FRAMING THE DESIGN STRATEGIES FOR NET ZERO ENERGY OFFICE BUILDING

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ACKNOWLEDGEMENT

Behind these pages are hidden tones of hard work, sleepless nights and guidance of many people. To begin with I would like to thank my parents, my sister, in-laws, specially my husband and daughter who helped me sustain my belief in my endeavors to achieve my goals.

I sincerely thank Ar. Sangeeta Sharma, my guide for guiding me in every stage.

I would like to thank Ar. Varsha Varma, Ar. Richa Gupta for their kind support.

I would like to thank all the concerned authorities for helping me during my studies.

Last but not the least I would like to thank my faculty members and my friends for their moral support.

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SYNOPSIS

INTRODUCTION

- Amid growing concerns about rising energy prices, energy independence, and the impact of climate change, statistics show buildings to be the primary energy consumer.
- This fact underscores the importance of targeting building energy use as a key to decreasing the nation's energy consumption.
- The building sector can significantly reduce energy use by incorporating energy-efficient strategies into the design, construction, and operation of new buildings and undertaking retrofits to improve the efficiency of existing buildings.
- It can further reduce dependence on fossil fuel derived energy by increasing use of on-site and off-site renewable energy sources.
- The concept of a Net Zero Energy Building (NZEB), one which produces as much energy as it uses over the course of a year, recently has been evolving from research to reality.
- Currently, there are only a small number of highly efficient buildings that meet the criteria to be called "Net Zero".
- As a result of advances in construction technologies, renewable energy systems, and academic research, creating Net Zero Energy Buildings is becoming more and more feasible.
- While the exact definitions of metrics for "Net Zero Energy" vary, most agree

  that Net Zero Energy Buildings combine:-

  - Exemplary building design to minimize energy requirements.
  - Renewable energy systems that meet these reduced energy needs.

- The net zero concept is applicable to a wide range of resources due to the many options for producing and conserving resources in buildings (e.g. energy, water, waste).
- Energy is the first resource to be targeted because it is highly managed, expected to continually become more efficient, and the ability to distribute and allocate it will improve disaster resiliency.
- Net Zero Energy Building Principles can be applied to most types of projects, including office buildings in both new construction and existing buildings.

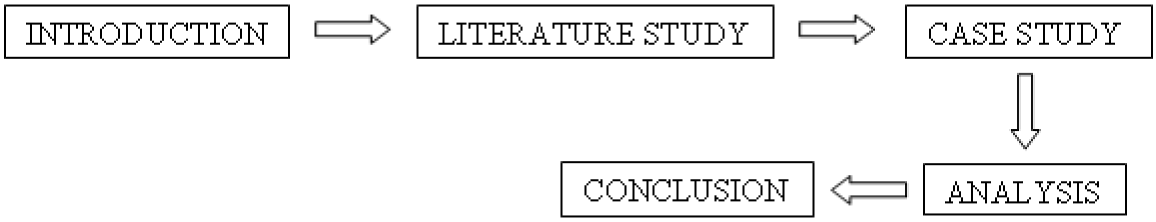
AIM AND OBJECTIVE

- To study and develop the various methods and strategies of design that will result in reduced energy needs for office buildings and technological advances that will allow and enable this.
- To study and evaluate the viability of application of on-site renewable sources of energy in order to achieve Net Zero Energy building status.

SCOPE AND LIMITATIONS

- The net zero concept is applicable to a wide range of resources due to the many options for producing and conserving resources in buildings (e.g. energy, water, waste).
- Net Zero Energy Building Principles can be applied to most types of projects, including office buildings in both new construction and existing buildings.
- Currently, there are only a small number of highly efficient buildings that meet the criteria to be called "Net Zero".
- As a result of advances in construction technologies, renewable energy systems, and academic research, creating Net Zero Energy Buildings is becoming more and more feasible.

METHODOLOGY



LITERATURE STUDY

LITERATURE STUDY 1

PUSAT TENAGA MALAYSIA'S ZERO ENERGY OFFICE, MALAYSIA

Project Data

- Project Name
    - Malaysia Energy Centre: Zero Energy Office
- Location
    - Section 9, Bandar Baru Bangi, Bangi, Selangor

- Completion
    - July 2007
- Site Area
    - 2 hectares
- Gross Floor Area
    - 4,000 m2
- Number of Rooms
    - 41 rooms
- Building Height
    - 47.50 metres
- Client/Owner
    - Malaysia Energy Centre (Pusat Tenaga Malaysia-PTM)
- Architecture Firm
    - Ruslan Khalid Associates
- Principal Architect
    - Professor Dato' Ruslan Khalid

- Necessity—the mother of all inventions—lends her mark of approval to Pusat Tenaga Malaysia's (PTM) new Zero Energy Office (ZEO).

- While buildings play a fundamental role in providing the recreational and work structures that people work, play and live in, it is also impossible to ignore the negative effects they can have, especially when a sustained amount of massive energy is needed to power them.

- Heeding the call to best manage energy resources, PTM's ZEO rises to the occasion by capitalising on energy efficient measures implemented through various facets of the overall design.

- Construction work on the building started in March 2006, which was followed by the successful installation and commission of the four solar building integrated photovoltaic (BIPV) systems in June 2007, leading to the completion of PTM's ZEO in July 2007.
- Fashioned after the Low Energy Office (LEO) building initiated by the Ministry of Energy, Water and Communications (MEWC) in Putrajaya, the PTM's ZEO building has placed Malaysia on the regional map as the first completely self-sustainable building in Southeast Asia.
- Spread over a 5-acre site in Bandar Baru Bangi, Selangor, the building, located 40 kilometres south of the city centre of Kuala Lumpur, operates on the dynamics of both passive and active techniques and onsite renewable energy generation, as exemplified in the solar BIPV system.
- The building is seen as a feasible and timely solution to growing concerns surrounding the pressing issues of global warming and energy security.
- Figures point to the alarming reality that in developed nations, buildings tend to take up a third of total energy consumption.
- The business of sustainability is big news, by any standards.
- The PTM's ZEO building serves as a pilot project that provides a platform for proof of concept in driving forward the goals of the Malaysian building industry (developers, consultants, architects, local professionals and academia at large) in the subject of sustainable building design.
- This is great news as most buildings in Malaysia are energy inefficient—most of them record higher Building Energy Index (BEI) beyond the benchmark for Energy Efficient Buildings (EEB) set at 135 kWh per square metre per year (the kWh per square metre of the BEI is derived based on dividing the total kWh or electricity used per year by the building area based on metre square calculations).

Energy efficient architecture

- Pre-programmed into the building's DNA are energy efficient features and the BIPV system—they make up the backbone of this self-sufficient, fully sustainable landmark.
- As such, PTM‘s ZEO building does not use fossil fuels, driving home the point that an office building need not consume electricity derived from this sour.
- Instead, all electricity needed by the building is being generated by its own solar BIPV systems.
- In all, four different solar BIPV systems utilising four different technologies have been installed into PTM's ZEO.

Atrium with glass semi-transparent PV modules (11.64kWp)

Monocrystalline PV modules (27kWp) on the carpark roof

Polycrystalline modules (47.28kWp) on the main roof

Types of PV panel

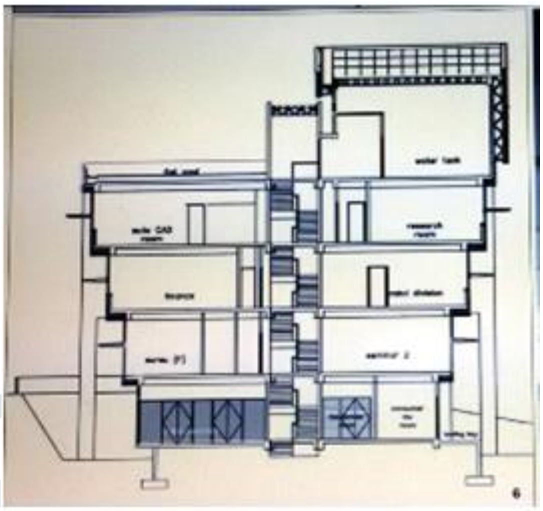
North-South Axis

Types of PV Panel	PV Panel	Information
Package A Poly-Crystalline		• Panel 394 nos • Produce 47 kWp • 356 meter square
Package B *Amorphous silicon*		• Panel 95 nos • Produce 6kWp • 100 meter square
Package C Mono-Crystalline, see through		• Panel 64 nos • Produce 12kWp • 110 meter square
Package D Mono-Crystalline		• Panel 150 nos • Produce 27 kWp • 200 meter square

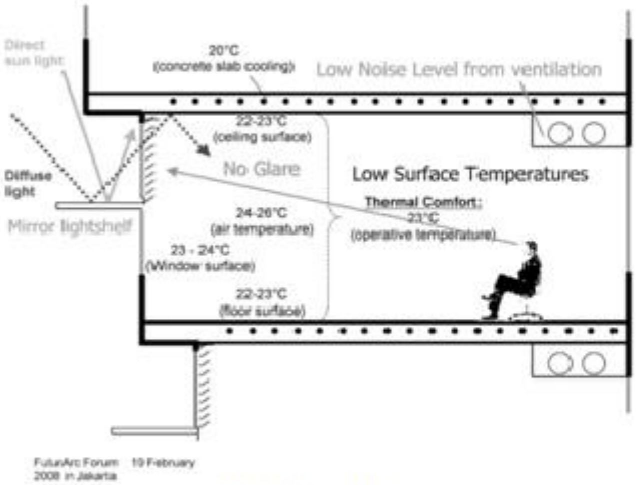
- The first and biggest component features the 47.28 kWp polycrystalline BIPV system on the main roof; the second component lies with the 6.08 kWp amorphous silicon BIPV system incorporated into the second main roof; the third system stored in the atrium of the building highlights the use of the 11.64 kWp monocrystalline glass-glass BIPV system; and lastly, the car park roof is fitted with 27 kWp monocrystalline BIPV system.
- The solar BIPV systems are all linked up to grid-connected inverters that convert the produced direct current (DC) electricity into alternating current (AC) electricity.
- For purposes of verifying the electricity production, electricity generation is recorded through the meter.
- In this case, no battery is installed as the generated solar electricity is directly consumed and the net surplus sold to Tenaga Nasional Berhad (TNB) on a net meter basis.
- Looking at the example of a total BIPV capacity of 92 kWp, the anticipated target for annual electricity generated from solar BIPV systems stands at 102 MWh.

- To date, the BIPV systems have produced about 103 MWh/year average, based on actual output over three months.

Colour of office interior reflects light



Step-in design (self-shading)



Typical section

- Buildings that are not energy efficient would need more than 92 kWp as compared to PTM's ZEO.

- This is because the super energy efficient (EE) features of ZEO reduces the energy consumption of the building and complements the 92 kWp solar BIPV to make the total payback time for the whole systems to be less than 22 years.

- And this is based on current subsidised electricity tariff and technologies that are mostly imported today.

- It is acknowledged that the costs of future electricity would increase and the EE as well as the solar technologies would reduce.
- Furthermore, it is important to bear in mind that there is no payback price for the environment.
- To achieve the super EE outputs, the building incorporates features utilising passive techniques as well as orientation and vegetation, balanced with active features seen in efficient lighting systems, floor slab cooling, double-glazed windows as well as a thermal wall at its east- and west-facing façades.
- The implementation of high performance glazing and sealed double-glazing also complements the call for energy efficiency.
- This is reflected in its ability to harness high visible light at low infra-red (IR) and ultra-violet (UV) transmittance.
- The result is the effective harnessing of natural daylight minus, to a great degree, unnecessary heat radiation into the building.
- Playing an unseen yet fundamental role in the sustainable design feature of PTM's ZEO, the floors of the building take on a cooling effect role, thanks to the insertion of embedded tubes within the concrete floor slabs.
- During the day, the stored cooling effect is released from the floor slabs to the rooms above and below them, directly contributing to the cooling effect of the building that is also supplemented minimally by air-cooling systems.

Colour of building exterior minimises heat gain

- Careful thought has also gone into the preservation of air quality achieved via the process of dehumidification.
- Given the fact that dehumidification of air quality in buildings consumes a great amount of electricity, a desiccant heat wheel that operates by replacing incoming hot and humid fresh air with cooler and drier exhaust air is used to counteract this effect.

Emphasis on holistic design approach

- The critical approach towards ZEO is the holistic design involving all consultants, led by the architect, working together in order to achieve the client's zero energy vision.
- The initial architectural concept of the building was enhanced with super EE features, followed by the solar BIPV capacity to offset the remaining energy demand.
- The usage of solar BIPV technology not only displaced conventional building materials, but also adds value to the architecture of the building.
- Today, PTM's ZEO continues to function as a showcase building to facilitate and explore the concept of sustainability in buildings, while assisting to create opportunities for the involvement of other relevant industries.

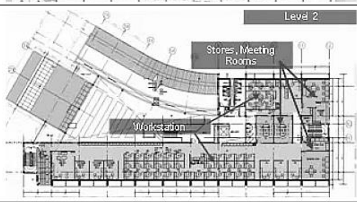
- The building is exemplifying the use of energy efficiency, with solar BIPV setting a new standard for sustainable building in the ASEAN region.

Maximising daylighting

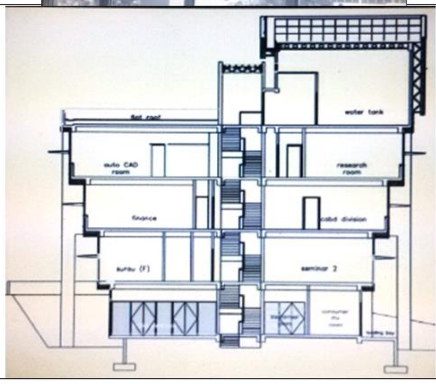
Glass semi-transparent PV modules (11.64kWp)

Daylighting

Malaysia Green Technology Coproration office building's internal layout

Level	Layout plan
Level One	
Level Two	
Ground Level	
Lower Ground Level	

Types of Shading

Types of Shading	Photo
Plate Shading	
Fixed Ram Unit	
Step-in design (self-shading)	

Building façade facing to the north

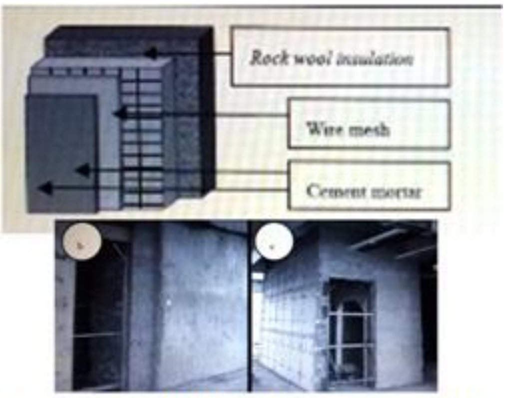
Building façade facing to the south

East-West Axis

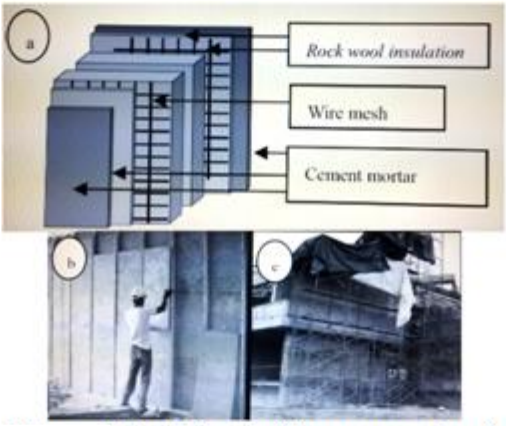
Building façade facing to the east

Building façade facing to the west

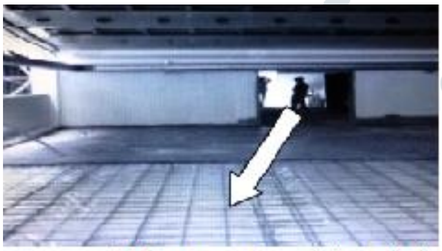
Malaysia Green Technology Corporation office building's orientation.



(a) Office building internal wall
(b) & (c) Internal wall installed with insulation system during construction of the building



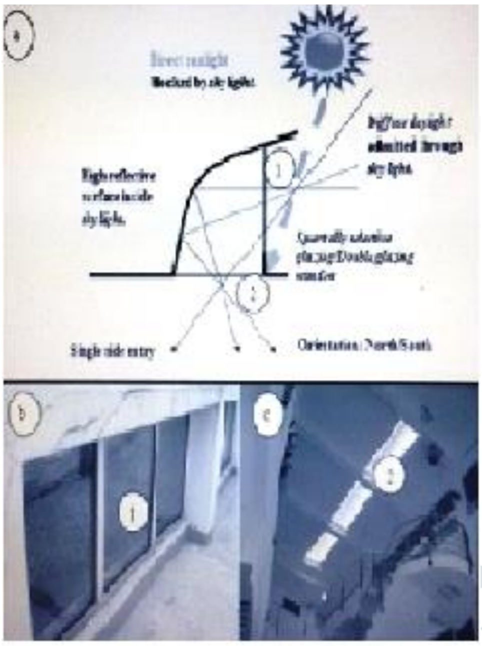
(a) Office building external wall
(b) & (c) External wall installed with insulation system during construction of the building.



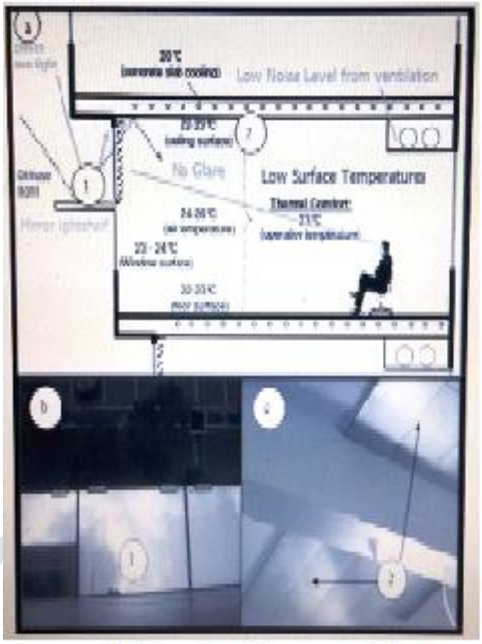
Polystyrene layer is installed on the uppermost floor of the office building (Source: Malaysia Green Technology Corporation, 2010)

The photo showed the installation of Styrofoam during the construction of the roof.

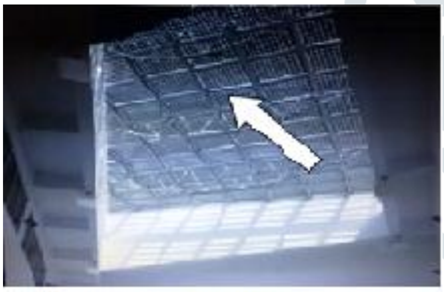
Mineral wool layer is installed on the slanting roof



- Diffuse daylight admitted through sky light.
- Spectraly selective glazing.
- Daylight source from skylight



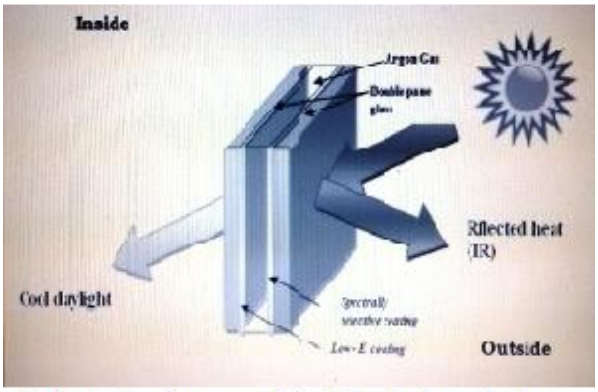
- Diffuse daylight entered into building.
- Mirror light shelf
- High reflective surface on the ceiling surface



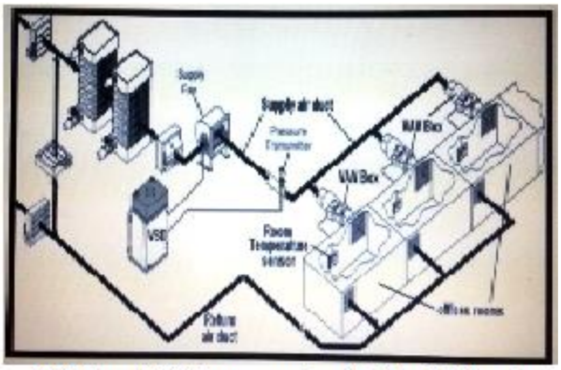
Light source enter the building through BIPV panel

PEX pipe installed on the slab during the construction process.

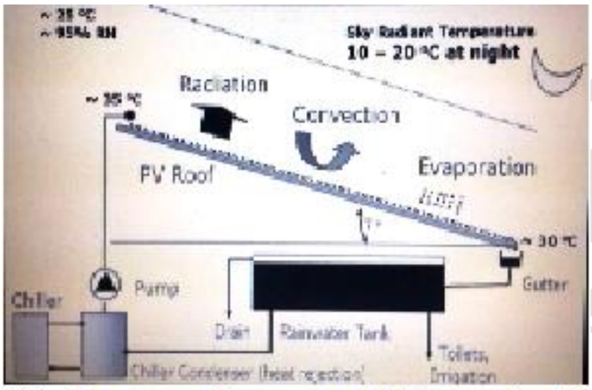
Chilled metal ceiling (CMC)



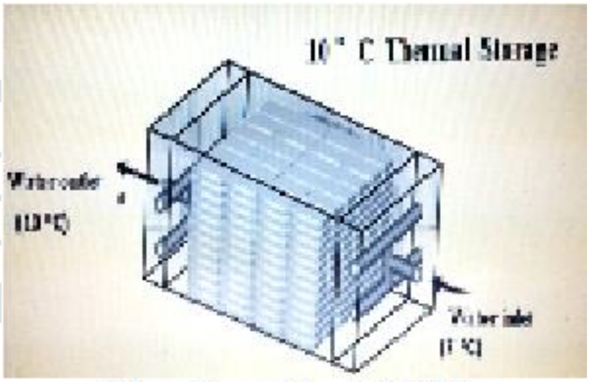
Schematic diagram of double glazing window



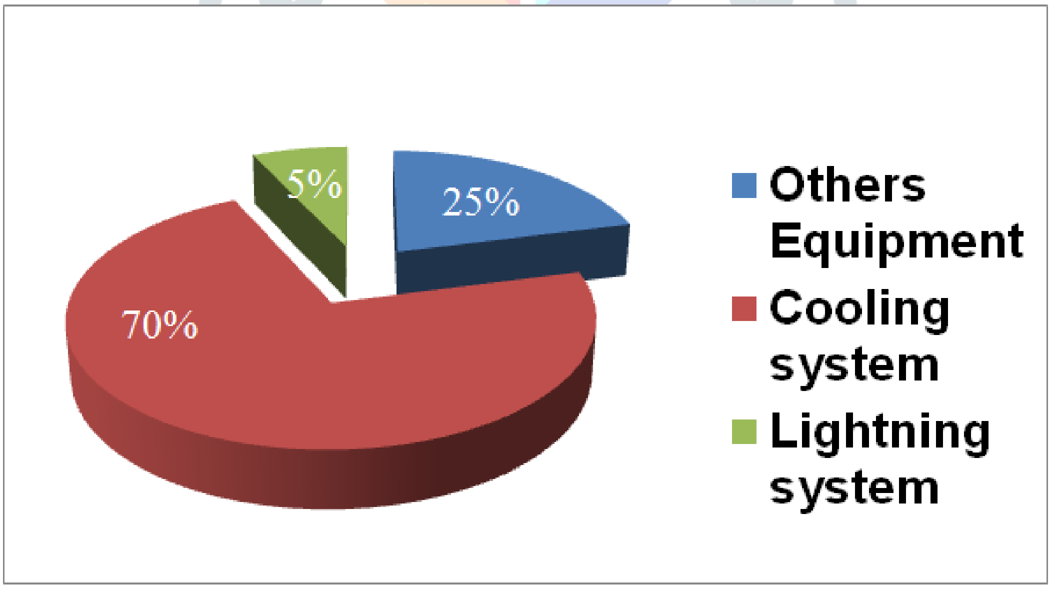
VAV and VSD system installed in Malaysia Green Technology Corporation office building.



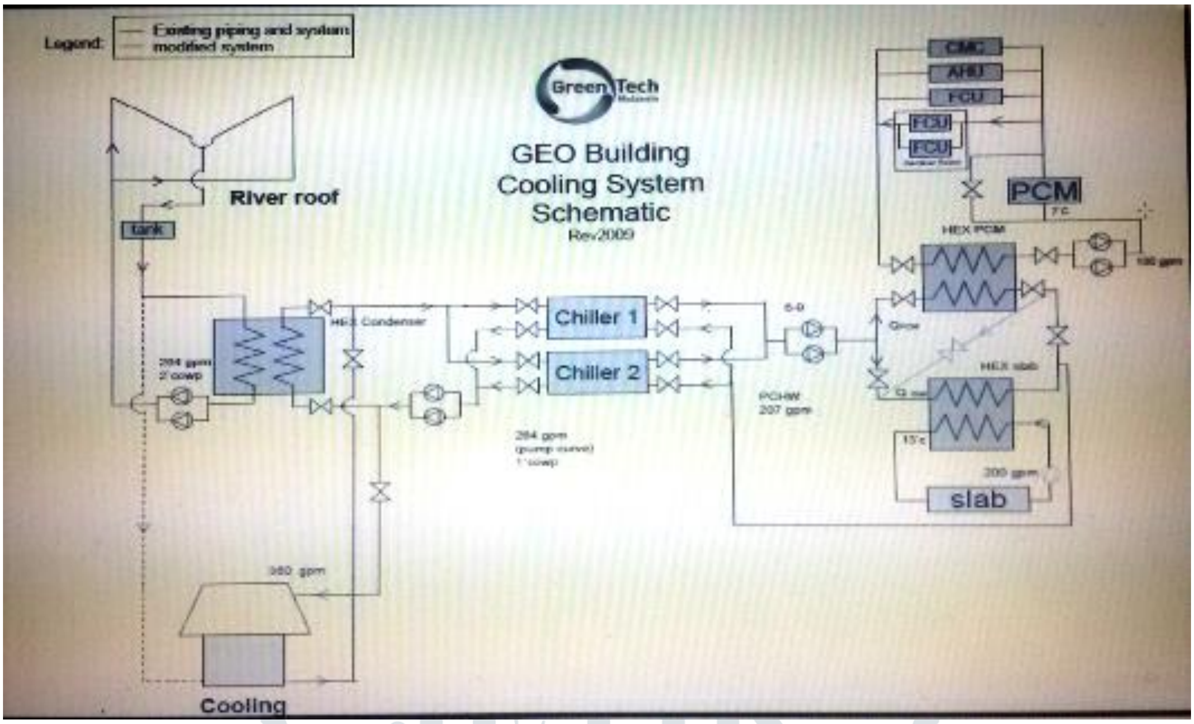
Cooling process happens on trickling cool roof.



Phase Change Material (PCM)



Distribution of energy consumption for Malaysia Green Technology Corporation office building.



Schematic diagram of the cooling system

DPR CONSTRUCTION PHOENIX REGIONAL OFFICE, PHOENIX, ARIZONA, USA

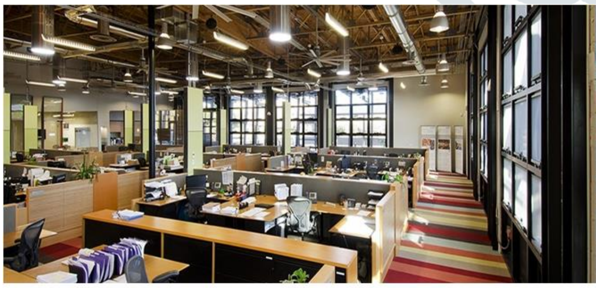
General Information

- Building Name: DPR Construction Phoenix Regional Office
- Building Location:
  - City: Phoenix
  - State: Arizona
  - Country: USA
- Construction Type: Existing Building Renovation or Retrofit
- Project Size: 16533 ft^2
- Market Sector: Private
- Building Type: Office
- Project Completion Date : October 7, 2011

- Architect Name(s): Mark Roddy
- Firm: Smith Group JJR, Phoenix, Arizona

- A living laboratory for the community, DPR's LEED®-NC Platinum, net-zero energy office is a unique example of urban revitalization and sustainability.
- Conceptualized as a "workplace of the future," DPR created an open-office environment housing 58 workstations and floater spaces, nine conference/training/innovation/mediated technology rooms, support spaces, fully-equipped gym/locker facilities, and a zen room for a quiet retreat.
- DPR incorporated passive/active cooling solutions including 87 operable windows, four shower towers, an 87-foot long, zinc-clad solar chimney, and a 79 kW-dc rated photovoltaic solar panel covered parking lot to control the indoor environment naturally and produce energy onsite.
- A Lucid Building Dashboard system is utilized to allow DPR to monitor and share building water and gas usage, lighting and power consumption, and photovoltaic energy production in real time.

Features



- In 2013, the office was certified as a its Living BuildingNet-Zero Energy Building (NZEB) from the International Living Future Institute (ILFI) through Challenge (SM) program.
- It is the first in Arizona and only the second in the U.S. to achieve NZEB certification.
- It was, at one point, the largest building in the world to receive the certification.

- DPR created an adaptive response to the environment via innovative building solutions.
- The office utilizes rapidly renewable wood products, recycled and reused materials, and adapts alternative ways to light and condition the space by incorporating natural ventilation through the use of operable windows, shower towers, a solar chimney and Big Ass Fans to drastically reduce the building's power demand.
- The expansive walls of windows and 82 strategically positioned Solatubes nearly eliminates the need for artificial daytime lighting 365 days a year
- A first-of-its-kind commercial building in the Valley, DPR's office has become a showcase for neighbors, colleagues and students.
- It serves as a statewide example of how sustainable design can be integrated into an efficient, effective, and environmentally responsible office space.

SWOT ANALYSIS

LITERATURE STUDY I	LITERATURE STUDY II	CASE STUDY I	CASE STUDY II
PUSAT TENAGA MALAYSIA'S ZERO ENERGY OFFICE, MALAYSIA	**DPR CONSTRUCTION PHOENIX REGIONAL OFFICE, PHOENIX, ARIZONA, USA**	**INDIRA PARYAVARAN BHAWAN, JOR BAGH, NEW DELHI**	**MALANKARA TEA PLANTATION, KOTTAYAM, INDIA**
			
STRENGTHS • Integration of Passive and Active Strategies Leads to Net Zero. • Net Zero Energy is achieved by the proper	**STRENGTHS** • Integration of Passive and Active Strategies Leads to Net Zero. • Adaptive response	**STRENGTHS** • Integration of Passive and Active Strategies Leads to Net Zero. • Energy efficient planning.	**STRENGTHS** • First Net-Zero energy building in India. • Energy cost savings payback

integration of both active and passive system. • Super energy efficient features of ZEO reduces the energy consumption of the building and remaining energy need being fulfilled through the application of BIPV system. • The initial architectural concept of the building was enhanced with super EE features, followed by the solar BIPV capacity to offset the remaining energy demand. • The usage of solar BIPV technology not only displaced conventional building materials, but also adds value to the architecture of the building. • The building is exemplifying the use of energy efficiency, with solar BIPV setting a new standard for sustainable building in the ASEAN region. • Careful thought has also gone into the preservation of air quality achieved via the process of dehumidification. • Given the fact that dehumidification of air quality in buildings consumes a great amount of electricity, a desiccant heat wheel that operates by replacing incoming hot and humid fresh air with cooler and drier exhaust air is used to counteract this effect.	to the environment. • To minimize the energy needs, energy efficient measures have been taken care of. • Remaining energy need is fulfilled by onside generation. • All these measures helped to get net zero energy target. • Hierarchy of open spaces, design consideration of modern office space and culture.	• Landscaping as climate modifier. • Hierarchy of open spaces, design consideration of modern office space and culture. • Proper natural lighting is provided at all spaces thus cutting down the electricity consumption. • IPB reduces energy requirement by 70% overall vis-à-vis conventional • N-S Orientation – Insulation on wall & roof– Extensive • Greenery to reduce heat load • Maximizing Day lighting to reduce lighting loads • Extremely Low Lighting Power Density – 5w/sqm • Planning to Minimize AC loads (Keeping open atrium for cross ventilation, Non conditioned lobbies) • Efficient HVAC with Screw Chillers, Chilled Beams, etc. • Ground based heat exchange for Condenser Water • Remote Computing - thin client servers • Energy efficient appliances (5 star BEE) • …. SPV's for the remaining load. • Integration of Green Architecture and on-site generation by solar photovoltaic system. • Access Friendly to differently-abled persons.	in fewer than five years. • Complete disconnection from the unreliable grid, functioning solely on self-generated solar power • Reduction of up to 47 tons of carbon emissions per year, saving an estimated 97% in diesel fuel consumption. • Capability to sell excess electricity generated back to the grid, making the complex an energy-plus building.

WEAKNESSES	WEAKNESSES	WEAKNESSES	WEAKNESSES
• Only surface parking is provided which at times becomes insufficient and creates chaos. • Access Friendly to differently-abled persons should be considered.	• Access Friendly to differently-abled persons should be considered.	• No weaknesses reported till date.	• Methods adopted to get net zero target is suitable only for small scale projects like this.

OPPORTUNITIES

- Continuos development in technology and increased awarness among people will develop the market.
- Can be a very good solution towards sustainable development and help to get rid off energy crisis.
- Proper development with expertise teamwork from the base level is helpful for achieving the net zero target .

THREATS

- Improper plaaning and mismanagement lead to the failure of these type of projects.
- Without expertise teamwork may fail the project.
- Technical failure can be the cause of not achieving net zero target.
- Total cost of the project should be taken care of from the beginning either the excessive project cause can be the main reason for the project failure.

INFERENCES

- Net Zero Energy office building is possible.
- Integration of Passive and Active Strategies Leads to Net Zero.
- Zero needs a thoughtful approach and takes a coordinated effort.
- Owner needs to set measurable goals and communicate those to the team.
- Net Zero Energy is a target today, but will be a requirement tomorrow.

INFERENCES

LITERATURE STUDY I	LITERATURE STUDY II	CASE STUDY I	CASE STUDY II
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- Integration of Passive and Active Strategies Leads to Net Zero.


To Create a Zero Energy Building...
STEP 1 Increase energy efficiency
Efficient building construction
Efficient systems and appliances
Operations and maintenance
Change in user behavior
STEP 2
Address remaining needs with on-site renewable energy generation
Solar

CASE STUDY