

## Impacts of Indoor Environmental Quality (IEQ) Elements on Residential Property Market: A Review

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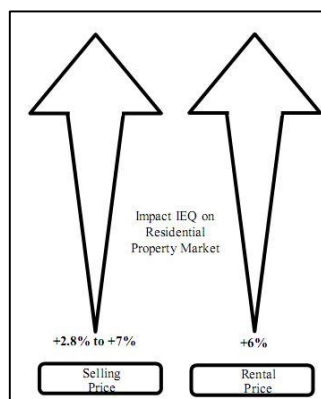
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### Graphical abstract



### Abstract

Indoor environmental quality (IEQ) is among six criteria of Green Building Index (GBI) that need to be achieved by building owner in order to recognize their building as 'green' in Malaysia. The benefit of IEQ is to create conducive environment for human health. Besides influenced their overall image, leasing and resale value of the buildings, does indoor environmental quality (IEQ) features will give impact on real estate market in terms of price and rental particularly for residential building property? Therefore, this paper will review the broad literature regarding the impacts of indoor environmental quality (IEQ) for residential building property and its implication to towards property price and rental. The early hypothesis of this paper anticipates that indoor environmental quality (IEQ) features will indirectly increase residential property market price and rental. From this paper, it is hope that the positive impacts of these features will encourage building owners, developers and other main development actors to put these criteria into the same consideration as other criteria in GBI as one of the way to compensate the impact of the building towards economic, environment and social.

**Keywords:** Green Building Index (GBI); green building features; indoor environmental quality; property price and rental; residential property

### Abstrak

Kualiti persekitaran dalaman (IEQ) adalah antara enam kriteria Indeks Bangunan Hijau (GBI) yang perlu dipenuhi bagi mencapai status sebagai bangunan hijau di Malaysia. Manfaat yang diperolehi dari elemen (IEQ) adalah untuk mewujudkan persekitaran yang kondusif untuk kesihatan manusia. Selain dapat mempengaruhi imej keseluruhan pihak yang berkepentingan, nilai pajakan dan nilai jualan semula bangunan, adakah (IEQ) akan memberi kesan kepada pasaran hartanah dari segi harga dan sewa terutamanya untuk hartanah bangunan kediaman? Oleh itu, kajian ini akan meninjau dan mengupas kajian lepas mengenai kesan (IEQ) terhadap hartanah bangunan kediaman dan implikasinya ke atas harga hartanah dan sewaan. Hipotesis awal kajian ini menjangkakan bahawa elemen kualiti persekitaran dalaman (IEQ) akan meningkatkan harga pasaran hartanah kediaman dan nilai sewaan secara tidak langsung. Kajian ini diharap akan membekalkan informasi mengenai kesan positif daripada ciri-ciri ini justeru akan menggalakkan pemilik bangunan, pemaju serta konsultan dalam mengaplikasikan kriteria sebagai salah satu cara untuk mengimbangi kesan bangunan ke arah ekonomi, alam sekitar dan sosial.

**Kata kunci:** Green Building Indeks (GBI); ciri-ciri bangunan hijau; kualiti persekitaran dalaman; harga dan sewaan; hartanah kediaman

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### 1.0 INTRODUCTION

Previous studies have identified four main categories of factors that are affecting the residential housing price namely structural, economic, demographical and environmental factors [1, 2]. Environmental factor by means it is related to the environmentally resources consumption and energy savings. When it comes to energy consumption, based on the analysis conducted, almost 40% of the total energy consumption is for the construction sector and about 30% of energy consumption is for the purpose of housing. [3]

Malaysia shows a moderate population growth with population density is about 30.3 million and continues to grow at the rate of 2.4% per annum [4]. The need and demand for housing sector were overwhelming especially in urban area. The compact and rapid growth of development consists of the several types of construction were encourage and leads for energy consumption as well as the releasing the carbon emission. Due to phenomenon issue on global warming and other imbalance environmental problem, construction sector took parts in reducing the impacts by balancing up the average air temperature and composition of green-house gases by introduced the green building concept [5].

However, Malaysian housing developers are still weighing the costs and benefits to build a green building since many of them are very concerned with the extra construction cost as well as there is not enough demand for these types of homes in Malaysia. Besides, the additional cost during green construction is recognized among ten (10) main barriers in green building development. Thus, these issues were more crucial due to as reported that the unstable housing prices in Malaysia.

In Malaysia, green building is certified by six main criteria. They are energy efficiency (EE), water efficiency (WE), indoor environmental quality (IEQ), sustainable site management and planning (SM), material and resources (MR) as well as innovation (IN) [6]. IEQ is located at the second position for new non-residential building and third for residential types of building.

Issues related to housing health, energy performance and environmentally friendly design were discussed among 80 to 90 percent of building owners (including owners-occupiers, landlords and housing companies) and take the view that an improvement of their buildings' energy performance will lead to increase in the buildings' market value [6].

There are numbers of studies on climate change impacts on diverse aspects of human life, such as energy consumption, water resources, health, public awareness, politics; government incentives and agriculture have been conducted. Besides, the discussion about the importance of sustainability issues in housing and the interrelation between people attitudes concerning the environmental protection and residential market in other countries are widely referred [7].

Other than that, direct contact with nature through green space allocation around the building for air quality enhancement, health and interior quality improvement does bring positive impacts on the urban real estate market. Therefore, every single aspects especially in terms of how much to pay for green and environmental benefits should be discussed.

## ■2.0 BENEFITS OF GREEN BUILDING

Green buildings are designed to reduce negative impacts on the environment as well as increase health of the occupants by addressing these five categories [8].

- i. Sustainable site planning;
- ii. Safeguarding water and water efficiency;
- iii. Energy efficiency, renewable energy and lower greenhouse gas emissions;
- iv. Conservation and the reuse of materials and resources; and
- v. Improved health and indoor environmental quality.

Many researchers have listed green building benefits through different standpoint and aspects. When it comes to green building, the environmental benefits will be the ultimate aims to be achieved.

In the Table 1 below show the numbers of benefits reported by those engaging in green building for new green buildings as well as the greening of existing building through retrofits and renovation projects [9].

**Table 1** Benefits by percentage of green building through retrofits and renovation projects

Benefits	New Green Building	Green Retrofit
Decreased operating costs over one year	8%	9%
Decreased operating costs over five years	15%	13%
Increased building value for green versus non-green projects (According to AEC Firms)		
	7%	5%
Increased Asset value for green versus non-green projects (According to owners)	5%	4%
Payback time for green investments	8 years	7 years

The idea seems to be that housing characteristics may lead to buying intentions for eco-friendly homes. The physical structure of the house could be important in explaining the motivations of green home owning intentions [6]. However, to the best of researcher's knowledge, in the context of Malaysia there is no single study emphasized on the significant role of indoor environmental quality (IEQ) especially its interrelation with property price and rental.

The requirement to satisfy the users and occupants of sustainable has to be included by the characteristics [10] shown in Table 2. With regards to these characteristics and attributes enable them with the information to contribute in the sustainable development. Economic, environmental and social aspects of occupants are among important aspects to fulfill in order to perform the green building in better way. The element will be affecting the occupant's perspective in determining whether to acquire the green building as the environmental elements have the great impact on property market.

## ■3.0 INDOOR ENVIRONMENTAL QUALITY FEATURES

Indoor environmental quality (IEQ) is a key component in the evaluation for meeting the concept of green building towards

sustainable development. There are four main elements in IEQ, which are (1) thermal (temperature and humidity); (2) noise comfort; (3) indoor air quality (air movement CO<sub>2</sub> concentration); and (4) lighting. The main purpose of applying the IEQ element is the prevention step from contributes to sick building syndrome [11].

Global warming is anticipated to have strong implications on future energy demands of buildings; with regards to the overheating aspects. Therefore, indoor environmental quality characteristic is the solution. An imbalance of IEQ will give negative impacts to facilities, building and occupants. It is not limited for air pollution, thermal conditions, humidity, sound, lighting and odour but also includes the use of energy, design and natural ventilation [12].

IEQ elements account for 12% of green building evaluation criteria for residential building [6]. However, the concentration for the balancing of indoor environmental quality are crucial as IEQ are very closely related to thermal comfort that comprise the temperature and humidity that will influence the quality of indoor. Moreover, the occupant's health quality and satisfaction are more important since it will be affected by the quality function in a building. 13% of respondent review and give suggestions to improve building indoor quality through green technology [11].

**Table 2** Requirement to classify sustainable building

Minimization of life cycle cost from full financial cost-return perspective. Reduction of land use and use of hard surfaces Reduction of raw material Avoidance in reduction of hazardous substances Reduction on environment pollution Protection of health and comfort building occupants Preservation of buildings' cultural value	Economic, environmental and social aspects
Maximization of the building serviceability Maximization of the building functionality	Aspects related to the fulfillment of users and occupants needs.

According to GBI, IEQ can be achieved through good quality performance in indoor air quality, acoustics, visual and thermal comfort. These will involve the use of low volatile organic compound materials, application of quality air filtration, proper control of air temperature, movement and humidity. Based on this achievement, IEQ will contribute on conducive environment to human health and productivity [13]. Hence, occupants will be more satisfied on the thermal comfort, air quality and overall workspace.

#### ■4.0 GREEN BUILDING OCCUPANTS' SATISFACTION CONTRIBUTES TO THE PROPERTY PRICE.

##### 4.1 IEQ Contributes Positive Impacts to the Building Occupants

Construction industry with the high contribution to gross domestic product has undeniable impacts on the economy. In addition, local

economic factor regarding property pricing market is one of the crucial elements to be considered in order to explain the meaning of the equitable standards of living.

It has been pointed out that IEQ is relatively providing many benefits as well as minimize the building conditions. IEQ can effect on occupant's productivity, organization profitability, customer [14]. Additionally it has been said that IEQ create conducive environment for human health and improve productivity than building which use standards practices [13]. The following Tables 3 and 4 below include more comprehensive discussion on impacts of green building to occupant satisfaction, productivity generally.

**Table 3** Discussion on impacts of IEQ to the occupant satisfaction

Author(s)	Methodology and Approach	Key Findings (occupant satisfaction)
Abaszadeh, S., Zagreus, L., and Huizenga, C., (2006)	Surveyed on 215 green office buildings, United States, Canada and Finland. Invitation e-mail survey	Occupants in green office buildings were more satisfied with thermal comfort and air quality in their workspace.
Eichholtz, P., Kok, N., & Quigley, J. (2009)	494 of the Energy-Star-certified rated green office building in The US.	Benefits of green building occupant's satisfaction by satisfy the indoor environmental aspects could improve productivity.
Kamaruzzaman, S. N., & Sabrani, N.A. (2011)	How indoor air quality (IAQ) affects psychological performance and health impact to the occupants in government high rise office buildings in Malaysia. (Kuala Lumpur and Selangor). Questionnaire of building occupants	The level of productivity and the stress level depending on the level of occupant satisfaction.
Sadek, A. H., and Nofal E. M. (2013)	Address different factors, which affect both physical and psychological health of occupants in healing environment. Literature Review	Both spatial and environmental IEQ factors which affect the occupant satisfaction in healing environment.
Meins, E., Wallbaum, H., Hardziewski, R. and Feige, A. (2010)	Develop a new approach to provide integrate those aspects of sustainability relating to value into valuations.	<ul style="list-style-type: none"> <li>• 5 Five groups of value-related sustainability features;               <ol style="list-style-type: none"> <li>1. Flexibility and polyvalence</li> <li>2. Energy and water dependency</li> <li>3. Accessibility and mobility</li> <li>4. Security,</li> <li>5. Health and comfort.</li> </ol> </li> <li>• By minimizing the risk of loss in value through future developments, those sustainability features contribute to the property value</li> </ul>

<b>Tan, Teck-Hong (2009)</b>	Examine relative of psychological, determine influencing intention to inhabit eco-friendly in Malaysia	Construction sector addressing the important of indoor air quality by introducing the green building concept.
<b>Falkenbach, H. Lindholm, A. and Schleich, H.</b>	Identify the drivers and benefits of environmentally sustainable buildings from the real estate investor's perspective. One of the external drivers is customer strategic decision.	Tenants are willing to pay due to increase in occupant productivity, potential image benefits towards stakeholders. Creating healthier and more productive working environment.
<b>Lorenz D. and Lutzkendorf T. (2008)</b>	Both financial benefits	Better environmental and social performance can lower the investment risk.
<b>Fisk, W. J. (1999)</b>	Estimates the nationwide productivity potential and Health Benefits from better Indoor Environment.	Better indoor environmental can cost-effectively increase health and productivity.
<b>Liang et al. (2014)</b>	Compared the green and conventional office buildings in middle of Taiwan on various aspects of IEQ.	Overall, the occupants in Taiwan satisfied on IEQ in green building greater than their conventional buildings.
<b>Edwards, B. W. and Naboni, E. (2013)</b>	Explain the	Green design provide healthier environment especially for workspace

**Table 4** Discussion on impacts of IEQ to the occupant productivity

<b>Author(s)</b>	<b>Methodology and Approach</b>	<b>Key Findings (Human Productivity)</b>
<b>Browning, W. and Romm J. (1995)</b>		IEQ will contribute on conducive environment to human health and productivity.
<b>PrakashPretti (2005)</b>	Different between the occupant's perceptions of performance in a LEED certified higher education building with not LEED certified in the US.	The occupants of the LEED certified building would perceive the IEQ of their building of their significantly better. As well as have positive effect on their performance.
<b>NaziatulSyimaMahbob, SyahrulNizamKamaruzzaman, NaziahSalleh, RahaSulaiman. (2011)</b>	Observe the correlation of IEQ and productivity in working place. Office building in Malaysia. Literature Review.	Indoor Environment Quality gives impact on physical and psychological. Increased in productivity since comfort.
<b>Smith A., Pitt M., (2011)</b>	Examines role of sustainable buildings in work place in physical perceptual terms. Literature Review	Environmentally sustainable should be regarded as strategy for productivity enhancement and management in designing work space
<b>Kamaruzzaman, S. N., &amp;Sabrani, N.A. (2011)</b>	How indoor air quality (IAQ) affects psychological performance and health impact to the occupants in government high rise office buildings in Malaysia. (Kuala Lumpur and Selangor). Questionnaire of building occupants	Occupants are comfort and satisfy indoor ventilation quality hence increased the productivity.
<b>Tanabe, S., Haned, M., Nishipana, N. (2007)</b>	Explain the importance of and the needs of the concept of productivity in building environment. Japanese Office Buildings.	Human responses are important for the evaluation of productivity. • The subject performed well when in they were satisfied with the indoor environmental quality.
<b>Roaf, S., Crichton, D., Nicol, F. (2009)</b>	Strong relationship between the comfort temperature and the temperature.	People are influenced by the climate as well as the indoor climate. Building occupants comfort increased the productivity.
<b>Heerwagen, J. (2014)</b>	Explores the integrating of organizational (productivity, customer satisfaction and innovation) and sustainable design.	As more the factors in better indoor environmental quality present, the more likely the symptom of SBS and lead to decrease in absenteeism thus increased the level of productivity.

Since the construction sector has also identified the importance in focusing on the characteristics of IEQ especially indoor air quality in buildings, these three (3) elements will added value expected for housing development. Based on the addition of elements that exist in residential building those features will contribute to the property value.

Although the effects of indoor environmental quality elements that contribute in terms of value and prices are not directly affected, however building occupant health improvement will be the significance element in the selection of residential buildings.

Building occupants are willing to pay for the benefits provided by good indoor environmental quality. Investor was attracted to invest in sustainable property with indoor environmental elements characteristics. This is due to the energy conservation as well as the social performance resulting in decreasing the investment risk.

A study had found [15] that overall occupant in Taiwan satisfied on IEQ in green building greater than conventional building. In addition, building occupant begin to focus on conservation agenda in order to increase awareness in health care.

#### 4.2 Green Building Occupants Preference in Mature Property Market

Green building is the sustainable construction developments' foundation. The United Nations (1987) explains that "sustainable World development is a collection of methods in order to relieve poverty, create the equitable standards of living, satisfy the basic needs of all peoples, and set up sustainable political practices all while taking the steps essential to avoid irreversible damages to be natural environment in the long-term".

Environmental is one of the factors to be take into account in determine housing property value. Initially, selling price, occupancy rate and rental rate are inter-related. When the demand for house increases, consequently there will be an increase in the rental rate, as the supply for housing in the short run is fixed. This will attract investor to purchase building as an investment and in due course as there is limited supply, the price for the building will increase [16].

Due to the increase of price in the green building, investors find it profitable to build new green building, hence increasing the supply in the long run. Occupancy and take up rate is dependent on the tertiary activity of national economies. Where there is an increase in the tertiary activity of the economy, it will reflect in the increase in demand for housing, hence it increases in occupancy and take up rate of existing green housing.

The main difference between green office building and conventional building is the green features implemented on the building and they are given green certification according to their degree of green features. In order to determine the greenness of the building, various countries have their green accreditation agencies that are responsible in calibrating the green standard features. The green eco-labeling has a positive impact on the market and rental value [17, 8, 19, 20, 21]. At the local context, there are no studies yet to reveal that green eco-labeling give a positive impact on the market value and rental value.

There are several studies and articles that been measuring the impact of sustainable design features or of particular aspects of environmental aspects on the building market value [22, 10, 7] However, there still far behind the resolution and finding which can be concludes that their direct impact of these design features.

For instance, generally there are many researchers focused that on the energy efficiency green features impacts rather than

others criteria. The virtuous circles of green features impacts are consist of:

1. The 3 classifications of main drivers in green investment are consist of external drivers, corporate drivers and property level drivers , these three are responsible to assist to create opportunity to real estate. In green investment, investor could indicate that green property fetched a higher in market value compared to non-certified buildings [17, 20, 19, 8]
2. In energy efficiency building, it shows that this type of building quantify the added value i.e. green office building are 64 percent higher in sale price while Energy Star rated buildings were approximately 15 percent higher prices [23].
3. Certified green building and higher green index building had more environment friendly features and commanded a higher rental premium as well as fetched relatively higher in rental income [17, 20, 19, 8]
4. Precisely, the green office buildings indicates 36 percent higher in rental rates while Energy Star rated buildings were approximately 8 percent higher in rental income compared to non-rated building [23]
5. LEED and Energy Stars rated office building fetched better occupancy rate [24] and green building reported to be 5 percent higher occupancy rates compared to conventional buildings.
6. US building owner indicates that energy efficiency building will assist in increasing building value [18] and large proportion of residential property market participants consider the buildings energy consumption as an important criteria when deciding to buy or rent a flat.
7. On other hand, World Green Council stated that green building practices can reduce a building's operating costs by as much as 9 percent, increase building values by 7.5 percent and realize a 6.6 percent increase in return of investment.

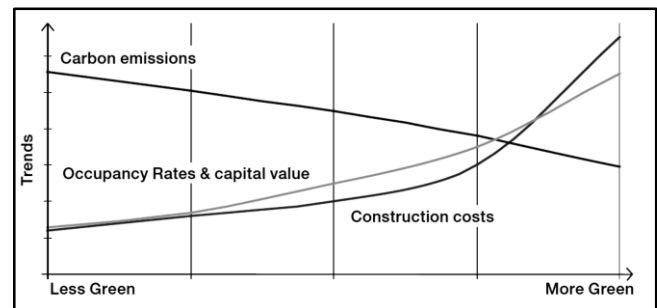


Figure 1 Initial impact of green building

Figure 1 above demonstrates that the interrelations of the Green features level with occupancy rate and capital value and construction costs. The graph illustrate there are directly proportional and positive impact between green aspects and capital as well as the occupancy rate. However, the construction costs are relatively increased as the more green trends promoted.

Table 5 below summarized the discussion and synthesis of impacts of green features to the property price, occupancy rates as well as other property market in line with the occupant satisfaction.

**Table 5** Discussion on impacts of IEQ on property market

Author(s)	Methodology and Approach	Key Findings (Property Market)
Eichholtz, P., Kok, N., & Quigley, J. (2009)	494 of the Energy-Star-certified rated green office building in The US.	Will drive to increase rental bids from potential occupiers. Green rating rental rates 3% higher sq. ft. Premium effective are higher- above 6%. Selling price higher 16%.
Papargyropoulou, E., Padfield, R., Harrison, O., Preece, C. (2012)	Six semi-structured interviews with representatives from three engineering consultancies offering sustainability services for the Malaysian.	Development will achieve for lower operational costs and higher value of the building that aim to balance off the costs over the building's lifetime.
Fuerst, F., and McAllister, P. (2009)	Investigates the effect of voluntary eco-certification on the rental and sale prices of US commercial office properties. Hedonic and logistic regressions	LEED and Energy Star buildings Exhibit higher rental rates and sales prices per square foot.
Harrison, David and Seiler, Michael. (2011)	To examine whether rental premium accrue to environmentally certified office buildings in US. Literature review	Both higher rents and lower vacancy rates for green buildings relative
Pivo, G., Fischer, J. (2008)	Examines 1119 of office properties throughout the USA using NCREIF data.	336 green office buildings and 1114 non-green buildings in the USA. 5.9% higher net income, 9.8% fewer utility expenses, 4.8% higher rents and 13.5% higher market values
Matthiessen, L. F. & Morris, P. (2007)	A total of 221 buildings were analyzed included academic buildings, laboratories and libraries, community centers and ambulatory care facilities in US.	A study in the USA green building can command higher rents and prices, attract tenants more quickly, reduce tenant turnover and cost less to operate and maintain

## ■ 5.0 INDOOR ENVIRONMENTAL QUALITY CRITERIA AFFECTS RESIDENTIAL PROPERTY MARKET

As discussed in previous subchapter, there are indirect connection among IEQ element and the contribution to residential property price. We simply base our paper on the four main elements in IEQ, which are 1) thermal (temperature and humidity); (2) noise comfort; (3) indoor air quality (air movement CO<sub>2</sub> concentration); and (4) lighting will be discussed the interrelation and chain process that cause changes and different occupant paradigm about the indoor environmental quality and property price and value.

While the commercial green building has shown and given attention to the role of environmental quality on property value, it is yet to be ascertained whether the same occurs in a residential property market. Residential property market often associated with the sale and rental of land and housing to individual and families for a day living. The price paid for a property differences in people's desirability based on the individual preference and sense of place and comfortability rendered by the property. [25]. From human ecology perspective, the comfortable and satisfaction building indoor characteristics is important since peoples' were spend most of their time in the building especially in their home.

As a result of occupants are now more conscious of the importance of sustainability for a better quality of life. Good thermal environment is essential for human wellness and comfort. Hence, the residential developments modify the materials, structure and energy balance in urban climate effects of human economic activities. A study has disclosed that the indoor thermal

environment should be designed to maximum human productivity and performance. Thus, accounting for indoor environmental is important in assessing people's willingness to pay.

In particular, as indoor environment is influenced by outdoor condition, the factors affecting indoor thermal environment are crucial in improving a comfortable and healthy environment in residential building [26]. Basically, excellent and energy efficient indoor environmental conditions has significant impact and people are willing to pay for proper ventilation indoor. In fact, based on the findings it could be estimated that asset value of buildings with excellent indoor environment is 10% higher that with the standard buildings with high quality indoor environment the occupancy rate is approximately 10% higher and the rent is 5% with the standard building.

Good indoor environment improves the occupancy of the buildings. The highest effect was achieved with air quality where the percentage of dissatisfied decreased. [27]. A study emphasizes that a clear correlation exists between sustainability and asset value premium.

**Table 6** Discussion on impacts of IEQ on residential property market

Study/ Authors	Country	Property Type	+/- Magnitude	Impact on
Brounen and Kok 2010	The Netherlands	Residential Homes	+2.8%	Selling Price
Salviet. al. 2008	Switzerland	Residential Homes	+7%	Selling Price
City of Darmstadt Rental Index 2010	Germany (Darmstadt)	Residential multi-family houses	+0,50 €/m <sup>2</sup>	Rental Price
Salvi et. Al, 2010	Switzerland	Residential Flats	+6%	Rental Price

This article provides new insight on the economic value of indoor environment based on recent research results. Based on the findings it could be estimated that asset value of buildings with excellent indoor environment is 10% higher than with the standard buildings and the premium is likely significantly increase in the 5 years. Moreover, in buildings with high quality indoor environmental quality and the occupancy rate is approximately 10% higher and the rent is higher than with the standard building.

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