GREEN STRATEGIES FOR BUILDING DESIGN

CASE STUDY & COMPARATIVE ANALYSIS

ZERO ENERGY BUILDING

BCA Academy, Singapore

PIXEL BUILDING

Carlton, Melbourne, Australia

TUTOR | NIK SYAZWAN WAHAB

GROUP 5

VALLEN AQUILIN VIRGINE	0362113
CARREN LYNN ADMOJO	0365533
CH'NG KE NI	0355956
CHONG KHAI LIN	0357454
GAN LIN JIE	0358349
TAN SZEN WAY	0352173

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INTRODUCTION

Basic information for both buildings

01 INTRODUCTION

ZERO ENERGY BUILDING

The Zero Energy Building at BCA Academy showcases Singapore's early move toward sustainability, transforming a conventional structure into an eco-retrofitted educational hub that sets the standard for tropical green buildings.

LOCATION
BCA Academy,Singapore

YEAR OF COMPLETION
2009 (Retrofitted)

ARCHITECT
DP Architects / BCA

FUNCTION
Educational and Research Facility

ENERGY TARGET
Net Zero Energy

SUSTAINABILITY FOCUS
Tropical Climate Optimization, Education

PIXEL BUILDING

The Pixel Building represents Australia's architectural innovation, merging experimental design with strong environmental principles. Its distinctive facade and advanced systems embody a forward-thinking approach to sustainability, making it a pioneer in net-positive architecture.

LOCATION
Carlton, Melbourne, Australia

YEAR OF COMPLETION
2010

ARCHITECT
Studio 505

FUNCTION
Commercial Office / Prototype

ENERGY TARGET
Net Positive Energy & Carbon Neutral

SUSTAINABILITY FOCUS
Innovation in Temperate Design

SITE PLANNING

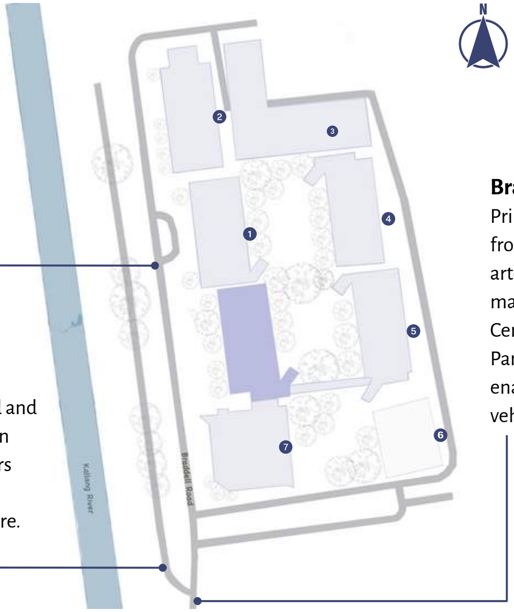
- Site Context
- Climate Analysis
- Solar Analysis
- Building Analysis

LOCATION

BCA Academy, 200 Braddell Road, Singapore 579700 is sits in a central Singapore corridor, **surrounded** by **residential**, **institutional**, and **green spaces**, supporting the nation's vision for a **sustainable built environment**.

ACCESSIBILITY

Public Transport:
The campus is accessible via several SBS and SMRT bus services, providing direct connections to nearby MRT stations and towns.



Braddle Rd:
Primary access to BCA Academy fronts Braddell Road, a key arterial road that connects to major expressways such as the Central Expressway (CTE) and Pan Island Expressway (PIE), enabling direct access by private vehicles from across the island.

Cycling and Walking:
The area is accessible by road and public transit, with pedestrian walkways and park connectors supporting walkability and potential cycling infrastructure.

SURROUNDING LANDMARKS

Educational Institutions:
BCA Academy sits within an educational cluster that includes institutions such as the ITE College Central (Ang Mo Kio) and Raffles Institution, reinforcing its role in built environment education and research.

Cultural and Commercial Amenities:
Bishan Junction 8 and Toa Payoh Town Centre, located nearby, provide a range of dining, shopping, entertainment, and essential services, offering convenience for students and staff.

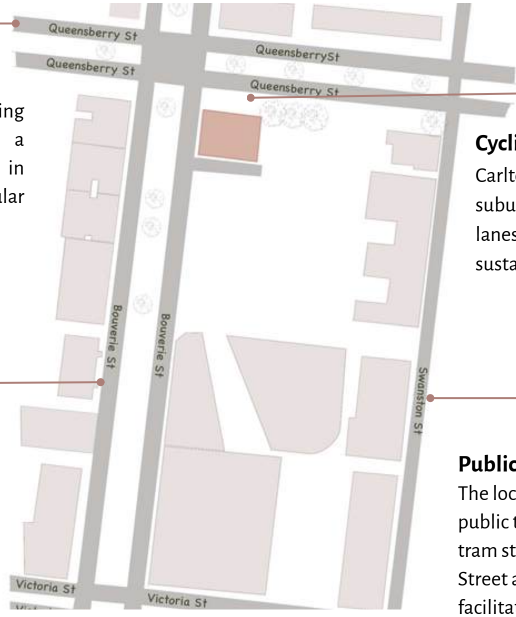
Parks and Recreation:
Green spaces such as Bishan-Ang Mo Kio Park and MacRitchie Reservoir Park offer opportunities for recreation, fitness, and environmental learning, complementing the academy's focus on sustainability and green practices.

LOCATION

205 Queensberry Street, Carlton, Victoria, Australia, is **situated** on a **prominent urban site**, **formerly part of the Carlton & United Breweries precinct**, the area has been into a vibrant mixed-use neighbourhood with commercial, residential, and educational spaces.

ACCESSIBILITY

Queensberry St:
Primary access to The building fronts Queensberry Street, a major east-west thoroughfare in Carlton, providing direct vehicular and pedestrian access.



Cycling and Walking:
Carlton is a pedestrian-friendly suburb with dedicated cycling lanes and footpaths, encouraging sustainable modes of transport

Bouverie St:
Running north-south, Bouverie Street intersects with Queensberry Street at the Pixel Building's location, enhancing its accessibility.

Public Transport:
The location is well-served by public transportation, with several tram stops along nearby Swanston Street and Lygon Street, facilitating easy access to Melbourne's Central Business District and surrounding areas.

SURROUNDING LANDMARKS

Educational Institutions:
The building is in proximity to major educational institutions, including the University of Melbourne and RMIT University, fostering a vibrant academic atmosphere.

Cultural and Commercial Amenities:
Nearby attractions include the State Library of Victoria, Melbourne Central Shopping Centre, and various dining and

Parks and Recreation:
The area offers access to green spaces such as Carlton Gardens, providing recreational opportunities for occupants and visitors.

Singapore has a **tropical rainforest climate**, with **consistently high temperatures, high humidity, and heavy rainfall** throughout the year. The average annual temperature is around **27.0°C**.

According to the Köppen-Geiger classification system, this climate is categorized as **Af**, indicating a **tropical climate with no dry season and year-round rainfall**.

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	25.8 °C (78.4) °F	26.2 °C (79.2) °F	26.7 °C (80.1) °F	27.1 °C (80.7) °F	27.4 °C (81.2) °F	27.3 °C (81.1) °F	27 °C (80.6) °F	26.9 °C (80.5) °F	26.9 °C (80.4) °F	26.7 °C (80.1) °F	26.3 °C (79.3) °F	26 °C (78.7) °F
Min. Temperature °C (°F)	24.3 °C (75.8) °F	24.5 °C (76.1) °F	25 °C (76.9) °F	25.4 °C (77.7) °F	25.7 °C (78.3) °F	25.7 °C (78.2) °F	25.5 °C (77.8) °F	25.4 °C (77.7) °F	25.3 °C (77.5) °F	25.1 °C (77.1) °F	24.8 °C (76.7) °F	24.6 °C (76.3) °F
Max. Temperature °C (°F)	27.9 °C (82.2) °F	28.7 °C (83.6) °F	29.1 °C (84.4) °F	29.2 °C (84.5) °F	29.1 °C (84.4) °F	29 °C (84.1) °F	28.5 °C (83.4) °F	28.5 °C (83.2) °F	28.6 °C (83.4) °F	28.7 °C (83.6) °F	28.3 °C (82.9) °F	28 °C (82.4) °F
Precipitation / Rainfall mm (in)	108 (8)	97 (3)	152 (6)	166 (7)	232 (9)	200 (7)	190 (7)	159 (7)	164 (6)	214 (8)	280 (11)	277 (10)
Humidity(%)	84%	82%	83%	85%	85%	84%	83%	83%	84%	85%	88%	87%
Rainy days (d)	14	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18	[illegible]	19	20	[illegible]
avg. Sun hours (hours)	8.8	9.1	9.1	8.9	8.8	9.1	9.1	9.1	9.2	9.2	8.7	8.2

TEMPERATURE

Average temperature in a year : 27 °C

Hottest month : May (avg. 31 °C)

Coldest month : January (avg. 29 °C)

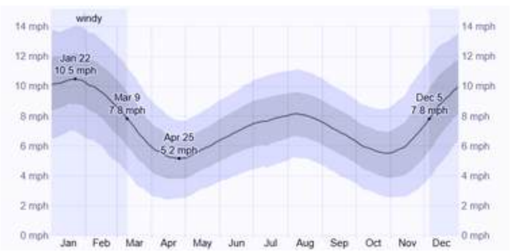
PRECIPITATION

Total avg. precipitation in a year : 2,522mm

Hottest month : November (280mm)

Coldest month : February (97mm)

WIND SPEED



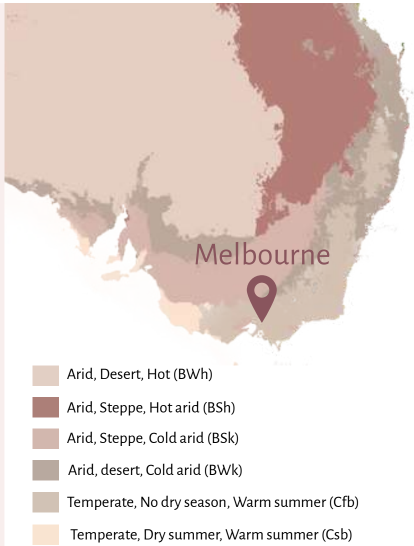
Average of mean hourly wind speeds

Windiest part of the year : December - March

HUMIDITY COMFORT

Apr - Jun : Most uncomfortable months (miserable)

Oct–Feb : Slightly less intense but still oppressive humidity.

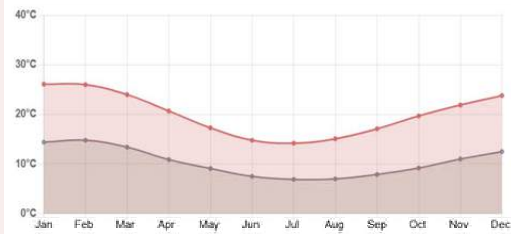


Melbourne has a **temperate oceanic climate**, with **warm summers and cool winters**. The average annual temperature is approximately **15.7°C**.

According to the Köppen-Geiger climate classification, Melbourne falls under the **Cfb** category, which stands for a **temperate climate with no dry season and a warm summer**.

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	20.2 °C (68.4) °F	20.1 °C (68.2) °F	18.4 °C (65.1) °F	15.3 °C (59.5) °F	12.4 °C (54.3) °F	10.1 °C (50.2) °F	9.6 °C (49.3) °F	10.2 °C (50.3) °F	12.2 °C (53.9) °F	14.2 °C (57.6) °F	16.5 °C (61.7) °F	18.4 °C (65.1) °F
Min. Temperature °C (°F)	15.4 °C (59.8) °F	15.6 °C (60) °F	14.1 °C (57.4) °F	11.4 °C (52.6) °F	9.4 °C (48.9) °F	7.4 °C (45.4) °F	7 °C (44.5) °F	7.2 °C (45) °F	8.6 °C (47.4) °F	10.1 °C (50.1) °F	12.1 °C (53.7) °F	13.6 °C (56.5) °F
Max. Temperature °C (°F)	25.9 °C (78.7) °F	25.6 °C (78) °F	23.6 °C (74.4) °F	19.8 °C (67.7) °F	16.1 °C (61) °F	13.5 °C (56.3) °F	12.9 °C (55.3) °F	13.8 °C (56.9) °F	16.3 °C (61.4) °F	18.9 °C (66) °F	21.6 °C (70.8) °F	23.7 °C (74.7) °F
Precipitation / Rainfall mm (in)	50 (1)	46 (1)	36 (1)	50 (1)	47 (1)	54 (2)	49 (1)	57 (2)	65 (2)	64 (2)	65 (2)	62 (2)
Humidity(%)	58%	62%	63%	68%	74%	78%	77%	74%	69%	65%	65%	60%
Rainy days (d)	5	4	4	5	7	8	8	9	9	8	7	6
avg. Sun hours (hours)	9.5	8.6	7.6	6.4	5.4	5.1	5.4	5.9	7.0	7.8	8.6	9.5

TEMPERATURE



Average temperature in a year : 15.7 °C

Hottest month : January (avg. 26 °C)

Coldest month : July (avg. 14 °C)

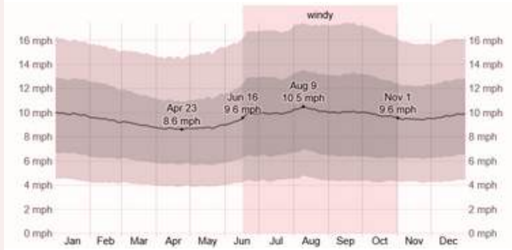
PRECIPITATION

Total avg. precipitation in a year : 600.9mm

Hottest month : November (63.3mm)

Coldest month : March (39.0mm)

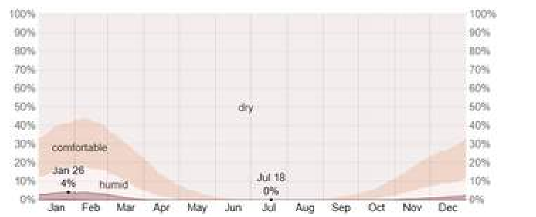
WIND SPEED



Average of mean hourly wind speeds

Windiest part of the year : June - November

HUMIDITY COMFORT



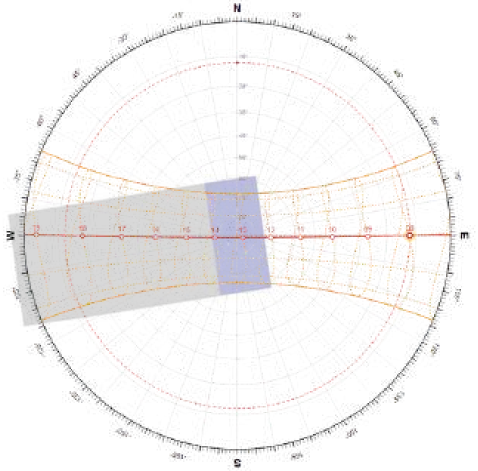
Apr - Oct : Dry and comfortable

Nov - Mar : Moderate humidity increases

Jan - Feb : Peak humidity, but still manageable

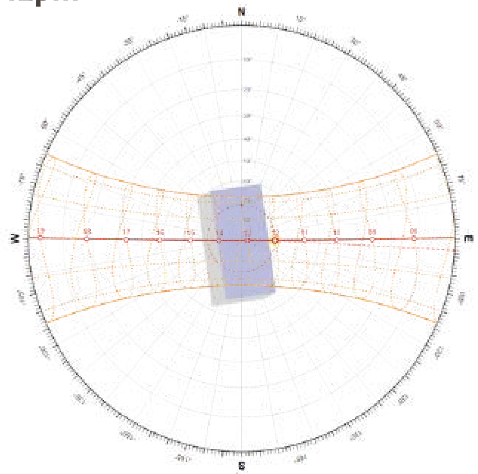
SOLAR ANALYSIS

8am



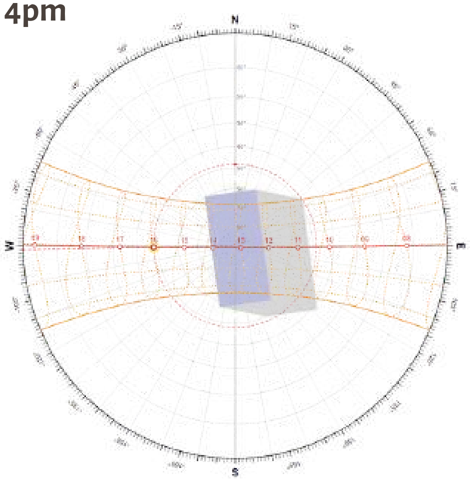
- Simple rectangular mass with minimal articulation.
- Form optimized for **solar panel installation** and **ventilation flow.**
- Compact and efficient, avoiding unnecessary complexity.

12pm



- Sun is at its highest point, casting minimal shadows on the horizontal plane.
- The **roof absorbs the most heat**; however, **integrated green roofs** and **shading devices reduce internal heat load**.
- Facade design with **plantations** and **louvers intercepts sunlight**, **minimizing direct penetration** into indoor spaces.

4pm



- The **west facade** receives **intense direct sunlight**, **increasing heat gain**.
- **Vegetation and shading strategies** are critical here to **reduce glare and thermal discomfort**.
- The building's orientation limits large, exposed west-facing walls, focusing shading design on afternoon sun protection.

Key Strategies

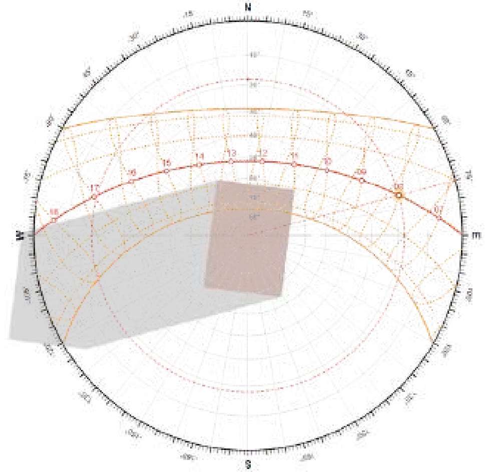
Louvres and **green roof** act as **natural shading**.

Compact building massing reduces exposure.

Green wall buffer heat at critical times (morning & evening).

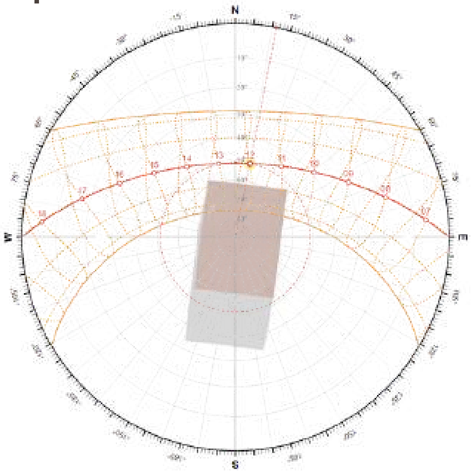
SOLAR ANALYSIS

8am



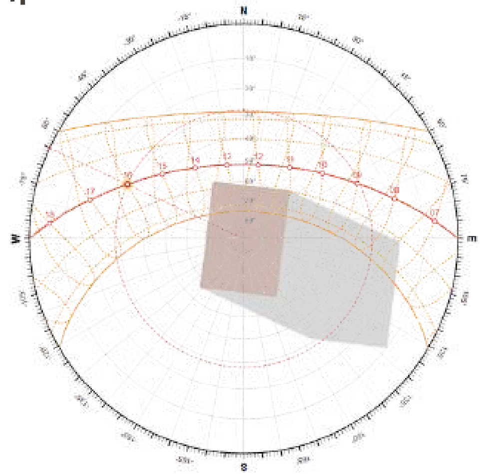
- The **sun path** is **low**; the **east facade** is **exposed** to **direct morning sunlight**.
- Building form is **tilted** to catch or **deflect light**, with shading devices and angled facades helping to **minimize low-angle sunlight penetration**.
- Shadow projections show partial shading over the ground floor.

12pm



- The sun is nearly overhead; **roof surfaces** are the **primary heat gain areas**.
- **Solar panels** and **roof gardens reduce solar absorption** and **manage heat load effectively**.
- Vertical elements create **shorter shadows**, allowing controlled daylighting within interiors.

4pm



- The **west facade faces significant solar exposure**, with **long shadows cast** on adjacent areas.
- The **angled facade** and **overhangs** help **shield west-facing glass**, **reducing afternoon heat gain**.
- Some solar access for interior spaces is maintained for passive lighting strategies.

Key Strategies

Angled facades and rooftop design optimize **daylighting** and **shading**.

Facade **articulation balances solar access** with shading.

Strategic planting and solar devices **minimize overheating** on critical facades.

02 SITE PLANNING

Building Analysis

ZERO ENERGY BUILDING

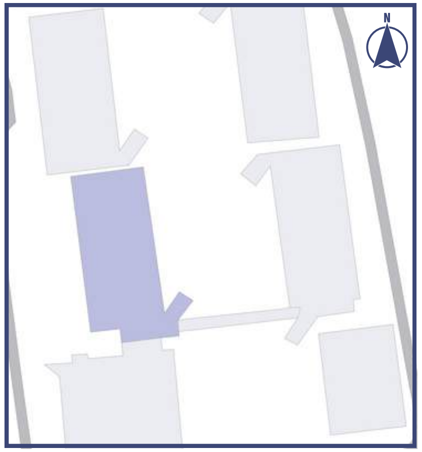
BUILDING ORIENTATION

East-West Orientation :

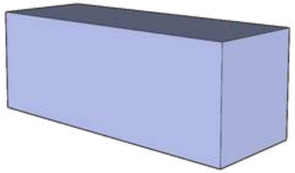
- Originally had an **east-west orientation**, which is less favorable in tropical climates.

High Solar Heat Gain on Facades :

- The east and west facades were especially **prone to high solar heat gain**, making heat absorption and indoor cooling a significant challenge.



MASSING



- **Simple rectangular mass** with minimal articulation.
- Form **optimized for solar panel installation** and **ventilation flow.**
- Compact and efficient, **avoiding unnecessary complexity.**

SITE REPONSE

GENIUS LOCI

Context

Positioned in Singapore's educational district, emphasizing sustainability.

Response

Acts as a symbol of Singapore's environmental leadership in education.

TOPOGRAPHY

Context

Flat, urban terrain on an educational campus.

Response

To optimize solar panel performance and manage stormwater using permeable surfaces.

HARDSCAPE

Context

Surrounded by educational facilities and streets with high pedestrian traffic.

Response

Permeable walkways and shaded areas for circulation and cooling.

SOFTSCAPE

Context

Surrounded by tropical greenery with abundant shade trees.

Response

Integrated rooftop gardens to cool the building and blend with the greenery.

PIXEL BUILDING

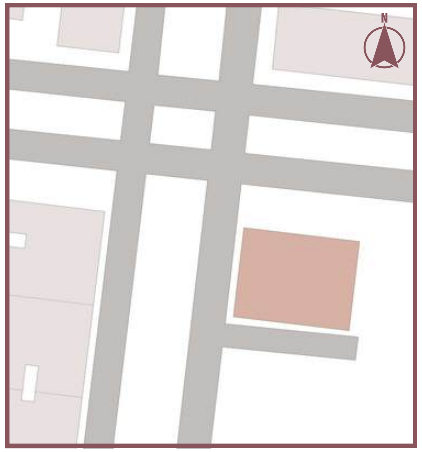
BUILDING ORIENTATION

North-Facing Orientation:

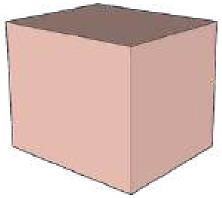
- To **maximize north-facing exposure**, which is **ideal for natural daylighting** in Melbourne's southern hemisphere location.

Minimized East and West Exposure:

- The design **reduces large east and west-facing openings** to **avoid low-angle sun** that causes glare and heat gain in the morning and afternoon.



MASSING



- **Compact cuboidal form**, **maximizing** limited site **footprint.**
- **Strong visual identity** with pixelated, layered facade.
- **Green roof integrated** within mass to **improve performance.R**

SITE REPONSE

GENIUS LOCI

Context

Located in Melbourne's commercial area, focusing on innovation and sustainability.

Response

Reflects Melbourne's identity as a hub for sustainable innovation in architecture.

TOPOGRAPHY

Context

Flat inner-city plot with tight space constraints.

Response

Vertical design to maximize space and enhance urban connectivity. Green roof acts as insulation.

SOFTSCAPE

Context

Located in a dense urban environment with limited green space.

Response

Utilizes a green roof to maximize the small urban plot and reduce heat island effects.

HARDSCAPE

Context

Located in a dense urban area with surrounding high-rises.

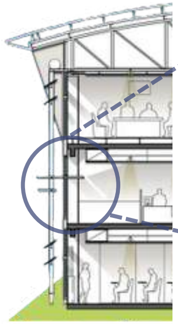
Response

Facade uses vibrant materials to stand out in the dense area.

DAYLIGHTING

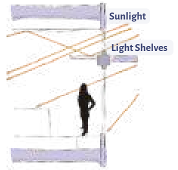
- Daylighting Responses
- Visual Comfort & Spatial Experience
- User Experience
- Comparative Analysis

LIGHT SHELF



ENHANCING NATURAL DAYLIGHTING

Incorporates light shelves as a key passive design strategy to reduce energy use.



Reflective Ceilings

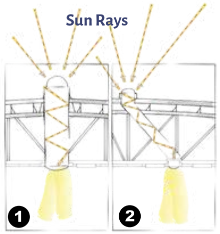
To help **light reach deeper** into rooms, ZEB uses ceilings with reflective coatings that **maximize light reflection** into the interior.

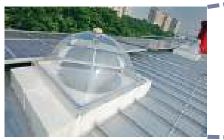
- Installed above eye level, they **extend into the interior.**
- Their reflective surface redirects daylight **deeper** into the space.
- **Cuts artificial lighting** use, boosting **energy efficiency and comfort**.

LIGHT PIPES

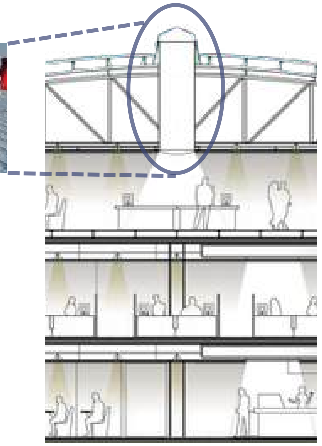
Vertical tubes that **channel natural light** from the roof into the **interior spaces** of a building, **brightening rooms** up to five meters deep.

1. One has rotating mirrors that track the sun to provide steady daylight.
2. Another has blades occupants can adjust to control daylight.



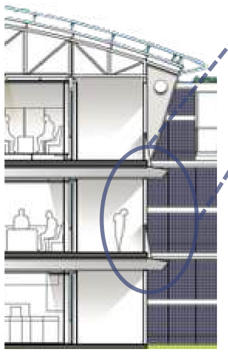


Rotating mirrors installed at the end of a light pipe



- One end of the pipe extends through the roof; the other opens inside the room.
- Light travels down the pipe by **reflection** and is emitted through the ceiling.
- These light pipes **boost natural light**, **increasing comfort** and **cutting artificial lighting** use.

MIRROR DUCT

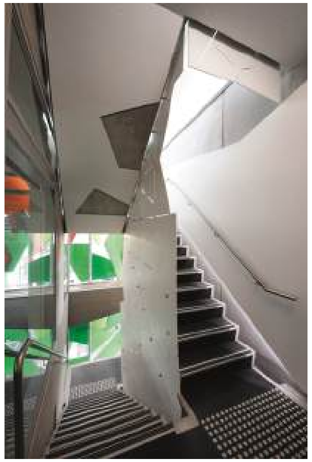


A simple, power-free system that **brings natural light** into interior spaces. The first in Singapore to incorporate this innovative daylighting solution.

- The system has a horizontal duct in the false ceiling linked to an external collector.
- The duct and collector are lined with **highly reflective materials** such as aluminium alloy, mirrored acrylic, or optical polycarbonate.

LIGHT WELL

Light wells are used to channel daylight into interior zones that would otherwise be poorly lit.



Light Entry & Distribution

- West-facing windows at the staircase top **allow natural light** to enter.
- Acts as a light well, channeling and **reflecting daylight** down the entire staircase.
- Ensures **balanced illumination** from top to bottom.

Material & Surface Effects

- **White-painted balusters** with linear cutouts reflect light, **enhancing brightness.**
- Cutouts create slivers of light that **add visual interest** while maintaining safety.
- Creates a **poetic atmosphere** when direct sunlight penetrates the space.

Spatial Transparency

- Full-height glazed panels separate staircase and office zones.
- **Allows daylight** to pass through both spaces, creating a **visual connection** while **maintaining privacy.**

Welcoming Entrance

- Clear glass main entrance **leads** directly to the staircase and lobby.
- **Allows daylight** to penetrate the entryway, making it inviting and open to outsiders.

LARGE WINDOW

To enhance **natural illumination, reduce energy use**, and **improve spatial quality** through visual openness and daylight access.

Maximizing Natural Light

- To **allow abundant daylight** to flood the interior, **reducing** dependence on **artificial lighting.**

Improving Visual Connection

- To **offer clear views** to the outside, enhancing users' connection with nature and time of day.

Before renovation

Pixel Building originally featured **full-height double-glazed windows** to **maximize daylight**. While this **enhanced natural lighting**, it caused **heat gain and glare.**

- The **glass** used often includes **solar control coatings** to **block excess heat** while **allowing light** in.
- Positioned to make full use of natural light without glare.
- Large windows **enhance daylighting** and contribute to **sustainability** and occupant well-being.

03 DAYLIGHTING

Visual Comfort & Spatial Experience

The ZEB building uses **passive daylighting** (light shelves, pipes, and mirror ducts) to **create bright, energy-efficient spaces** that enhance user comfort and well-being.

VISUAL COMFORT

Uniform lighting distribution :

Techniques like light pipes and mirror ducts help **avoid harsh contrasts and glare**, creating **balanced light levels** across rooms.

Top view of the mirror duct's external collector.

Openings in the duct and false ceiling allow daylight to exit and illuminate the interior space.

Natural light quality :

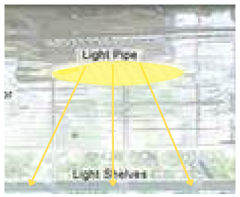
- Natural daylight **improves color rendering** and **reduces visual fatigue.**
- Supports circadian rhythms, **enhancing alertness and comfort.**

Reduction in glare :

- **Light shelves block direct sunlight** and **reduce glare** while redirecting daylight inside.
- **Reflective ceilings** and adjustable blades help **control indoor brightness.**

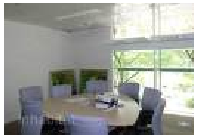
SPATIAL EXPERIENCE

Brighter, more open interiors :



- Light from above (light pipes, mirror ducts) gives rooms a **sense of vertical openness and clarity.**
- Light shelves **distribute light deeper**, making rooms **feel larger** and **more welcoming**.

Connection to the outside :



- Natural light allows users to **sense time** and **weather changes**, supporting psychological well-being.

User control of environment :

- Operable blades in light pipes empower users to adjust light levels, **improving comfort and satisfaction.**

USER EXPERIENCE

- Daylighting strategies create a **comfortable, glare-free environment** that supports occupant well-being and allows user **control over light levels**.

The Pixel Building uses colour panels, large windows, and light wells to **reduce energy** use and **boost indoor comfort and well-being**.

VISUAL COMFORT

Filtered daylight through colour panels:

- Translucent colored facade panels **soften incoming daylight** and **reduce harsh glare.**
- Create **pleasant light tones** inside and enhance **visual comfort and mood.**

Consistent natural lighting:

- Large windows and light wells **evenly distribute daylight,** preventing visual strain.
- **Reduce** reliance on **artificial lighting** during the day, especially in shared/open spaces.

Controlled heat and brightness:

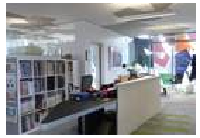
- Panels and glazing **filter** excessive **sunlight**, **balancing light quality** and **indoor temperature.**
- **Reduce high-contrast zones** and eye fatigue from direct sun exposure.

SPATIAL EXPERIENCE

Bright and inviting interiors:

- Daylight from windows, wells, and panels creates **open, vibrant, uplifting spaces.**

Natural orientation & time awareness:



- Large windows **connect occupants to nature, time, and weather**, boosting mental well-being.

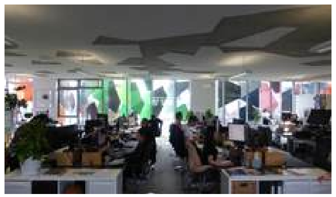
Engaging colour effects:

- Coloured panels add a **dynamic play of light** and **shadow** throughout the day, **enriching** the **spatial character.**

Deep daylight penetration:

- Large window **bring daylight** into deeper zones, **reducing enclosure** and **enhancing spatial openness.**

USER EXPERIENCE



- Natural light and colour effects **enrich the space**, **enhancing mood** and **providing occupants** with a dynamic, engaging environment.

03 DAYLIGHTING

Comparative Analysis

SIMILARITIES

Maximize Daylight :	Both buildings aim to **reduce** dependence on **artificial lighting.**
Multiple Light Sources:	Use **various architectural strategies** like light wells and large openings.
Improve Occupant Well-being:	Natural light used to **boost comfort, mental health, and productivity.**

DIFFERENCES

Zero Energy Building		Pixel Building
Light wells, ducts, and reflective ceilings guide light deeper inside	**Light Delivery**	Perforated facades reflect daylight into the interior
Adjustable light shelves, sloped ducts, glazed partitions	**Control Techniques**	Static but effective panel geometry and window positioning
Prioritizes glare control, visual connection, circadian alignment	**User Comfort Goal**	Focuses on maximum daylight and visual stimulation
Brings light into core areas, reducing enclosure and improving spatial feel	**Spatial Experience**	Creates open, bright, and visually connected interior spaces

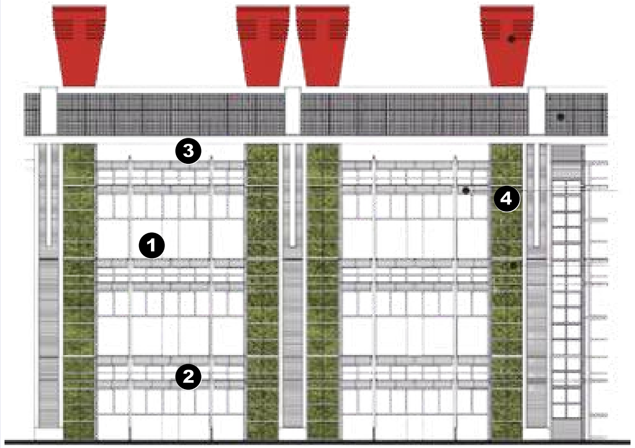
04

FACADE DESIGN

- Facade Analysis
- Facade Materiality
- Facade Strategies
- Comparative Analysis

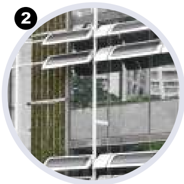
04 FACADE DESIGN

Facade Analysis & Facade Materiality



Energy Efficiency Glazing

Roof Overhang



Louvers

Green Wall

FACADE MATERIALITY

ZEB is a high-performance research facility that integrates passive and active strategies to achieve zero energy.

Primary Material :
Double-Glazed Low-E Glass

- **Reduces solar heat gain** while allowing visible daylight.
- **Minimizes** reliance on **artificial cooling** and reduces glare.
- Contributes to **visual comfort** and **energy savings.**

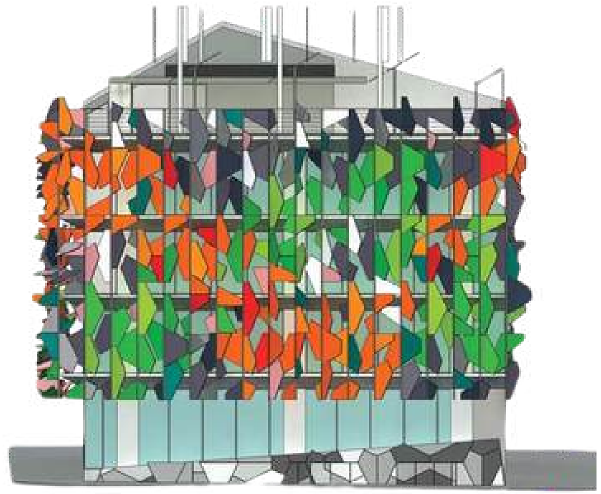
Secondary Material :
High-Performance Insulated Wall Panels

- Provides excellent **thermal insulation.**
- Reduces heat transfer from the external environment.
- Helps maintain **indoor thermal stability.**

Supporting Elements :
Reflective Finishes & Facade Treatments

- **Reflective external coatings** lower surface heat absorption.
- **Improves** passive **cooling performance**.
- **Durable** and **low-maintenance** surface **materials.**

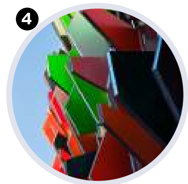
The facade materials are carefully selected to **reduce heat gain**, **enhance daylighting**, and **improve indoor comfort** while maintaining energy efficiency.



Colorful Perforated Panels

High-Performance Glazing

Sun-Shading System



Dynamic and Faceted Facade Geometry

FACADE MATERIALITY

- This building is a **carbon-neutral structure** that combines vibrant design with **high-performance materials.**
- Its innovative facade system not only **expresses identity** but also e**nhances environmental performance**, **comfort, and light quality.**

Primary Material :
Perforated Recycled Metal Panels

- Made from **recycled aluminum**.
- Colorful, perforated design gives the building its **"pixelated" aesthetic.**
- **Reduces** solar **heat gain and glare.**
- **Allows filtered daylight** to enter the building.
- Contributes to **passive cooling** and **energy efficiency.**

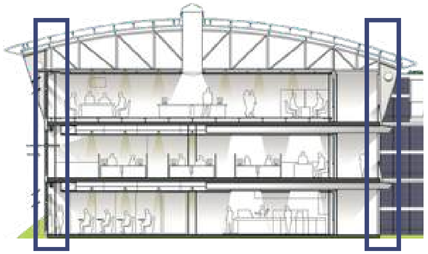
Secondary Material :
High-Performance Glazing

- Uses **double-glazed, Low-E coated glass.**
- **Minimizes** the need for **artificial lighting.**
- **Improves** indoor **thermal comfort.**
- **Reduces** cooling **energy demand.**

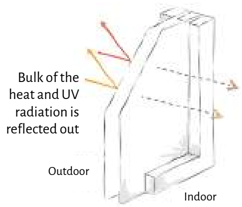
The materials were selected to strike a balance between **aesthetics, energy performance, and environmental sustainability.**

ENERGY EFFICIENCY GLAZING

FENESTRATION



Low-Emissivity (Low-E) Glass



- Features a special **low-emissive coating.**
- **Reduces solar radiation** transfer through the glass.
- **Minimizes heat gain** while allowing visible light through.
- **Enhances indoor thermal comfort** and lowers cooling load.

Benefits

- **Reduces** reliance on **artificial cooling systems.**
- **Improves energy efficiency.**
- **Supports indoor visual** and **thermal comfort.**

Solar Film Coating

- **Thin UV/infrared reflective film** applied to glass.
- **Reflects ultraviolet (UV) rays** and **infrared heat.**
- **Reduces** unwanted solar **heat** gain.
- **Maintains clear visibility** and **daylight penetration.**

The glazing is to **reduce heat gain** by reflecting infrared rays while letting in natural light—**improving comfort** and **energy efficiency** without blocking views.

GREEN & ENERGY-GENERATING FACADES

Green Wall

A **vertical layer of vegetation** attached to the exterior wall of the building.

Functions of Green Wall

Reduces Heat Gain :

- **Plants** provide **natural insulation**, lowering surface temperature.

Improves Air Quality :

- **Absorbs CO_2** and filters dust and pollutants.

Aesthetic Appeal :

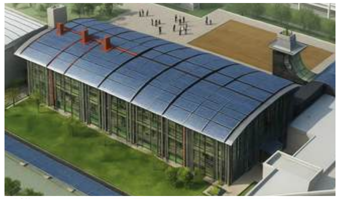
- To **minimize cooling load** by lowering indoor heat gain.

Benefits

- **Improves thermal comfort** and **reduces** cooling **energy needs.**
- **Promotes biodiversity** in urban settings.
- **Creates a calmer, more refreshing atmosphere** for users.

PV Solar Wall

Uses silicon-based and thin-film PV panels on facades, positioned for optimal solar exposure.



Various types of PV cells installed on the facade

ZEB's monthly energy output has remained consistent over the years, indicating stable performance with no noticeable drop in efficiency.

Electric Output

The PV facade contributes to ZEB's total capacity of **190 kWp**, supporting building functions and **reducing dependency** on the grid.

Energy Use

Grid-connected :	**Off-grid :**
Main use, with surplus power sent to nearby buildings or returned to the grid.	Certain panels directly power specific functions like outdoor kiosks.

COLORFUL PERFORATED PANELS & DYNAMIC AND FACETED FACADE GEOMETRY

A simple but intricate assembly of **zero waste, recycled colour panels** not only enhances visual appeal but also

Benefits

- Provides visual dynamism.
- Improve heat insulation.
- Minimizes Cooling Load.

Material of Facade

Perforated Aluminum Panels

Reduced Surface Temperature

- Aluminium **reflects** a good portion of **infrared radiation** (heat energy), especially with bright-colored powder coatings.

Durability

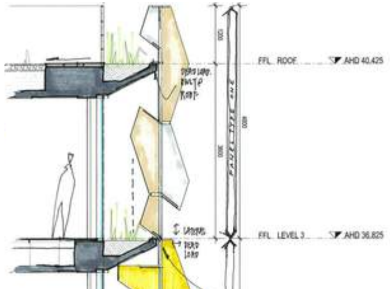
- Aluminium is **lightweight**, **durable**, and **low-maintenance**—ideal for Melbourne's climate and reducing long-term costs.

After Colour Panels Added:

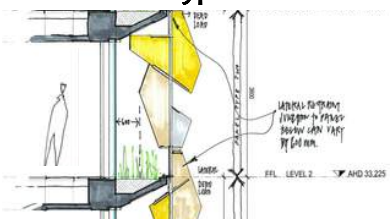
To address these issues, colorful perforated panels were added to the facade. These panels help to:

- **Filter** and diffuse **daylight**, **reducing** harsh **glare.**
- **Minimize solar heat gain**, improving thermal comfort.
- Maintain **aesthetic appeal** while enhancing energy efficiency.

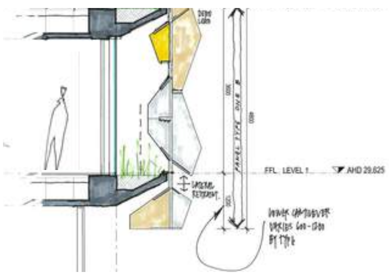
Facade Panel Type One



Facade Panel Type Two

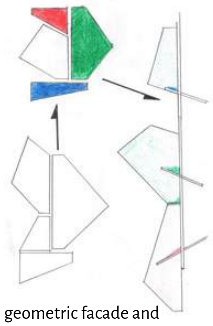


Facade Panel Type One B



Typical Facade Section Detail (N.T.S)

Visual Dynamism



geometric facade and sunshading cross section

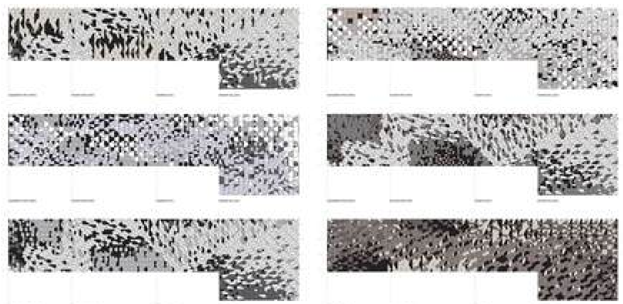
A collection of **multi-coloured geometric panels** and an **automated sun-shading system** provide **solar protection** for the full-height glazed curtain wall.

- Panels **catch direct sunlight**, appearing brighter and more intense in color.
- **Shaded panels** create **contrast and depth**, adding dimensionality to the facade.
- Perforations cast **soft, moving shadows** on the building and its surroundings, **enhancing visual texture**.

Free Night Cooling

The pixel facade includes smart technology that **automatically open window** of the facade on cooling night to **enable** the **night air flow** in the building and **cool the structure.**

Facade Pattern Development



ZERO ENERGY BUILDING

04 FACADE DESIGN

Facade Strategies

PIXEL BUILDING

LOUVERS

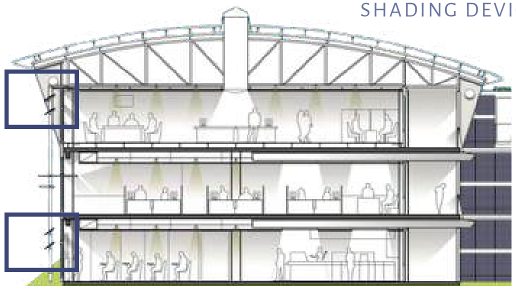
SHADING DEVICES

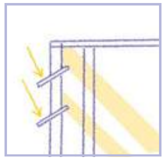
Functions of Louvers

Solar Control :
- To **reduce glare** and blocks excessive heat from direct sunlight.

Daylighting :
- To **permit filtered daylight**, reducing the need for artificial lighting.

Daylighting :
- To **minimize cooling load** by lowering indoor heat gain.

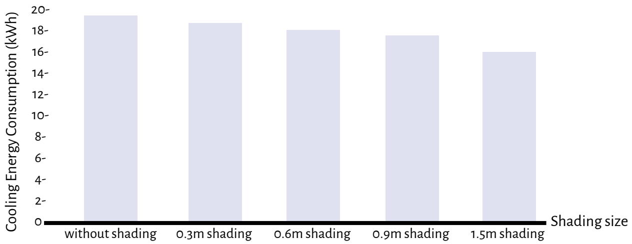




Benefits

- **Enhances** visual comfort and privacy.
- **Improves** indoor environmental quality.
- **Contributes** to sustainable and energy-efficient design.

Figure shows the impact of shading on consumption of energy for cooling purpose



Shading Size	Energy (kWh)	Energy Saving (%)
without shading	19.52	-
0.3m shading	18.83	3.5
0.6m shading	17.95	8.0
0.9m shading	17.14	12.2
1.5m shading	15.91	18.5

From research project "Thermal Performance of facade Material & Design and its impact on Indoor and Outdoor Environment, NUS"

Multi-functions Louvers - Louvers with Integrated PV Panels

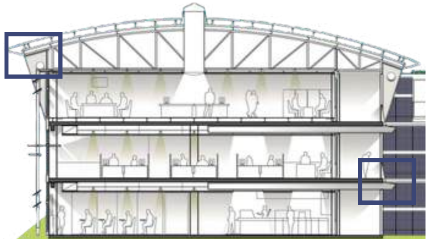
- **Integrated Tech :** Each **louver** is fitted with thin-film amorphous photovoltaic (PV) panels.

Energy Output

- Each **m² of PV panel** can generate enough electricity to power a **45-watt light bulb.**
- The total **PV area** on ZEB's sunshades can power **24 light bulbs** using only solar energy.

ROOF OVERHANG

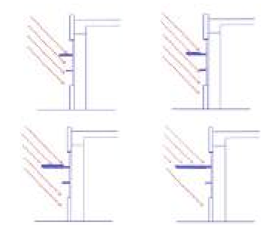
SHADING DEVICES



- A **passive** shading device.
- A **horizontal extension** of the roof beyond the building's wall line.
- Positioned to block **high-angle sunlight**, especially during midday.

Benefits

- Improves **indoor thermal comfort.**
- Cuts **cooling energy demand.**
- Protects windows and facades from weather, **extending** their **lifespan**.



The overhang **blocks heat** and **glare** while allowing natural light, **enhancing visual comfort** and **reducing cooling energy.**

Functions of overhang roof

Sun Shading :
- **Reduces direct solar heat** gain through windows.

Daylighting Control :
- To **allow soft daylight** while minimizing glare.

Weather Protection :
- **Shields** openings from **rain and wind.**

SUN-SHADING SYSTEM

Reed Bed Overhang

Function & Integration :
- **Integrated** into both the **interior floor and external facade**.
- Acts as a **passive shading device**.

Sustainable Design Impact :
- **Reduces** reliance on **mechanical cooling and heating.**
- Contributes to **energy efficiency** and indoor comfort year-round.

Summer Performance :
- **Overhang shape** provides shade, **reducing direct solar heat gain**.
- Helps keep the building **cool during hot months.**

Winter Performance :
- Sloped design **allows sunlight** to enter and **reflect heat** into the building.
- **Enhances thermal comfort** and **reduces heating demand.**

Facade Cladding Panels

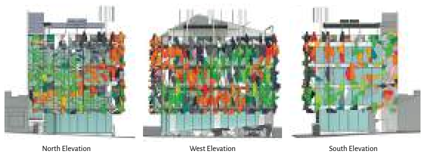
- Made of **aluminum skins** with **mineral-filled core** and **fluorocarbon paint finish.**
- Installed as a **layered screen** on north and west facades.

Functions :
- **Blocks direct sunlight** (especially during midday).
- **Prevents glare** and **reduces interior discomfort.**
- **Reflects** and **refracts daylight** for even light distribution indoors.

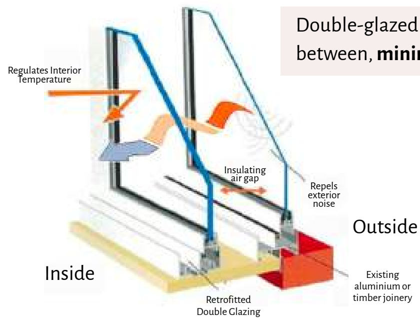
Designed to provide :
- 100%Lighting power density (LPD): **100 lux·W/m².**
- **100%** daylight penetration
- A maximum of **160 lux** during daytime.

FENESTRATION

Double Glazed Glass Window



- Installed on the north, south, and west facades.



Double-glazed units consist of **two layers of glass** with an insulating air or gas layer in between, **minimizing heat transfer.**

High-performance double-glazed windows in the Pixel Building **filter natural light**, **reduce glare**, and **balance daylight** with energy efficiency.

Functions :
- **Glare Control :**
  The double-glazing system helps to **reduce glare** from direct sunlight, **improving indoor visual comfort.**
- **View Quality :**
  - Provides **clear views** to the outside, maintaining **strong visual** connection with the surroundings.
  - **Cladding system** adds a **pixelated aesthetic** without blocking the view.
- **Thermal Efficiency**
  To **enhance energy efficiency** by **reducing heat gain/loss**, lowering the cooling and heating load.

04 FACADE DESIGN

Comparative Analysis

SIMILARITIES

Sustainable Design Focus :	Both buildings incorporate **facade strategies** to **reduce energy consumption.**
Glare Reduction :	Each uses specific **shading elements** to **control glare** and enhance visual comfort.
Daylight Integration :	Both facades are designed to support **natural daylight entry** while **minimizing heat.**

DIFFERENCES

Zero Energy Building		Pixel Building
Simple, functional, green-integrated	**Aesthetic Style**	Vibrant, artistic, and dynamic with colorful panels
Uses PV-integrated louvers, roof overhangs, and green walls	**Shading System**	Features perforated cladding panels that reflect/refract sunlight
Double-glazed glass, eco-materials	**Material Use**	Aluminum panels with reflective coatings and mineral core
Clear views maintained through glazing	**View Strategy**	Views are filtered or pixelated by cladding

NATURAL VENTILATION

- Building Layout & Massing Response
- Natural Ventilation Components
- User Experience
- Comparative Analysis

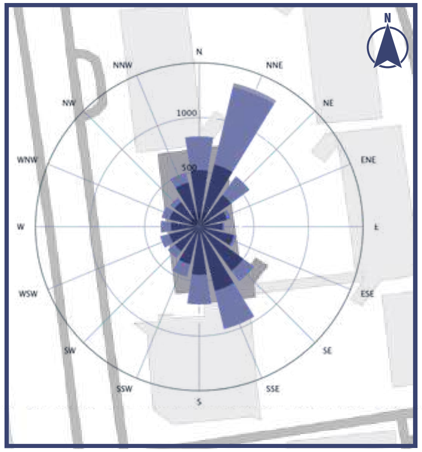
05 NATURAL VENTILATION

ZERO ENERGY BUILDING | PIXEL BUILDING

Building Layout and Massing Response & Natural Ventilation Components

ZERO ENERGY BUILDING

LAYOUT RESPONSES



- **Singapore's consistent northeast and southern winds**, coupled with **moderate wind speeds**, enable the **ZEB** to perform **effective natural** ventilation year-round, reducing reliance on **mechanical cooling systems.**

Purpose of Natural Ventilation

Reduce dependency on ACMV systems

- By promoting **passive cooling strategies** suited for **Singapore's tropical climate.**

Reduce dependency on ACMV systems

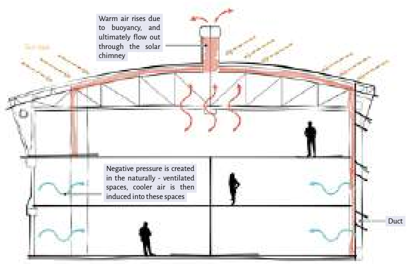
- **Solar chimneys** draw **warm air** upward, creating **airflow** that **cools indoor spaces** without **mechanical assistance.**

Maximize natural wind flow

- Designed to capture **prevailing NE and S winds**, improving **cross ventilation** and **air exchange.**

SOLAR CHIMNEY

NATURAL VENTILATION COMPONENT



How it works :

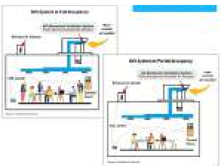
1. **Heat absorption**
   - Dark-colored metal ducts and chimneys **absorb solar radiation.**
2. **Stack effect**
   - As **air heats up**, it becomes **buoyant** and **rises through ducts** toward the chimneys.
3. **Air movement**
   - This rising **warm air escapes** via the **solar chimney**, creating **negative pressure** that pulls cooler outdoor air into occupied spaces.

Implementation in ZEB :

- Located at the **top of the school hall** (3rd floor).
- **Ducts connect** various **naturally ventilated rooms** to the hall.
- Facilitates **continuous airflow** without mechanical systems.

Performance Highlights :

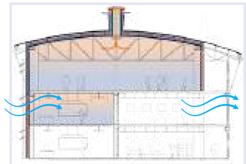
- **Airspeed inside the hall :** 1.0 – 2.5 m/s.
- **Airspeed inside the chimney :** over 5.0 m/s.
- **Effective in cooling and ventilating** large enclosed spaces like school halls.



Design Considerations :

- Chimney height influences performance : **taller = better airflow.**
- In ZEB, chimney **height was limited** due to **roof load capacity.**
- Future designs should consider **chimney height** and **structural support** during **early planning stages.**

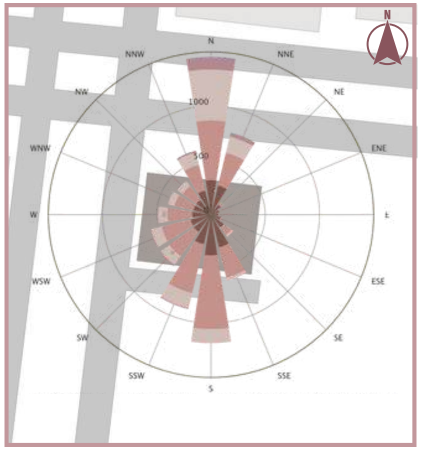
User Experiences :



- **Occupants** experience a **consistent airflow** within **interior spaces** due to the integration of **solar chimneys**, which promote **passive stack ventilation.**
- The environment remains **comfortable** and **well-ventilated** even during warm periods, reducing reliance on **mechanical air-conditioning.**
- Users benefit from **improved indoor air quality** and **reduced stuffiness**, especially in larger spaces like the school hall, enhancing comfort and concentration levels.

PIXEL BUILDING

LAYOUT RESPONSES



- **Melbourne's dominant north–south winds** and **moderate to strong wind speeds** create an ideal condition for **natural cross ventilation** in the Pixel Building, reducing dependence on **mechanical cooling** and **improving indoor comfort.**

Purpose of Natural Ventilation

Reduce reliance on mechanical cooling

- **Utilizes** Melbourne's **cool night air** through **night purging** to flush out daytime heat.

Leverage prevailing N and S winds

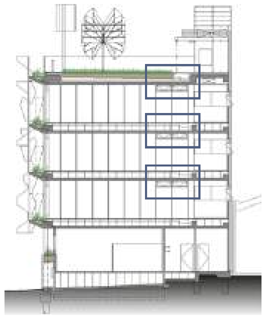
- Cross ventilation strategies align with **natural wind patterns** for **effective passive airflow.**

Promote thermal comfort naturally

- Cooler indoor temperatures are **achieved without energy-intensive** systems, especially during night hours.

NIGHT PURGING

NATURAL VENTILATION COMPONENT



Night purging passively cools the building by using cool night air to flush out heat built up during the day.

How it works in Pixel Building :

1. **Cool Night Air Enters**
   - **Windows and vents are opened** to **bring** in **cool** outdoor **night air.**
2. **Air Circulates Indoors**
   - Cool air moves through the building, **absorbing stored heat.**
3. **Heat Rises & Escapes**
   - Warm air **rises and exits** through higher vents.
4. **Morning: Cooler Indoors**
   - **Interior stays cool** in the morning, reducing need for AC.

Wind - Driven Cross Ventilation

- The building is designed to **maximize wind flow** through **internal spaces** when conditions permit.
- **Strategic window placement** and **openings** support passive cooling by enabling **cross ventilation**.

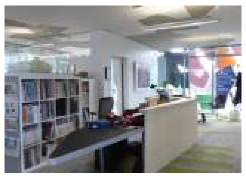
Design Intention

- Combined with **cross ventilation**, night purging **improves** the building's overall **thermal performance.**
- By starting the day with a **cooler indoor environment**, the building delays or even avoids the use of **mechanical cooling.**

Benefits for Occupants

- **Enhanced comfort** with fresher, cooler air each morning.
- Supports **healthier indoor air quality** by replacing stale indoor air.
- **Energy-saving**, as it minimizes dependence on **artificial cooling systems.**

User Experiences :



- The building offers a **cooler microclimate** around its facade through the **evapotranspiration effect** of **green roof systems and reed beds.**
- Users experience **improved thermal comfort** in semi-outdoor areas, such as shaded walkways or communal zones.
- The integration of **passive cooling strategies** contributes to a **healthier** and **more pleasant indoor environment**, supporting occupant well-being.

05 NATURAL VENTILATION

Comparative Analysis

SIMILARITIES

Energy Reduction :	Both buildings **reduce** reliance on **mechanical cooling systems** (like ACMV) through passive ventilation strategies.
Climate Adaptation :	Each system **responds effectively** to **warm climates**—maximizing airflow and heat removal.
Occupant Comfort :	Natural ventilation contributes to a **healthier indoor atmosphere** and **improved thermal comfort** for users.

DIFFERENCES

Zero Energy Building		Pixel Building
Solar Chimney (Stack Ventilation)	**Main Strategy**	Cross Ventilation & Night Purging
Uses buoyancy of hot air to draw in cooler air through ducts and vent it via metal chimneys	**Working Principle**	Leverages pressure differences between openings for daytime airflow, and cooler night air to flush out heat
Targets large indoor volumes for continuous airflow	**Ventilation Focus**	Enhances both day and night ventilation to reduce heat buildup and improve comfort
Chimney height restricted by existing roof structure	**Design Limitation**	Ventilation effectiveness may vary depending on wind direction and opening control

STRATEGIC LANDSCAPING

Landscape Strategies
Comparative Analysis

Green Roof

Green Wall

Surrounding Trees

GREEN ROOF

The **green roof** at ZEB uses **vegetation and soil** to reduce heat gain, manage stormwater, and **create a cooler microclimate** while **boosting aesthetics and biodiversity**.

GREENERY SYSTEM

Functions of Green Roof

Heat Reduction :

- **Plants on the roof shield** the building from **direct sunlight**, reducing heat transmitted through the roof and **lowering** the **Roof Thermal Transfer Value (RTTV)** to approximately **9.95 W/m²**. (Singapore's Green Mark Standards baseline 25 W/m²)

Evapotranspiration :

- The **process of evaporation** from soil and **transpiration** from plants **cools the air**, **lowering ambient temperatures**.

Stormwater Retention :

- The **green roof absorbs rainwater**, **reducing runoff** and lowering pressure on drainage systems.

Low Maintenance :

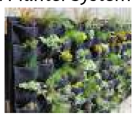
- Irrigation is **minimal** due to **capillary action** and **soil moisture retention**.

GREEN WALL

Types Tested:

1. Panel System

2. Planter System



3. Cage System

GREENERY SYSTEM

Functions of Green Wall

Shading:

- **Plants block direct sunlight**, **reducing surface heat absorption** by the building wall.

Thermal Insulation :

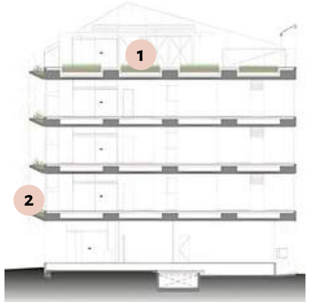
- Vegetation and soil add a **natural insulation layer**, **reducing heat transfer** through **building walls**, helping the building achieve a **low Envelope Thermal Transfer Value (ETTV)** of approximately **31.76 W/m².** (Singapore non-residential buildings baseline 50 W/m²)

Aesthetic and Ecological Value :

- **Breaks facade monotony** and improves urban biodiversity.

PERFORMANCE OF GREENERY SYSTEM

Greenery System		External Surface Temperature (°C)	Heat Flux (W/m2)	Ambient Temperature (°C)	Energy Savings Based on Heat Flux Difference (kWh/m2/year)
Green Roof		24	53	7	70.2
Green Wall	Panel type	10	4	2	4.16
	Planter type	16	3.5 - 5	2 - 3	5.72
	Cage type	6	1.75	2	2.86



Green Roof

Reed Bed

These systems **lower surface temperatures** and **improve the microclimate**, effectively helping to **reduce urban heat island effects** around the building.

ROOFTOP GARDEN

Creation and Preservation of Habitat & Ecological Biodiversity

Roof Plan

- Planted species selected to meet **Greenstar points** and to **re-establish original vegetation**.
- Rooftop garden acts as a **trial ground** for **Native Victorian Grass species** adapted to **Melbourne's climate** (drought resistant, underground organs, root production at nodes, leaf succulence).
- **75%** of rooftop covered with **Native Victorian Grass species**; garden has **four beds**, each 28m² and 300mm substrate depth, creating an **extensive green roof**.

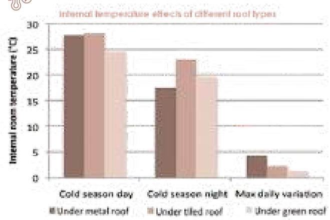
GREEN ROOF

Functions of Green Roof

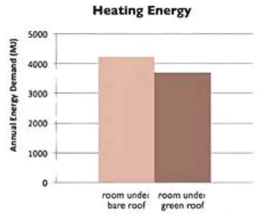
Heat Reduction :

- **Vegetation reflects** most **direct sunlight**, reducing heat absorption.
- **Water vapor** released by plants during **evapotranspiration lowers roof temperature**, reducing heat transfer into the building.
- Green roof **reduces internal and external heat fluctuations**, preventing heat gain in summer and heat loss in winter.

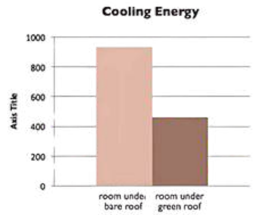
Thermal Performance:



- Buildings with **green roofs** show **lower internal temperature variations** compared to metal or tiled roofs.



- **Heating energy** required is **12% lower** compared to conventional bare concrete roofs.



- **Cooling energy required** is **50% lower** than buildings with bare concrete roofs.

Stormwater Management & Rainwater Filtration :

- **Green roofs retain and filter rainwater**, **reducing runoff** into drains.
- **Substrate layers** (Scoria and Envir-O-Agg) filter water by **allowing fine particles through** while trapping larger substances.

LIVING EDGE REED BED

Other floors planted with **reed beds** for **passive greywater treatment**.

Floor Plan

Functions of Reed Bed

Evapotranspiration :

- Evapotranspiration includes evaporation from soil and transpiration from plants absorbing water through roots and releasing vapor through leaves.
- These processes **absorb heat**, **lowering surrounding temperatures** and **cooling the building**.

Maintenance and Treatment :

- 100% of **irrigation water is greywater** from basins and showers.
- Reed beds provide **greywater treatment via evapotranspiration**, **releasing water vapor** to **cool the building**.

06 STRATEGIC LANDSCAPING

Comparative Analysis

SIMILARITIES

Both use green roofs as a core passive design strategy.
Both apply evapotranspiration for passive cooling.
Both manage stormwater through vegetation.
Both improve thermal performance using vegetation.

DIFFERENCES

Zero Energy Building		Pixel Building
Used for insulation, cooling, stormwater, lowering the RTTV	**Green Roof**	Used for insulation, cooling, stormwater, energy savings
Through green roofs	**Evapotranspiration**	Through green roof and reed bed
General planting for cooling & biodiversity	**Vegetation Type**	Native species suited for Melbourne's climate
Quantitative data on temperature & energy	**Performance Measurement**	Bar chart comparison; % energy savings

07 ACTIVE DESIGN

- Renewable System
- Cooling System
- Comparative Analysis

07 ACTIVE DESIGN

Renewable System & Cooling System

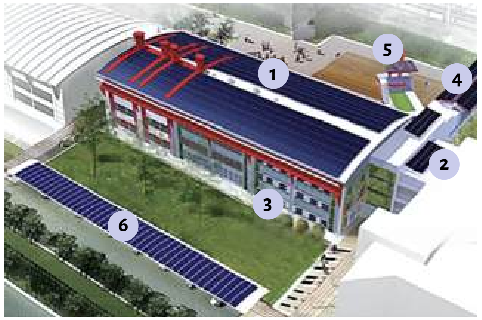
ZERO ENERGY BUILDING

SOLAR PHOTOVOLTAIC (PV) SYSTEM

RENEWABLE SYSTEM

Main Goal : Achieve zero energy by **generating energy equal to or more than consumed**.

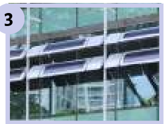
Location of PV systems in ZEB



PV Main Roof

PV Lower Roof

PV Sunshade



PV Link Way

PV Viewing Gallery

PV Carpark

Types of PV Technology

PV Cell Types:
- Silicon-based
- Thin-film

Grid Connection:
- Grid-connected PV (feeds excess power to grid)
- Off-grid PV (used for specific needs e.g., solar charging kiosk)

Panel Packaging:
- Glass-covered for protection

System Coverage & Specification

Total PV Area	:	1,540 m^2
Total Installed Capacity:		195.13 kWp
Panel Power	:	395 Wp
Panel Efficiency	:	22.3%
Total No. of Modules	:	494 nos

Working Principle

PV converts solar energy to direct current **(DC)** electricity.

↓

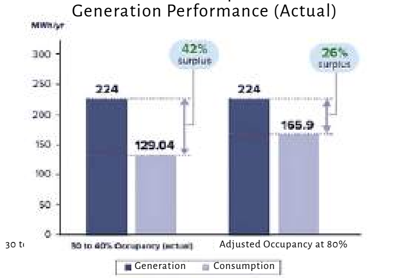
Inverter is used to **convert DC** to alternating current **(AC)** for use in buildings.

↓

Panels are **connected in arrays** for **higher power output**.

Efficiency & Retrofit Performance

ZEB Plus' Consumption versus Generation Performance (Actual)

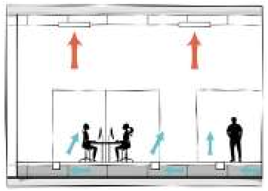


Original efficiency (before retrofit): ~13%
Retrofitted panels:
- Efficiency: 22.3% @ 395 Wp/panel

Pre-retrofit energy surplus: 7%–9%
Post-retrofit (ZEB Plus):
- 42% surplus at 30–40% occupancy
- 26% surplus at 80% adjusted occupancy
- Expected surplus with full occupancy: ~20%

DISPLACEMENT VENTILATION SYSTEM

COOLING SYSTEM



Air Supply Location:
Supplied **from the floor** at **low velocity**.

Working Principle:
Cool air spreads across the **floor**; **warm, polluted air rises** naturally and is extracted at the **ceiling**, promoting **efficient air circulation** and reducing energy use.

PERSONALISED VENTILATION SYSTEM

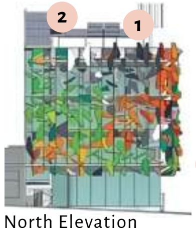
COOLING SYSTEM

Air Supply Location:
Supplied directly to **each occupant** via **dedicated ducts** at the worktable.

Working Principle:
Delivers 100% fresh, cool air to the **individual's breathing zone**; allows **personal control of air volume**, improves comfort, and enables **higher ambient temperatures**, reducing overall energy use.

PIXEL BUILDING

Location of Renewable Sysytem



North Elevation

Wind Turbines

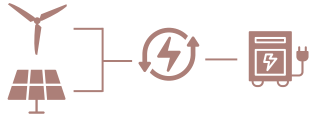
PV Panels

WIND ENERGY SYSTEMS

RENEWABLE SYSTEM

Vertical-Axis Wind Turbines
Three turbines are installed on the rooftop, **capturing wind from any direction** to supplement the building's energy needs.

Integration
These turbines **work in tandem with the solar panels** to ensure a **consistent renewable energy supply**.



SOLAR PHOTOVOLTAIC (PV) SYSTEM

RENEWABLE SYSTEM

Photovoltaic (PV) Panels
- Extensive photovoltaic array on the roof

PV Cell Types:
- Monocrystalline Silicon
- Thin-film

Panel Mounting
- Elevated steel framing on green roof

System Coverage & Specification

Total PV Area	:	38.4m2
Total Installed Capacity	:	6.3kWp
Panel Power	:	215 Wp
Panel Efficiency	:	17%
Total No. of Modules	:	29 nos

Energy Output

Produces more energy than consumed; excess is **fed back into the grid**.

Tracking Mechanism

Enhances energy capture by **adjusting panel orientation throughout the day**, **increasing efficiency** by up to 40%.

Dual-Axis Trackers

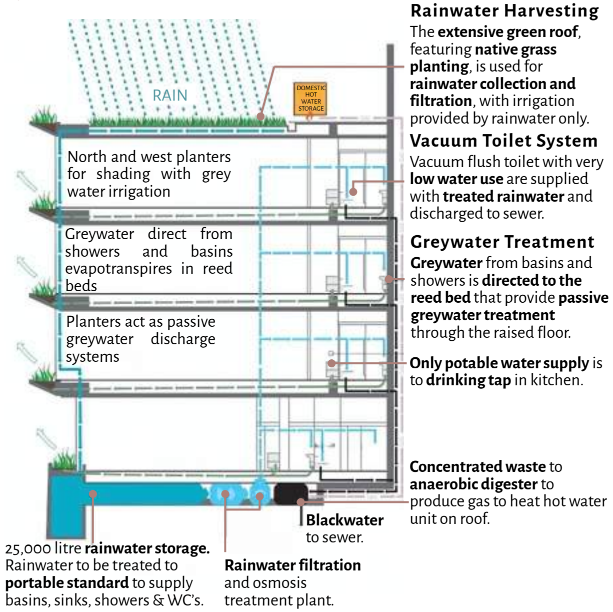
Orient the **panels towards the sun** at all times of the year.

Fixed Arrays
Two additional arrays are **fixed on tilted frames** (including stairwell roof).

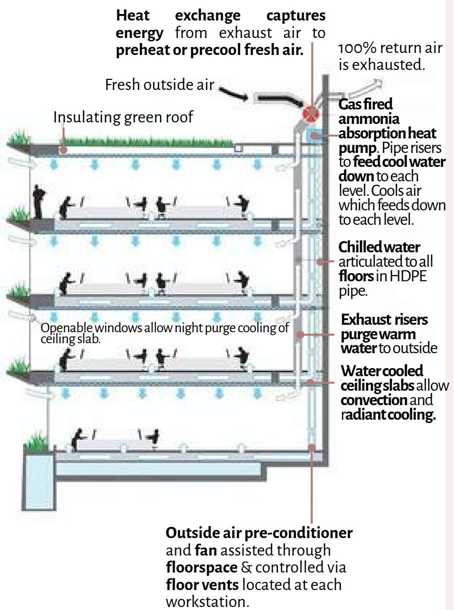
This combination **maximizes solar exposure** and **energy generation** within the limited rooftop area.

BIOENERGY & WATER REUSE SYSTEMS

RENEWABLE SYSTEM



COOLING SYSTEM



SIMILARITIES

- Both use solar energy (PV panels) for renewable energy generation.
- Both feed surplus energy back to the grid.
- Both apply energy-efficient personalized or zoned cooling systems.
- Both are net-zero or net-positive energy buildings.

DIFFERENCES

Zero Energy Building		Pixel Building
PV Panels	**Main Renewable System**	PV Panels + Wind Turbines
Displacement + personalized ventilation	**Cooling Method**	Heat exchange, underfloor supply, localized air
Floor supply and direct-to-breathing zone	**Air Supply Method**	Raised floor with diffusers at each station
High surplus even at full occupancy	**Energy Output**	Produces surplus energy, feeds back to grid

08

CONCLUSION

08 CONCLUSION

ZERO ENERGY BUILDING

PIXEL BUILDING

CLIMATE RESPONSE

This project demonstrates a strong commitment to sustainability through the comparison of two eco-friendly buildings is **Zero Energy Building** in Singapore and the **Pixel Building** in Melbourne. Each building is carefully designed to respond to its local climate. Zero Energy Building to **Singapore's hot, humid environment**, and Pixel Building to **Melbourne's cooler, temperate conditions**. Zero Energy Building uses **solar chimneys, green roofs and green walls, and solar panels** to **reduce energy and resource use**. Pixel Building employs **external shading, native green roofing, and passive cooling techniques** such as night ventilation and cross-breezes to **improve efficiency and comfort**.






DAYLIGHTING & FACADE DESIGN

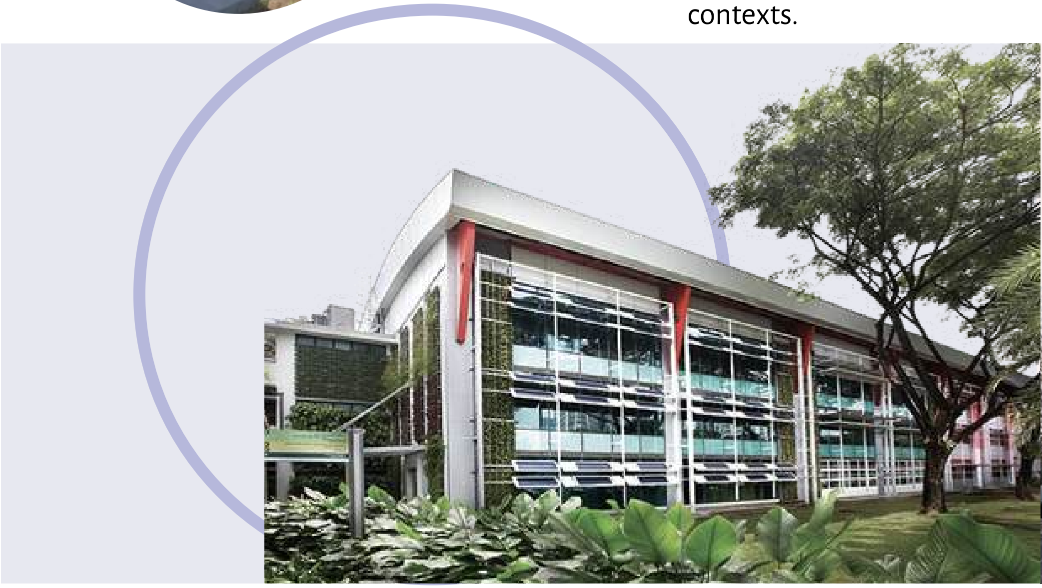
Both buildings **priorities daylighting** to **reduce energy consumption** and **enhance the indoor environment**. Zero Energy Building uses features like **light pipes, mirror ducts, and reflective ceilings** to draw natural light into deeper interior spaces, while Pixel relies on **large windows, perforated panels, and light wells** to brighten rooms and reduce reliance on artificial lighting. For the **facades**, Zero Energy Building facade design is includes **solar panels, roof overhangs, and green walls to block heat**, while Pixel Building **colourful facade integrates shading and solar control technologies** to maintain comfort and energy efficiency.

NATURAL VENTILATION & STRATEGIC LANDSCAPE

Natural ventilation and thoughtful landscaping play a key role in both buildings, enhancing **thermal comfort** while **reducing energy demand**. Zero Energy Building **solar chimneys and green roof** manage airflow and stormwater, while Pixel Building **green roof and reed beds** provides insulation and supports urban biodiversity.

ACTIVE DESIGN

Renewable energy systems are central to both designs, with Zero Energy Building **generating more energy than it consumes** through its extensive **solar panel network**, and Pixel Building **striving for carbon neutrality** with **integrated PV systems**. Beyond performance, both buildings also serve as educational models, promoting sustainable practices and demonstrating how green design can thrive in different environmental and urban contexts.




09 REFERENCES

REFERENCES - ZEB BUILDING SINGAPORE

1. Archello. (n.d.). Zero Energy Building at BCA Academy. Retrieved June 4, 2025, from https://archello.com/project/zero-energy-building-at-bca-academy
2. Building and Construction Authority. (n.d.). Zero Energy Building. https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/digitalisation/zero-energy-building-brochure.pdf:contentReference[oaicite:2]{index=2}
3. Green Buildings Innovation Cluster (GBIC) Programme ZEB Plus. (n.d.). Retrieved June 6, 2025, https://www.sleb.sg/UserFiles/Resource/GBIC/ZEB%20Plus%20%20Singapore%20First%20Existing%20Office%20Building%20Achieving%20Positive%20Energy_2343_.pdf
4. Lim, J. (2016, October 26). Zero Building Energy @ BCA Singapore- The first retrofitted ZERO energy building in South East Asia - JAPHETH LIM.COM. JAPHETH LIM.COM. https://blog.japhethlim.com/index.php/2012/12/06/zerobuildingenergy_bca_singapore-the-first-retrofitted-zero-energy-building-in-sea/
5. Passive House Canada. (n.d.). Leading the way to net zero: 2009–2014—Inside SE Asia's first retrofitted building. Passive House Canada. https://www.passivehousecanada.com/downloads/Leading-the-Way-to-Net-Zero-2009-2014-Inside-SE-Asias-First-Retrofitted-Building.pdf
6. Zero energy building. (n.d.). BCA Corp. https://www1.bca.gov.sg/buildsg/sustainability/zero-energy-building

REFERENCES - PIXEL BUILDING MELBOURNE

1. Around the World. (2019, January 24). Pixel Building, Australia. Penn State. https://sites.psu.edu/aroundtheworld/2019/01/24/pixel-building-australia/
2. DesignInc & Studio505. (n.d.). Pixel Building. DesignInc. Retrieved June 4, 2025, from https://www.db-a.co/projects/pixel-building
3. Giuroiu, A. (2024, September 22). Pixel / Studio505. Architecture Lab. https://www.architecturelab.net/pixel-studio505/
4. King, V. (2025, May 28). Pixel / studio505. ArchDaily. https://www.archdaily.com/190779/pixel-studio505
5. Meinhold, B., & Meinhold, B. (2011, December 16). Pixel Building: Australia's First Carbon Neutral Building is Now Complete! Inhabitat - Green Design, Innovation, Architecture, Green Building | Green Design & Innovation for a Better World. https://inhabitat.com/pixel-building-australias-first-carbon-neutral-building-is-now-complete/
6. PIXEL - a piece of tomorrow, today. (2025). Pixelbuilding.com.au. https://www.pixelbuilding.com.au/innovative.html?utm_source
7. Pixel by Studio505. (2015, October 14). Architizer. https://architizer.com/projects/pixel/
8. Profile, V. (2019, March 2). Pixel Building / Studio505 / Australia. https://civilarchitectureconstruction.blogspot.com/2019/03/pixel-building-studio505-australia.html
9. Sustainability Victoria. (2012). Carbon Neutral Offices -DRAFT > The Pixel Building Case Study SNAPSHOT Organisation Building type Commercial Offices Project name Pixel Project objective. https://cdn.archilovers.com/projects/4b28f524-bfac-47eb-93db-cc44f16bd2e4.pdf
10. Work - Studio 505. (n.d.). https://www.studio505.com.au/work/project/pixel/8.html