

## DAYLIGHTING AND ENERGY PERFORMANCE OF POST MILLENIUM CONDOMINIUMS IN SINGAPORE

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### Abstract

Condominiums are the most common typology of housing next to public housing in Singapore. In Singapore, government planning directives and incentives play a major role in market trends. Facade projections promoted by the URA ([www.ura.gov.sg](http://www.ura.gov.sg)) in recent years had subsequently found way into the post-millennium facades (glass balconies and bay windows). Expectations of living conditions have grown as Singaporeans gradually adapt to the air-conditioned lifestyle. Design of private residential developments (condominiums) in Singapore is mostly undertaken by foreign architects and this has resulted in a typology that neglects the wholesome concept of tropicality both in terms of climatology as well as living style. Extensive use of glass in these units has resulted in lack of privacy, poor day lighting performance as well as uncomfortable thermal conditions. Plastered facades of the seventies have given way to modern glass-skinned facades and high-end condominiums today have started to provide inbuilt air-conditioning. Statistics show that monthly household electrical bills have increased steadily over the years and 50% of Singapore's overall energy consumption is solely consumed by air-conditioning. A thorough case study of one such condominium development was attempted and the results obtained through this pilot study were then used to analyze the trends across prototype units using simulation tools. The results show that the residents of such units pay a very high rate

for electricity resulting from air conditioning the habitable spaces in their residence.

This paper is an attempt to discuss a few examples of condominiums around the western part of Singapore as a means of discussing the emerging design trends as well as to discuss the performance aspects of the design solutions in terms of day lighting and energy consumption.

### Keywords

condominiums, tropical facades, ETTV, insolation, day-lighting

### Introduction

Singapore's pertinent land scarcity problem resulted in the intervention of the government with the Land Titles (Strata) Amendment Act in 1999, which eased the legal problems, associated with en bloc sales, whereby the requirement for unanimous consent from the members was removed and a majority vote was replacing the same. This facilitated private development and has resulted in an effective increase in the number of condominiums that developed during the last five years. Singapore had moved into a techno – era,

in which almost all the buildings in Singapore became air conditioned. Almost 80% of the energy consumption in buildings of Singapore comes from the air conditioning systems. However, with the growing awareness around the world on the concept of green buildings and with even more critical issues including global warming, Singapore has now realized its part to play and is slowly moving towards an energy conservative approach across all fields. Particularly, on the buildings side, "Green Mark scheme" and "Energy smart buildings scheme" ([www.bca.gov.sg](http://www.bca.gov.sg)) are some of recent attempts by the country to induce the momentum amidst the designers and contractors to move towards developing an energy conscious country as a whole. A very high energy penalty is associated with the ventilation component in air conditioning, particularly in the tropical climates and this is apparently due to the very high enthalpy difference that exists between the outdoor and indoor air conditions. This is reflected in the increase in energy use across all typologies of buildings, and even in domestic electricity consumption, approximately 50% increase was evidently seen over the last decade. To add on to the complexity of the issue, the design of these private residential apartments are becoming more and more transparent in terms of their facade and this often results in very high cooling loads in the living spaces, in turn higher energy consumption. This paper is an attempt to address the complex phenomenon of energy consumption in private condominiums developed during the recent times, with a relatively transparent facade design.

### Condominiums in Singapore – A Prelude

Condominium developments were conceived as an urban planning strategy to address 4 main problems then:

- ❖ Wasteful sprawl of low density developments in suburbia
- ❖ Fragmentation of plots
- ❖ Provision of land for recreational communal activities in residential zones
- ❖ Inadequate maintenance for community facilities

In other countries, condominiums have the tendency of arising in central districts for convenience and accessibility whereas in Singapore, it was the suburban areas which yielded Singapore's first condominiums as a governmental reaction to under-utilization of suburban land resources (Lee, 1989). The ability to afford private housing in Singapore is limited by the scarcity of land and understandably, high prices. Consequently, the ability to own a private property has become "the Singapore dream" (Ong, 2000). Condominiums typically refer to a form of property ownership in which each owner holds the ownership to their individual unit including a small fraction of entitlement to the common areas of a multi-unit project. Typically, the concept of condominiums ad-vented in the early 70s of the last century with **Pandan valley and Ridgewood** being the first two condominiums that developed in Singapore.

Typically, more than 50% of the total development of condominiums is targeted around the prime residential districts of Singapore and the balance is scattered around the fringe areas of the island. The

demand for private housing types in Singapore is constantly increasing and the economic boom in the recent years has resulted in a much higher demand for such development. With the increase in demand, the number of condominium developments around Singapore has also increased in number tremendously. These units which were typically purchased by foreigners in the past are now being purchased extensively by the locals (Singaporeans) and

this reinforces the escalation of living standards of Singapore citizens. This dynamism in the demand and supply as well as the occupant type (local or foreigner) seems to be having a high correlation with the design of the prototype as well. Figure 1 shows a range of condominiums ordered according to the years of completion and it is suggestive of the change that has happened during years in the design thinking of a condominium.



Figure 1: Condominiums of Singapore

The concept behind the design of a condominium block has been constantly changing and the most obvious change is in the transparency of the facade design. The facades of the post – millennium condominiums have become more transparent and the upcoming condos fully rely on clear glass facades. The

irony in the design of these condominiums is that they are often conceptualized and designed by foreign architects for the unique tropical climate. Typically, many of the upcoming designs of facades for such buildings are just clear glass and the privacy of the occupants is highly questionable. Facades

of condominiums of a low height and with clear glass are constantly found to be blinded by the occupants to safeguard their privacy and protect the inside from the scorching tropical sun. With the growing numbers of such developments and the coarse grain nature of the design, this matter would soon need to be highlighted to the Urban Redevelopment Authority (URA) ([www.ura.gov.sg](http://www.ura.gov.sg)) which aims to develop a harmonized global city in the future.

### A Visual Analysis of the Upcoming Glass Facade Trends in Condominiums

In every modern and post-modern city, ponderous facades of masonry and brick are constantly being dissolving into modern curtain-wall facades and this change could be attributed to the increasing density of the urban-scape. The claustrophobic compactness has perhaps contributed to a general renouncement of the physicality and visual dead-weight of masonry and plastered facades. Lightness, transparency and dematerialization have become central themes in modern architecture applicable both to commercial and residential buildings. This movement towards lightness as a spatial concept could be traced back to the medieval European Gothic church, where great expanses of glass and the verticality of the pointed arch were architectural allusions to spiritual attainment, by technically creating a visual straining of space heaven-ward. Evidently, the purity and ascetic character of glass has been carried forth into today's architecture.

Fully-glazed buildings are delineated cleanly by curtains of glass which sharply define

spatial boundaries creating a sense of tautness and economy to modern space. The impermanence of incorporeal glass facades can also be interpreted as a cultural symbol of 'Globalism'.. Transparency is evocative of the profound influence of public mediatization, the animated surface, maximum 'visibility' and boundlessness of the internet dimension which is the prevalent basis of today's socio-economic progression. These ideologies behind the curtain-wall facade have percolated Singaporean architecture. In following sections, various reasons glass facades have been increasingly applied to condominiums in Singapore, particularly in the post-millennium period were discussed. Some of the newer developments assume that the young crowd wishes to see and be seen, at once becoming part of the spectacle of the cityscape as they observe the spectacle.

However, two notable points deserve mention here. Firstly, although later generations of Singaporeans in general might not oppose Western influence and may even be said to be highly receptive to its pop culture, some social preferences are more deeply-rooted in our Asian psyche than are immediately apparent. A deep-set, almost inbred propensity for privacy can be traced back to the Chinese courtyard house; its three-tiered spatial layering by means of internal courtyards separates the various sections of a household, with the innermost courtyard being the most private space reserved for those with the highest family status.

Thus in traditional Asian architecture, spatial differentiation not only acts as an organizational device but also accords manifold meanings to

communal spaces, where the conferment of privacy and tranquility is regarded as a measure of one's social status. In contrast, the Western communal outdoor space consists of a front lawn facing the main street. In this manner, the Western private space is somewhat more loosely defined. Thus perhaps the 'openness' of a facade may be tolerated in Western culture, but this cultural disposition is not readily transferable to the Singaporean Asian society. This distinction between private and public life can be observed in newer condominiums where curtains or blinds are habitually drawn to preserve the occupant's privacy.

Another imported Western concept is the desire for daylighting in temperate geographical zones. However, in Singapore's harsh tropical climate, direct midday light is barely tolerable, especially when it floods enclosed and poorly ventilated spaces. The architectural imagery of austere modern glass facades that has been transplanted here is inappropriate in our unremitting heat from high-angle overhead radiation. Overseas architects who typically design for temperate climates and who have been commissioned to design condominiums in Singapore tend to overlook the harsh tropical conditions occupants here inevitably face. Two such examples are the 'Edge on Cairnhill', designed by Moshe Safdie, and Kent Vale, designed by an American architecture firm. Both condominiums use clear glass in fully glazed facades which have proportionally small open-able areas.

The condominiums are designed based on the assumption that air-conditioning will perpetually be available and have given neither thought to nor allowance for natural ventilation. Qualities

such as machine-like economy and clinical detachment in architecture have arisen as new conceptions of beauty, but it seems comfort has not been considered a function of beauty in architecture. The 'Image-ability' of the glazed facade in Singapore seems to be based on the 'idea of modernism' rather than the principles of modernism itself such as progressive thought and self-reflection. It is a symbol, rather than artifact of modernity. The baseless replication of these transparent facades ignores the pluralism of vernacular architecture and materials available to architects. Ecological technology and differentiated treatment for facades at different storey heights can prove to be more valid generators of 'image-ability' than the unrestrained use of glass.

### Insolation and Daylighting Studies of a Typical Condominium Facade

A preliminary overshadowing study and a sun path analysis on the various facades in the layout of the **condominium xxx** were done and sample results are presented in the form of stereographic diagrams in figures 2 and 3. The studies showed that the facades were completely exposed at least during half of year, in the morning periods or the afternoon periods depending on their orientation. The inner facades facing the courtyards received the overhead sun consistently during the time periods between 11.30 a.m. to 3.00 p.m. (Figure 3). A set of insolation studies were conducted to identify the total incident radiation in  $W/m^2$  is also presented in figures 2 and 3. The scale shows that most of these facades received very high incident radiation levels of the order greater than  $150 W/m^2$ . The ETTV regulations of Singapore stipulate an optimum value for

ETTV as  $35 \text{ W/m}^2$  and most of these facades are completely glazed with clear glass. This would in turn result in very high ETTV values which in turn could result in uncomfortable indoor temperature conditions. The current trend in the condominiums is to centrally air condition the whole unit and these high radiation levels incident on the facade has a direct bearing on the cooling loads resulting in the indoor spaces. For the particular condominium xxx under consideration, it is very clear that the resulting cooling load in the living space behind the fully glazed facades will be very high. The direct to diffused radiation levels in Singapore is also

unique thus posing problems in terms of shading device designs. However, it is evident from figure 1 that most of these condominiums are fully glazed with a curtain wall style of cladding to the facade which in other terms would mean "zero or minimal" shading.

The diffused radiation is predominant in the case of tropics in approximately a ratio of 3:1 with the direct radiation. Hence, combating the high angle sky reflected components, the low angle ground components and the reflected radiations from the opposite and adjacent reflective surfaces is a major task in the case of



Figure 2:  
Insolation Study  
to Identify the  
Total Incident  
Radiation in  
 $\text{W/m}^2$

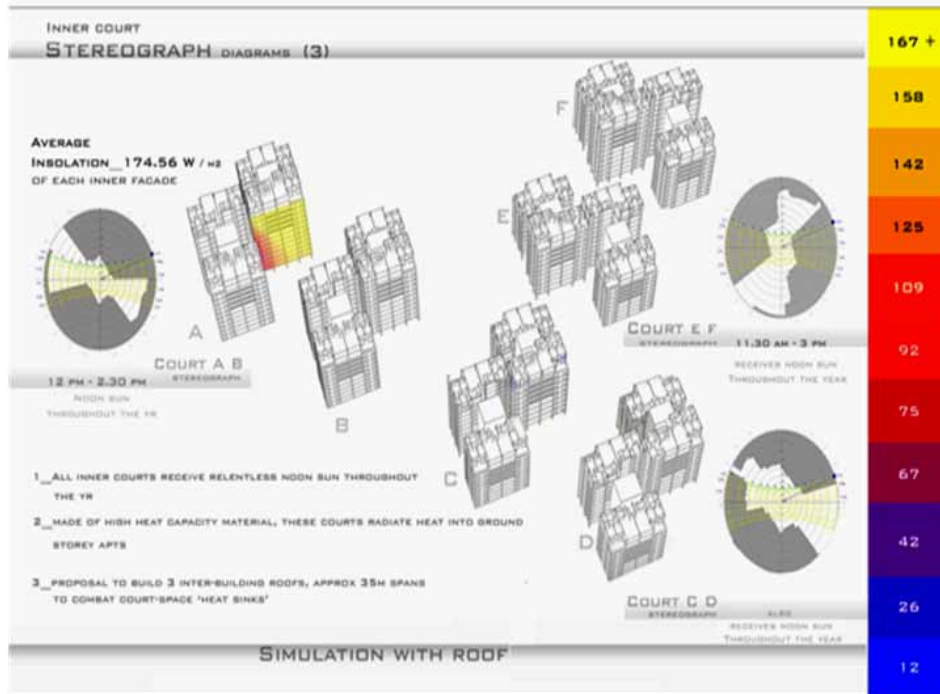


Figure 3: Insolation Study to Identify the Total Incident Radiation in W/m<sup>2</sup>. The Study Illustrates that the Inner Facades Facing the Courtyards Received the Overhead Sun Consistently during the Time Periods between 11.30 a.m. to 3.00 p.m.

Singapore. This consideration is also absent in the current designs of the condominiums.

Figure 4 shows a sample day lighting simulation on the 10<sup>th</sup> storey of a block that is oriented with its long facades facing east – west. The lighting levels shown in the figure clearly portray the situation in Singapore which is also unique in terms of its lighting patterns. As the stereographic diagrams clearly show that most of these facades are exposed to the overhead sun, the sun rays are almost at a very high angle

and hence, there is a predominant glare issue around the window area, and the lighting levels immediately die down after the perimeter zone of 3 m span. The reduction in lighting levels is drastic in the lower floors and the higher floors have situations, where the occupants have constantly had their screens drawn to protect the space from glare. This situation is worsened in the case of fully glazed facades as the original design intent of the architect of “having an environmentally interactive facade through which the occupant inside can feel the outdoor

spaces” is completely lost when the occupant draws his blinds or screens continuously. The lighting levels on the top floors near the balcony spaces reach nearly 1000 lux and the interior

spaces are often under very contrasting lighting levels as low as 150 – 300 lux.

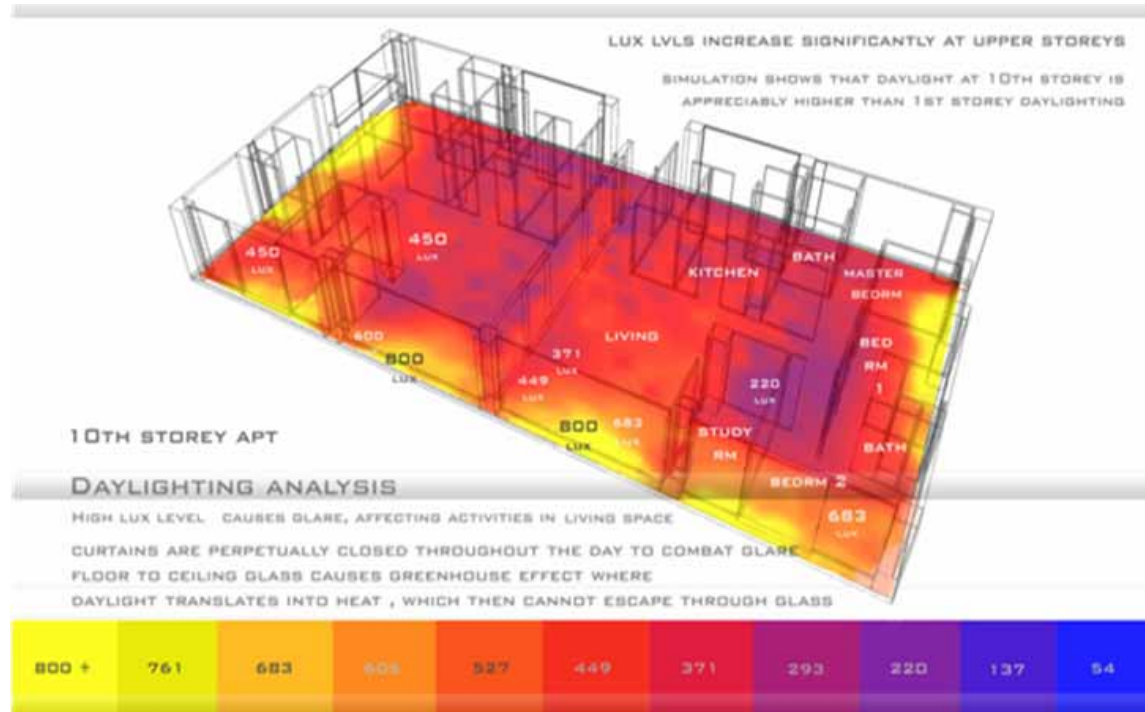


Figure 4: A Sample Day lighting Simulation on the 10<sup>th</sup> Storey of a Block that is Oriented with its Long Facades Facing East - West.

### Energy Analysis of the Condominium

A simple energy analysis of the condominium xxx was done with the VisualDOE software based on the following assumptions:

- ❖ The condominium was considered to be centrally air conditioned for the living

areas including the vestibule, dining, study rooms and the bed rooms.

- ❖ The dimensions of the aluminum frames in the windows of the fully glazed living rooms and bed rooms are assumed to have the default software values.

The energy analysis clearly showed that the predominant component of the cooling loads resulted from the radiation component of the facades. This attributed to be around 1/3<sup>rd</sup> of the total wall conduction which in turn resulted in very high ETTV values (approximately 116 W/m<sup>2</sup>) when a single clear glass facade was considered. Considering the total number of units to be approximately 500 in a private condominium development, the estimated utility bill for a single unit in terms of electricity consumption worked out to be around \$ 220 per month. Out of this total amount, 50% was attributable to the air conditioning costs of the unit. Based on the current condominium configuration and the facade design, the overall energy efficiency index for the development worked out to be 252.4 KWh/m<sup>2</sup>/year, which is much higher than the recent targeted values of less than 125 to 130 KWh/m<sup>2</sup>/year based on the Green mark buildings scheme.

The basic simulation in terms of the energy consumption showed very high values of electrical energy resulting out of poor facade design and lack of due consideration to the tropical climates. An estimate was made in terms of the savings potential of this particular development with a comparison of the utility bills to that of a standard 3 - bed room public housing unit. The average consumption of a typical unit of similar size in the public housing types is about 444 KWh per month (www.spsservices.com.sg), which would work out to be \$95 per month approximately. Considering the class of private housing and the demand type, if we even reduce the electricity consumption by 25%, the whole estate would be able to save approximately S\$ 1 million every year.

## Conclusion

The design of facades is a highly critical aspect in the design of a building. With the growing awareness in terms of energy conscious building designs, it is necessary that building designers give due considerations to the various factors that determine the efficiency of a facade. The perimeter area of the facade, the orientation of the facade, the time period of facade exposure and the level of self shading and designed shading for the facades, the position and sizes of openings and the materials used for the facades are some of the very critical aspects to be considered in the design of energy efficient facades. Singapore's private residential properties are transforming into more transparent outlooks. The concept of office cum home, Central Business District living and others have slowly transformed residential developments into full glass boxes. Many latest designs of condominiums follow curtain wall glazing types similar to commercial buildings. However, for the tropical subjects, both in terms of their climatic zone type and their living style, such facades pose a number of problems. The designers often fail to understand this fact and they design with dreams far away from realistic situations. The underlying question that this paper poses after this analysis is as follows:

*"If glass facades are preferred to be kept always blinded or screened by the occupants in order to secure their privacy and also to protect the space from problems of too much heat and glare in tropical climates, then why do architects provide fully glazed facades?"*

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