2014.pdf?sfvrsn=0 [June 1, 2014]
6. 摘自《工作空间的进化》- 高认可度的工作空间，休斯敦国际设施管理协会。(2014)

7. Belko, M. (2011), "PNC to build new 'ecofriendly' headquarters Downtown," Pittsburgh Post-Gazette, May 23. Available: http://www.post-gazette.com/breaking/2011/05/23/PNC-to-build-new-eco-friendly-headquarters-Downtown/stories/201105230200 [June 1, 2014].
7. 摘自《匹兹堡邮报》第五月二十三期报导: PNC将建造市区新型环保总部，作者Belko, M. (2011)

defined by the outer façade, reduces wind loads by 24%, with a corresponding 32% reduction in structural material.

In the case of Shanghai Tower, the design of the double façade was synthesized with the initial conception of the tower as a vertical city comprised by a series of stacked zones. This creates a spatial experience of the double façade that is unique, with a vertical layer of space separating the inside and the outside. In addition, the double façade made it possible to create a unique and iconic form on the outside, while maintaining a rational, efficient, and repetitive floor plan on the inside. The undulating layer of space between the façades defines the dynamic experience (see Figure 3.30).

Shanghai Tower is organized as nine cylindrical buildings stacked one atop another. The inner layer of the double-skin façade encloses the stacked buildings, while a triangular exterior layer creates the second skin, or building envelope, which gently rotates as it rises. The spaces between the two façade layers create nine atrium sky gardens. Much like plazas and civic squares in traditional cities, the sky atria offer spaces within Shanghai Tower for interaction and community with restaurants, cafés, coffee shops and convenience stores, as well as lush landscaping.

设计过程: 重塑上海中心大厦的"基座"

除了节能性能，上海中心大厦的设计过程还引发了人们对双层外立面其它方面的关注。上海中心大厦的设计愿景为建成现代中国的一个标志建筑，组成上海天际线的地标建筑。上海中心大厦建设开发有限公司董事长孔庆伟先生表示："上海中心大厦是我们这个充满了无限未来的国家的符号象征。"为了满足该要求并赋予独特的外形，必须克服重力的巨大惯性及台风引起的极端风力荷载。由外层立面营造出的扭转锥形外形将风力荷载降低了24%，并相应地将结构材料的使用降低了32%。

上海中心大厦的双层外立面设计与竖向城市的初步概念综合，包含了一系列竖向区

Design Tools: Simulations and Mockups

Figure 3.30. The vertical zones of Shanghai Tower organize the tower into a vertical city. (Source: Gensler)
图3.30. 上海中心的垂直分区让塔楼成为了垂直城市 (来源: Gensler)

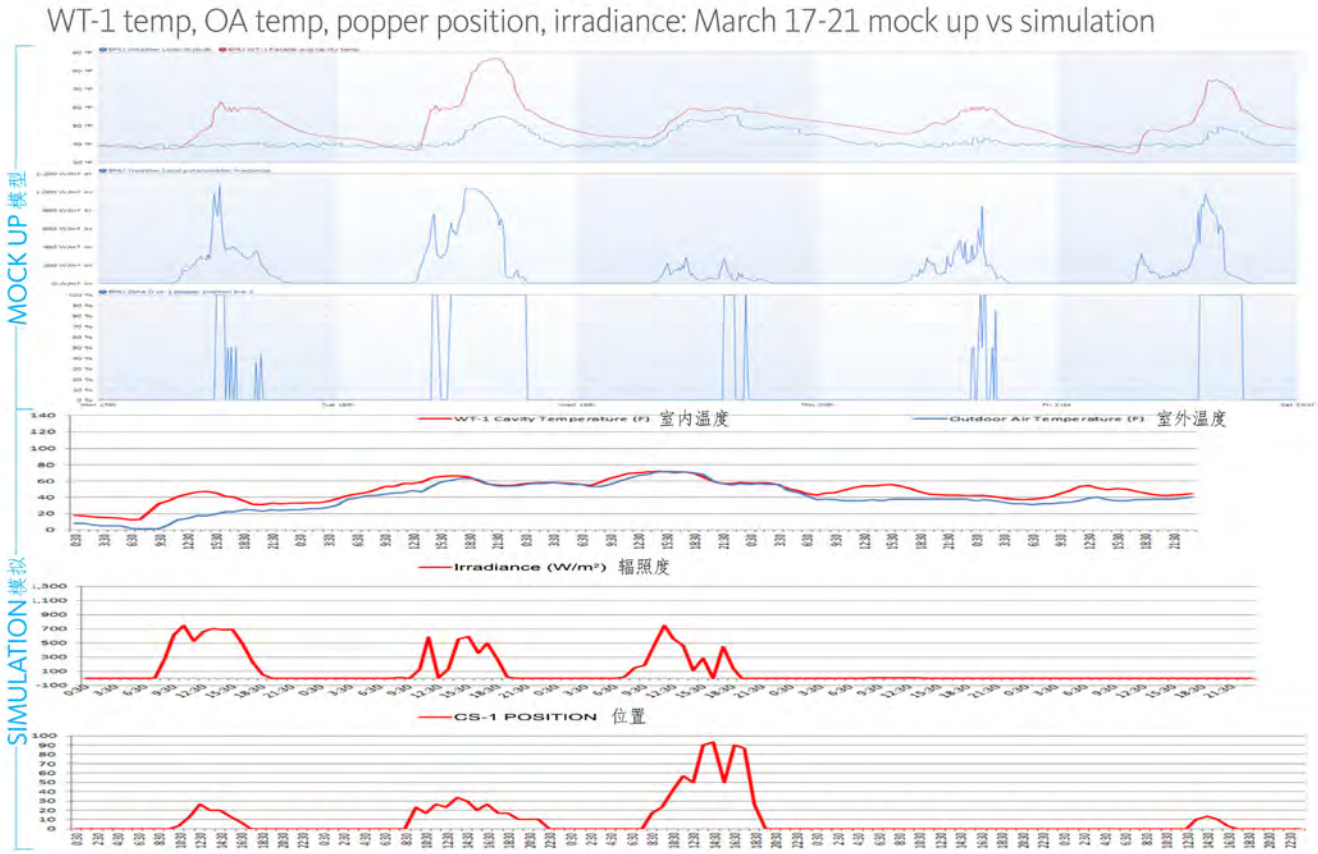

Figure 3.31. Comparison of predictive CFD modeling with mockup results. (Source: BuroHappold)
图3.31. 预测性CFD建模与模型结果比较 (来源: BuroHappold)

Both projects established working hypotheses that built upon well known principles of air movement induced by thermal stack effect to achieve energy savings, and in the case of The Tower at PNC Plaza, natural ventilation. To test these hypotheses, a rigorous regimen of simulations and mockups was put in place with the goal of cross-referencing mockups and simulations for accuracy and predictability of performance.

The Tower at PNC Plaza

Examples of comparative data from simulations and mockups illustrate how the project goals will be achieved, how design options were evaluated, and how variations can affect the building system and user comfort. For example, while it is possible to simulate design performance with CFD analysis, a physical mockup of certain pieces of the building provides valuable data that can inform the design of the building. To fully vet the design of the Tower at PNC Plaza, multiple simulations of the building and its detailed components were produced. Mockups were built in conjunction with these simulations in order to further inform the design. The comparison of the output provides helpful insights into the tools used for evaluation, the design process itself, and the functionality of the building. As an example of this reiterative process, wind tunnel test result data was loaded back into the whole building CFD model to evaluate the effects of wind patterns on the ability of the building to naturally ventilate. As new data is received from the continuous monitoring of the mockups, it is checked against the simulation for verification and if necessary the simulation model and/or the mockup are adjusted and the process is repeated. This effort seeks to improve the accuracy and predictability of the design result (see Figure 3.31).

Shanghai Tower

Extensive use was made of mockups and simulation to vet the design and its performance. In addition to whole building energy modeling, detailed CFD models of more discreet aspects of the project, such as an atrium of a 14-story zone, were completed to test and validate how air flow would work (see Figure 3.32). The principle of thermal stack effect was employed to induce hot air to rise to the top of the atrium, thereby creating a cooler area at the bottom of the atrium that would be comfortable where users occupy the space, without wasting energy trying to

间，营造出了独特的双层外立面内外层之间的竖向空间体验。除此之外，双层外立面使得在外层形成了独特的标志性外形的同时内层保持合理、高效及可复制的楼层平面布置成为可能。内外立面之间的空间波状层级提供了建筑的动感体验 (见图3.30) 。

上海中心大厦由九个圆柱形建筑彼此层叠而成。双层外立面的内层将层叠的建筑围合起来; 三角形外层作为大楼的第二层立面或建筑围护，随着高度的增加而小幅旋转。利用两层立面之间的空间营造了出九个中庭空中花园。与传统城市的购物广场或市民广场类似，上海中心大厦中的空中中庭营造出了互动空间，以及包含餐厅、咖啡馆、便利店及拥有繁茂景观的社区。

设计工具: 模拟及模型

两个项目均根据烟囱效应引发气流运动的公认原则建立工作设想，以达到节能以及自然通风的目的 (后者在PNC广场塔楼中实现) 。为了对这些设想进行测试，采用了严格的模拟及模型原则，用来实现模型及模拟的相互参考，确保建筑性能的精确性及预期性。

condition the entire height of the atrium. Because Shanghai Tower does not include natural ventilation, in contrast to the Tower at PNC Plaza, the intricacies of air movement were simpler to evaluate. Natural ventilation must meet a minimum number of air changes per hour but must also not exceed a certain air velocity that would be experienced as uncomfortable. Hitting that narrow window is harder than predicting thermal stack effect, so mockups of the thermal stack effect at Shanghai Tower were not required, as CFD modeling is able to reasonably accurately predict how that air movement will work.

Design Results

The double façade at The Tower at PNC Plaza operates in three modes: 1) passive natural

PNC广场塔楼

从模拟及模型中获得的对比数据明确了项目目标实现方式、设计方案评估方法及变量对建筑系统及用户舒适度的影响方式。例如，虽然可用CFD分析模拟设计性能，大楼特定区域的实体模型也提供了大楼设计所需的宝贵数据。为了对PNC广场塔楼进行全面审查，进行了多项大楼及其具体部位的模拟。此外，还建造了一些实体模型与模拟一起提供设计所需信息。输出数据的对比为评估工具、设计流程及大楼功能提供了有用的洞见。作为迭代过程的范例，风洞测试结果数据被重新载入整个大楼的CFD模型，用来评估不同类型的风对大楼自然通风能力的影响。根据从实体模型持续监测获得的新数据，对模拟进行审查核实，如有必要，将调整模拟或实体模型并重复该流程。该项工作旨在提高设计结果的精确性及预期性。(见图3.31)

上海中心大厦

项目广泛采用了模型及模拟，以审查设计和性能。除了整合了大楼的能源建模，项目还完成了更加精细的CFD模型 (如14层高的中庭)，以测试和核实气流的运动模式 (见图3.32)。基于烟囱效应原则，热空气升上中庭的顶部，而在用户使用的中庭底部产生凉爽空间，无需浪费能源为整个中庭提供空调。由于上海中心大厦不含自然通风，因而与PNC广场塔楼不同的是，其气流运动的精细评估更简单。自然通风必须满足每小时最低换气次数，但不得超过导致不舒适的特定气流速度。这比烟囱效应的预测困难得多，因而上海中心大厦无需为烟囱效应而做实体模型，CFD建模足以作为合理精确地预测气流的运动的可行方式。

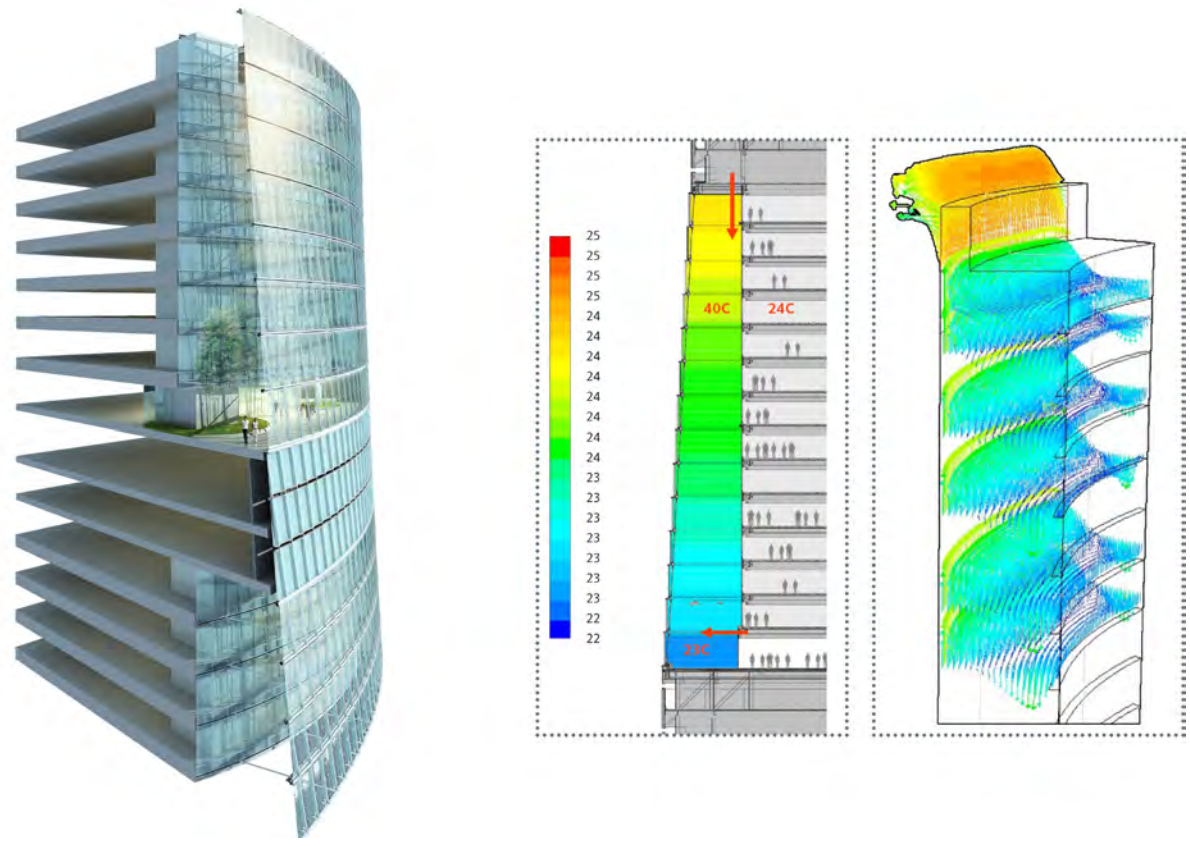

Figure 3.32. CFD analysis of the atrium between the façades at Shanghai Tower. (Source: Cosentini)
图3.32. 上海中心双层外立面间中庭CFD分析 (来源: Cosentini)

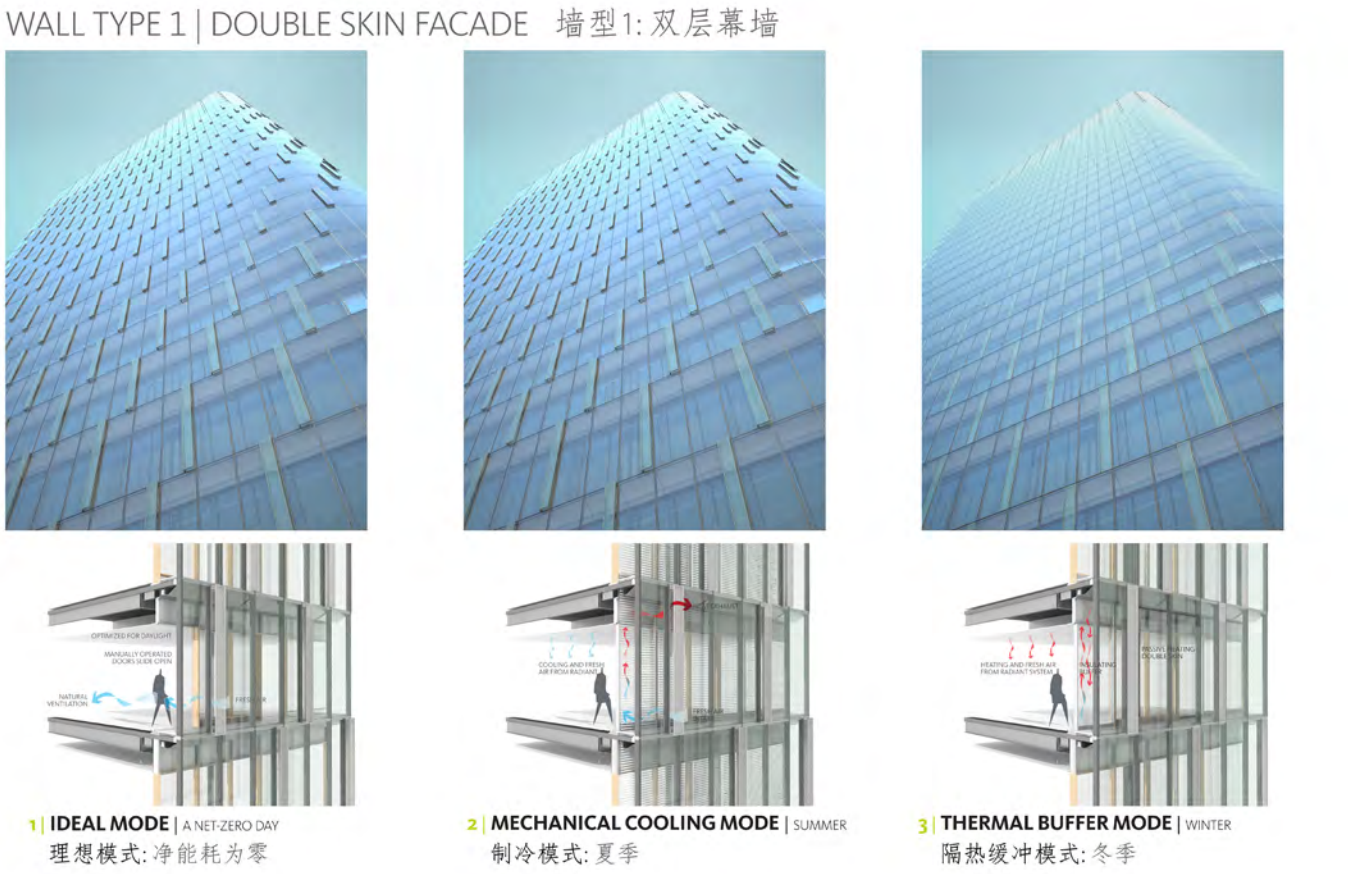

Figure 3.33. Modes of operation for the double façade at The Tower at PNC Plaza. (Source: Gensler)
图3.33. PNC广场塔楼双层外立面运作模式 (来源: Gensler)

ventilation, 2) cooling, and 3) heating. In the passive natural ventilation mode both the inner and outer layers of the façade are open, allowing fresh air to flow into the building. The user may also open a door on the inner façade, augmenting the flow of fresh air from outside. In the cooling mode, the outer façade is open while the inner façade remains closed, thus shedding heat in the cavity back to the exterior. The sunshades in the interstitial space adjust throughout the day and season to prevent direct solar penetration, thereby eliminating solar heat gain into the interior space and dramatically lowering the cooling load of the building. In the heating mode both layers of the façade remain closed, trapping the air in the cavity to create an additional layer of warm insulated air around the building. As the cavity temperature is naturally warmed by the sun, the delta temperature between the cavity and the interior space is reduced, in some cases completely, which directly reduces the heating load of the interior space of the building (see Figure 3.33).

In numerous double façade precedents that were evaluated, the double façade acts as a return air path, an exhaust air path, and/or as an insulating buffer (see Figure 3.34). In those precedents that are user accessible, access tends to be limited to a few discreet locations and the user does not gain an appreciation for how the façade operates based on their interaction with it through access. The goal of The Tower at PNC Plaza, therefore, was to bring the user experience to the forefront by allowing the user to access to the façade throughout the space, and by doing so in a way that user engagement will augment how the building is already operating. Thus when the building is in natural ventilation mode, a user can open the door of the inner façade and feel fresh air moving from outdoors into the space. When the building is in heating mode, a user can step out into the cavity and feel a temperature differential to the interior space, either warmer or cooler, that provides the effect of going outside for a breath of fresh air. While the double façade provides the most significant energy savings of any single system on the project, the amenity and experience it provides to building occupants, and their subsequent enjoyment of the workspace overall, is where the true ROI of the project is born out (see Figure 3.35).

In the case of Shanghai Tower, the outdoor air quality precluded the use of natural ventilation in the double façade, so the user experience focused on the spatial aspects of occupying a layer

设计结果

PNC广场塔楼的双层外立面以三种模式运作: 1) 被动自然通风; 2) 制冷; 3) 供暖。在被动自然通风模式下，外立面里外两层都保持开启状态，外部新风得以流入建筑内部。用户也可以开启内层上的门，加速室外新风的流入。制冷模式下，外层保持开启而内层保持关闭，因而将空间内的热量送回室外。内外层间的遮阳在季节及一天的时间内不断调整以防止直接日晒，从而消除了进入室内空间日照的热量，大大降低了建筑的冷负荷。在供暖模式下，两层外立面都保持关闭状态，将空气锁定在两层外立面之间的空间内，在建筑周围形成了一层附加保温层。由于日照，中间空间内的温度自然升高，外立面中间空间及室内空间的温度差减少，在某些情况下温差减为零，这可直接降低建筑室内空间的热负荷 (见图3.33) 。

在之前多个进行评估的双层外立面例子中，双层外立面成为了回风路线、排风路线和/或隔热缓冲带 (见图3.34) 。在那些用户可用的例子中，出入口多被限制在某些特定位置，用户无法在与其互动的过程中欣赏外立面的运作。因此，PNC广场塔楼的目标旨在优化用户体验，使用户在整个空间都可以自由进出外立面间层，采用这

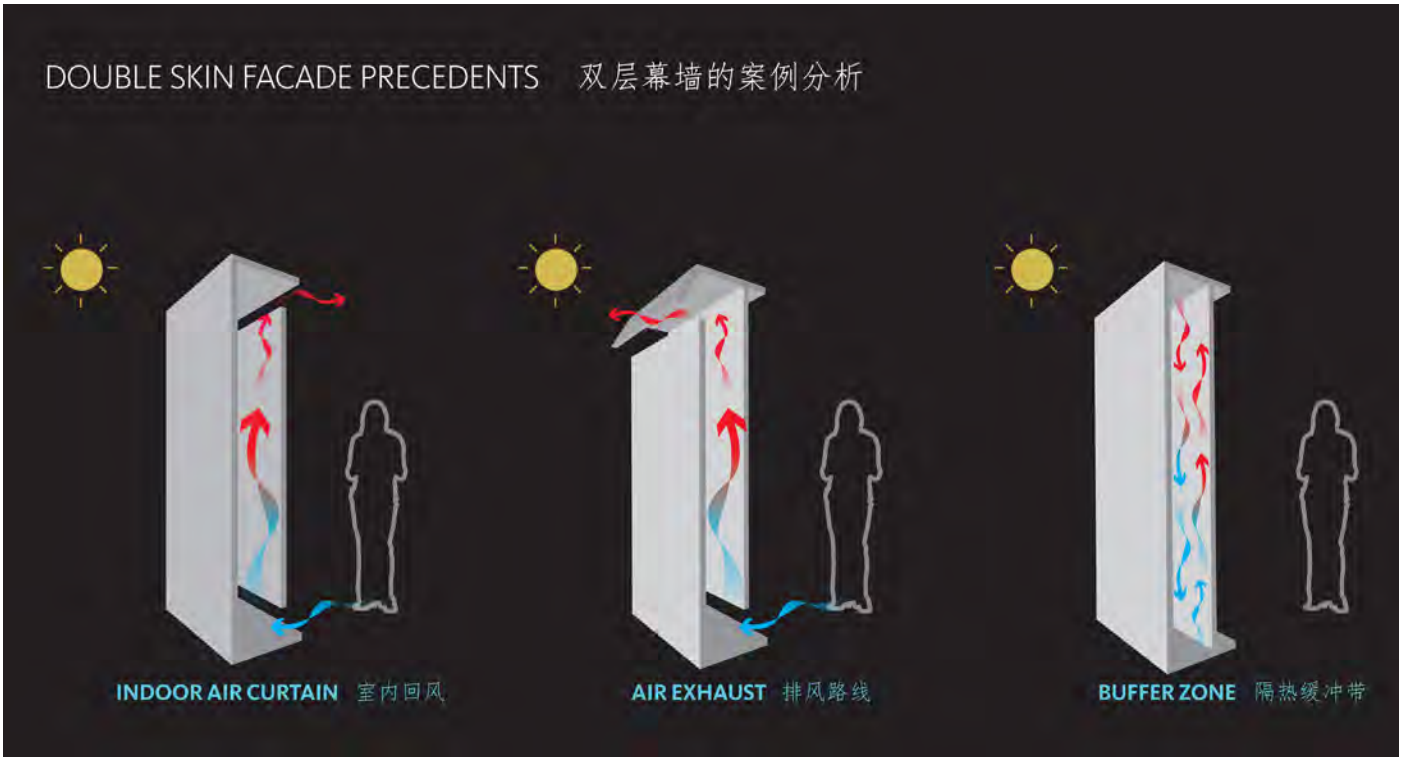

Figure 3.34. In numerous double façade precedents that were evaluated, the double façade acts as a return air path, an exhaust air path, and/or as an insulating buffer. (Source: Gensler)
图3.34. 在之前多个进行评估的双层外立面例子中，双层外立面作为回风路线、排风路线和/或隔热缓冲带。（来源: Gensler）

of space that buffers indoor office space from the true outdoors. This layer of space is accessed on the amenity floors at each zone of the tower. The double façade at Shanghai Tower operates in two modes: summertime cooling and wintertime heating. In summer months, the atrium cavity of the double façade captures heat before it penetrates the interior environment, and sheds this heat back to the exterior. In winter months, this heat is recaptured and used to heat the interior of the floor plates. These two modes of operation provide significant energy savings to the building while also allowing for the use of an entirely glass façade which in turn provides daylight to the interior, reducing reliance on electric lighting and further saving energy (see Figure 3.36).

While these energy savings are significant and help to pay for the added first cost of the double façade, like The Tower at PNC Plaza, the real ROI for Shanghai Tower is borne out by the unique spatial experience created by the double façade. The amenity floor where the double façade is experienced is also the transfer floor between express elevators that serve the whole building and local elevators serving the 14 stories within a particular zone. The amenity levels are programmed

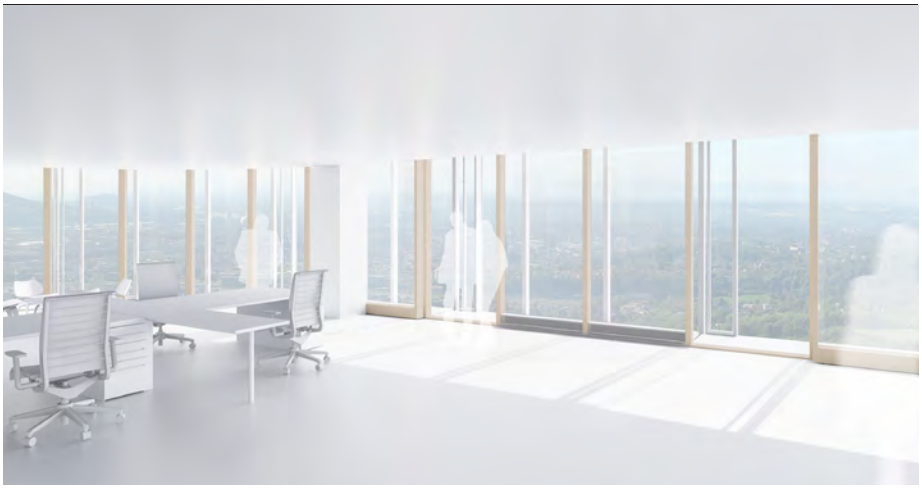

Figure 3.35. The user enjoyment of the double façade amenity at The Tower at PNC Plaza is central to its design. (Source: Gensler)
图3.35. PNC广场塔楼双层外立面带来的用户享受为其设计核心。（来源: Gensler）

with functions that users access daily, such as small shops for coffee or lunch, as well as casual gathering areas around landscaping that give the sense of stepping outdoors without actually having to traverse the entire height of the building. Beneath the amenity floors are the required fire refuge areas, mechanical areas, and structural outrigger and belt trusses. Thus, the double façade at Shanghai Tower integrates and synthesizes energy benefits, vertical transportation, fire and life safety requirements, mechanical planning, and structural design, all while providing users with additional amenities and an experience that is unique in the world of high-rise buildings (see Figure 3.37).

Material Selections

Material selection is an integral part of both performance and supporting the qualitative aspects of user experience. The use of highly transparent glass over an entire façade would not normally be possible for large scale projects with increasingly stringent energy code requirements and in the case of these two projects would seem to compete directly with the sustainability aspirations. Yet the benefits of providing users with access to daylight and views, and reducing energy demand by using daylight to offset electric lighting, all give ample support to the desire to use large expanses of glass. In the case of The Tower at PNC Plaza, another material example is the use of a wood curtain wall that offsets embodied carbon content, while supporting the

种方式可让用户参与促进建筑已有的运作方式。因而，当建筑处于自然通风模式下时，用户可以打开内外立面的门，感受新鲜空气从室外流入室内。在供暖模式下，用于可以步入两层外立面之间的空间内，感受与室内空间不一样的温度，更暖或更凉，从而给用户一种走出门呼吸新鲜空气的别样感受。双层外立面在为项目提供了最有成效的单一节能子系统的同时，还为用户带来舒适及独特体验，用户对整个工作场所的日益喜爱才是项目投资最为重要的回报 (见图3.35) 。

在上海中心项目中，不理想的室外空气质量妨碍了双层外立面采用自然通风模式，因此在该项目中，用户体验重点在于打造室内办公空间与真正户外间的空间体验。在塔楼每个区的配套层都可通往该层空间。上海中心双层外立面以两种模式运作:

Figure 3.36. Modes of operation for the double façade at Shanghai Tower. (Source: Cosentini)
图3.36.上海中心双层外立面运作模式 (来源: Cosentini)

Figure 3.37. The user enjoyment of the double façade space at Shanghai Tower is central to its design. (Source: Gensler)
图3.37. 上海中心双层外立面空间带来的用户享受为其设计核心。 (来源: Gensler)

夏季制冷及冬季供暖。在炎炎夏日，双层幕墙的中庭空间在热量进入室内环境前将其隔离在这一空间内，并让热量流回室外。在冬天，双层外立面间的空间同样留住这一热量，并将其用于室内楼板供暖。这两个运作模式为大楼节约了很多能源，因此可以采用全玻璃幕墙，而这为建筑室内提供了良好的自然采光，减少了对电力照明的依赖，从而进一步节约能源 (见图3.36) 。

如同PNC广场塔楼，这些节能措施意义深远，同时弥补了双层外立面的额外初期成本; 上海中心的真正投资回报就是双层外立面打造的独特空间体验。进入双层外立面的配套层同时也是快速电梯 (服务于整栋大楼) 与区间电梯 (服务于某一区内的14个楼层) 间的转换楼层。配套层提供满足用户日常需求的功能，如小型咖啡店或餐厅，同时还设有景观围绕的休闲聚会区，在无需穿过整个建筑高度的情况下给人一种步入户外的感觉。配套层下方为要求的避难区、设备区、结构悬臂梁及带状桁架。因此，上海中心大厦的双层外立面结合了能源效益、垂直交通、消防与生命安全、机电规划及结构设计，这一切为用户提供了额外的世界高层建筑中独一无二的舒适和体验 (见图3.37) 。

材料选择

材料选择是建筑性能表现及提高用户体验方面必不可少的一部分。在节能规范要求越来越严格，且这两个项目都旨在按照可持续设计推进的情况下，这类大体量项目整个外立面都采用高度透明的玻璃一般是不可能的。然而，这样做可以为用户提供阳光与开阔视野，同时自然采光能够减少因电力照明带来的能源消耗，这些好处为设法实现大范围玻璃的采用提供了充分的

community with locally sourced materials and providing users with a unique and enhanced experience.

Quantifying User Experience

User experience is by definition a qualitative metric. It can be challenging, therefore, to identify suitable quantitative measurements to evaluate the quality of user experience. Nevertheless, in studies that have been done within controlled environments, such as call centers, there is a noticeable improvement in performance when users are provided access to daylight and the ability to control the temperature. In a study published in Fast Company, May 2011, a range of 1–11% increase in productivity was reported where occupants were given access to natural ventilation.[10] A Cornell University study measured a 150% increase in typing output along with a 44% reduction of errors when office temperature was allowed to fluctuate from 68°F up to 77°F.[11] Companies too are recognizing the value of health and wellness programs for employee retention and engagement. In a study by The National Business Group from 2012, 48% of companies plan to use incentives to get workers involved in wellness in 2013, and there is a 29% increase in employee satisfaction in a sustainably designed environment.[12]

Conclusion

Taken together, Shanghai Tower and The Tower at PNC Plaza posit a unique hypothesis in the world of double façade design: that in order to fully ascertain the benefits of a proposed double façade design, any evaluation must take into account more than just energy. Saving energy is of paramount importance, but alone this goal cannot justify the cost of many double façade proposals. When factoring in human experience, however, the equation changes, tipping the balance in favor of façade design that achieves high sustainability aspirations and provides unique user experiences.

依据。在PNC广场塔楼项目中，另一个材料例子就是利用木制幕墙抵消产生的碳含量，这样不仅实现了就地取材，而且为用户提供更好、更独特的体验。

量化用户体验

从定义来看，用户体验为一项定性指标。确定合适的定量方法进行用户体验评估是极具挑战性的。然而，受控环境 (如客服中心) 中进行的研究表明，在为用户提供采光及温度控制权的情况下，工作表现有了明显提高。[10]《快速公司》2011年5月刊发行的一个研究报告表明，在为用户提供自然通风的情况下，生产力可提高1–11%[11]。康奈尔大学的一项研究表明，办公室内温度允许在68°F-77°F之间波动时，员工打字速度提高了150%，同时错误减少了44%。同样，各个公司都意识到健康保健计划对于员工留任及员工参与方面的价值。全国企业集团 (The National Business Group) 2012年做出的一项研究表明，48%的公司计划在2013年采用各种激励措施鼓励员工参与健康计划，同时，在可持续设计环境中，员工满意度提升了29%[12]。

结论

总之，上海中心及PNC广场塔楼在双层外立面设计领域提出了一个独一无二的设想: 为确定双层外立面设计带来的好处，应考虑对所有方面的评估，而不仅仅是能源。节能是至关重要的，但仅凭节能这一项无法为众多双层外立面提案提供成本的解释。但在考虑用户体验因素时，等式变化了，天平倾向于能达成高度可持续性同时提供独特用户体验的立面设计。

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10. 摘自《中心建筑环境》之 通风对工作效率的影响。 摘自《快速公司》五月刊 - 提高职员工作效率的办公室三措施，Schwartz, A. 2011年

11. Hedge, A. (2004), "Linking Environmental Conditions to Productivity." Ithaca: Cornell University. Available: http://ergo.human.cornell.edu/Conferences/EECE_IEQ%20and%20Productivity_ABBR.pdf [June 1, 2014]

11. 摘自《环境条件连接生产力》 Hedge, A.著。伊萨卡， 康奈尔大学出版。

12. National Business Group on Health (2012), "Large Employers' 2013 Health Plan Design Survey." Available: http://media.benefitspro.com/benefitspro/article/2012/08/06/2013%20Plan%20Design%20Survey%20Report_FINAL.pdf [June 1, 2014].

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