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Comparison of Zero Energy Building from Different Climates

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Abstract: **A Zero Energy Building (ZEB) is a residential or commercial building that consumes its required energy from sources that are renewable with less energy consumption through the use of efficient technologies such that the balance of energy needed can be supplied with renewable technologies. In this paper four samples of existing building in two different climates (temperate and tropic) will be examined to explore the strategic differences of zero energy buildings in these climates.**

The paper will analyze the zero energy buildings in terms of climatic differences, the strategies used in each of these climates. Four well documented cases studies from two different regions of the world are studied, in terms of their floor types, window systems, façade design and Passive design orientation. The findings from these case studies will be used to identify the large difference between these buildings.

Keywords: **Zero Energy Building, Façade Design, Passive Design Orientation, Window System, Photovoltaic and Floor Structure.**

1. INTRODUCTION

A Zero Energy Building (ZEB) is classified as a building that produces enough renewable energy to meet its own annual energy requirements, through the reduction in the use of non-renewable energy sources such as fossil fuels. The principle behind Zero Net Energy consumption is to reduce the dependence on fossil fuels and carbon emissions. ZEBs usually harvest energy on site through technologies such as wind & solar and using efficient lighting technologies and HVAC to reduce the use of energy. The ZEB concept is becoming gradually popularity as the prices of fossil fuels increases worldwide and alternative energy technologies decreasing.

Buildings have played a significant impact on the consumption of energy. Almost 40% of energy generated is consumed by commercial and residential buildings and approximately 70% of electricity (EIA 2005). The energy used by the building sector continues to increase, primarily because of the increased rate in the construction of newer buildings is higher than that of old ones been retired. The consumption of electricity in commercial building sector has doubled within 1980 and the year 2000, and this number is expected to double by the year 2025 (EIA 2005).

Energy consumption from buildings will have to be reduced drastically in the future to combat climate change and to reduce use of fossil fuels. In a few years time, buildings are going to be developed with very low or zero consumption of fossil fuel. Reduction in a buildings energy consumption is a step that occurs in the process of the building's design. (Vieira, 2006) New technologies are being developed from different regions of the world, harnessing to the nature of the environment.

Advantages of zero energy buildings are:

- The increase of energy cost on conventional buildings is relative to the value of ZEBs.

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- Lower environmental impacts.
- Less operating and maintenance costs.
- Improved energy security.
- Less damages in the occurrence of natural disasters and electricity disruption.
- In the near future carbon emission taxes and legislative restriction may force expensive retrofitting of inefficient buildings.

Disadvantages of zero energy buildings are:

- Solar photovoltaic cells price falls by 17% per annual, this will lead to depreciation in value of capital invested in solar system.
- The lack of designers and skilled builders well experienced in building ZEBs.
- Requires effortless research.
- Resale cost may depreciate due to the constant gradual changes in energy rating systems.
- The use of solar energy only works in building envelopes that has no obstructions from the south.

2. CASE STUDIES

- PTM Zero Energy Building (Tropic Region)
- Centre for Sustainable Energy Technologies (Temperate Region)
- Mosaic Center (Temperate Region)
- BCA Academy (Tropic Region)

CASE STUDY 1: PTM Zero Energy Building:

Pusat tenaga Malaysia (PTM) building is located in Bandar Baru Bangi in south-west Malaysia. Construction started in March 2006 and was completed in July 2007. The PTM building is Southeast-Asia's first self-sustainable building and thus was designed to be energy efficient and consume a little amount of fossil fuels.

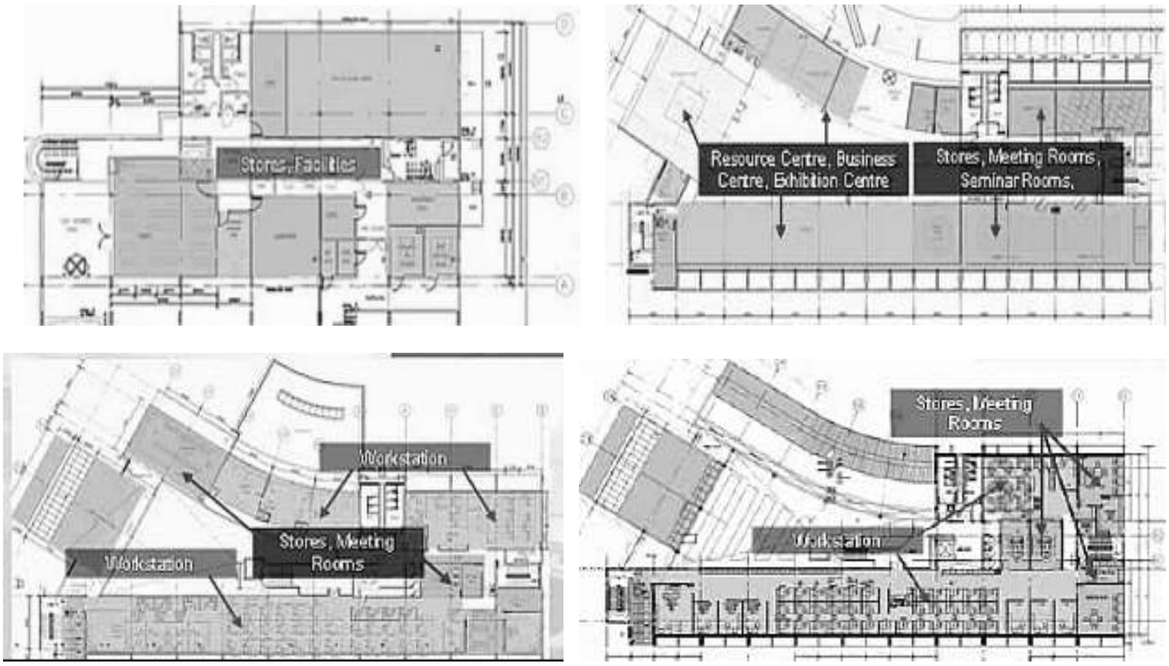

Fig 1: Malaysia Green Technology Corporation building's Floor Plans (Malaysia Green Technology Corporation, 2010)

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The lower ground level consists of the mechanical and electrical room, Main pantry and a Laboratory. The ground floor is mainly reserved for public spaces, where all the seminar halls, meeting rooms, exhibitions and library center are situated. The first floor consist of workstations, stores and meeting rooms, with the workstations placed near the windows for the purpose of natural lighting. Facility rooms and stores are located at the center of the building or near the western and eastern façade where it is not frequently used. The PTM (ZEB) building is noted as a timely solution to the issues of energy security and global warming. A high number of buildings in Malaysia record a high Building Energy Index (BEI) above the Energy Efficient Buildings (EEB) benchmark which is 135Kwh per square meter per year. In the PTM building four different solar Building Integrated Photovoltaic (BIPV) systems were installed. These BIPV systems include

A. 47.28kwp polycrystalline BIPV system on the main roof

B. 6.08kwp amorphous silicon BIPV system installed on the second main roof

C. The Atrium with use of 11.6kwp Monocrystalline glass BIPV system

D. The car park roof installed with 27kwp monocrystalline BIPV system

Fig 2: Integrated Photovoltaics (https://www.youtube.com/watch?v=kDdvL2N7LUI)

All these systems are connected to a grid-connected inverter that generates direct current (DC) into alternating current (AC) electricity. Meters are installed to monitor and record electricity generation. The PTM building has a total BIPV capacity of 92kwp, the annual anticipated target for solar BIPV IS 102mwh. The building utilizes passive techniques as well as orientation and vegetation with features such as efficient lighting system, floor slab cooling, double glazing windows and thermal wall at its east and west-facing facades.

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Building Orientation:

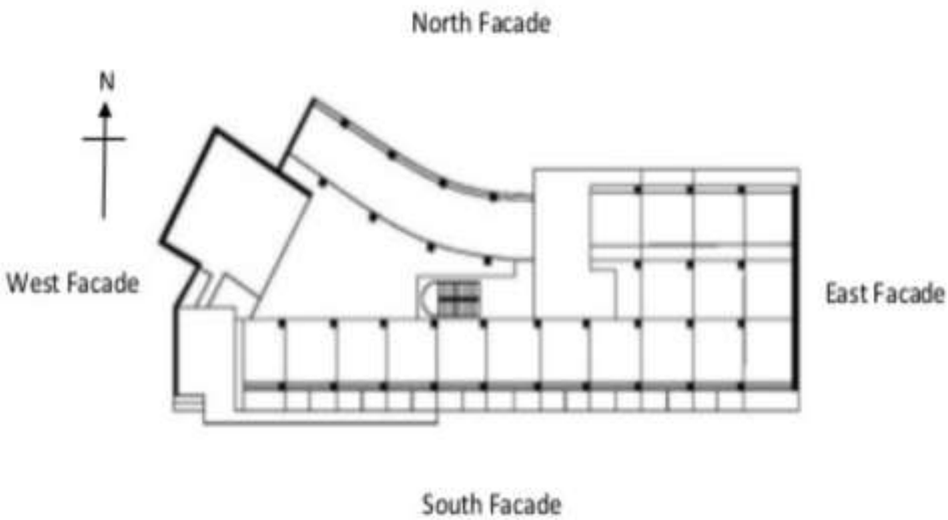

Fig 3: Building Orientation (http://www.slideshare.net/yassyed31/building-science-1-ptm-geo-2)

The PTM building is considered well orientated because of its long north and south facades, and shorter facades on the east and west. (Department of standards Malaysia, 2007, P.5) with this orientation direct sunlight only shines at the shorter façade in the morning and evening.

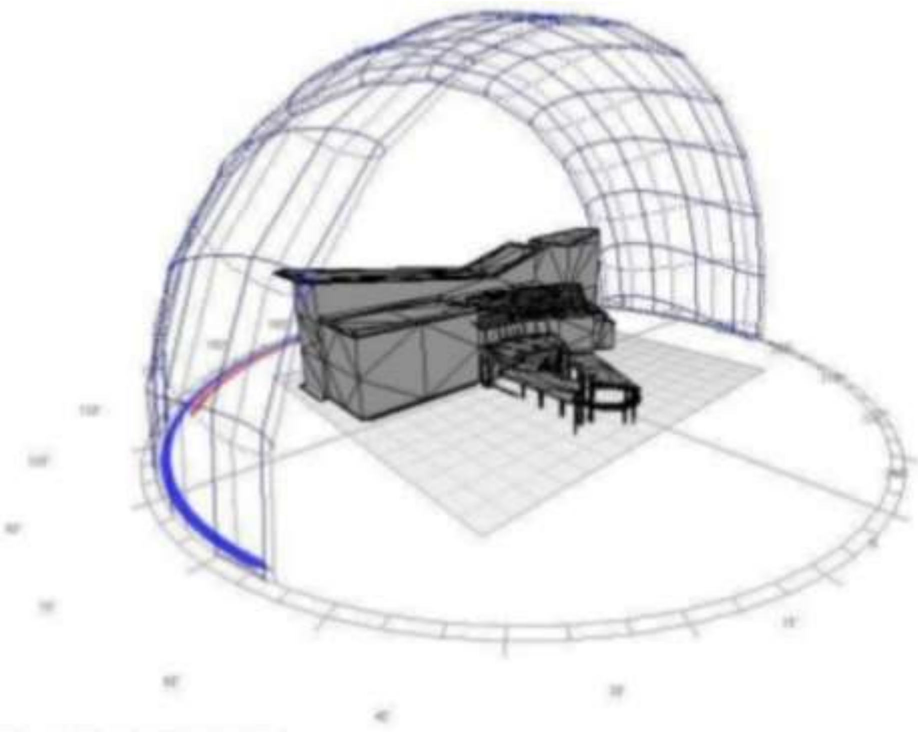

Fig 4: Geo Building Sun Path (http://www.slideshare.net/yassyed31/building-science-1-ptm-geo-2)

To avoid direct entrance of sunlight into the facades, this building is designed to have minimal windows at the eastern and western facades. The northern and southern facades are equipped with windows to allow maximum penetration of natural lighting into the building. Daylight that enters the building through the long facades is diffused light, which has lesser thermal impact if compared to direct sunlight. With this strategy, thermal comfort is achieved. (Ng & Akasah, 2011, p.)

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Fig 5: East and west facades with minimum windows (http://wikimapia.org/619168/PTM-GEO-Building)

Fig 6: North and South facades http://www.greenbuildingindex.org/why-green-buildings.html)

Facade Design:

Fig 7: Extended vertical walls (http://www.greenbuildingindex.org/why-green-buildings.html)

The PTM building has a façade with a “step-in” as the floor level goes higher. This design enables the building to be self-shaded by its own structure. (Ng & Akasah, 2011, p. 221) The section below shows the width of each floor increases as the floor goes higher by a meter per floor. The idea behind this logic is to control the glaring from direct sunlight, vertically erected walls were created to serve as shading device. The glaring control and shading is helped overhangs installed.

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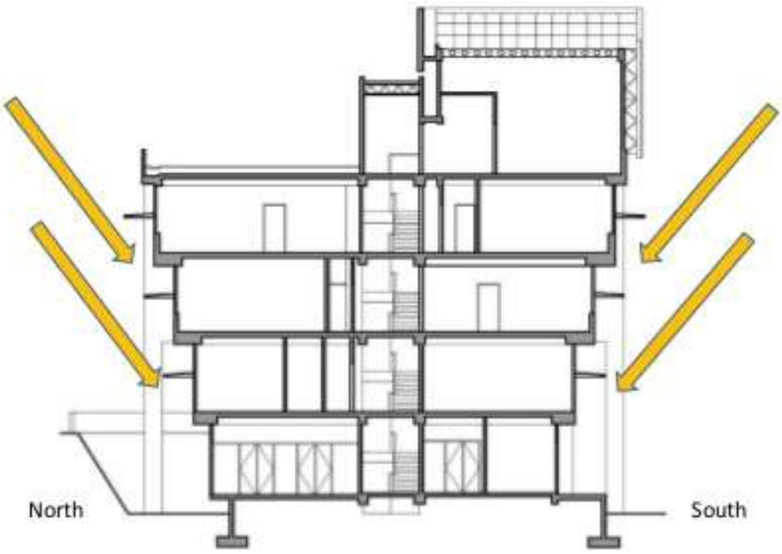

Fig 8: Section (http://www.greenbuildingindex.org/why-green-buildings.html)

Windows are located along the facades of the building to minimize the use of artificial lights, roof lights are installed on the roof to produce natural lighting in the interior part of the building. The GEO building uses an open space design with its workstations placed near windows and the use of minial partition enables the influx of light to reach the workstations. (Pusat Tenaga Malaysia, 2008)

Windows:

The installation of high performance glazing and sealed double glazing windows was done to reduce heat gained in the interior part of the building. This window provides the ability to harness high visible light at Ultra-violet and low infra-red transmittance, hereby reducing the transfer of heat by 25%. With the use of radiant cooling through the floor slab and air-conditioning, there is a minimum difference of 7^0C between the indoor and outdoor temperatures. (Yoong, 2008, p. 67)

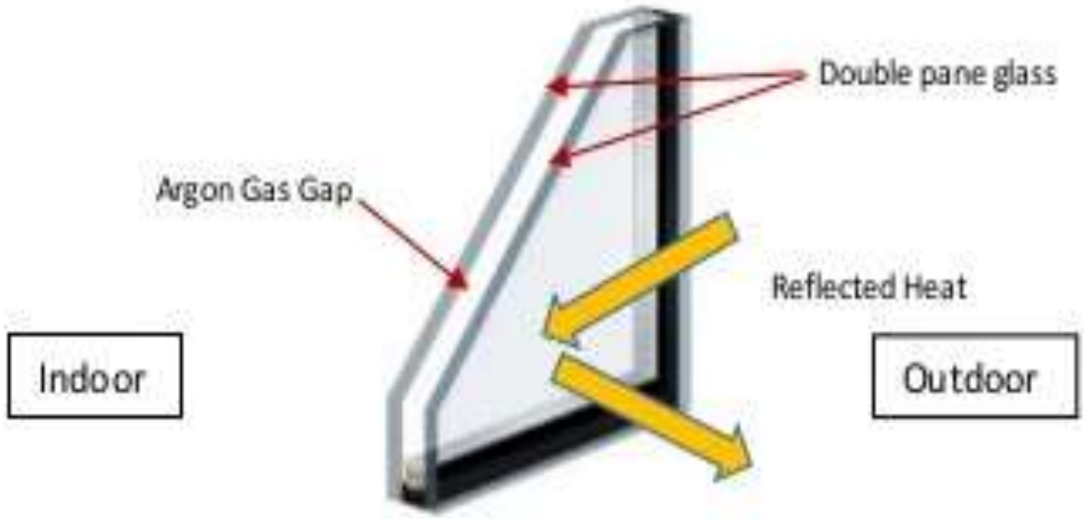

Fig 9: Double Glazing Window (http://www.slideshare.net/yassyed31/building-science-1-ptm-geo-2)

Daylight is available in Malaysia through the office hours 08:00-18:00. Daylight is available near windows, but not deep in the building. In order to achieve that in this building the sealed double glazed window was integrated with blinds. The blinds acted against direct view of the sky through the upper daylight window. However, light is reflected through an exterior shelf and blinds to the ceiling and further to the back of the room. The lower surface of the blinds is white with low gloss whereas the upper surface of the blinds is reflective aluminum to allow reflection. (Muhammad, 2014)

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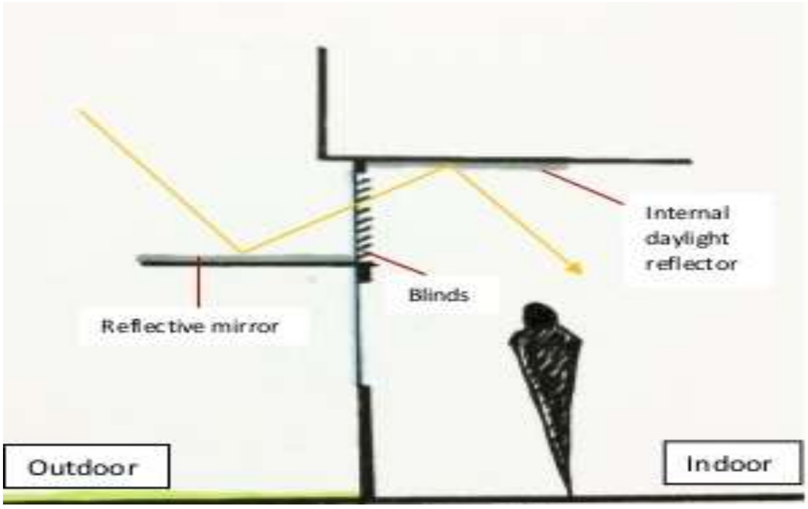

Fig 10: Diffuse light going through window (http://www.slideshare.net/yassyed31/building-science-1-ptm-geo-2)

Fig 11: Exterior Overhangs and internal reflector (http://www.slideshare.net/yassyed31/building-science-1-ptm-geo-2)

Roof Light:

Roof lights were installed on the highest level to distribute diffused natural lighting which compared to direct sunlight carries less heat energy. This was possible through the installation of mirror reflections on the insides of the structure which serve to magnify light.

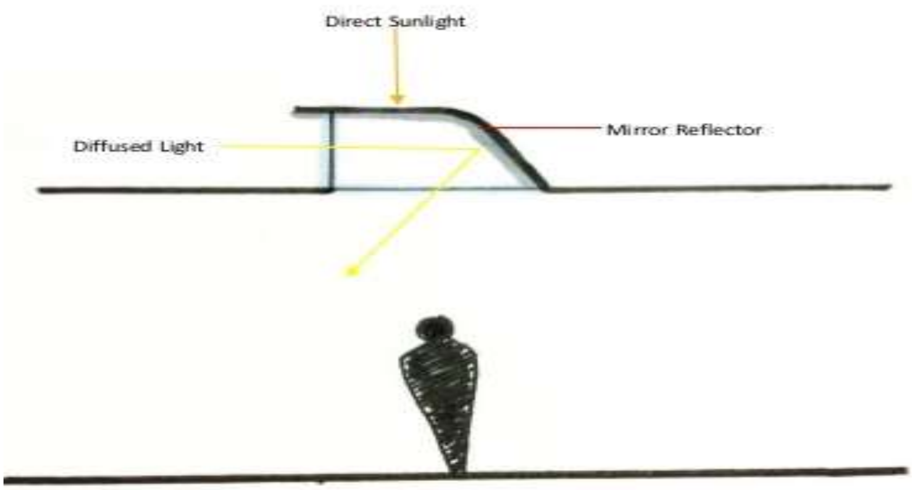

Fig 12: Pathway of diffused light from Roof light (http://www.slideshare.net/yassyed31/building-science-1-ptm-geo-2)

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Fig 13: Roof light (http://www.slideshare.net/yassyed31/building-science-1-ptm-geo-2)

Floor Slab:

The floor of the building is installed with embedded tubes with in the floor slabs, this provides a cooling effect role on the floor. During the day, the stored cooling effect is released to the rooms below and above them directly contributing to the cooling effect of the building, thereby supplementing air-cooling systems. Preservation of air quality was achieved by the process of dehumidification.

Fig 14: Manifold for PEX cooling pipes, and PEX pipes laid, before pouring of concrete. (Kristensen. P.E & Tang. CK & Reimann. G & Ismail. A.Z, 2008, p.225)

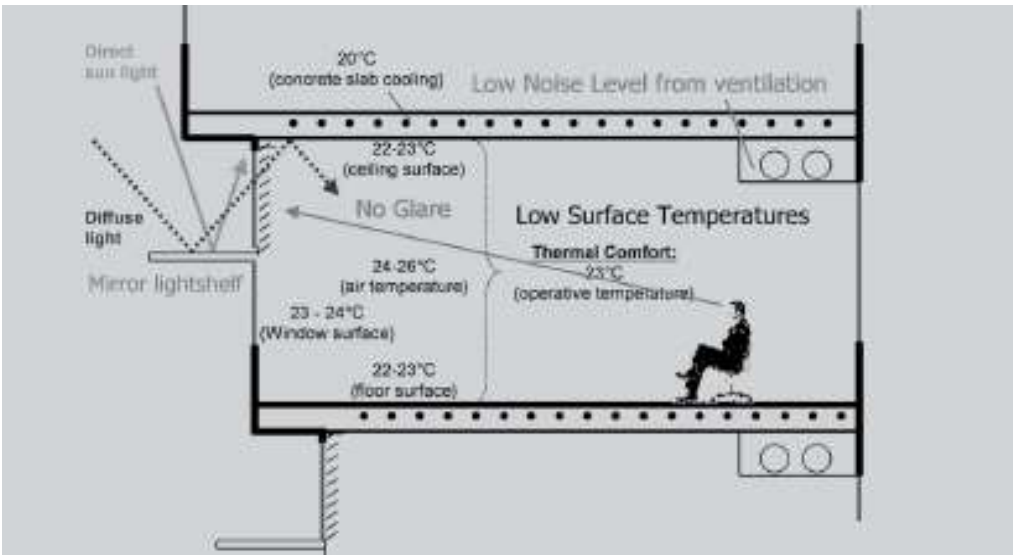

Fig 15: Indoor Temperatures (Yoong, 2008, p. 67)

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Lighting:

The most energy efficient lighting fixtures have been installed, using T5 fluorescent tubes with high frequency ballasts mounted in very efficient fixtures. Light is controlled according to demand in all zones of the building using a DALI control system. The use of daylight sensors assure that light is only on when daylight is insufficient and in rooms that are occupied.

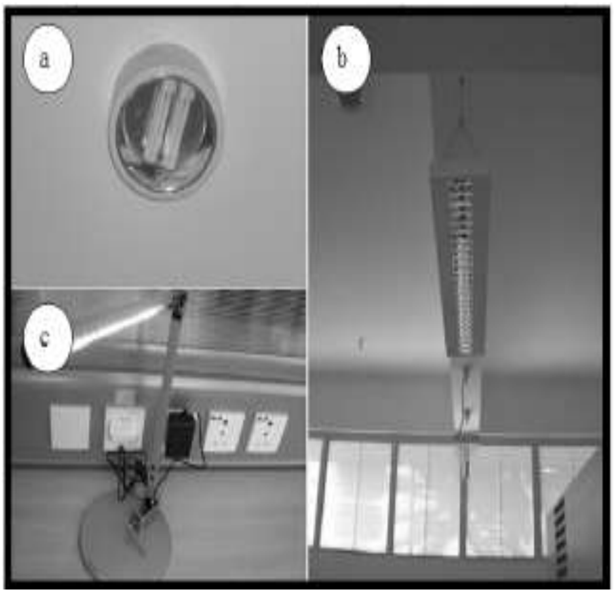

Fig 16: (a) Compact Fluorescent Light (CFL)

Fig 17: Current Fan Coil Unit (FCU)

(b) Fluorescent Light

(c) LED Light (Malaysia Green Technology Corporation, 2010).

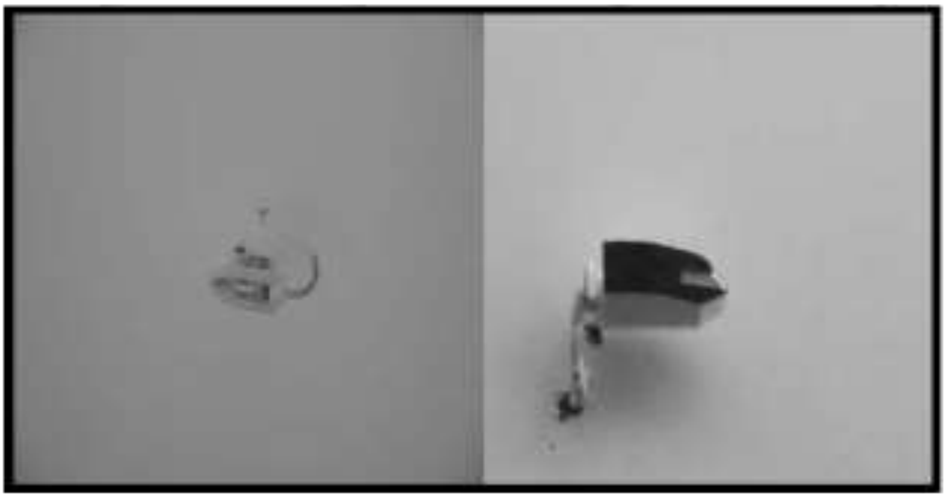

Fig 18: Daylight Sensor (Malaysia Green Technology Corporation, 2010).

Case Study 2: Centre for Sustainable Energy Technologies (CSET):

The university of Nottingham China, is located in china's northeastern city of Ningbo. In September 2008, the university completed a project called the Centre for sustainable energy technologies (CSET). This Centre was led by the university's department of built environment. It was designed to provide seminar halls, offices and laboratories that will make the structure serve as an exemplar building, reveals state-of-the-art-methods of construction in sustainability and environmental response. As the world's 2nd largest consumerof energy, saving energy is important to the Chinese social and economic development. (Altomonte, S. 2010)

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Fig 19: Perspective view (The university of Nottingham Ningbo, China, 2008)

The CSET building is China's first zero carbon building, with its design inspired by traditional wooden screens and the Chinese lantern. Twisting with the height of 22m, the CSET building is visible from all over the university campus. The building is designed with six floors, a semi basement and five floors with a total net area of 1,200m^2. The basement level serves as an exhibition space used in promoting the university's research. The first floor also contains an exhibition space with teaching and research halls located on the second and third levels. The CSET building also includes seminar halls and offices on the upper levels.

The building responds to diurnal and seasonal variations in ambient conditions by means of a five-point sustainability design strategy:

- High Performance Envelope
- Exposed Thermal Mass
- Daylight & Solar Control
- Natural Ventilation to tower
- Ventilation to the Workshop & Laboratory via pipes

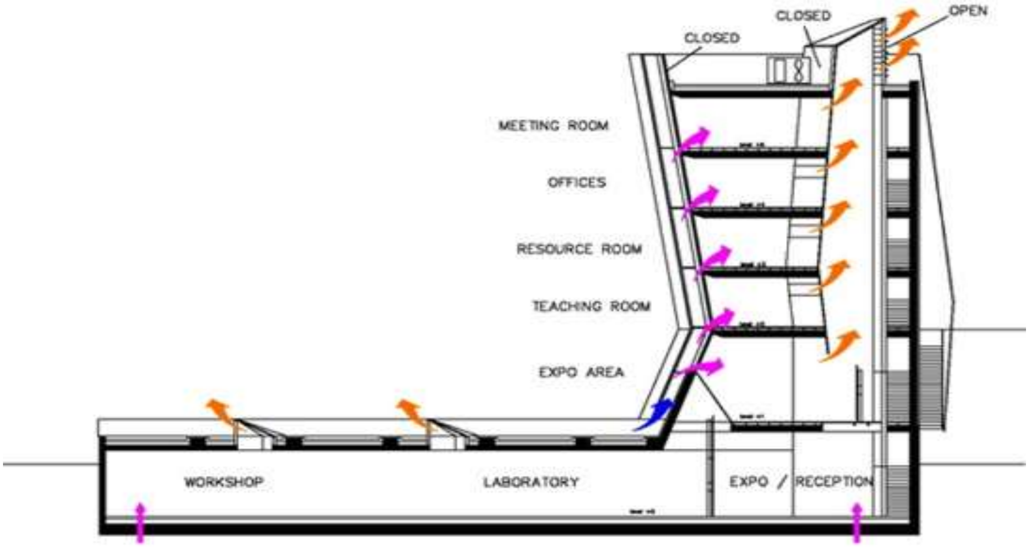

Fig 20: Section through the building (https://www.educate-sustainability.eu/mobile/print/3322)

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Passive Design Orientation:

The CSET building was designed with floor orientation facing north and south with no openings or glazing on the three other facades to avoid direct penetration of solar radiation.

Fig: 21: Solar Orientation (https://www.educate-sustainability.eu/mobile/print/3322)

Fig 22: The four elevations of the building with window opens on the north and south facades (https://www.educate-sustainability.eu/mobile/print/3322)

Building Envelope:

CSET's building envelope gives it a contemporary image but most importantly it helps control the passive strategies integrated in the building. To a certain extent, parts of the basement is glazed from west and east in order to utilize natural lighting and direct solar radiation. The facades are composed by a structural curtain wall system with pre-painted aluminum profiles and double glazing unis. The revolving door located at the main entrance on the east provides a barrier between the external and internal spaces. (Altomonte, S, 2010)

Fig 23: Building envelope (https://www.educate-sustainability.eu/mobile/print/3322)

Facade Design:

The façade is designed with concrete slab without any openable modules. With double glazing units that are designed with high performance glass that combines with the external façade providing the sufficient level of protection from solar radiation and thermal insulation, optimizing at the same the daylight level into the internal spaces. (Altomonte, S, 2010)

Fig 24: Facade (https://www.educate-sustainability.eu/mobile/print/3322)

Lighting and Photovoltaic System:

The CSET building was designed to exploit daylight. With the use of a glazed opening of about 100cm of height followed the building from the ground level on the west part of the building allowing the penetration of natural light to the inner spaces of the laboratory. Four inclined skylights serve as an opening for natural lighting. The inclined openings are orientated to the north and are triangular in shape. An opening on top of the roof provides natural light to all the floors. This opening brings about the flue effect contributing to the efficient natural ventilation.

Photovoltaic (PV) system is used in generating artificial light and efficient energy for office computers and equipment. During the day when the sun is at its peak, the PV produces enough energy to power mechanical ventilation, chilled water system and elevators. Extra energy not used is stored in batteries and later transferred to the campuses sport Centre.

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Fig 25: Section (The university of Nottingham Ningbo, China, 2008)

Fig 26: Glazed Openings (https://www.educate-sustainability.eu/mobile/print/3322)

Ventilation:

The building was designed to meet it conventional cooling and heating by the use of renewable energy sources, minimizing the need for extra energy to cool, heat and ventilate. The design also considered Ningbo's seasonal variations and diurnal, to cool during the summer and heat during the winter. Natural ventilation during the autumn and spring season, making the building well insulted. Been located in the temperate region, during the winter season additional heating required is done by pre-heating ventilated air and raising internal surface temperatures. During the summer, the concrete surfaces keeps the interior spaces cool. An additional cooling system helps in pre-cooling the ventilated air and when hot outside reduces the temperature on the surface. Air is supplied to the laboratory and workshop located in the basement level through the ground tubes and then dehumidified. The air is cooled by an air handling unit (AHU) located in the basement.

"During the Spring and autumn season, natural ventilation is provided in most spaces, controlled automatically by the means of vent opening gear within the perimeter glazing. During the summer, when it is both hot and humid, it is necessary to de-humidify and supply cool air, the process is powered by the photovoltaic system." (The University of Nottingham, Ningbo, China, 2008, p. 6)

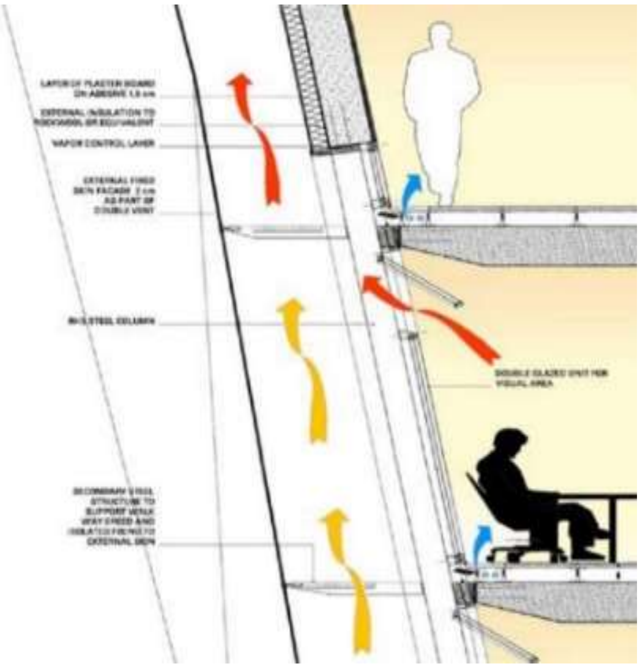

Fig 27: Ventilation System (https://www.educate-sustainability.eu/mobile/print/3322)

CASE STUDY 3: BCA ACADEMY:

Fig 28: Perspective view (High Performing Buildings, 2015)

The Building Construction Authority (BCA) is located in Singapore. It was previously a center for craft workers for rapid growth of the construction industry. The building was renovated in October 2009, it presently serves as home for corporate offices and academic classrooms. BCA is a government agency in Singapore tasked with the development of green technologies to meet Singapore's 2030 80 percent green building goal. ZEB is BCA's flagship project and the first net-zero energy building in Singapore. (Juniper, 2009)

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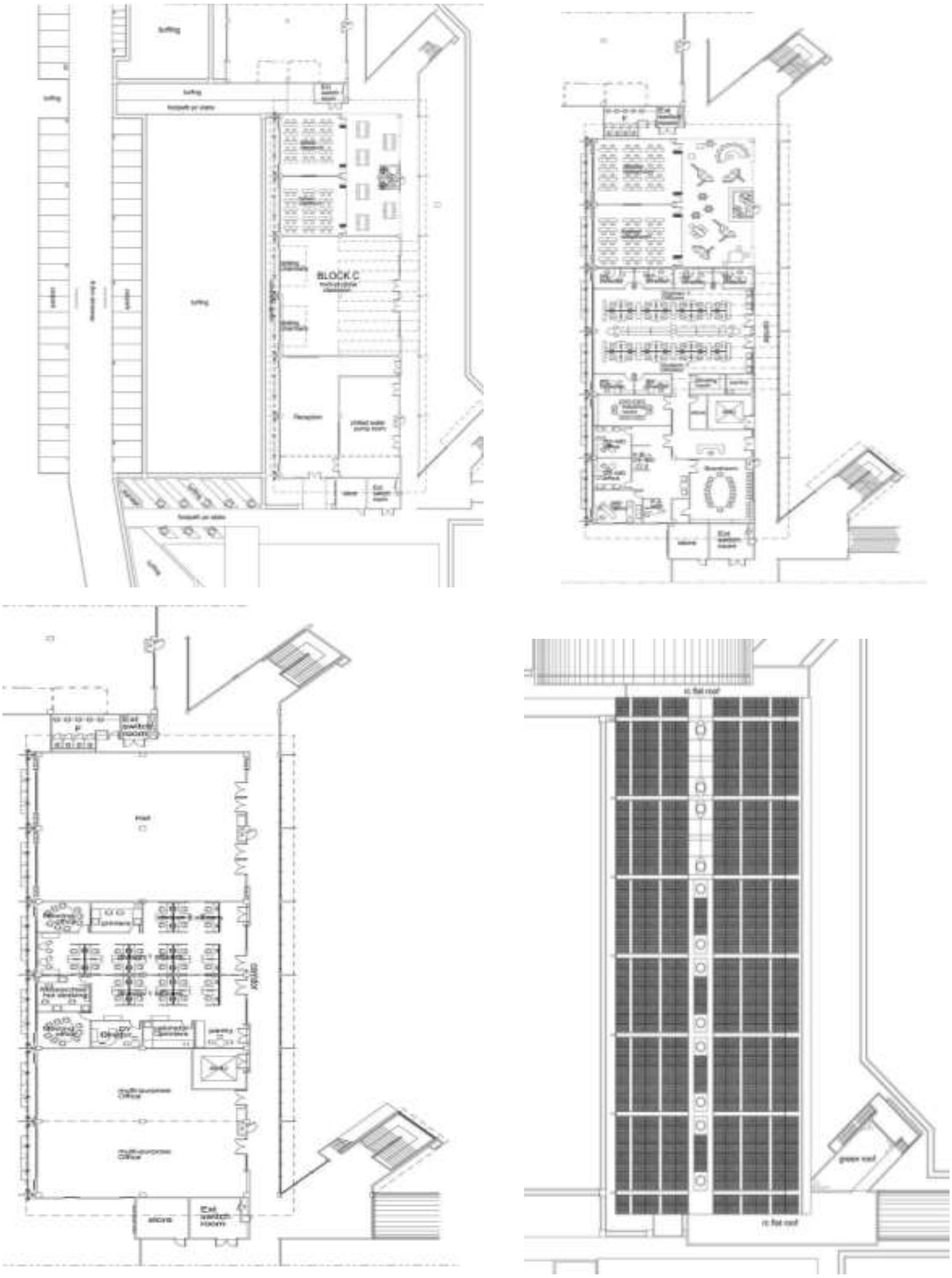

Fig 29: Floor Plans (http://architizer.com/projects/zero-energy-building-at-bca-academy/)

The ground floor is where the laboratory and exhibition halls are located. The first floor is occupied by work stations while the second floor is a function hall. The building produces all of its energy needs by the means of solar power. With an estimate of 1540m^2 of photovoltaic panels mounted on its roof and external façade. It generates about 200,000 kWh of electricity a year, providing for all ZEB’s energy needs. (National Climate Change Secretariat, 2013).

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Fig 30: Integrated Photovoltaic (The Design, Development and Performance of a Retrofitted Net Zero Energy Building in Singapore, 2015)

Building Orientation:

The building footprint is about 250ft (76m) long and 65ft (20m) deep, with an external corridor on the longer east side providing access to the deep building spaces on all three stories. The façade is orientated north-south and faces an internal rectilinear courtyard. (Wittkopf, 2015, p.45)

Façade Design:

The building's façade was retrofitted with multiple passive design strategies. These strategies included vertical green walls, PV serving as shading (louvers), horizontal light pipes (used in reflecting sunlight into deep parts of the building), glazing integrated shading and semitransparent PV in windows. The green walls supported the study of their shading and evaporative cooling effect on reducing heat transfer and resulting cooling energy use. (Wittkopf, 2015, p.48)

Fig 31: Façade Designed with passive strategies and Light Ducts (Building and Construction authority of Singapore, 2014)

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Window:

Different glass types were installed to regulate the amount of sunlight entering the building directly. The first type is the low-e glass, regulates the amount of solar radiation going into the building by using low emissive coating on the glass. The second type is the double glazed unit which helps in reducing the transfer of solar radiation from the dry vacuum sandwiched between glass sheets and lastly, the solar film coating reduces the entrance of harmful repelling heat and ultraviolet rays.

Ventilation:

One-third of the BCA academy building is cooled by natural ventilation. The average air temperature and relative humidity in tropical Singapore during the day is around 88^{0}F (33^{0}C) and 80%, respectively, with relatively little seasonal change. (Wittkopf, 2015, p.46) Specially developed metal solar chimney for tropical climate was used to ventilate the school hall and class rooms. Four chimneys were established on top of the roof, which are the end series of partially hidden ducts along the building envelope. The solar chimneys make use of convection and buoyancy effect to enhance the natural ventilation.

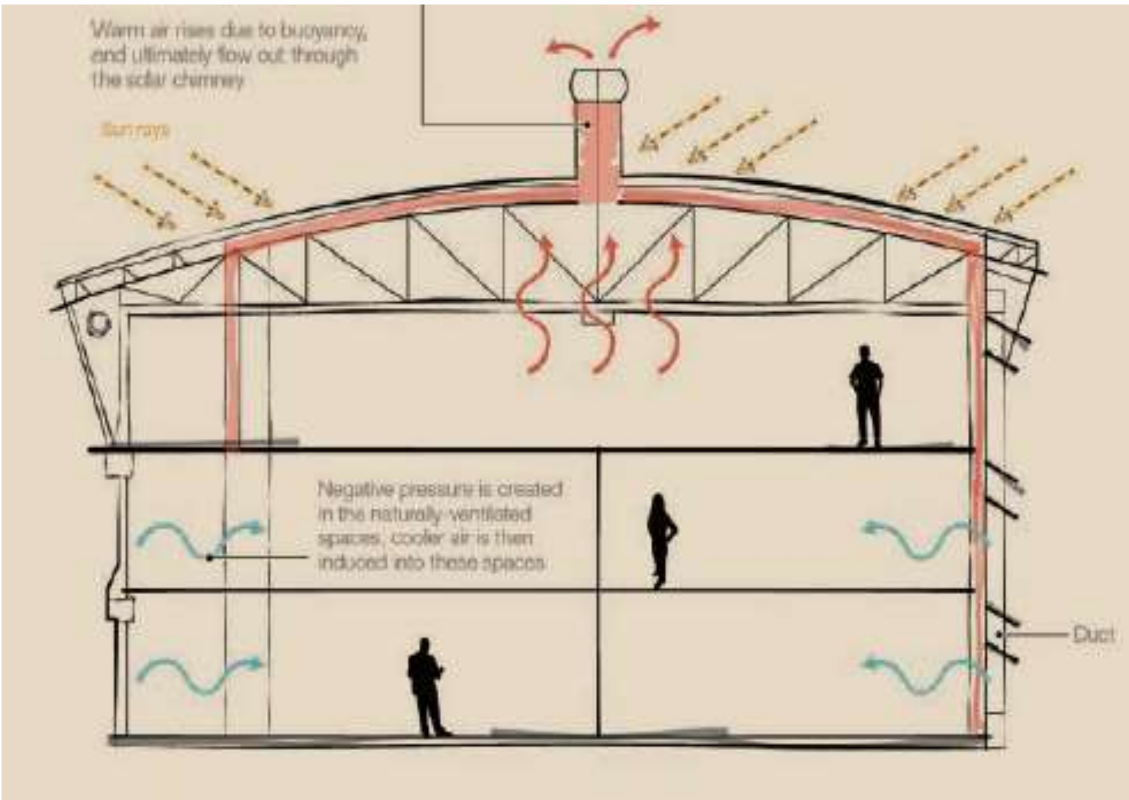

Fig 32: Solar Chimney (Tropical Net Zero,2015)

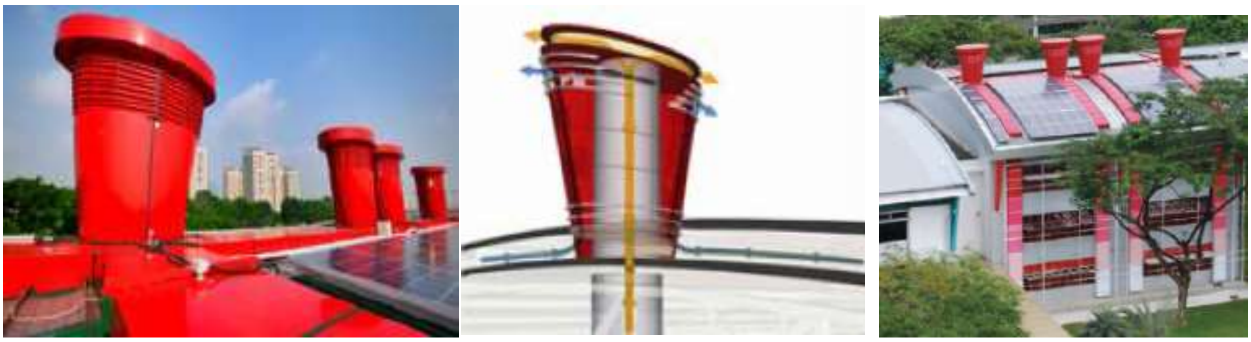

Fig 33: Solar Chimney (The Design, Development and Performance of a Retrofitted Net Zero Energy Building in Singapore, 2015)

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Natural Lighting:

Three lighting strategies were incorporated into the BCA building, these strategies include a highly reflective mirror dust, Light shelves and light pipes. The mirror ducts are used to capture zenith daylight with external collectors. The light harvested from mirror ducts is usually glare-free and the technology involves no mechanical parts and requires no power. At BCA's ZEB three types of mirror ducts were installed to test their reflectivity and effectiveness. (Building & Construction Authority, 2011) Light shelves are highly reflective surfaces that reflects daylight to inwards spaces of the building. Externally installed on the façade and serve as shading devices protecting against direct sunlight. Light shelves are enhanced by using ceiling material that are reflective. (Building & Construction Authority, 2011) Light pipes are essentially pipes that stick out of a building's roof and direct sunlight into interior rooms. They are more energy efficient than skylights because less energy escapes owing to reduced surface area. Two types of light pipes are in use at the ZEB, one that is equipped with rotating mirror and one without. (Building & Construction Authority, 2011)

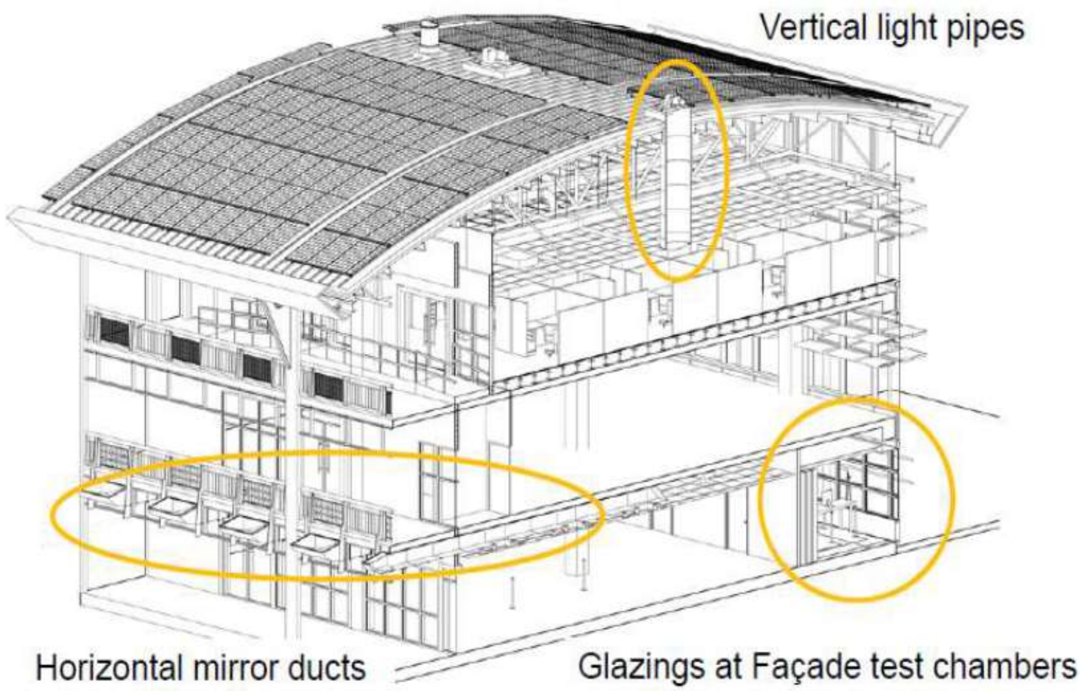

Fig 34: Daylight Solutions (Zero Energy Building @BCA Academy, 2015)

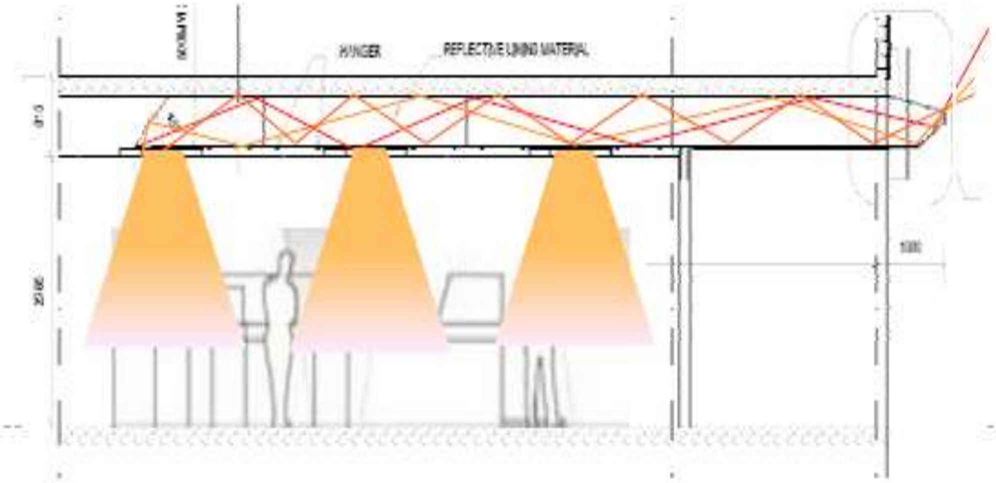

Fig 35: Mirror Duct System (The Design, Development and Performance of a Retrofitted Net Zero Energy Building in Singapore, 2015)

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CASE STUDY 4: The Mosaic Centre for Conscious Community and Commerce:

Fig 36: Perspective

Mosaic Centre is located in Edmonton Alberta in Canada. It is Canada's first Net Zero commercial building and was completed in April 2015. The building 30,000 ft^2 at an emerging commercial strip in Edmonton. It will be used as the Mosaic family companies and will not only house office but it will include a fitness Centre, game hall, a child day care and a restaurant. The client's primary goal is to build a Net Zero Commercial building.

Passive Orientation:

The Centre was designed with large north and south-facing curtain wall windows. With small windows on the east and west parts of the building. The north and south windows provide natural lighting into the building.

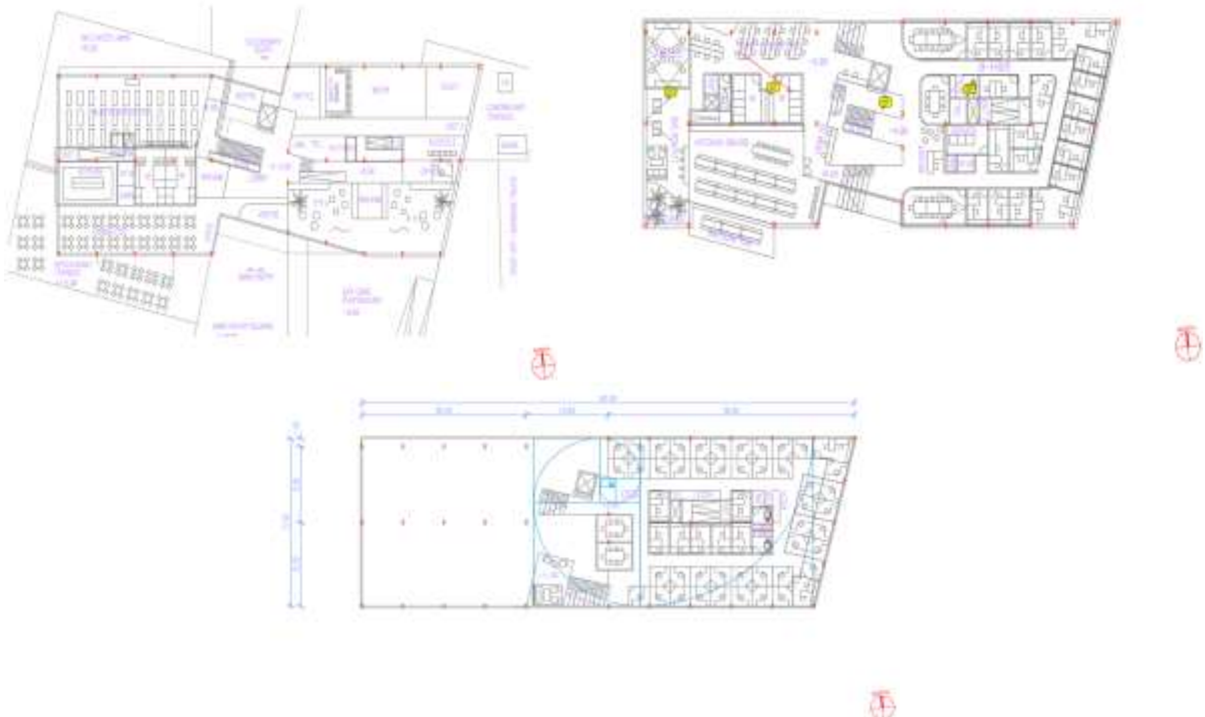

Fig 37: Floor Plans (Manasc Issac Architects,2013)

Facade Design:

The façade is designed with curtain wall, PV solar panels and Wooden finishes. In order to achieve a good connection with the outdoors, curtain walls were used on the northern and southern facades, allowing majority of the spaces to be naturally day-lit.

Fig 38: Facade (Manasc Issac Architects,2013)

Photovoltaic Integration:

The Centre used solar modules (Photovoltaic, or PV panels), these modules were installed on the roof and the south west façade. All modules and inverters are located within the building, none of the panels were installed in the parking or offsite. The design team looked at other possible renewable energy sources like the wind turbines, but the site wasn't suitable. A number of testes were carried out, flat, angled and a combination of the two to determine which is more cost economical. The flat mount design was discovered to be the best, even though during the winter season the PV can be totally cover with snow slowing down the production. During the winter season at Edmonton there is little potential of solar. In the winter months, electricity is "withdrawn" from the grid when the system cannot produce enough to power the building. (The Mosaic Centre, 2015)

Fig 39: PV Panels on the Roof and Facade of the building (Manasc Issac Architects,2013)

Lighting:

Lighting was achieved through task lights and natural lighting in workstations, meeting areas and the restaurant, the building's energy consumption was reduced. Lighting is controlled by motion sensors located on each of the buildings corridors, therefore no provision of light switched were made for both the office spaces and workstations due to the availability of task lighting.

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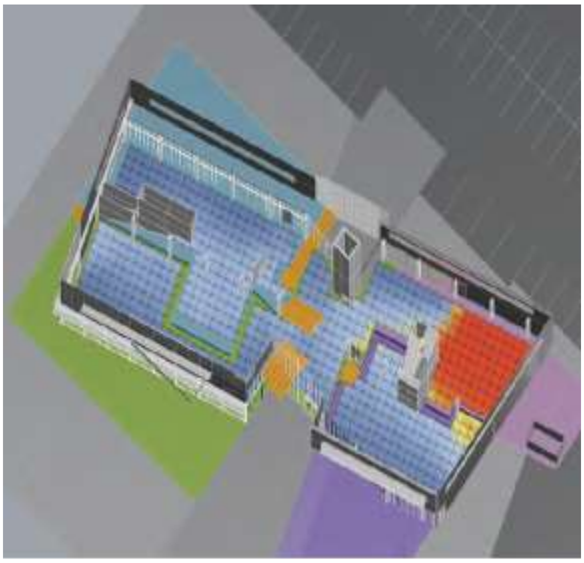
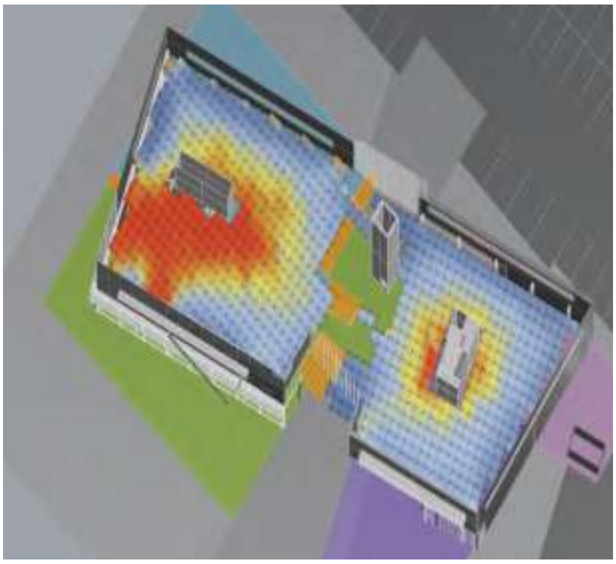

Fig 40: Daylight Autonomy Model for the 1st and 2nd Floor (Manasc Issac Architects,2013)

Heating, Ventilation and Air Conditioning System:

The building's orientation contributes in minimizing the ventilation, heating and air-conditioning throughout the building. This is achieved by the use of target shading and the building envelope design. Natural ventilation is used through manually operated perimeter windows and powered louvres or awnings in the upper atrium. A dual-core air to air heat exchange system was installed that extracts contaminated air. In terms of heating and cooling, two options were considered within the building. The first option is the thermal floor system that uses plastic water piping embedded in a concrete floor and the second option is a heat recovery variable refrigerant flow VRF-HR system. This system uses direct expansion fan.

Fig 41: PEX cooling pipes (Vasiliu,2015)

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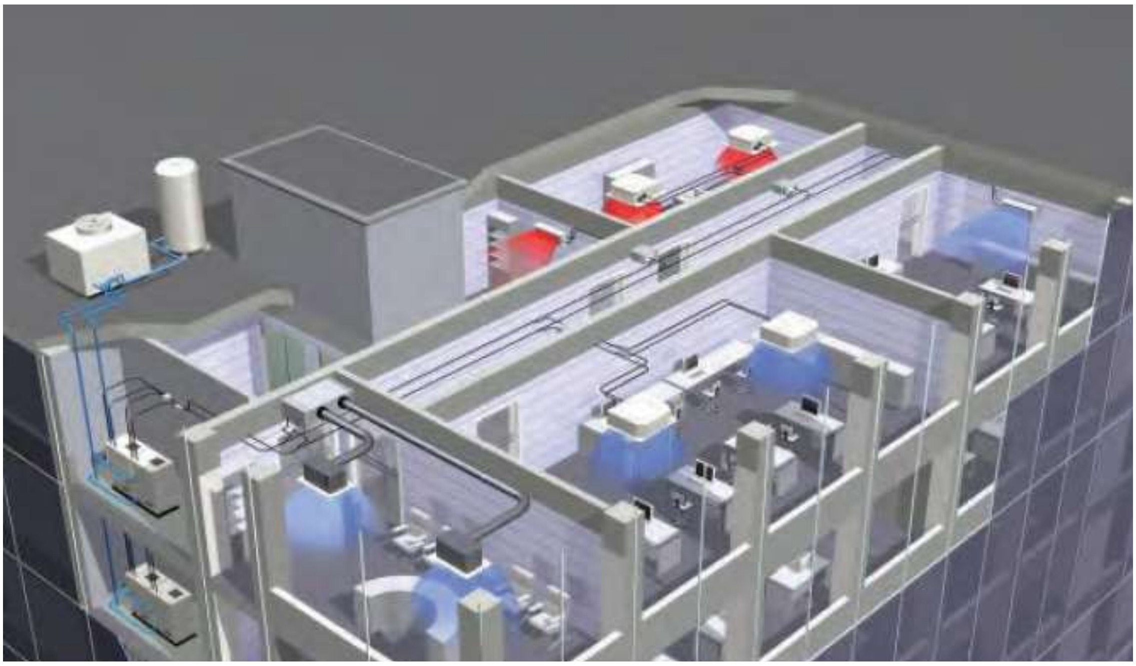

Fig 42: VRF-HR System (Manasc Issac Architects,2013)

3. COMPARISON TABLE

Design Strategies	Façade Design	Building Orientation	Window System	Floor Structure
PTM	Façade was designed with a step-in concept, hereby enabling the building to self-shade. This was done to control the glaring from direct sunlight with vertical walls and overhangs.as shading device.	The building is orientated with its long facades facing north & south and short facades facing east and west.	High performance glazed and glazing windows were installed to reduce heat gain in the building, providing the ability to harness high visible light at low infra-red (IR) and Ultra-violet (UV) transmittance.	The floor is designed with embedded PEX tubes laid in the concrete slabs. These tubes provide a cooling effect on the floor.
CSET	The CSET is designed with dual facades, external and internal façade. The external envelope is made of a mechanically fixed system of silk-screen laminated glass modules. Connected by a steel structure, the gap between is treated with a silk-screen pattern giving it solar protection and a decorative effect to the building.	CSET has a floor orientation that has it floor plan mainly facing the south, with large curtain wall openings and completely sealed on the 3 other sides to protect the building from the winter winds.	Windows optimize the influx of sunlight reducing the need for artificial lighting. This is done by the use of triangular shaped skylights inclined to the north to avoid direct solar influx. A series of openings provide natural light to all floors, creating a flue effect by promoting efficient natural lighting.	The floors are equipped with chimneys for natural ventilation with openings in between the concrete walls and the silk-screen.
BCA Academy	The façade is a result of passive design strategies. Several strategies were integrated including green wall, PV panels serving as louvers, light ducts, glazing	Unlike the other ZEBs the BCA building has its long facades with windows facing the east and west, with	Windows were designed with three different glass systems -Low e-glass that regulates solar radiation by the use of emissive coating on	Designed with an underfloor cooling system supplying air at low velocity through diffusers from the floor.

	integrated shading and semi-transparent PV in windows.	a few windows on the north and south facades.	glass. -Double glazed unit -Solar film coating that reduces harmful ultraviolet rays and repels heat.	Cool air raises as it gets polluted by occupants and is extracted from the room at ceiling level.
The Mosaic Centre	Designed with semi-transparent curtain wall, PV panels and Wooden finishes.	With small windows on the east and west parts of the building, large windows on the north and south to influx natural lighting in to the building.	The use of curtain wall as an exterior envelope allows majority of the spaces to be naturally day-lit. Perimeter window and powered louvers or awnings were installed in the upper atrium.	The floors are designed with concrete floor slabs that have a thermal storage capacity. This was achieved by laying embedded pipes within the concrete floor, used in heating and cooling the rooms above and below.

4. DISCUSSION

The first case study, pusat- tenaga Malaysia (PTM) located in a tropical region adopted several passive strategies to reach its goal of zero energy. These strategies include an orientation that harnesses natural light by placing majority of its windows and doors facing north and south and a few windows on the west leaving the east sealed to avoid direct influx of sunlight. The ZEB took good advantage of the climate of Malaysia by applying solar energy through the integration of PV panels, providing the building with efficient energy. The façade is self-shaded, protecting the building from solar influx from the south and north. This orientation saved development costs of electricity and cooling. High performance glazing and sealed double glazing windows were used on the northern, southern and western facades along with blinds and a large overhang on the western façade. The integration of daylight reflectors was an efficient way of lighting the deepest interior spaces and lastly cooling with the aid of PEX pipes. The PTM ZEB did not achieve zero energy index due to poor performance of the oversized chiller, cooling system and air movement within the building.

The Centre for sustainable energy technologies (CSET) is the second case study. This building is located in the temperate region of china, it was designed to serve as china's response to environmental issues and an exemplar building for sustainable construction. The building envelope contributes in the control of the passive strategies integrated in the building. With the envelope sealed on the northern façade with a few openings on the other three facades and the floor orientation facing north and south brought about sufficient natural lighting in the building. PV systems located on the ground green roof serves as efficient energy generators to power the office equipment, mechanical ventilation, chilled water system and the building's elevators. Windows were designed to allow the influx of natural lighting, reducing the need for artificial lighting and the floors equipped with chimneys that serves as ventilation openings. Cross ventilation was achieved by a series of openings on the sides of the building positioned on the concrete wall.

The third case study is the building construction authority (BCA) located in the tropic region, the BCA was retrofitted to an energy efficient showcase to advance green building technologies. The building had an unfavorable east-west orientation making it not very suitable to be retrofitted to a ZEB. Several passive systems were implemented to achieve this goal. These systems include the integration of photovoltaic technologies to generate efficient energy, light pipes and mirror ducts to reflect light into the interior of the building, Various shading devices were incorporated to the windows on the east and west facades. Personalized ventilation systems were introduced to the workstations to improve the air quality and to enable occupants to be able to control the air flow. Green roof and walls were incorporated to contribute in lowering the heat gained and reducing the transfer of heat into the interior.

Lastly the mosaic Centre, located in the temperate region of Canada. The Centre is Canada's first net zero commercial building, designed with state of the art passive strategies to achieve its goal of net zero. These strategies started with the building's orientation, with its large curtain wall and windows facing the north and south and an overhang on the east side. The façade is partly covered with curtain wall, PV panels and wooden finishes. The integration of the PV panels on the façade and roof was the design teams second energy generation option, their initial option was wind turbines but was

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discovered not suitable for the site. PV panels generate the total energy needed in within the building even though during the winter, the panels get covered by snow and the availability of sunlight is less. Energy is withdrawn from the grid at any point the panels cannot perform. The use of large curtain wall, artificial lighting is only needed at certain areas of the building. Heating and cooling was achieved by the use of thermal floor system through embedded pipes within the concrete floors and a heat recovery variable refrigerant flow (VRF-HT System). The building envelope contribute in terms of natural ventilation with the use of perimeter windows and power louvers and a dual-core air to air exchange system that extracts contaminated air.

Although these four case studies are located in different regions of the world, it is observed that they all have a number of similarities in terms of their building orientation, lighting, floor heating and energy generation. Despite the large number of similarities, it is observed that some of the Zero energy strategies adjust better than they do in other regions like the tropics enhances the adaptation of natural lighting with less chances of interference compared to the temperate climate that witnesses four different seasons. During the winter season in temperate regions, integrated solar panels becomes the less suitable power generator because of blockage by snow and low solar. The tropic region witnesses an all year round solar availability. The integration of shading devices is a necessity when it comes to ZEB in the tropics while in the temperate it is integrated to a minimum. In terms of heating and cooling, the temperate region requires less energy in cooling unlike in the tropics that needs a tremendous amount of energy to cool because of the high level of humidity. During the winter season in the temperate region, heating is as well energy consuming while no heating is required in the tropics. Task lights are required in certain spaces of a temperate region due to the winter effect of short day and longer nights. It is observed that all these Zero energy buildings were designed in their unique passive designs in most cases determined by the climate and occupants.

5. CONCLUSION

The findings show that Net Zero energy buildings (NZEBs) in different climatic regions of the world are very much designed with a lot of similarities, especially in terms of their orientation. Because of the nature of solar orientation across the globe, it is evident that having openings (doors and windows) on the east and west facades or sides of a building is not the ideal building orientation. ZEBs adopted the concept of having large openings on their north and south sides. From the four case studies discussed this passive design strategy worked on three of these buildings with the exception of the Building Construction Authority (BCA) Building, due to its nature before been retrofitted. But even though it had its windows and doors on the east and west facades in a tropic region, the idea of using the green wall, shading devices, mirror ducts and a system of light shelves was well integrated to adopt to the nature of the orientation enhancing the building's efficiency.

The facades on each of these case studies differs, the PTM building, BCA Academy and the Mosaic Centre's façades were determined by the passive strategies integrated in the building, these strategies include PV panels, curtain wall (for influx of light), the step-in concept, vertical walls, overhangs and many more. Unlike the other three, the CSET adopted a different and more interesting strategical approach on its façade design. The idea of having an external envelope that is partly sealed and has a lighting and ventilation effect on the internal envelope made it stand out. This idea could be integrated on the PTM and BCA building and still maintain their passive features.

The integration of PV panels manifested to be highly efficient in all four of these ZEBs. But in the case of the mosaic Centre, the variation in Canadian weather brought about failure in the PV panels operation. During the winter season, the PV panels located on the roof top are blocked totally by snow and low availability of solar also alters the building's energy efficiency goals, leading the ZEB to acquire energy from the grid. By making the panels inclined, the snow could easily fall off and would have solved or reduced the issue. In the temperate region, it is advisable to have another alternative power generation for efficient energy apart from the photovoltaic source.

Furthermore, the findings show that the floor structures of each of these buildings studied are in a way connected to the ventilation, heat and cooling systems. The idea of the embedded pipes proved to be a common way of heating and cooling rooms in ZEBs, but the particular design used in the BCA academy of underfloor cooling that supplies air through diffusers proved to be the more efficient system.

In conclusion, research findings evaluated that zero energy building in these two climates compared have a lot of similarities, it is carefully observed that the sensitization of user is also essential in this new types of building to explain the specific building operation.

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