Registration ID: 2440.

ISKL: Advancing Sustainability in Tropics

ABSTRACT

The new International School of Kuala Lumpur (ISKL) is designed to be near zero carbon emission, near zero potable water use, near zero solid waste to landfill while incorporating permaculture strategy.

Near zero carbon emission target will primary be achieved via reducing the energy index of the building below 50 kWh/(m².year). A photovoltaic is then placed on the roof to provide most of the energy that is required.

Near zero potable water use will be achieved via rainwater, greywater and condensate harvesting. In addition, very efficient water fittings will be used. Harvested rainwater, greywater and condensate water will be treated and used for the cooling tower, irrigation and toilet flushing.

Near zero solid waste to landfill will be achieved via an anaerobic digester system where it will harvest all organic waste from the kitchen, cafeteria's leftover foods and landscape trimmings, into methane gas, high nutrient soil and waste water. Methane gas will be diverted to the kitchen for cooking hobs, while the high nutrient waste water will be used for irrigation of landscape. Soil produced will be used in the landscape. All other solid waste will be segregated and recycled.

A permaculture strategy in put in place with the planting of local fruit trees surrounding the building perimeter. Stingless bees are then introduced to promote pollination of fruits trees. Flowering plants will be planted in between the trees to maintain the bees within this area. Organic vegetable gardens is planted on the roof to provide fresh vegetables to the school cafeteria.

Keywords: High-performance building; Sustainable neighbourhood; Permaculture

1. INTRODUCTION

The construction of large building is an essential part of any major city's development. As world's population migrates from rural to urban areas, it is almost certain that cities will grow in size and density. According to the World Bank, urban population in Malaysia increased from 67% in 2006 to 74% in 2014 and it continues to be on the uptrend. The growth in urban population spurs the demand of more buildings in the city. However, the conventional construction method of buildings has an adverse effect on the environment. It is a major consumer of raw materials, generates waste, consumes energy and emits greenhouse gases. That is why sustainable construction and green buildings have become an important part of the construction industry in Malaysia since 2009 (Suhaida, Tan, & Leong, 2013).

ISKL is a proposed international school located at the heart of Kuala Lumpur city in Malaysia. Construction of the building started in 2016 and targeted to be completed by the end of 2018. The school will have a capacity for 2500 students covering early years, elementary, middle, and high school. The whole campus consists of clusters of low rise buildings. This includes a 5 storey administrative building with library, sports, and academic facilities and a cafeteria. There are also 5 teaching blocks with 3 or 4 storeys each, a gym and a performing arts centre.

The proposed new International School of Kuala Lumpur (ISKL) is designed to push the boundary of sustainability from all design angles holistically.

2. ENERGY EFFICIENCY

Building Energy Intensity (BEI) value is widely used as an indicator of a building's energy consumption in this region. The BEI unit is kWh/(m2.year) representing the total energy consumed per year over the gross floor area of a building. ISKL's BEI target is 50 kWh/(m2.year). The international average for schools in tropical/sub-tropical climates is 120 kWh/(m2.year) (Sharp, 1998). Therefore, ISKL aims to consume about 58% less energy than the international average.

IES<VE> software, was used to simulate each design improvement and its impact in reducing energy consumption for this project. The targeted strategies are as provided below:

- *Daylight Harvesting:* improves energy efficiency by 6.3%. Greater details are provided section 5 of this paper.
- *Additional Roof Insulation:* improves energy efficiency by 3.5%
- *Improved Wall Insulation:* improves energy efficiency by 2.3%
- *Low-E Glazing:* improves energy efficiency by 3.2%.
- *Air Tightness:* reducing infiltration rate from 0.5 air change per hour (ACH) (Ezzuddin & Tang, 2010) to 0.1 ACH improves energy efficiency by 2%.
- *Lighting Power Density:* reduced lighting power density for all area as compared to Ashrae 90.1 values. Improves energy efficiency by 6.5%
- *Air Conditioning Air Side:* improves energy efficiency by 10.1%.
  - Variable air volume (VAV).
  - Low Duct Static, larger ducts and less bends of 450 Pa.
  - Air filter with low pressure loss of 100 Pa.
  - Airfoil profiled fan with > 80% efficiency.
  - Carbon dioxide (CO_2) sensor and control system for fresh air.
  - Heat recovery system on all teaching blocks. Fresh air requirement is high due to the population density in school.
- *Air Conditioning Water Side:* improves energy efficiency by 9%.
  - A high delta-T of 10°C chilled water and condenser water.
  - Lower pump head of 25m with pipe size, reduce bends, tees, etc.
  - Variable speed motor to vary flow rate according to demand.
  - High efficiency chiller with a rated COP of 6.5.
  - Variable speed chillers for better part load efficiency.

  - Cooling tower efficiency reduced to 0.0275 kW/HRT.
- *Radiant Chilled Slab System:* potential for another 12% improvement
  - A radiant chilled slab system is proposed for all classrooms/teaching spaces in the teaching blocks. Classrooms are cooled by circulating water through concrete slab embedded cross linked polyethylene (PEX) pipes. Water has a thermal capacity of 4.2 kJ/kg.K, which is more than 4 times more thermal heat capacity than air. Therefore, to provide the same amount of cooling, water requires 4 times less mass flow rate compared to air for further fan power reduction.
  - The chilled slab system is operated together with the AHU (air handling unit) system to remove humidity and provide fresh air to the spaces. However, since the slab provides 50% of the cooling, the air flow required from AHU is reduced by approximately 50% too as shown in Figure 1.
  - The chilled slab is also a thermal storage system that are charged during night time, utilizing lower electricity tariff.
  - Finally, a chilled slab offers a lower mean radiant temperature, allowing the air temperature to be raised.
  - Ceiling fan is proposed as a mean to increase air speed in the classroom to enable a higher air temperature to be provided while maintaining comfort.

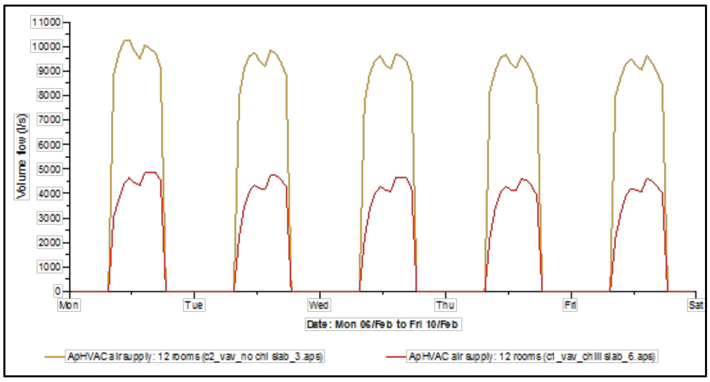

Figure 1. Simulation results showing that air flow rate of a conventional VAV system in orange compared to a chilled slab/VAV system in red

3. RENEWABLE ENERGY

Renewable energy is provided by photovoltaic solar panels. Due to budget constraint, the initial set of PV panels shall be placed on the roof of the spine block over a space of 2,500 m2. This is adequate for a minimum of 250 kWp generating up to 275 MWh of energy per year; providing up to 5% of the school's energy needs.

4. WATER EFFICIENCY

Strategies for water efficiency includes water efficient fittings, rainwater harvesting, grey water recovery, and condensate water recovery. The baseline water demand was estimated for ISKL and shown in Table 1. Combined baseline consumption is estimated to be 92,883 m3 per year. Baseline consumption is based on fixture performance standards of the International Plumbing Code (International

Code Council, 2012). With the strategies described below, total water demand is reduced by 47% to 49,489m3 per year.

Table 1. ISKL's baseline and design water demand

Items	Demand per year (m^3/year)	ISKL's design consumption (m^3/year)
Occupant Use	21,838	5,745
Landscape Irrigation	46,621	22,182
General Washing and Cleaning	725	725
Cooling Tower Make-up Water	16,253	13,391
Swimming Pool	7,445	7,445
Total	**92,883**	**49,489**

- *Water Efficient Low Flow Fittings:* Table 2 shows annual consumption with conventional/baseline fittings (International Code Council, 2012) while Table 3 shows annual predicted consumption with efficient fittings. Fittings labelled under the WELS (Water Efficiency Labelling Scheme, 2014) Table 4 have a much lower flow rate compared to conventional fittings. Consumption from water fittings reduces from 21,838 m3/year to 9,009 m3/year, a reduction of 59%.

Table 2. Baseline water fittings demand with conventional fittings.

Flush Fixture	Daily Use	Flow Rate (Liters/flush)	Duration (Flush)	Occupants	Water Use (m3)
Water Closet (Male)	1	6.00	1	1300	7.80
Water Closet (Female)	4	6.00	1	1300	31.20
Urinal (Male)	3	3.80	1	1300	14.82
				Subtotal	**53.82**
Flow Fixtures	**Daily Use**	**Flow Rate (Liters/sec)**	**Duration (Sec)**	**Occupants**	**Water Use (m3)**
Lavatory Faucet	4	0.15	15	2600	23.40
Café Faucet	3	0.15	15	2600	17.55
Kitchen Sink Faucet	3	0.15	1800	10	8.10
Showerhead	1	0.21	60	1000	12.60
Ablution	2	0.15	30	650	5.85
		Subtotal			**67.50**
		Total Daily Volume			**121.32**
		Annual Working Days			**180**
		Total Annual Volume			**21,838**

Table 3. Design case water fittings demand with water efficient fittings.

Flush Fixture	Daily Use	Flow Rate (Liters/flush)	Duration (Flush)	Occupants	Water Use (m3)
Dual Flush WC (Male)	1	4.00	1	1300	5.20
Dual Flush WC (Female)	1	4.00	1	1300	5.20
Dual Flush WC (Female)	3	3.00	1	1300	11.70
Urinal (Male)	3	2.00	1	1300	7.80
				Subtotal	**29.90**
Flow Fixtures	**Daily Use**	**Flow Rate (Liters/sec)**	**Duration (Sec)**	**Occupants**	**Water Use (m3)**
Lavatory Faucet	4	0.032	15	2600	4.99
Café Faucet	3	0.032	15	2600	3.74
Kitchen Sink Faucet	3	0.062	1800	10	3.35
Showerhead	1	0.100	60	1000	6.00
Ablution	2	0.053	30	650	2.07
				Subtotal	**20.15**
		Total Daily Volume			**50.05**
		Annual Working Days			**180**
		Total Annual Volume			**9,009**

- *Rainwater Harvesting:* Malaysia sees rainfall consistently throughout the year. Harvested rainwater is used for the landscape irrigation demand. An in-house rainwater harvesting simulation software was used to calculate the rainwater tank size; based hourly rain fall data from Meteonorm (Meteotest, 2015). Tank size is estimated by measuring hourly rain fall data against daily irrigation needs.
- *Grey Water Recycling:* Grey water is collected from all wash basins. Table 3, showed water collected from all basin faucets amount to 20.15 m3 per day. Recovered grey water will be used to serve all water closets in the building.
- Condensate Water Recovery: Condensate water is the water collected from the cooling coils from all the AHUs in the building. The amount of condensate water that is recovered is calculated from the latent load of simulation study with the latent heat of vaporization of water.

5. DAYLIGHT HARVESTING

A daylight harvesting strategy was implemented as part of the design. This includes daylight sensors at the building perimeter of each floor, and a window design to draw daylight into the classroom without glare. The window design consists of horizontal venetian blinds and light shelves as shown in Figure 2. Horizontal venetian blinds acts as glare protection devices by blocking direct views of the sky while allowing daylight in. External light shelve with a reflective top surface is placed to reflects daylight deeper into the room ceiling.

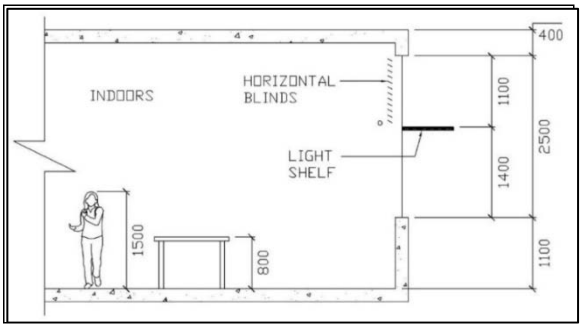

Figure 2. Cross section of the window design for classrooms

The daylight factor (DF) criteria used for ISKL is in the range of 0.5% to 3.5% for classrooms. In Malaysia, with a daylight factor of 0.5% will provide over 70% of the hours of 8am to 6pm a illuminance level higher than 100 lux. For DF above 0.5%, close to 100% of the hours of 8am to 6pm will have illuminance level higher than 100 lux (Tang & Chin, 2013). Daylight simulation software Radiance was used to simulate indoor daylight conditions to achieve these conditions.

6. INDOOR ENVIRONMENTAL QUALITY

Besides providing good daylight quality for the classrooms, ISKL is designed to meet the requirements of ASHRAE 55 and ASHRAE 62.1. These standards provide guidelines for thermal and environmental conditions for human occupancy and also acceptable indoor air quality. In addition, MERV 13 air filters will be installed for filtration of PM 2.5 particles.

7. SOLID WASTE REDUCTION

ISKL's goal is to reduce waste to landfills by 90%. The existing ISKL campus in Kuala Lumpur diverted nearly 40% of waste in the 2014 to 2015 school year (The International School of Kuala Lumpur, 2015). Waste such as paper, plastic, aluminium, glass and used cooking oil can be easily segregated and recycled, as there are facilities in Kuala Lumpur to collect and recycle these items.

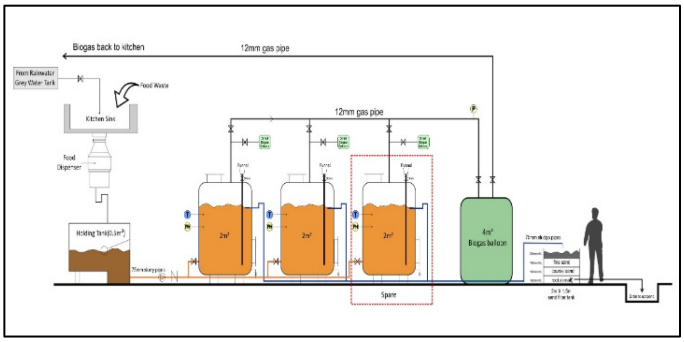

Figure 1. Concept schematic of the anaerobic digester in ISKL

The other form of waste is organic waste from the kitchen and landscape. The new ISKL proposed an anaerobic digester system to treat organic waste on-site to target 90% waste reduction. The anaerobic digester also serves as an educational demonstration to students in the school. An anaerobic digester is basically a system with microorganisms that break down organic waste in the absence of oxygen. The process then produces a biogas that are used as partial fuel for the cafeteria. By-product of the process is a nutrient rich digestate that can be used as fertilizer.

Figure 3 shows a concept schematic of the anaerobic digester. Kitchen sink and food waste dispenser. Organic food waste from the kitchen is disposed into the food waste dispenser (grinder) and flushed down with rain water or grey water, as a slurry mix into a holding tank below the sink.

8. URBAN FARM AND PERMACULTURE

An urban farm is a great solution to reduce the cost of transportation of foodstuff; reducing the carbon footprint associated with food production. In the case of ISKL, the urban farm is targeted to introduce the concept of urban farming and permaculture to the students and community.

Permaculture is a concept of “ecological” design that blends in various eco-system together in a sustainable manner as presented below:

Vegetable garden on the rooftop. Sting-less bees are introduced as a pollinator. Flowering plant with high nectars will be planted to keep bees at the site. Local fruit trees such as soursop, rambutan, papaya, or chiku will serve as an ideal perimeter trees around the campus and pollinated by bees. Crops rotation implemented to maintain the quality of the soil. Finally, the grounds are fertilized by disgestate from the anaerobic digester and watered by harvested rainwater.

Crop yield is calculated to be 4,100 kg of vegetables per year and 1,400 kg of fruits per year of fruits (Mobbs, 2002). This is based on a total farm size of 1000 m2 on the roof.

9. RESULTS AND DISCUSSION

Results of simulation conducted are provided in the subsections below:

9.1. Energy Efficiency

At full operating capacity of 2,500 students, simulated results gives a yearly energy consumption of 5,380 MWh. This is a BEI value of 56 kWh/m2 per year. Simulated results are approximately 53% lower than the international average (Sharp, 1998). Photovoltaic panels will provide up to 5% of the school’s energy needs.

The simulated BEI results is slightly above the target of 50 kWh/m2 per year. The technical team are looking into further operational strategies to further reduce energy consumption.

9.2. Water Efficiency

Occupant water usage is simulated to reduce by 74% from 21,838 m3 to 5,745 m3 per year. This is contributed by two water efficiency strategies; low flow water fittings and grey water harvesting.

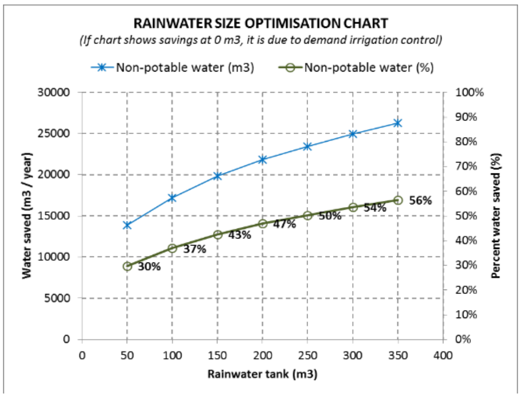

Figure 4. Rainwater harvesting tank chart

Landscape water usage shall be reduced by using a rainwater harvesting system. Figure 4 shows the results of the rainwater harvesting software calculations. The chart shows two patterns. Firstly, non-potable water (rainwater) collected in a year. Secondly, percentage of non-potable water (rainwater) from overall irrigation water demand. From the chart, we can see that if a tank of 250 m3 is used, 52% of the landscape irrigation needs will be met by non-potable rainwater. Which is equivalent to a saving of almost 24,439 m3 of water a year.

Condensate water collected per day is calculated to be 15.9 m3 per day. The average condensate water collected in a year is 2,862 m3 which reduces cooling tower water demand by 17% to 13,391 m3 per year.

Therefore, total water demand is reduced by 47% from a baseline of 92,883 m3 per year to 49,489m3 per year.

9.3. Daylight Harvesting

Results of the daylight simulation is shown in Figure 5. The chart shows that for Level 4, natural daylight can light up to 7m of the classroom from the perimeter of the building. This is nearly the whole width of the room. For Level 3, up to 6m is available, Level 2; 4.5m and Level 1; 3m. The classroom at lower levels have considerably less daylight indoors because of shading from adjacent buildings. Overall, it was simulated that 65% of the classrooms' artificial electrical lights can be switched off.

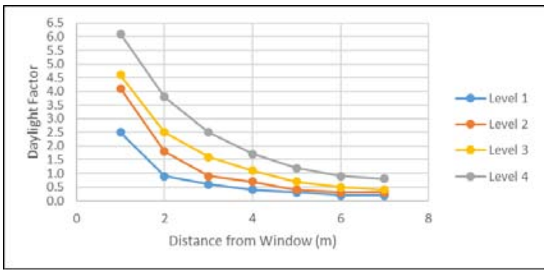

Figure 5. Daylight Factor results for a teaching block

9.4. Anaerobic Digester

The computed quantum of generation is small compared to overall kitchen needs. It is calculated that the system provides 1% to 3% of total kitchen needs. After a digestion period of 30~40 days, the system will produce about 150kg to 200kg of digestate a day at steady state operation. This digestate is used within the landscape area of the school, or bagged up and sold to nearby nursery.

10. CONCLUSION

The new ISKL campus strives to be a holistically sustainable school. Simulation software was used in the design process to quantify design parameters and results. Simulated energy consumption in terms of BEI is calculated to be 56 kWh/m2 per year.

Simulated daylight results show that 65% of the classrooms' artificial lights can be switched off. And designed water demand is reduced by 47% from baseline estimations. Zero waste will be targeted during operation of the school by digesting all organic waste produced, in addition to recycling all solid waste.

Permaculture concept of a urban micro-ecosystem is targeted to be implemented by the school upon completion of the construction of the building by the school themselves.

As the project continues from design to construction and then to operation, it is important that the design intend continues on as well. Strategies will be put in place to ensure all sustainability targets are met throughout the development of the school.

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