Seminar on

Energy Conservation in Tropical Climate

- Measures to Conserve Resources & Improve Profitability

Date : **19 January 2006 (Thursday)**

Time : **09:00 am – 05:30 pm**

Venue: **Holiday Inn Parkview**
Crystal Suite (Level 2)
11 Cavenagh Road
Singapore 229616

TIME	PROGRAMME
08:40 – 09.00 am	**Registration**
09:00 – 10:00 am	**Case Study on National Library Building - Design to Maintenance of a Green Building** By *Mr Sandamurthi Rethinam*
10:00 – 10:30 am	**Tea-Break**
10:30 – 12:30 pm	**Greening the City: The Role of Plants in a Sustainable City** By *Dr Ong Boon Lay*
12:30 – 02:00 pm	**Lunch**
02:00 – 04:00 pm	**Energy Saving Measures in Building** By *Dr Wong Yew Wah*
04:00 – 04:30 pm	**Tea-Break**
04.30 – 05.30 pm	**Towards Solar Architecture in Singapore** By *Dr Stephen Wittkopf*

Speakers' Profile

Mr Sandamurthi Rethinam
National Library Board

Mr Sandamurthi Rethinam graduated with a BSc (Building) (Hons) and MSc (Building Science) from NUS. Mr Rethinam joined NLB in 1999 and is currently a Senior Project Manager. He had been involved in the development of new libraries and the upgrading of existing libraries. Currently, his main duties involve overseeing development of new libraries and the running of the National Library building.

Dr Ong Boon Lay
School of Design and Environment, National University of Singapore

Prof Ong Boon Lay is currently a senior lecturer at the National University of Singapore in the School of Design and Environment. Dr Ong was a scholar under the Colombo Plan and graduated with a BArch and MArch from University of Auckland, New Zealand. He graduated from Cambridge with a Ph.D. Prof Ong's area of research includes an Ecological Approach to Architecture and Urban Planning, Green Plot Ratio, GreenX and Nurtured Landscape.

Dr Wong Yew Wah
Department of Mechanical & Production Engineering, Nanyang Technological University

Prof Wong Yew Wah is an Associate Professor, NTU. He has many years of experience in research, teaching and design of air-conditioning systems and building services. His areas of interest include building energy efficiency, fire safety, ventilation and indoor air quality.

Prof Wong is the Deputy Chair for SPRING TC on Building Services and he served on the working group for the revision of CP 13:1999 and CP 24:1999. He was President of the ASHRAE Singapore Chapter in 1992-93 and now serves on the Board of Directors of ASHRAE, Inc and also the Regional Chair for ASHRAE Region 13.

Dr Stephen Wittkopf
School of Design and Environment, National University of Singapore

Prof Stephen Wittkopf's research and teaching focus on Solar Architecture, Daylight and Computational Simulation. He joined National University of Singapore in 2001 as Assistant Professor in the Department of Architecture where he has led study on the potential of Building Integrated Photovoltaic (BIPV) for public housing in Singapore. His subsequent research is towards designing low energy responsive facades by integrating photovoltaic and daylight re-directing devices.

Case Study on National Library Building . Design to Maintenance of a Green Building

Mr Sandamurthi Rethinam

Design to Maintenance of a Green building

New National Library

Background

- **Need for New Building**
  - Growing demand for more/better library services
  - Lack of space in old building
- **New Chapter in NLB's Development**
  - Further strengthening of reference and research information services

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Design Brief

- **A Place for the People**
  - The NL Building will provide an open, hospitable and conducive learning and research environment for the people of Singapore
- **A Civic Institution**
  - The NL Building will be an enduring civic institution with a distinct character, reflecting Singapore's multicultural heritage and to support the creative and connected Singapore initiative

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Design Brief

- **A Flexible and Functional Building**
  - The NL Building will be a fully flexible and functionally clear building
- **An Efficient Building with Integrated Systems**
  - The NL Building will be an efficient building with integrated, user friendly and intelligent building systems

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Design Concept

- Library in the tropics
- "Green" (Environmentally responsive) tropical building
- Bioclimatic design techniques (eg passive lighting concepts, climate-response building orientation, effective facade systems)

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Building Highlights

- The Building Design:
  - GFA of approx. 59,000sqm, at a height of 102.8m
  - 16 storeys and 3 basement levels including an Observatory Pod on the roof
- The Building Comprises:
  - The National Library Component: (Lee Kong Chian Reference Library)
    - General Reference Collection
    - Arts/Business Collections
    - Singapore/Asian/Special Collections
    - Language Collection
    - Donor Collections
    - Rare Books Collection

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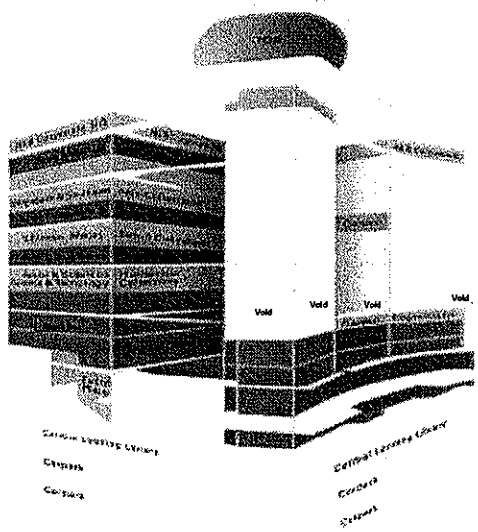
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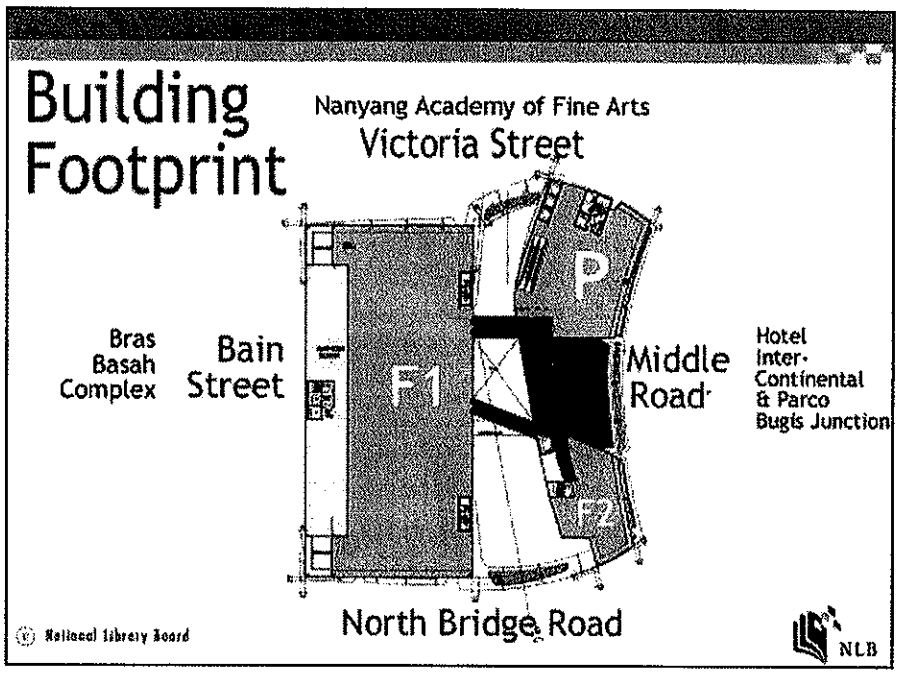
Building Highlights

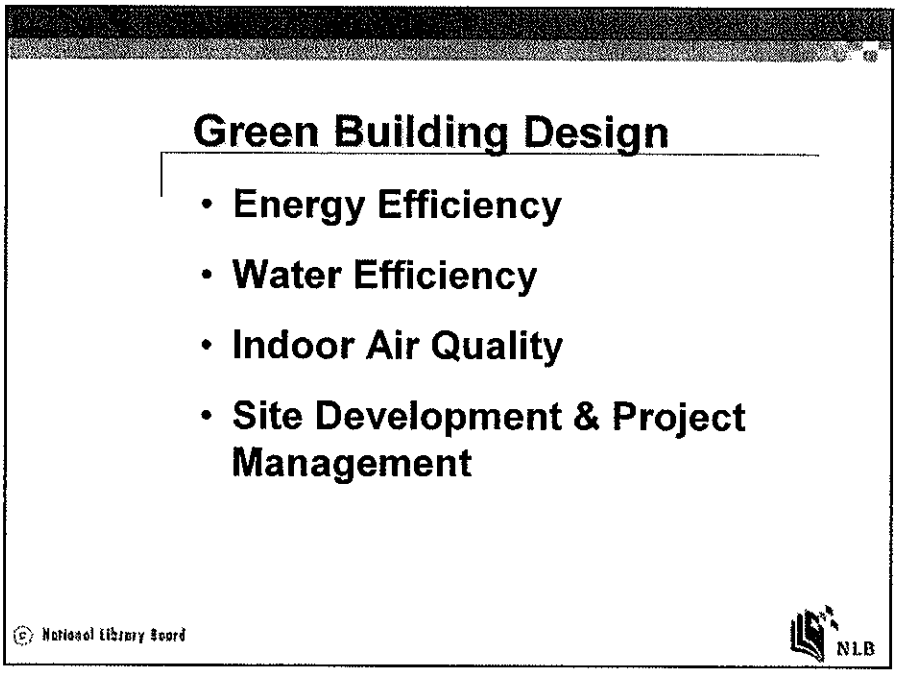
- **The Public Library Component:**
  - **Central Lending Library**
- **The Corporate Component:**
  - **Staff and Corporate Facilities**
- **The Public Component:**
  - **New Drama Centre (NAC)**
  - **Events Plaza**
  - **Terraces**
  - **Sky Gardens**
  - **Observatory Pod**
- **The Commercial Component:**
  - **Cafes**
  - **Leasable Space**

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Building Footprint
Nanyang Academy of Fine Arts
Victoria Street
Bras Basah Complex
Bain Street
F1
P
F2
Middle Road
Hotel Inter-Continental & Parco Bugis Junction
North Bridge Road
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Green Building Design
• Energy Efficiency
• Water Efficiency
• Indoor Air Quality
• Site Development & Project Management
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Energy Efficiency

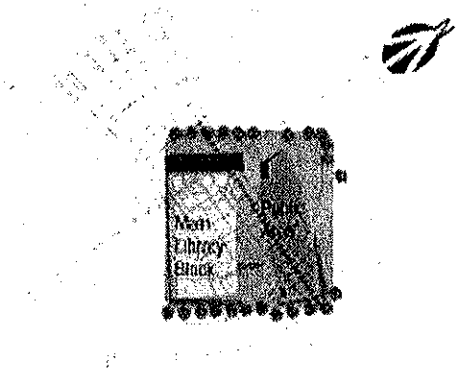
- Low-Emmissivity double glazing to reduce solar heat gain.
- Large overhangs on external facade to reduce solar heat gain.
- Light shelves extend into the library space which allows daylight to be optimized and thus reduce artificial lighting requirements.
- Extensive use of sky gardens and roof garden.
- Energy monitoring via BMS.
- Energy Saving Lightings are used.
- Stack effect at Events Plaza.
- Night setback for AC.

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By Building Orientation

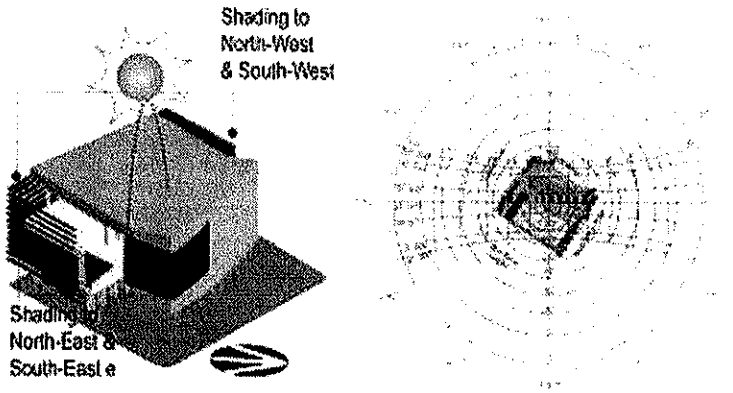
The two blocks are orientated to minimise solar insulation. The curved (noth-east) block is angled to achieve a more ideal North-South orientation as well as addressing the Victoria Street corner.

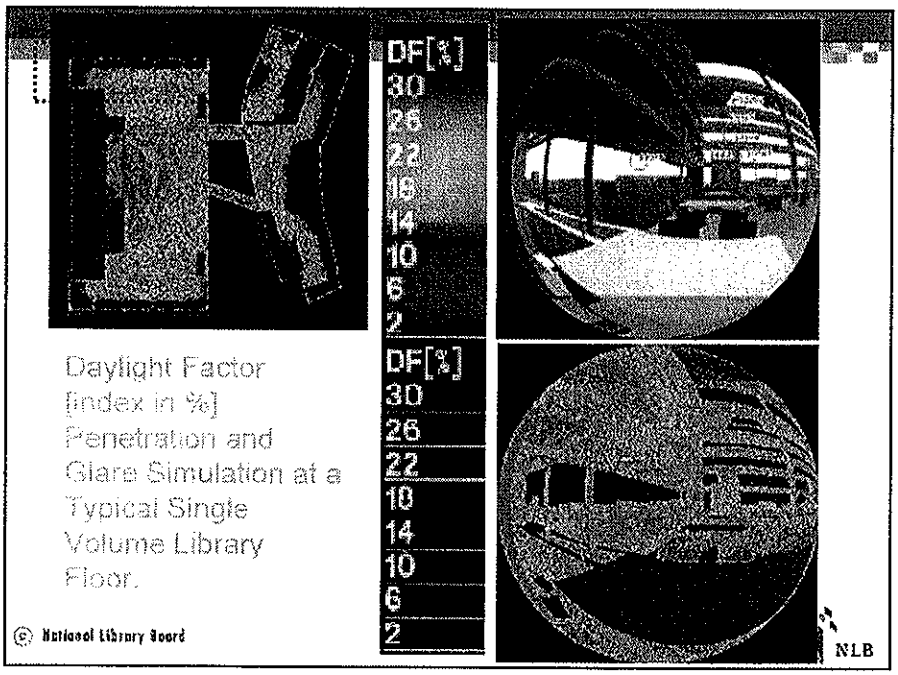


Schematic Design

By Solar Protection

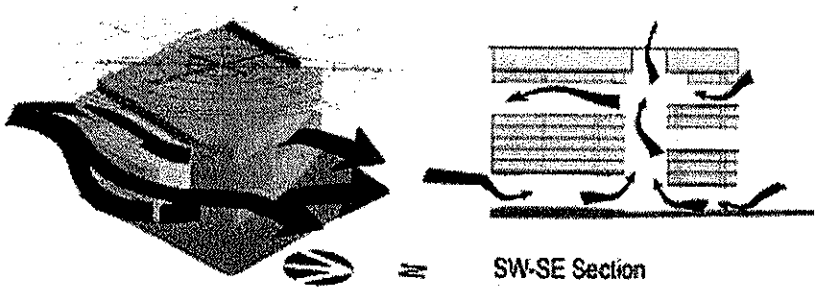
Solar protection is provided to the hot-sides of the building



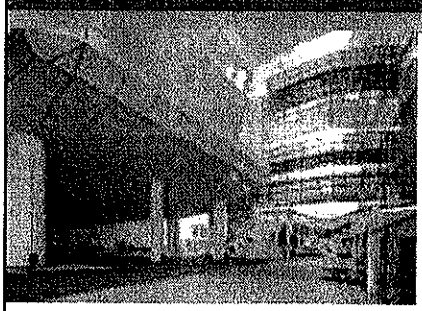


By Wind & Natural Ventilation

The transitional spaces and the atrium spaces are critically located in configuring the built form to make full use of wind and natural ventilation.



SW-SE Section



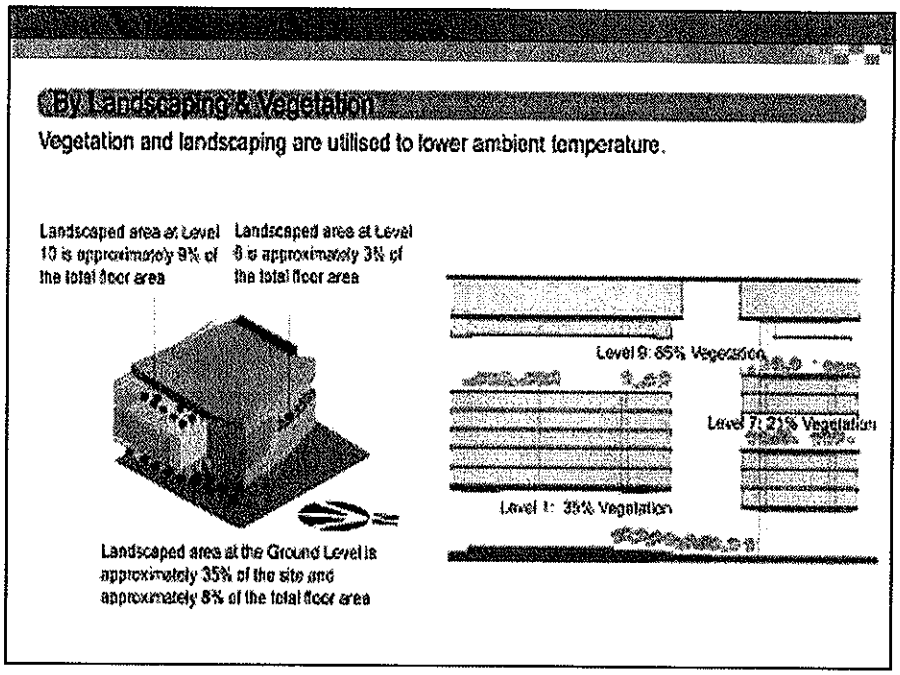
← AT GROUND LEVEL

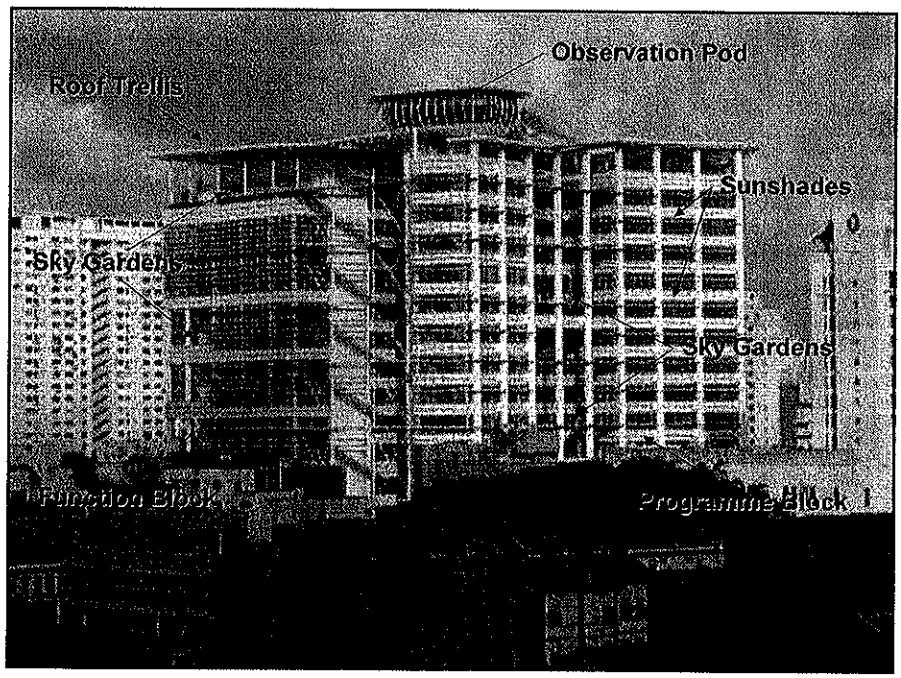
AT THE TOP →



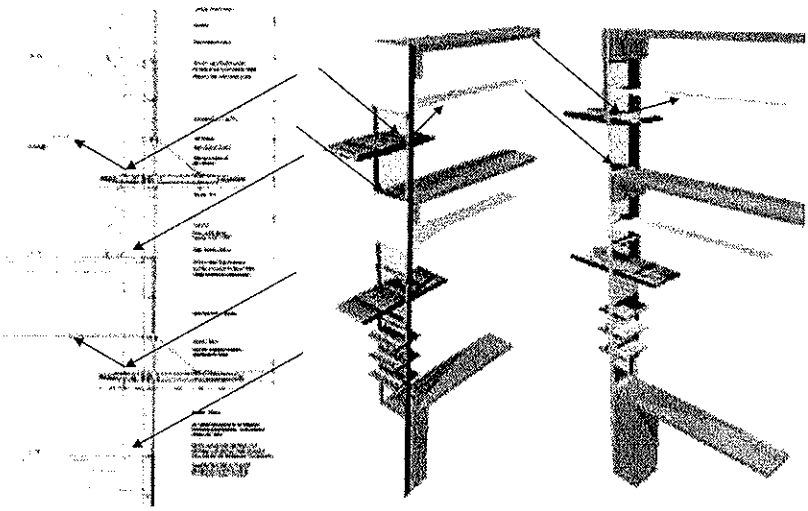
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By Landscaping & Vegetation
Vegetation and landscaping are utilised to lower ambient temperature.
Landscaped area at Level 10 is approximately 9% of the total floor area
Landscaped area at Level 8 is approximately 3% of the total floor area
Level 9: 65% Vegetation
Level 7: 21% Vegetation
Level 1: 35% Vegetation
Landscaped area at the Ground Level is approximately 35% of the site and approximately 8% of the total floor area


Observation Pod
Roof Trellis
Sunshades
Sky Gardens
Sky Gardens
Function Block
Programme Block 1

Light Shelves



Energy Efficiency

- Variable Speed Drives (VSDs) used in AHUs and pumps.
- Extensive use of Variable Air Volume (VAV) units.
- Light sensors at the perimeter of the library areas to switch off lighting when there is sufficient natural light to illuminate the building interior.
- Task lighting is used where appropriate.
- Automatic Blinds to reduce solar heat gain.
- Lights activated by motion sensors used in staff restrooms.
- Energy saving escalators.

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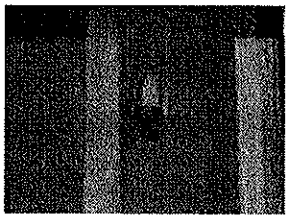
LIGHT SENSORS TO MINIMISE ARTIFICAL LIGHTING (ie OPTMISED USE OF NATURAL DAY LIGHT) FOR CERTAIN ZONES IN THE BUILDING

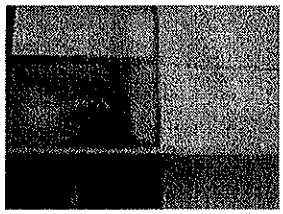
- Areas along building facade facing North Bridge Road and Victoria Street.

- Escalator Lobby

- Plaza

If the outside light lux level falls below 500lux / 200lux, lights in the internal areas / Plaza turn on and vice versa.





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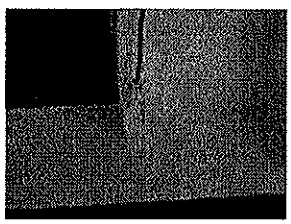
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DAYLIGHT SENSOR FOR AUTOMATIC ROLLER BLINDS

Roller blinds are located at areas along building facade facing Victoria street for Levels 5, 7, 8, 9, 10 and 11.

The daylight sensor is located at 9th storey sky terrace facing Victoria street .

If the external light lux level goes above 8,000 lux, roller blinds rolls down automatically and vice versa to reduce daylight glare from afternoon sun.



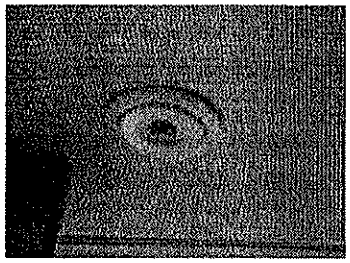


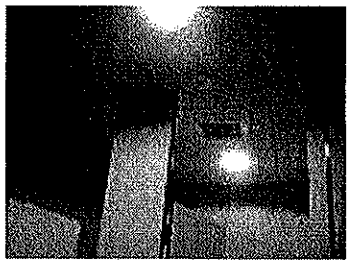
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MOTION SENSOR IN STAFF TOILETS TO CONTROL THE TOILET LIGHTS

If there is no human traffic for a pre set time limit (20mins) the lights are switched off automatically.





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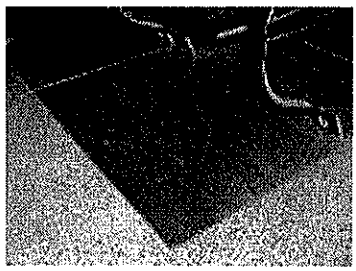
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AUTO START / STOP ESCALATORS

Escalators operation controlled by pressure sensor mounted at landing matt of escalator .

The escalator auto stops when there is no human traffic over a certain pre-set time and vice versa .

This feature helps to save energy as power consumption for motor is minimal when the escalator stops.



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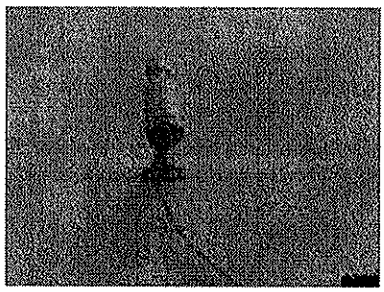
Water Efficiency

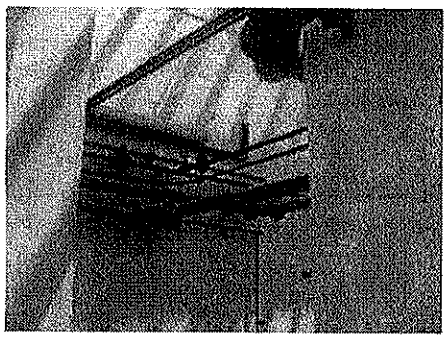
- Rain sensors are installed as part of the irrigation system so that the irrigation system is not operated during raining days.
- If it rains the auto irrigation system is not activated for a period of 8 hours after the rain.
- This feature helps to save energy as power consumption for irrigation pumping system is reduced when the system does not operate. It also helps to conserve water.

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RAIN SENSOR





AT L15 – Roof top

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Indoor Air Quality

- Carbon dioxide sensors are installed in AC system.
- In the basement carpark, Carbon monoxide sensors are installed to ensure that when the CO levels do not exceed 9ppm.
- Very low VOC (Volatile Organic Compounds) paints used.

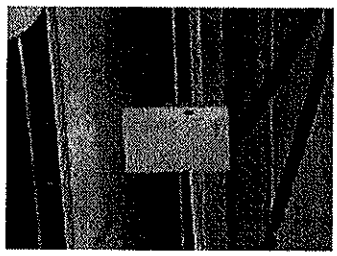
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CARBON DIOXIDE (CO_2) SENSOR INSIDE AHU ROOMS TO REGUALTE FRESH AIR INTAKE .

Located inside AHU rooms to regulate fresh air intake.

When the CO_2 level exceeds 800ppm (parts per million), more fresh air is drawn from outside.





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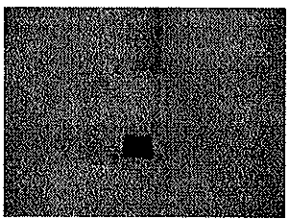
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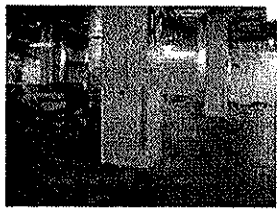
CARBON MONOXIDE (CO)SENSOR IN THE CARPARK

To regulate operation of ventilation fans in the carpark.

If the CO level exceeds 9ppm, more fresh air is drawn from from outside and ventilation fans run at high speed and vice versa.

This feature helps to save energy as power consumption for fans is reduced when running at low speed .





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Site Development & Proj Mgt

- All existing trees to be maintained as far as possible.
- Site easily accessible to Bugis MRT.
- All consultants and contractors have obtained either ISO 9000, 14000, and/or 18000.

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Challenges

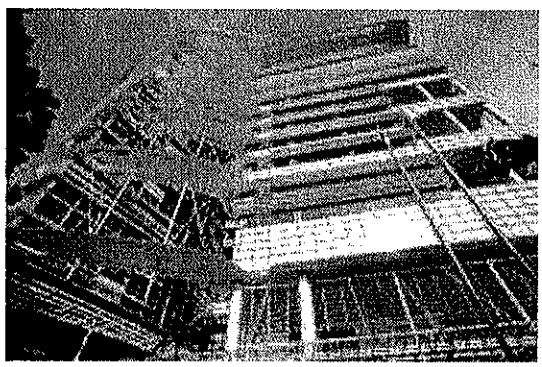
- Cleaning of External Facade
- Re-lamping
- Energy Management
- Water ingress

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External Cleaning

- **Includes facade and the sunshades some of which are 24m in length.**



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Re-lamping

- At the Plaza area – 7m to 16m ('cherry picker')



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Energy Management

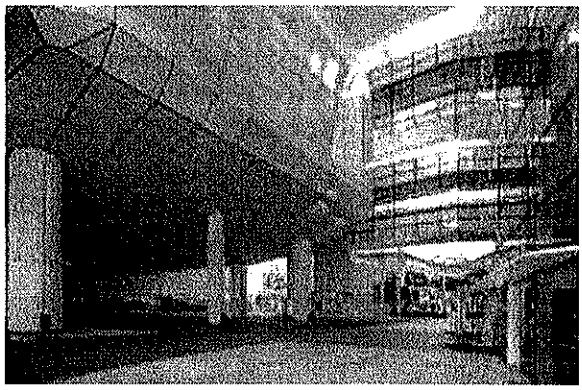
- Constant review of energy usage.
- Use of NLB's User Guide for energy conservation.
- Annual audits would be carried out on noise levels, temperature, lux levels, electrical and water consumption.

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Water Ingress

- "Open" nature of Internal Street



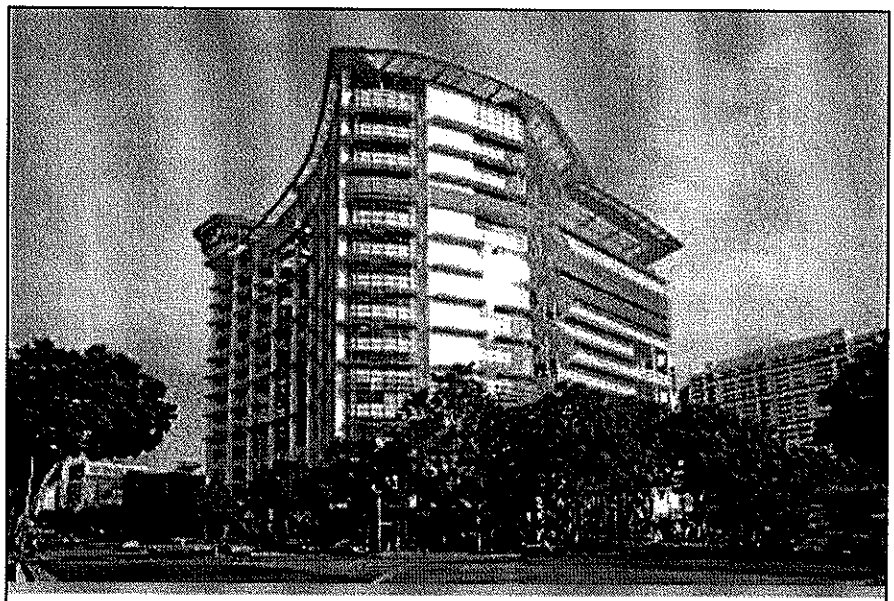
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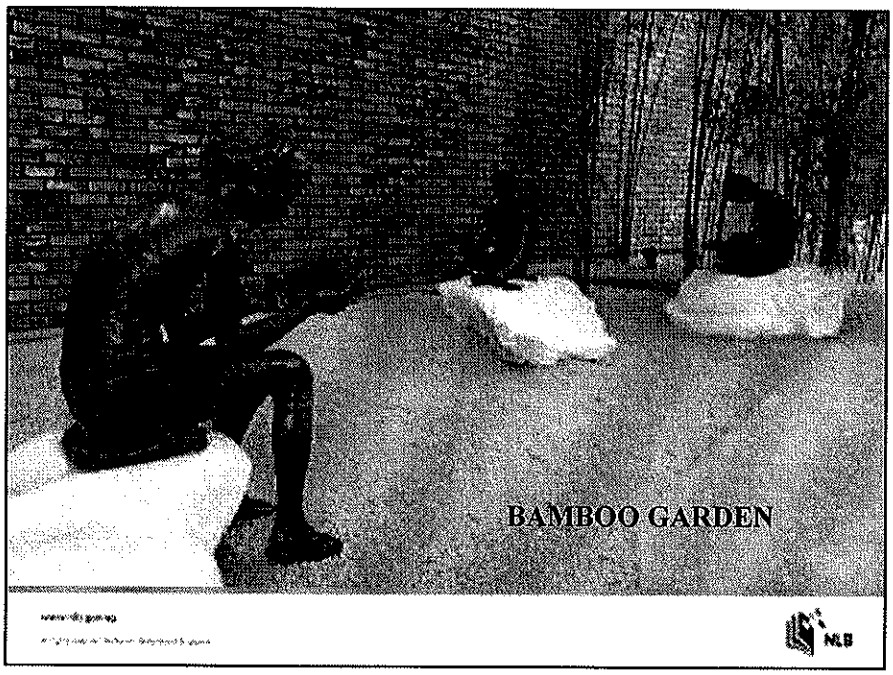
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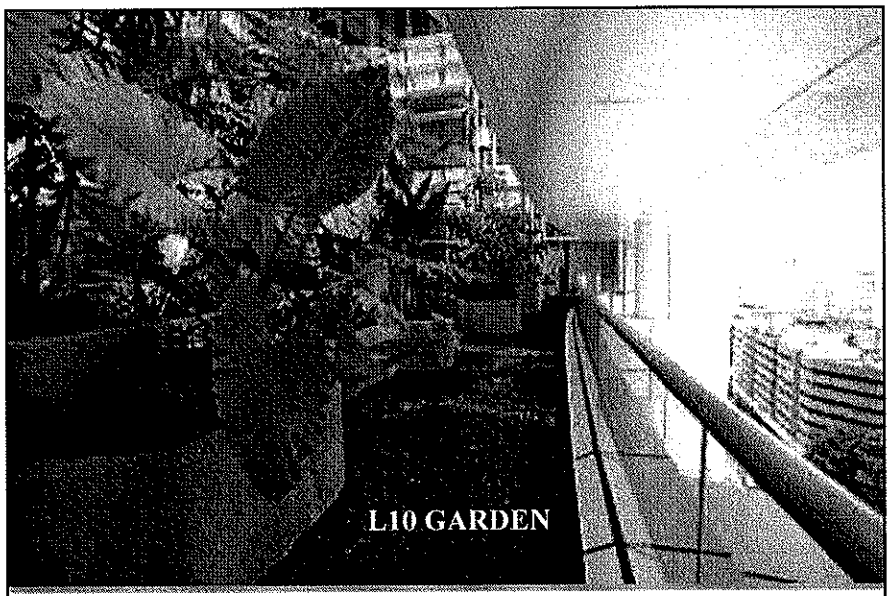
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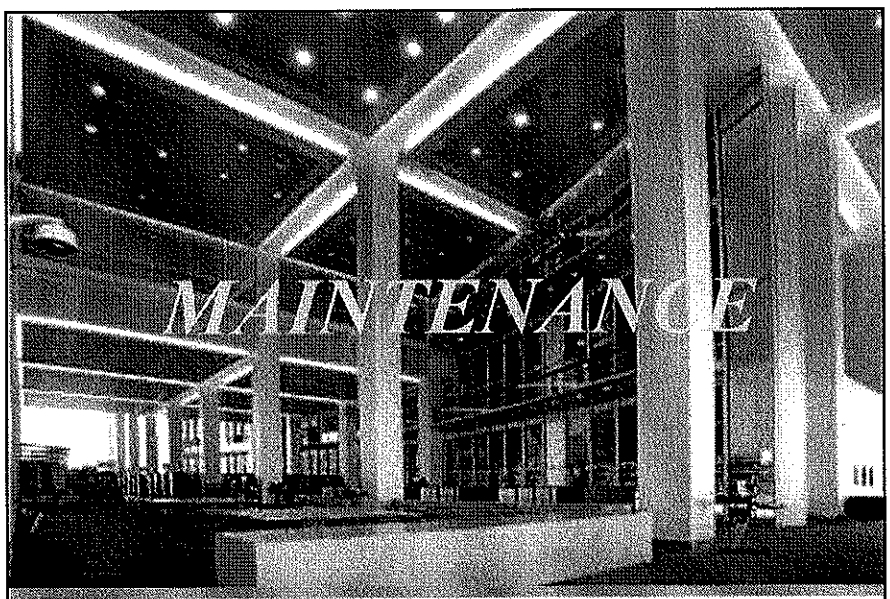
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BAMBOO GARDEN


L10 GARDEN


MAINTENANCE

Greening the City:
The Role of Plants in a Sustainable City

Dr Ong Boon Lay

dbsong@nus.edu.sg

Greening the City:

The Role of Plants in a Sustainable City

Dr Ong Boon Lay

Lecture Structure:

1. Greenery and Highrise
2. Greenery and the City
3. Case studies
4. Recent Research in Singapore

1.Greenery and Highrise: Match or Mismatch?

Why skygardens?

1) **Biophilia**
   - human need to be close to nature

2) **Sustainability**
   - association of the Green Movement with living in harmony with nature

2. Greenery and the City

3 Greenery Values

1. **Ecological value:**
   Landscape, especially natural landscape, provide habitat and biodiversity to the urban canvas. Not all landscapes are equally able to provide this facility – e.g. an agricultural land is more important as a social and environmental resource than it is as an ecological habitat. On the other hand, urban agricultural land reduces the ecological footprint of the city it serves.

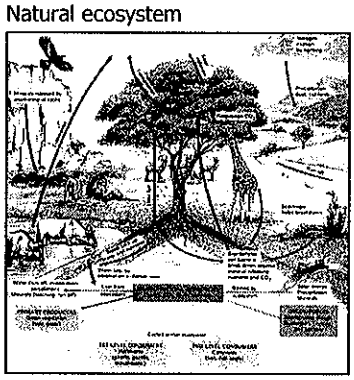
2. **Environmental value:**
   All plants provide O2, reduce air temperatures, shelter against wind and solar radiation, increase humidity and help to clean the air. In this sense, regardless of its other functions, all planted landscapes have an environmental impact. This impact is most closely related to leaf density or LAI (Leaf Area Index).

3. **Social value:**
   Urban landscapes have different social values to the city dweller. Landscapes with low social values are less likely to be well-maintained and are more likely to be appropriated for other uses. Natural landscapes need to be protected from human intervention but by doing so, the landscape is perceived as being of low social value. As such, in Singapore esp., such landscapes are in great danger of human destruction.

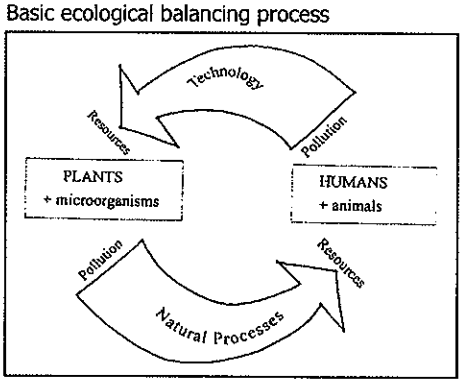
2a. Ecological Role of Greenery

Ecological Balancing Process

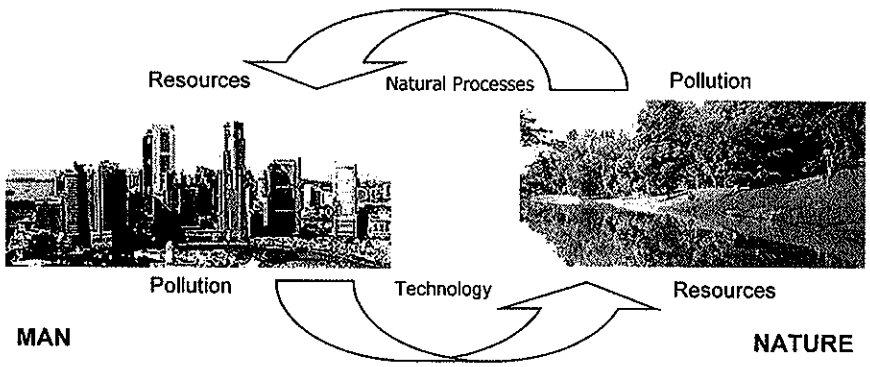
Natural ecosystem



Basic ecological balancing process



Man/Nature



MAN

Built Environment

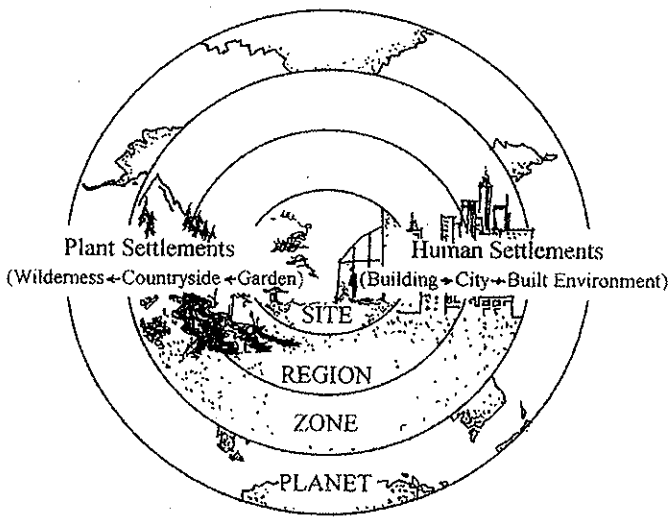
Urban Landscape

NATURE

Plants/Animals

Greenery

Interlocking Human Ecosystems



2b. Environmental Impact of Greenery

Creeper on a Wall

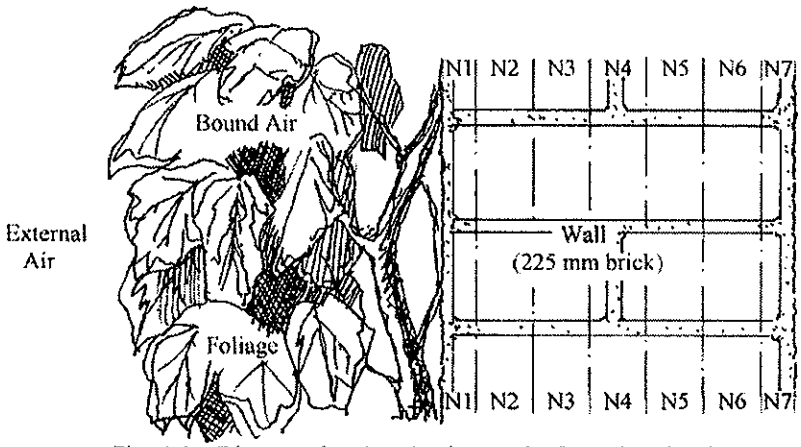


Fig. 4.4: Diagram showing the four main thermal nodes for a creeper on an external wall. The wall node is further subdivided into 7 nodes to better represent the flow of heat through the wall.

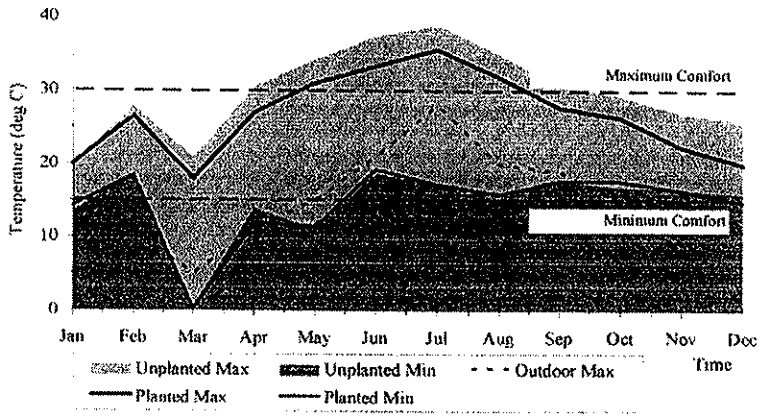
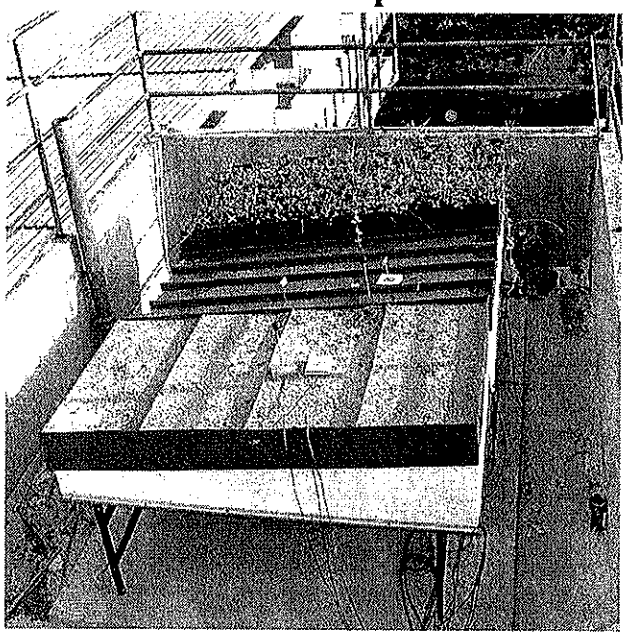
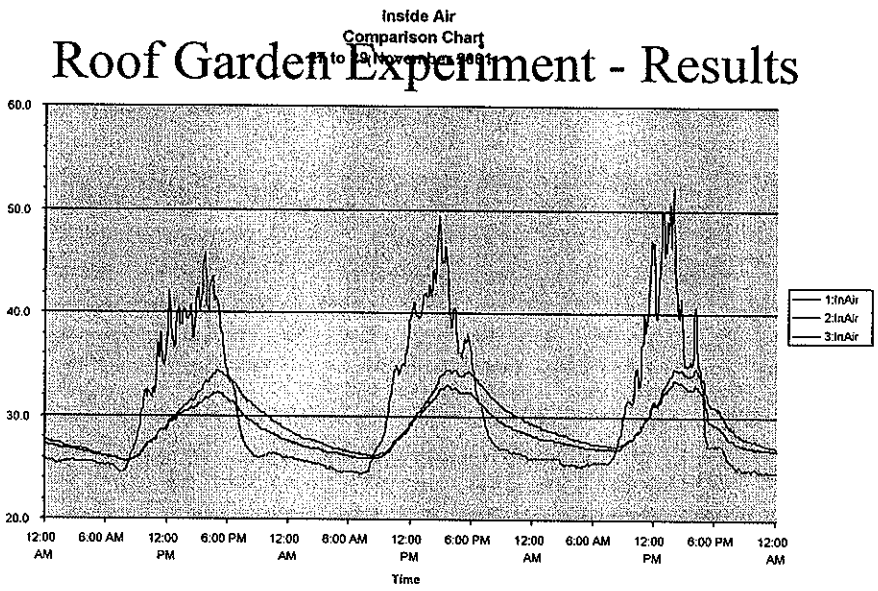


Fig. 6.32: Range of temperatures recorded at the UBC greenhouses over the period April 1994 to March 1995. The data were rearranged to provide a normal calendar axis. The minimum and maximum comfort temperatures were set according to the range recommended by Rev. Humphreys (1992 - see sect 2.6.3)

Roof Garden Experiment



Roof Garden Experiment - Results



2c. Social Role of Greenery

Amenity Green Space	**Recreation Green Space**	Parks and Gardens
		Informal recreation areas
		Outdoor sports areas
		Play areas
	Incidental Green Space	Housing green space
		Other incidental space
	Private Green Space	Domestic gardens
Functional Green Space	**Productive Green Space**	Remnant farmland
		City farms
		Allotments
	Burial Grounds	Cemeteries
		Churchyards
	Insititutional Grounds	School grounds
		Other institutional grounds
Semi-natural habitats	**Wetland**	Open/running water
		Marsh, fen.
	Woodland	Deciduous woodland
		Coniferous woodland
		Mixed woodland
	Other Habitat	Moor/heath
		Grassland
		Disturbed ground
Linear Green Space		River and canals, transport corridors
		Other linear features (e.g. cliffs)

Typology of urban green spaces (Swanwick, et al, 2003, Built Environment, Vol 29, No. 2)

The presence and function of greenspace

- supports recreational, experiential and health requirements of locals as well as visitors.
- encourages local use of leisure time
- provides 'quiet' and 'difference' to urban dwellers
- fosters community pride
- supports biodiversity
- supports local management of water flow
- allows local composting
- cleans atmospheric particulates
- reduce 'heat island' effect
- increases economic attractiveness to entrepeuners, developers, businesses and tourists

from Beer, et al. 2003, Built Environment, Vol 29, No. 2

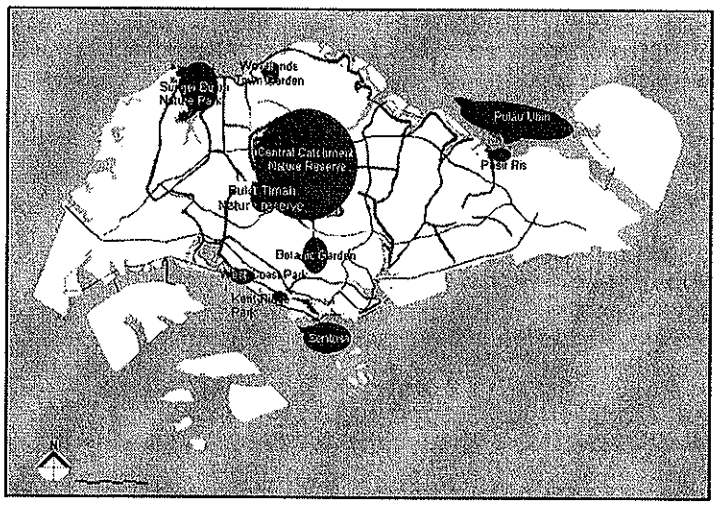
Particular issues of highrise greenspace

Ecological
- managed, therefore not 'natural' ecosystem
- connectivity to ground and other ecosystems
- suitability as habitat for small animals

Environmental
- exposure to high winds
- limited ground (soil) for planting
- limited space for growth

Social
- limited accessibility
- problems with escape routes in times of emergencies
- conflict of use between public-ness of greenspace vs privacy of resident users

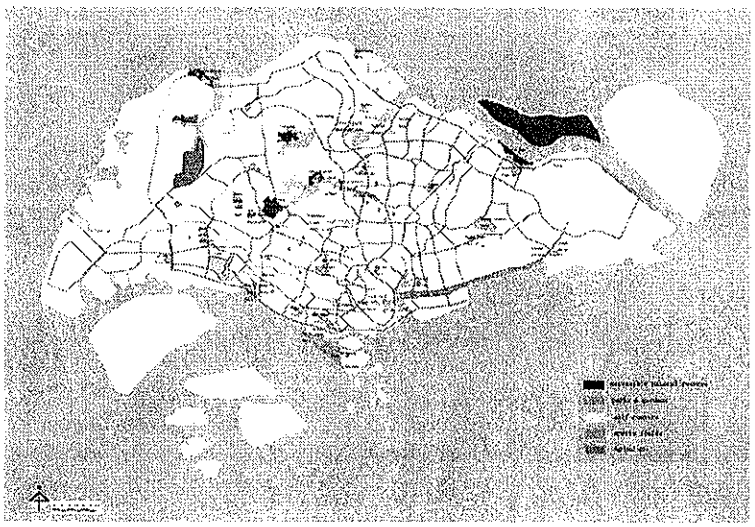
Ecological Map of Singapore



Environmental Map of Singapore

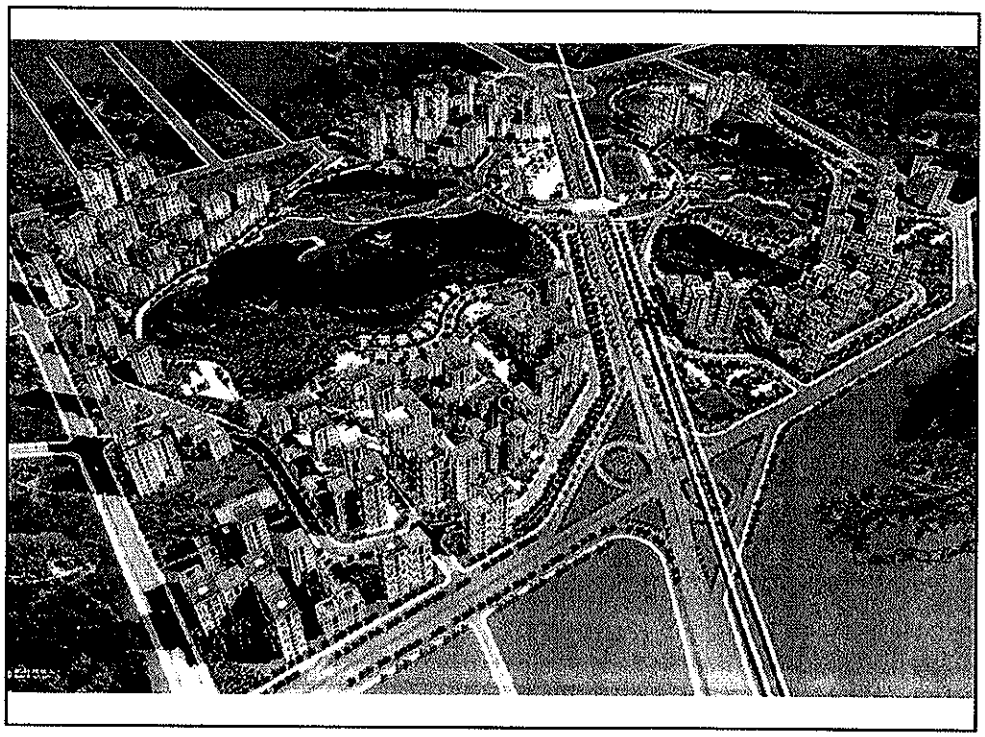


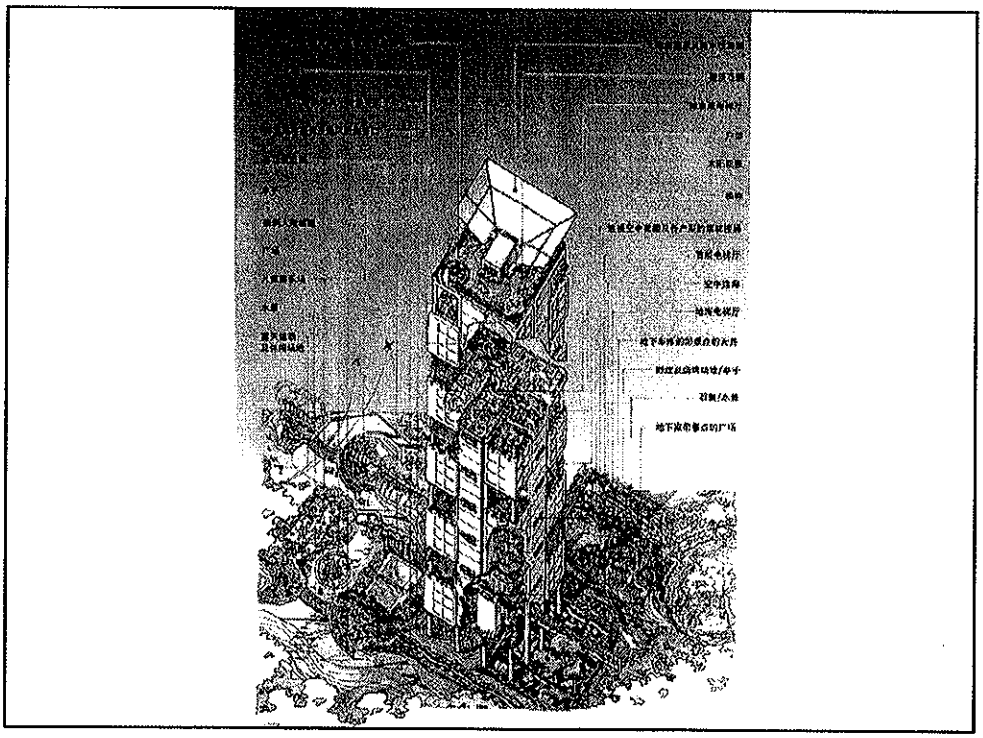
Social Green Map of Singapore

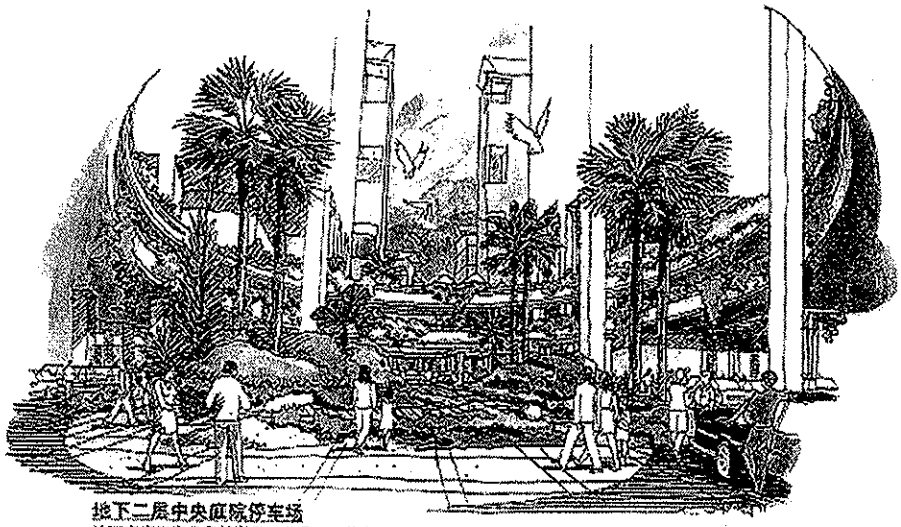


3. Case Studies

LiuXianCun
EcoCity

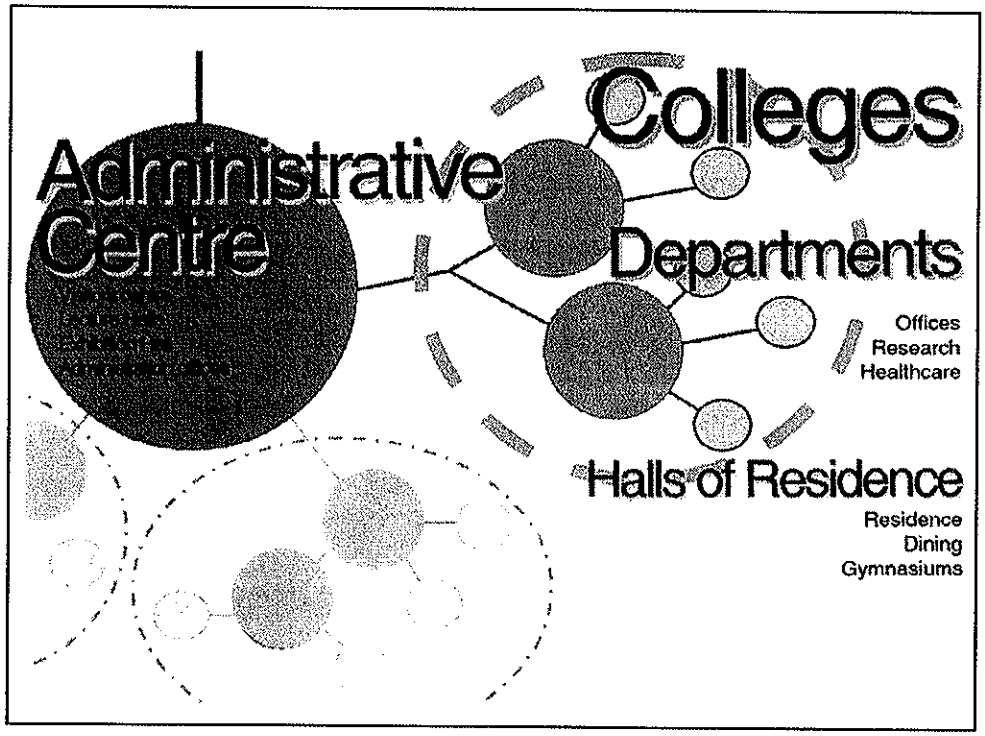


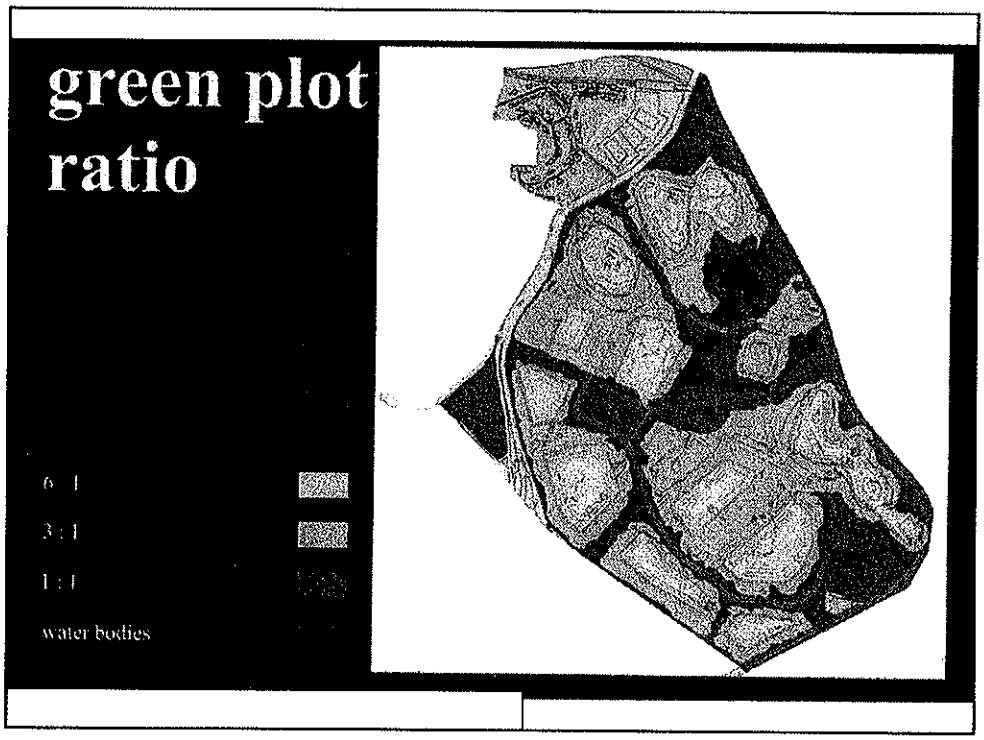


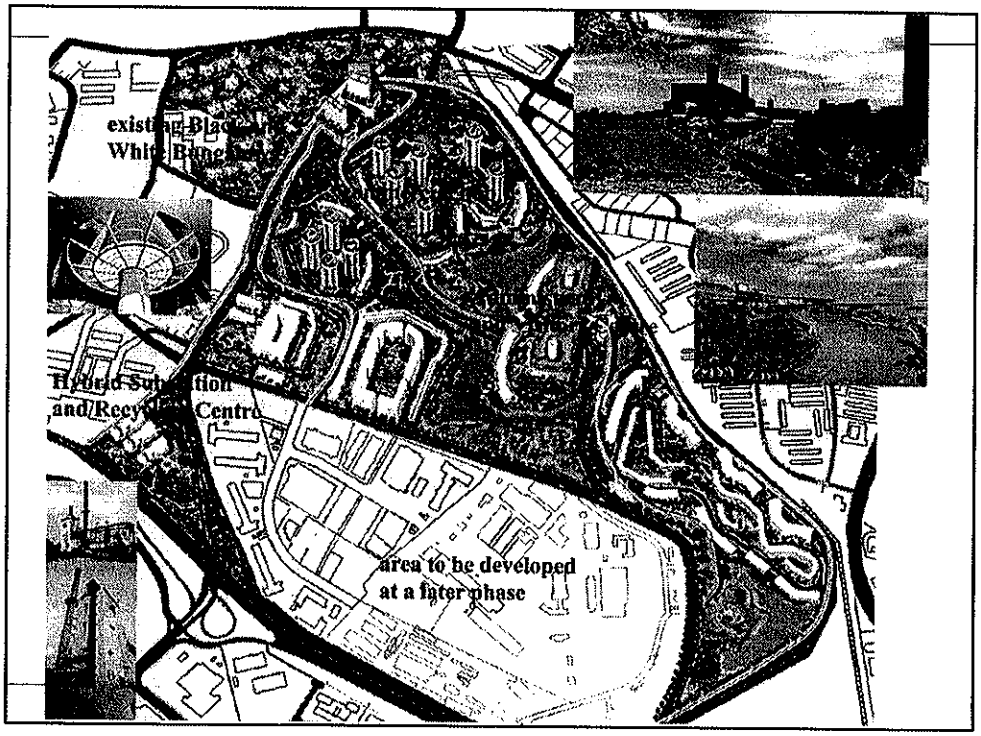


地下二层中央庭院停车场
地下车库明亮且有效通风，并且充分绿化、美化

1 North


Administrative Centre
Colleges
Departments
Offices
Research
Healthcare
Halls of Residence
Residence
Dining
Gymnasiums


green plot ratio
6 : 1
3 : 1
1 : 1
water bodies



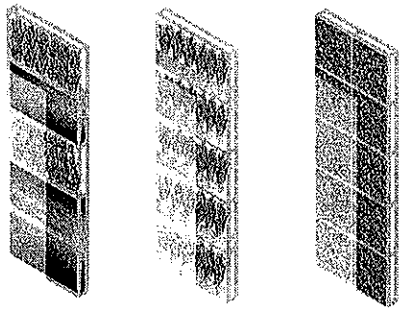
Changi Airport
Terminal II

DESIGN RESEARCH STRATEGIES

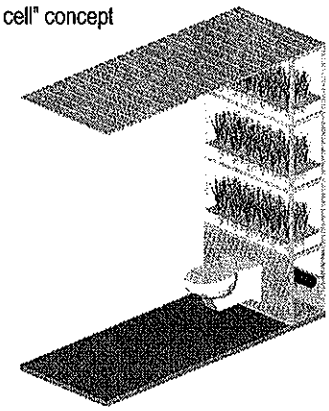
Combining Plants, Water and Light into an Innovative Proposal
requires experimentation, analysis and documentation

Systems Modular Design = Adaptable, Flexible, Maintainable, Sustainable, Experience

"living screen" concept



"living cell" concept



© 2002 CDEx

type 2 hydroponics





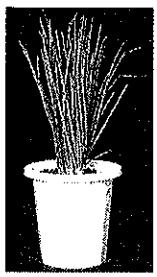
Basil



Mint

Parsley

Coriander



Spring Onion



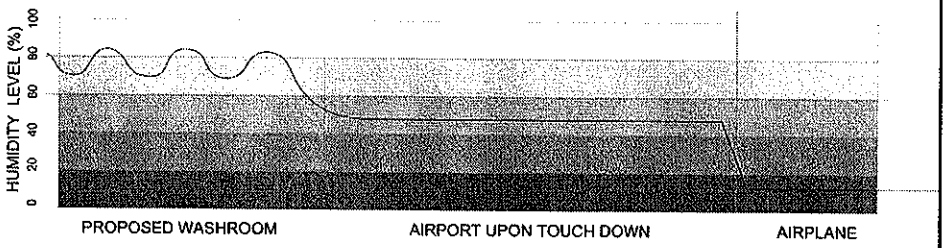
Fragrant Pandan

herbs and spring onions – grassy and green

2. STRATEGY OF WATER - REFRESHING MOISTURIZATION AND TEMPERATURE CHANGE

Present Condition of Monotony of Moisture and Temperature Levels

Human Comfort Levels, Variety of Conditions, Changes of Experience, Rejuvenation

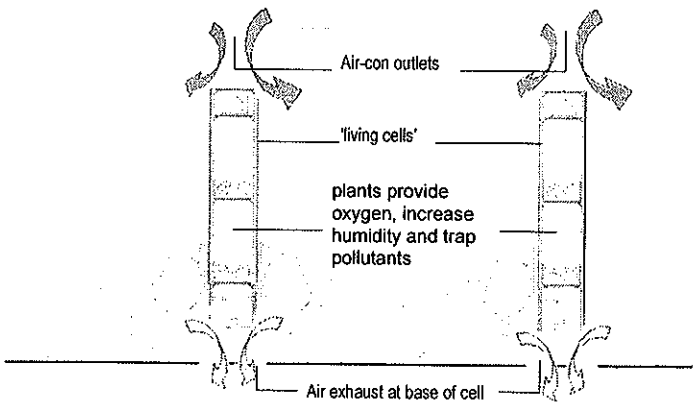


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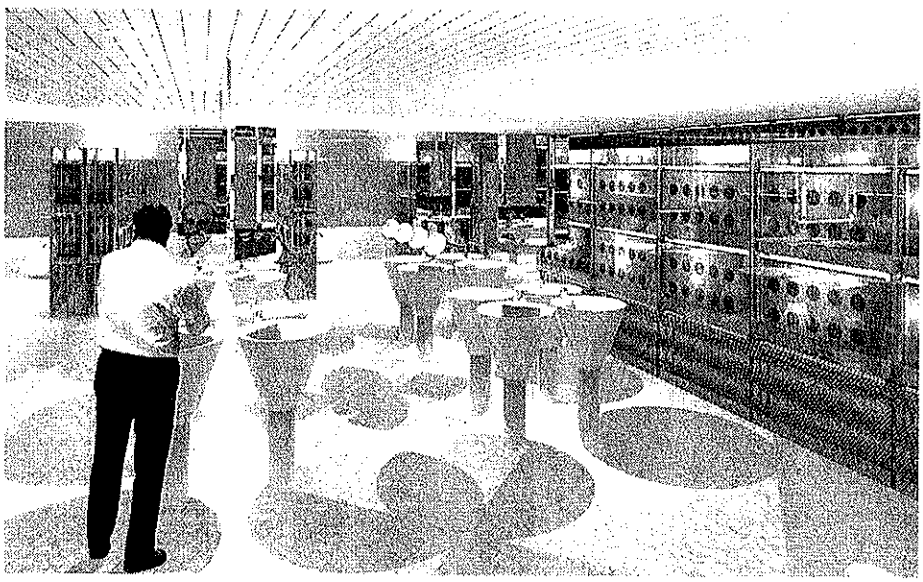
2. STRATEGY OF WATER

Integration of Services with Living Cells and Living Screens

incoming air interact with the living cells and screens and gets oxygenated, humidified and cleansed
slight heating of incoming air by light fittings will be offset by the misting / fogging mechanism.

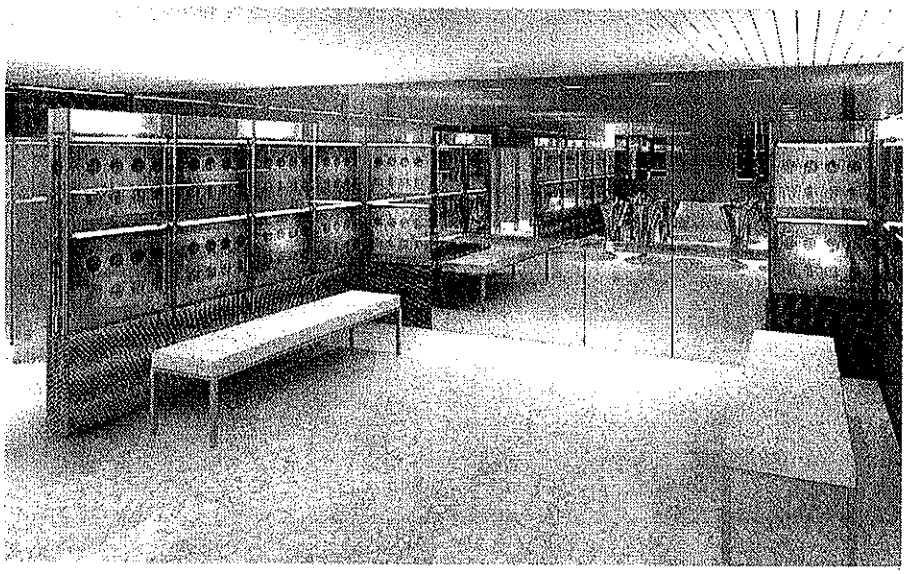


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male wash area (white option)

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female lounge area

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4. Recent Research In Singapore

4a. Green Plot Ratio

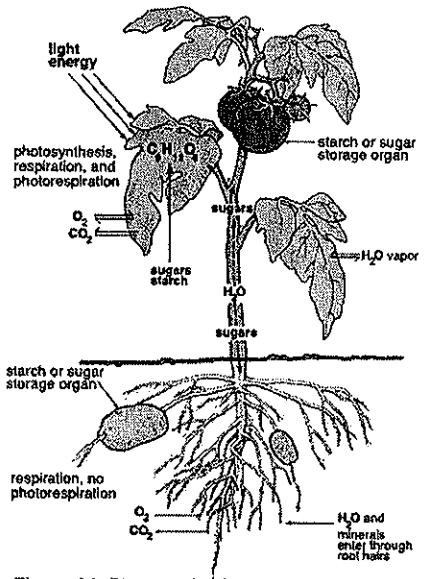


Figure 24. Photosynthesis, respiration, leaf water exchange, and translocation of sugar (photosynthate) in a plant.

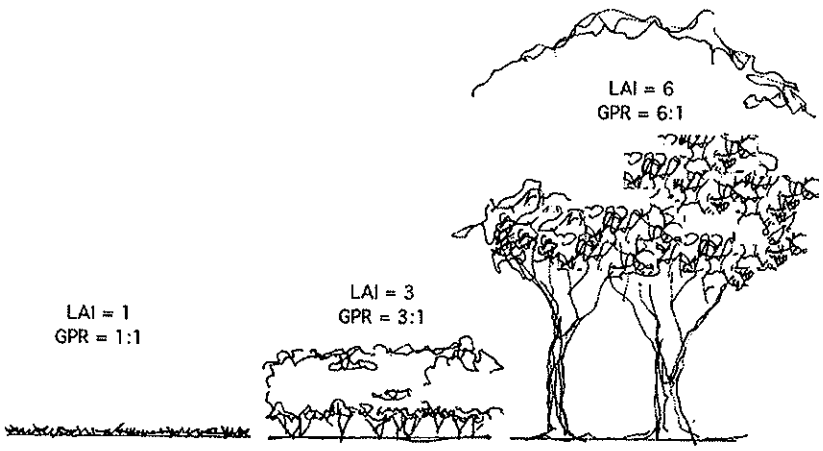
http://www.orst.edu/extension/img/botany/images/fig24.gif

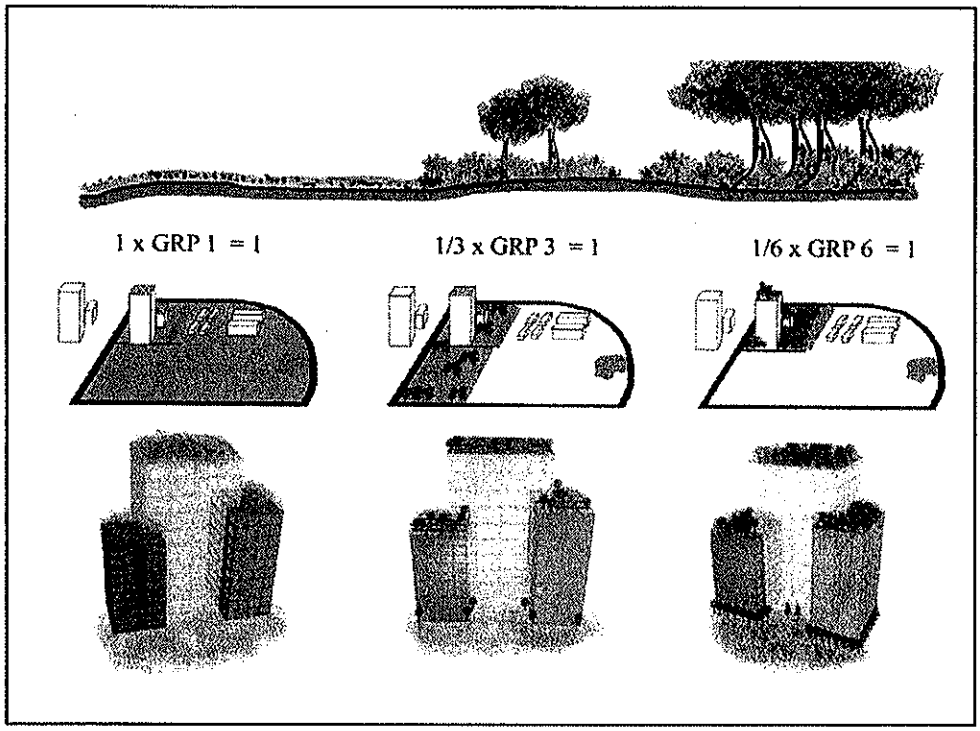
Leaf area index (LAI)

LAI is defined as the single-side leaf area per unit ground area and as such is a dimensionless number. The importance of LAI stems from the relationships which have been established between it and a range of ecological processes (rates of photosynthesis, transpiration and evapotranspiration: McNaughton and Jarvis 1983, Pierce and Running 1988; net primary production: Monteith 1972, Norman 1980, Gholz 1982, Meyers and Paw 1986, 1987; rates of energy exchange between plants and the atmosphere: Botkin 1986, Gholz *et al.* 1991). Measurements of LAI have been used to predict future growth and yield (Kaufmann *et al.* 1982) and to monitor changes in canopy structure due to pollution and climate change (Waring 1985, Gholz *et al.* 1991). The ability to estimate leaf area index is therefore a valuable tool in modelling the ecological processes occurring within a forest and in predicting ecosystem responses.

http://www.unesco.org/csl/pub/source/rs13.htm

	Original data					Data after IQR analysis				
Biome	Number of observations	Mean	Standard deviation	Min	Max	Number of outliers removed	Mean	Standard deviation	Min	Max
All	931	5.23	4.08	0.002	47.0	53	4.51	2.52	0.002	12.1
Forest / BoDBL	58	2.64	1.03	0.28	6.0	5	2.58	0.73	0.6	4.0
Forest / BoENL	94	3.50	3.34	0.48	21.6	8	2.65	1.31	0.48	6.21
Crops	88	4.22	3.29	0.2	20.3	5	3.62	2.06	0.2	8.9
Desert	6	1.31	0.85	0.59	2.84	0	1.31	0.85	0.59	2.84
Grassland	28	2.50	2.98	0.29	15.4	3	1.71	1.19	0.29	5.0
Plantation	77	8.72	4.32	1.55	18.0	0	8.72	4.32	1.55	18.0
Shrub	5	2.08	1.58	0.4	4.5	0	2.08	1.58	0.4	4.5
Forest / BoTeDNL	17	4.63	2.37	0.5	8.5	0	4.63	2.37	0.5	8.5
Forest / TeDBL	187	5.12	1.84	0.4	16.0	3	5.06	1.60	1.1	8.8
Forest / TeEBL	58	5.82	2.57	0.8	12.5	1	5.70	2.43	0.8	11.6
Forest / TeENL	215	6.70	5.95	0.002	47.0	16	5.47	3.37	0.002	15.0
Forest / TrDBL	18	3.92	2.53	0.6	8.9	0	3.92	2.53	0.6	8.9
Forest / TrEBL	61	4.90	1.95	1.48	12.3	1	4.78	1.70	1.48	8.0
Tundra	13	2.69	2.39	0.18	7.2	2	1.88	1.47	0.18	5.3
Wetlands	6	6.34	2.29	2.50	8.4	0	6.34	2.29	2.5	8.4





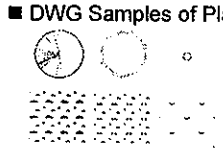


GnPR Program

An AutoCAD-Based Tool for Designer

Plant Database

- Plant Properties
  - Species
  - Name
  - LAI Value
  - Canopy Area
  - Mature Size
- DWG Samples of Plants



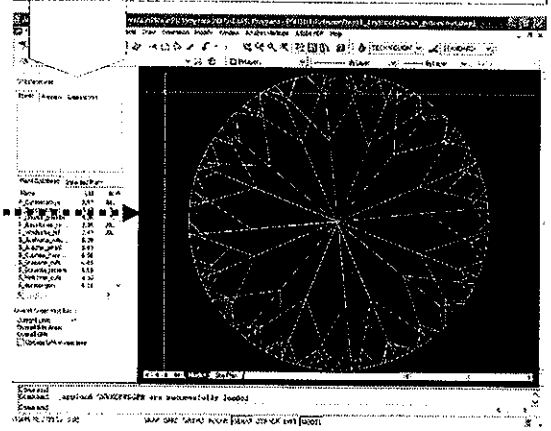
- Photo Samples of Plants



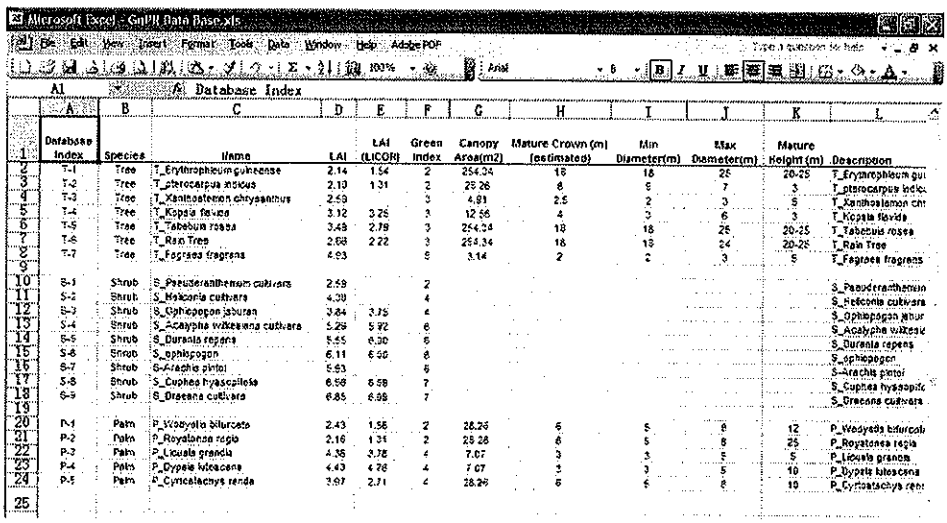
- Plants Descriptions

GnPR Program

- Work as an AutoCAD plug-in
- Input data from plant database
- Calculate GnPR value and summarize plant information based on DWG drawing
- Create new DWG sample to expand database



Plant Database in Excel File Format



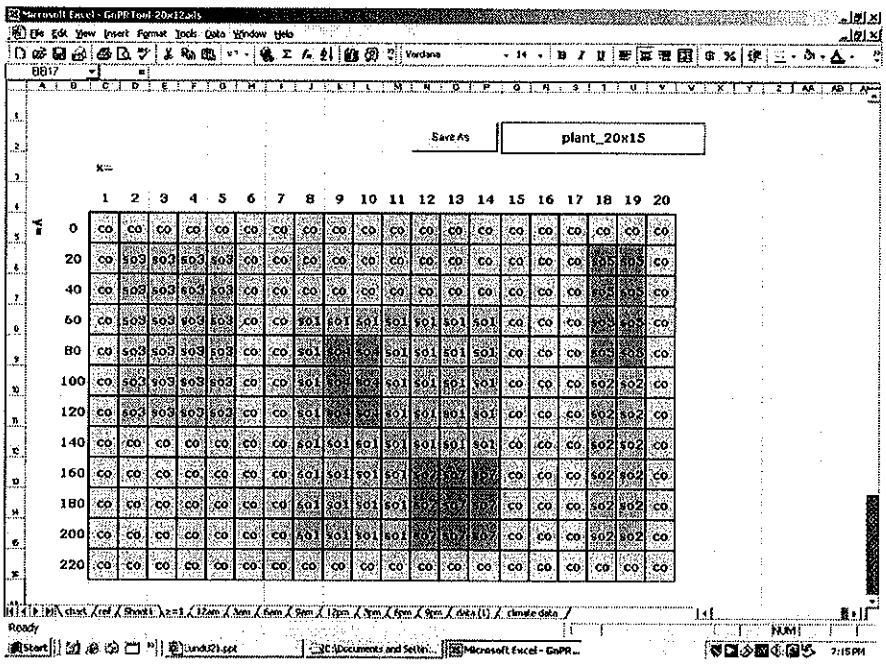
Microsoft Excel - GnPR Data Base.xls

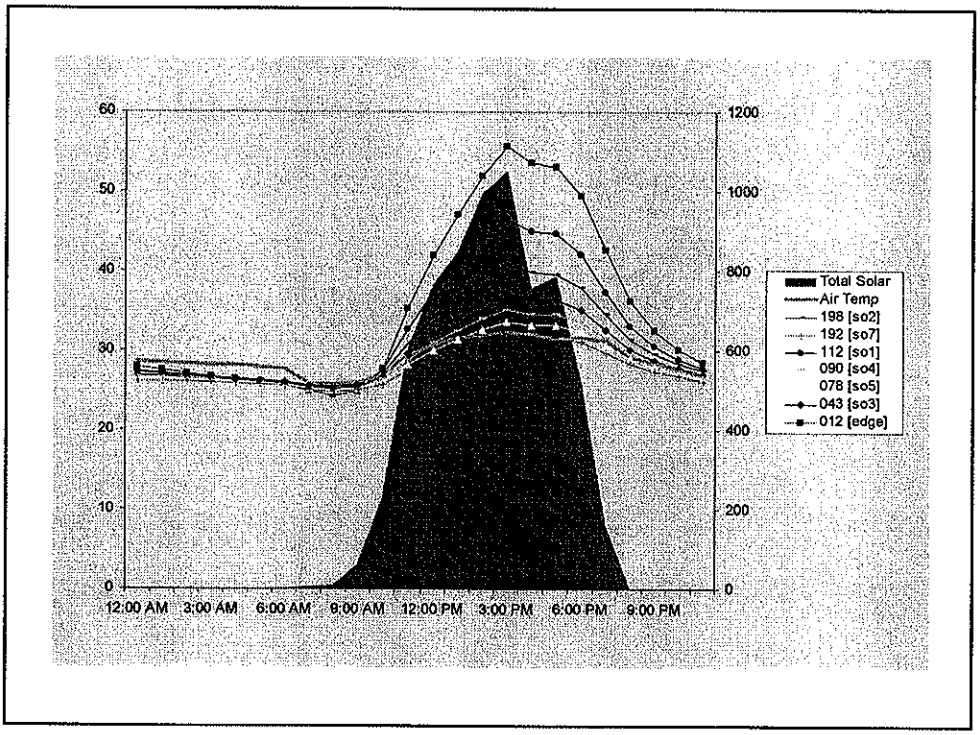
A1: Database Index

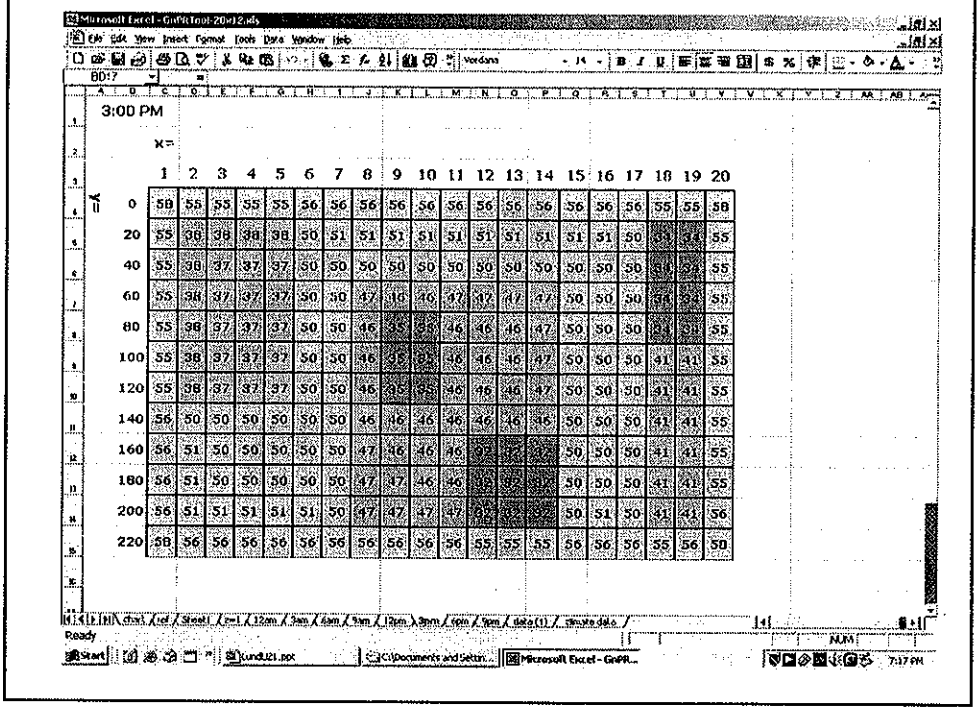
Database Index	Species	Name	LAI	LAI (LICOR)	Green Index	Canopy Area(m2)	Mature Crown (m) (estimated)	Min Diameter(m)	Max Diameter(m)	Mature Height (m)	Description
T-1	Tree	T_Erythrophleum guineense	2.14	1.54	2	254.34	18	18	25	20-25	T_Erythrophleum gui
T-2	Tree	T_pterocarpus indicus	2.10	1.31	2	25.26	6	6	7	3	T_pterocarpus indic
T-3	Tree	T_Xanthostemon chrysanthus	2.59		3	4.91	2.5	2	3	5	T_Xanthostemon chr
T-4	Tree	T_Kopsia flavida	3.12	3.26	3	12.56	4	3	6	3	T_Kopsia flavida
T-5	Tree	T_Tabebuia rosea	3.48	2.79	3	254.34	18	18	25	20-25	T_Tabebuia rosea
T-6	Tree	T_Rain Tree	2.68	2.22	3	254.34	18	18	24	20-25	T_Rain Tree
T-7	Tree	T_Fagraea fragrans	4.93		5	3.14	2	2	3	5	T_Fagraea fragrans
S-1	Shrub	S_Pseuderanthemum cultivars	2.59		2						S_Pseuderanthemum
S-2	Shrub	S_Heliconia cultivars	4.30		4						S_Heliconia cultivars
S-3	Shrub	S_Ophiopogon jaburan	3.84	3.75	4						S_Ophiopogon jabur
S-4	Shrub	S_Acalypha wilkesiana cultivars	5.29	5.92	6						S_Acalypha wilkesia
S-5	Shrub	S_Duranta repens	5.55	6.30	6						S_Duranta repens
S-6	Shrub	S_ophiopogon	6.11	6.58	6						S_ophiopogon
S-7	Shrub	S-Arachis pintoi	5.63		6						S-Arachis pintoi
S-8	Shrub	S_Cuphea hyssopifolia	6.58	6.58	7						S_Cuphea hyssopifo
S-9	Shrub	S_Dracaena cultivars	6.85	6.58	7						S_Dracaena cultivars
P-1	Palm	P_Wodyetia bifurcata	2.43	1.58	2	28.26	6	5	8	12	P_Wodyetia bifurcati
P-2	Palm	P_Royalanea regia	2.16	1.31	2	25.26	6	5	8	25	P_Royalanea regia
P-3	Palm	P_Licuala grandis	4.35	3.75	4	7.07	3	3	5	5	P_Licuala grandis
P-4	Palm	P_Dypsis lutescens	4.43	4.76	4	7.07	3	3	5	10	P_Dypsis lutescens
P-5	Palm	P_Cyrtostachys renda	3.97	2.71	4	28.26	6	6	8	10	P_Cyrtostachys ren

GreenRoof

The thermal effect of plants on roofs




60
50
40
30
20
10
0
1200
1000
800
600
400
200
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
Total Solar
Air Temp
198 [so2]
192 [so7]
112 [so1]
090 [so4]
078 [so5]
043 [so3]
012 [edge]


3:00 PM
x=
y=
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
0 59 55 55 55 55 56 56 56 56 56 56 56 56 56 56 56 56 56 55 55 55
20 55 50 50 50 50 50 51 51 51 51 51 51 51 51 51 51 51 50 50 50 55
40 55 50 47 47 47 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 55
60 55 50 47 47 47 50 50 47 46 46 47 47 47 47 50 50 50 50 50 50 55
80 55 50 47 47 47 50 50 46 46 46 46 46 46 47 50 50 50 50 50 50 55
100 55 50 47 47 47 50 50 46 46 46 46 46 46 47 50 50 50 41 41 55
120 55 50 47 47 47 50 50 46 46 46 46 46 46 47 50 50 50 41 41 55
140 56 50 50 50 50 50 50 46 46 46 46 46 46 46 50 50 50 41 41 55
160 56 51 50 50 50 50 50 47 46 46 46 47 47 47 50 50 50 41 41 55
180 56 51 50 50 50 50 50 47 47 46 46 46 46 46 50 50 50 41 41 55
200 56 51 51 51 51 51 50 47 47 47 47 47 47 47 50 51 50 41 41 56
220 56 56 56 56 56 56 56 56 56 56 56 56 55 55 55 56 56 56 55 56 56
Ready
NUM

Energy Saving Measures in Building

Dr Wong Yew Wah

Energy Conservation in Tropical Climate

CPG Laboratories

Energy Saving Measures in Buildings

Presented by
Wong Yew Wah
Associate Professor
School of Mechanical and Aerospace Engineering
Nanyang Technological University
Tel: 6790 5543
e-mail: mywwong@ntu.edu.sg

Introduction

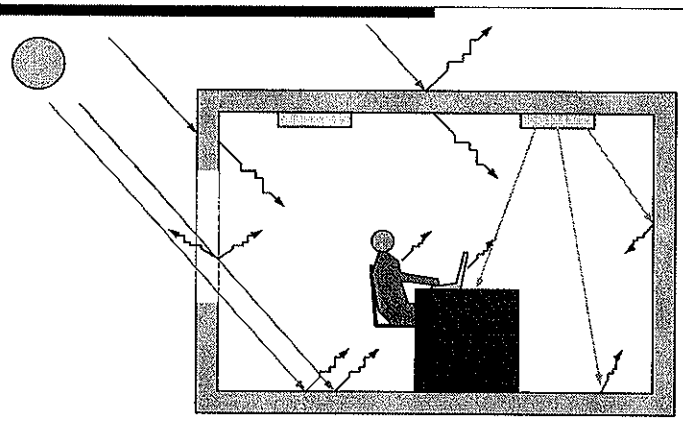
- Air-conditioning provides a proper environment in a modern building to achieve high productivity among the occupants.
- It is essential in many manufacturing processes.
- It consumes about 34% of generated electricity.

How to maximise benefits while minimising energy use?

- Reduce waste!
  - Understand the energy flows in a building.
  - Careful management of energy consumption.
- Where to look for reduction?
  - Reduce building loads.
  - Reduce distribution or parasitic loads.
  - Increase efficiency of primary energy conversion equipment.

Wong YW, NTU

Heat flow in Buildings



Wong YW, NTU

Energy Use Characteristics in Buildings

- Each building is unique but do show common characteristics.
- Characteristics influenced by climate, type of structure, and occupancy.
- Typical energy use in office building:
  - Chiller plant 29%
  - General lighting & power 26%
  - Fan and power 21%
  - Others (lifts, water, etc) 24%

Wong YW, NTU

Space heat gains

- Solar radiation through windows.
- Heat conduction through external walls.
- Heat conduction in space from occupants, lighting, and equipment.
- Cooling of ventilation and infiltration air.
- Space cooling load is the rate heat must be removed from space to maintain temperature.

Wong YW, NTU

Thermal Inter-relationship in Buildings

- Various features and systems using energy are inter-related in significant ways, eg lighting and cooling, ripple effect from zones.
- Changes in energy use in one form may lead to effects on other energy use.

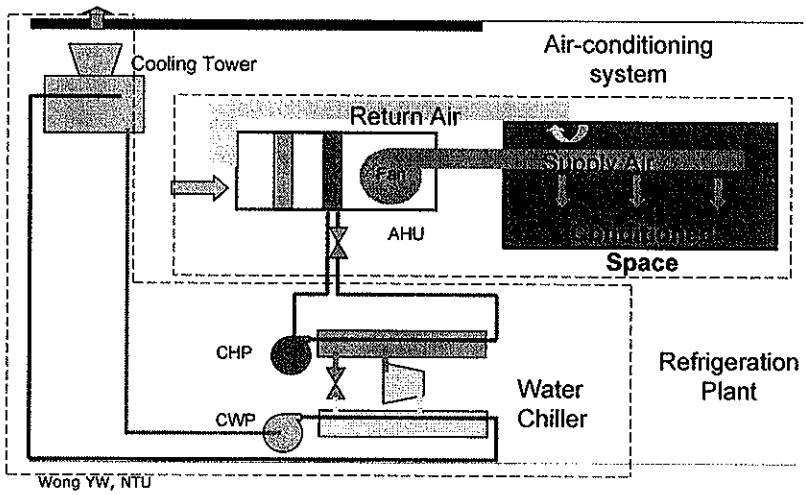
Wong YW, NTU

Energy loads

- Building loads eg envelope, occupancy, location.
- Distribution loads or parasitic loads not directly related to requirements of occupants, but from inefficiencies of fans, pumps and ducts, and pipes resistances.
- Primary equipment loads relating to efficiency of energy conversion processes due to design, maintenance, and operating times.

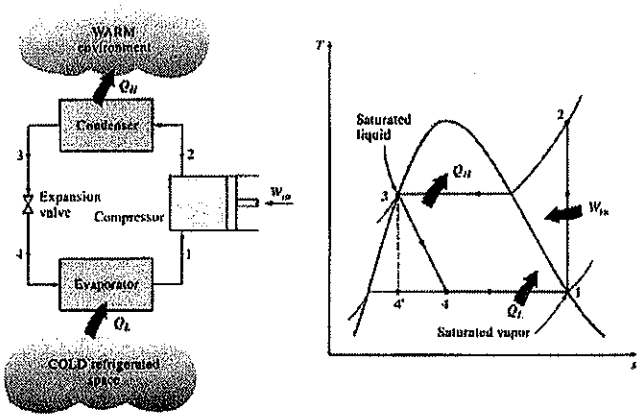
Wong YW, NTU

Schematic Diagram of a Large Air-conditioning System



Wong YW, NTU

Vapour Compression Refrigeration Machines



Wong YW, NTU

Evaporating and Condensing temperature

- Has significant effect on chiller efficiency in vapour compression machine.
- Effort focused on raising evaporating temperature and reducing condensing temperature.

Wong YW, NTU

Cummulative effect of load reductions

- Arises from thermal inter-relationships.
- Energy reduction implemented in a sequence,
  - effect operational ECOs.
  - reduce building loads (reduce air supply).
  - reduce distribution losses (reduce fan power).
  - improve efficiency of primary plant (reduce chiller load).
- Energy reduction must not affect building function!

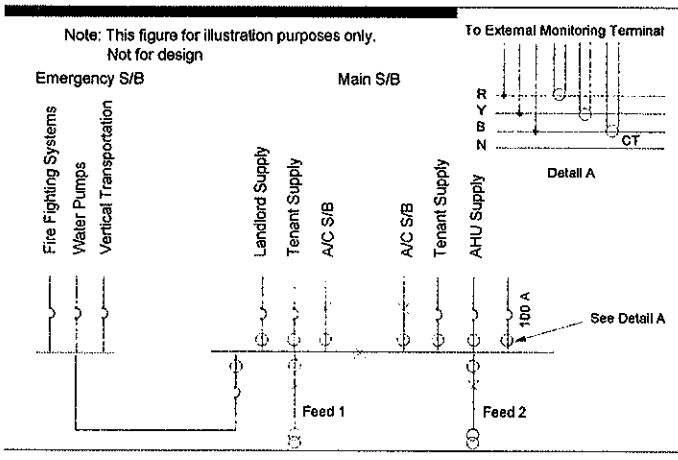
Wong YW, NTU

O&M requires good record keeping

- ☐ Schedules
- ☐ Metered data
- ☐ Space temperatures, water temperatures
- ☐ Pressures
- ☐ Water flow-rates

Wong YW, NTU

O&M Electrical end-use monitoring



Wong YW, NTU

O&M ECOs - Space temp & RH

- CP 13:1999
  - Space temperature: 22.5 °C to 25.5 °C
  - Air movement at 1.5 m level: 0.25 m/s
  - Maximum relative humidity: 70%
- Moderate conditions to suit the space function eg higher temp and air movement in circulation space, lobbies, etc.

Wong YW, NTU

O&M ECOs – Check Ventilation rates

- CP 13:1999
  - Generally rates increased 50% over previous recommendations.
  - Allows reduction in office, classrooms, theatres, and factories if standards of air quality can be met i.e. Monitoring air quality level to modulate ventilation rates.
- In car-parks exhaust systems can be operated to maintain CO level at 25 ppm averaged over 8 hour period.

Wong YW, NTU

O&M ECOs - Reduce Infiltration

- Uncontrolled inflow of unconditioned air, increases cooling load.
- Weather stripping on windows, automatic operating doors, to reduce effect.

O&M ECOs - Reduce Solar Gain

- Solar major contributor to space load.
- Apply solar control film.
- Apply drapes, blinds and screens.

O&M ECOs - Reduce Distribution Loads

- Flow resistance in ducts and pipes.
- Heat gain in ducts and pipes.
- CP13:1999
  - Friction in pipe < 4 m head per 100 m run.
  - Water transport factor: > 30 chilled water, > 40 condensing water
  - WTF = Heat transfer to water/Pump input Power
  - CAV system < 0.47 W/m^3/h supply air.
  - VAV system < 0.74 W/m^3/h supply air.

Wong YW, NTU

O&M ECOs - Reduce Distribution Loads

- Procedure:
  - Increase coil performance, reduce pressure drop across coil.
  - Replace filters with those of higher efficiency and lower resistance.
  - Repair damage to insulation.
  - Reduce power consumed by fans and pumps.
  - Replace oversized motors.

Wong YW, NTU

O&M ECOs - Reduce Distribution Loads

- Example:
  - Reduce cooling loads.
  - Reduce resistance to airflow.
  - Measure resulting increase in air volume.
  - Determine air flow required after changes.
  - Reduce air flow by reducing fan speed.
  - Replace motor with smaller capacity.

Wong YW, NTU

O&M ECOs - Increase plant efficiency

- Maintain designed conditions for evaporating and condensing temperatures.
- Maintain condition of cooler and condenser tubes.
- Optimize part-load operations.
- Maintain conditions of cooling tower water nozzles.
- Reduce plant operating time.

Wong YW, NTU

Summary

- ☐ Understand the energy flows in a building
- ☐ Know where to look to reduce energy wastage
- ☐ Reducing energy use in A/C systems through O&M is an on-going process.
- ☐ Simple measures can reap benefits.

Towards Solar Architecture in Singapore

Dr Stephen Wittkopf

Towards Solar Architecture in Singapore

Energy Conservation in Tropical Climate
– Measures to Conserve & Improve Profitability

CPG Training Centre
19 January 2006

NUS National University of Singapore

X-factor

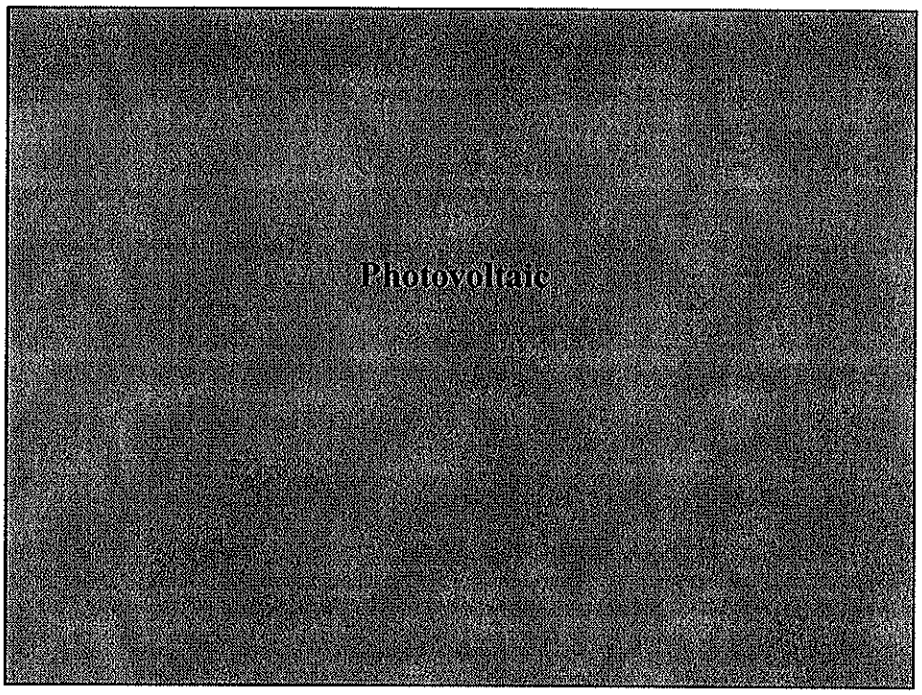
- *Sustainable Architecture?*
- *Green Architecture?*
- *Intelligent Architecture?*
- *Bioclimatic Architecture?*
- *Energy Efficient Architecture?*
- *No|Low|Light|High Tech Architecture?*

Towards Solar Architecture in Singapore

Solar Architecture – A definition

- *Architecture that harnesses Solar Energy by means of:*
  - **Integrated Photovoltaic to produce electricity**
  - **Integrated Solar Thermal to transform energy in heat (solar cooling)**
  - **Daylight re-directing devices to reduce artificial lighting and improve human well-being**
- *Contributes to an energy efficient build sustainable environment*

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World PV Production in 2003

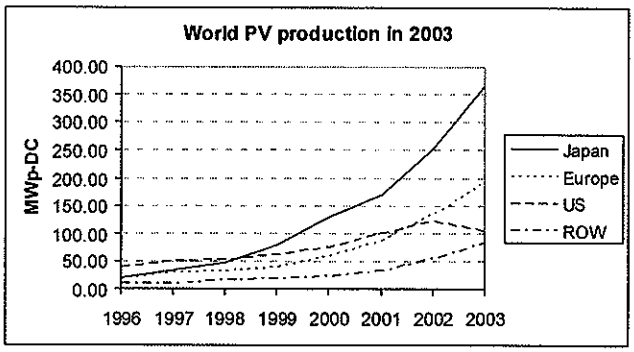


Figure 1.5 Source: REW, 2004

100 MWp solar panel covers an area of approx. 100 ha or 1 km²

Assumed Growth Rate for RES under AIP

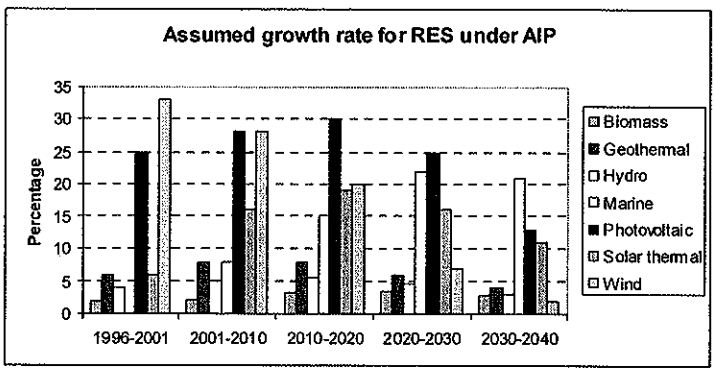
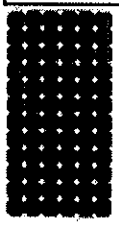


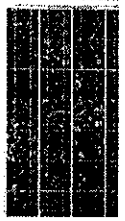
Figure 1.2 Source: EREC, 2004

Towards Solar Architecture in Singapore

PV Technology, Performance and Cost

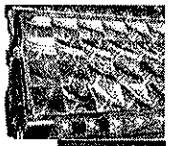
Cell Technology	Generation	Performance	Cost/Wp (US$)	Solar Radiation Preference
Mono-crystalline Silicon	1st	12-18	4	More direct
Poly-crystalline Silicon	1st	11-16	3.5	More direct
Amorphous Silicon	2nd	5-7	1.5-2	Direct and diffuse
CIS (Copper Indium Diselenide)	2nd	8-13	2-3	Direct and diffuse
Concentrator with III-V Materials	3rd	20-30		Direct (tracking)


Mono-crystalline silicon


Poly-crystalline silicon


Amorphous silicon


CIS (Copper Indium Diselenide).



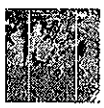

New: Concentrator Cells

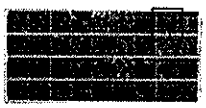
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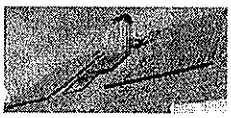
Towards Solar Architecture in Singapore

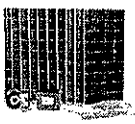
Wafer, Cell, Module, Array, System







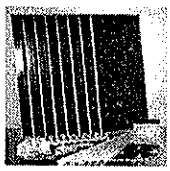




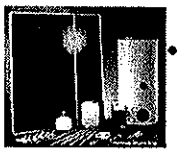
- *Wafer*
  - **Smallest component**
- *(Solar) Cell*
  - **Made of wafer**
  - **10cm x 10cm or 12.5cm x 12.5cm**
- *Module*
  - **Ready to use panel with cells and plugs**
  - **Modular cell size**
- *Array*
  - **Layout of modules**
- *System*
  - **All inclusive ready to produce AC power (Array, inverter, meter, cable, data logger, etc)**

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Standard products available in online shops



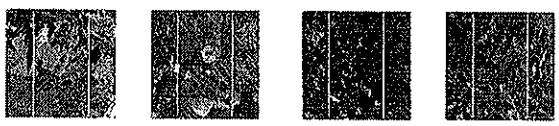
PV set ready for grid connection

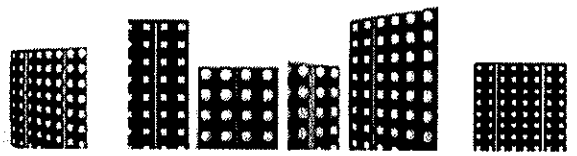


ST set for water heating

- *Photovoltaic (PV) Collector*
  - **Solar Radiation falling on PV modules is converted to DC electricity, subsequently converted into AC by inverter**
  - **Standard solutions commercially available**
- *Solar Thermal (ST) Collector*
  - **Solar radiation is used to heat up water flowing in collector cavities**
  - **Standards solutions commercially available**
- *Hybrid (PVT) Collector*
  - **Collector comprising PV modules on the surface and water tubes inside (cooling effect for PV besides warm water generation**
  - **R&D, Some solutions available**

Colored Solar / Transparent Solar Cells



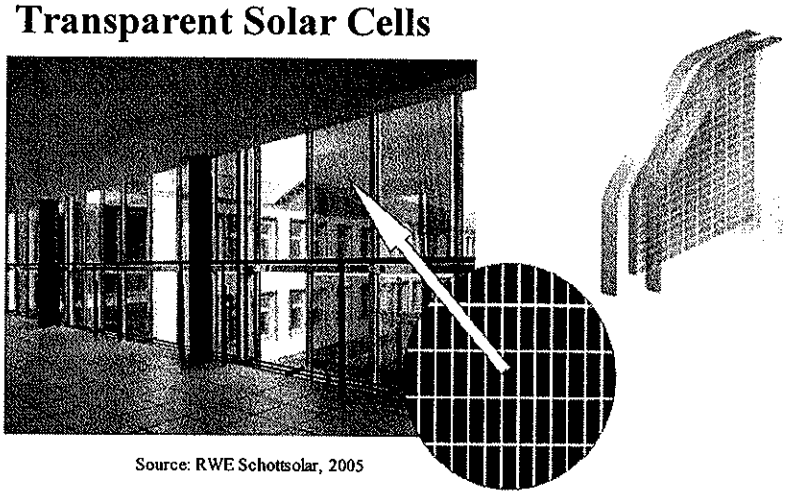


www.sunways.de

iF Ecology Design Award 1999 TOP 3

Towards Solar Architecture in Singapore

Transparent Solar Cells



Source: RWE Schottsolar, 2005

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Photovolatic technology:

- versatile
- adopted
- customizable
- growing

Towards Solar Architecture in Singapore

PV's Area of Application in 2003

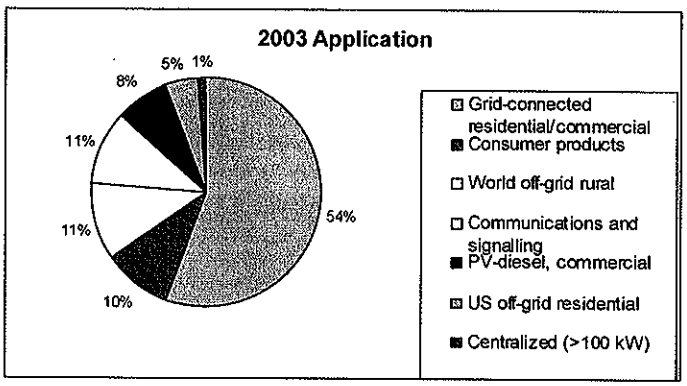
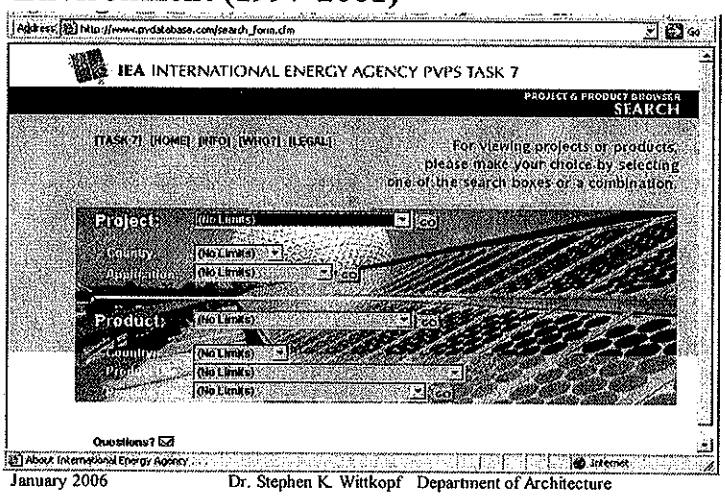


Figure 1.7 Source: REW, 2004

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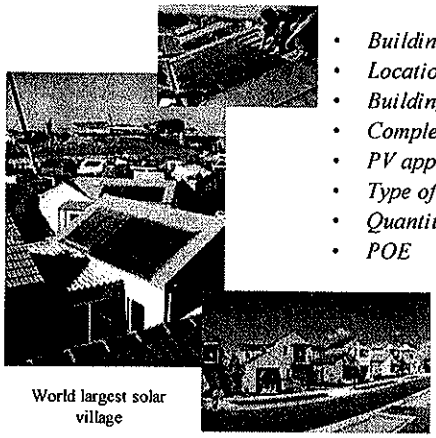
Towards Solar Architecture in Singapore

IEA, PV Power Systems, Task 7: PV in the Built Environment (1997-2001)



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BIPV Example in Australia

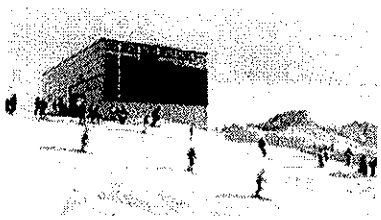


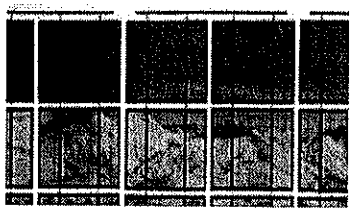
World largest solar village

- *Building name : Olympic Village*
- *Location : Australia, Sidney*
- *Building type : Residential*
- *Completion : December 1999*
- *PV application : Roof integrated PV*
- *Type of PV : Monocrystalline silicone*
- *Quantity : 629 kWp*
- *POE : 1400-1500 kWh output/year*

Source : http://www.oja-services.nl/iea-pvps/cases/aus_01.htm

BIPV Example in Austria

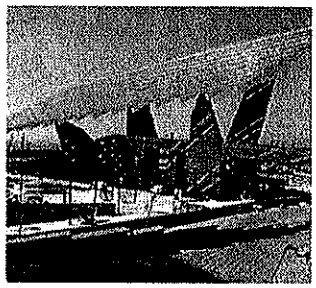




Building name: *Kriegerhornbahn*
Location: *Austria, Lech am Arlberg*
Building type: *Sport and Recreation*
Completion: *2004*
PV application: *Façade*
Type of PV: *transparent colored mono-cristaline*

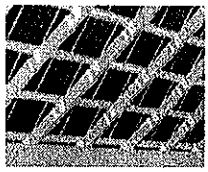
Source : www.solarserver.de

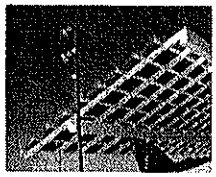
BIPV Example in Barcelona

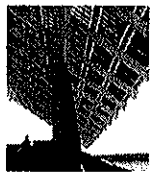


- *Building name : The Solar Pergola*
- *Location : Spain, Barcelona*
- *Building type : Pergola*
- *Completion : 2004*
- *PV application : Roof integrated PV*
- *Type of PV : Monocrystalline silicone*
- *Quantity : 449 kWp*
- *Yield : 1250 kWh/kWp*

The 50m height PV area is close to the size of a football pitch (112x50m²)

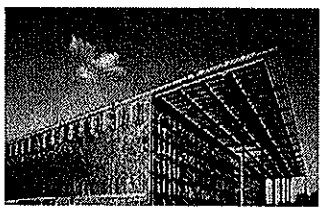




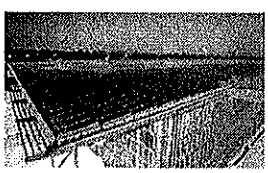


Source : http://www.isofoton.com/espaniol/forum.pdf http://www.earthscan.co.uk/news/article/mps/UAN/226/v/3/sp/332244698595342568278

BIPV Example in Germany



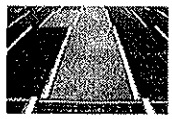
- *Building name : Mont Cenis Academy*
- *Location : Germany, Herne Sodingen*
- *Building type : Commercial*
- *Completion : 1999*
- *PV application : Roof & facade*
- *Type of PV : Multicrystalline silicium*
- *Quantity : 1000 kWp*
- *POE : 600000-650000 kWh output/year*





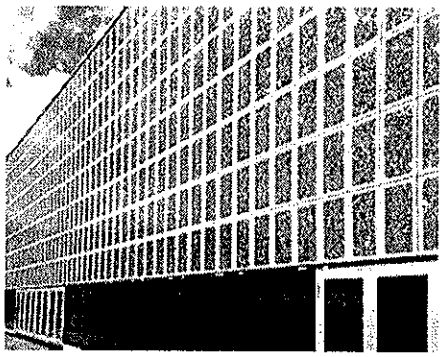




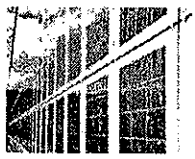


Source : http://www.oja-services.nl/iea-pvps/cases/deu_01.htm; Schittich (2003)

BIPV Example in Germany



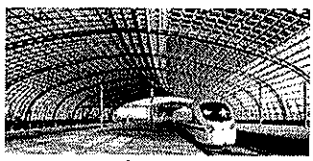




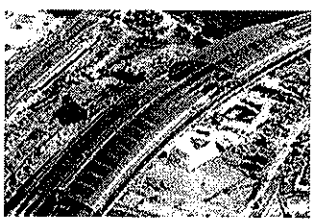
Building name:	*Mont Cenis Academy*
Location:	*Germany, Tuebingen*
Building type:	*Sport and Recreation*
Completion:	*2005*
PV application:	*Façade (ventilated)*
Type of PV:	*colored multi-crystallin*
Quantity:	*970 x 45 Wp (525 m2)*

Source : www.solarserver.de

BIPV Example in Germany



Source :
http://www.jxj.com/magsandj/rew/2003_05/lehrter.html



- *Building name : Lehrter Station*
- *Location : Germany, Berlin*
- *Building type : Railway station*
- *Completion : 2002*
- *PV application : Façade integration*
- *Type of PV : Monocrystalline*
- *Quantity : 189 kWp*
- *Estimated : 160000 kWh /year to feed the grid*

Due to the shape , there are no two modules are the same. Each is unique

Towards Solar Architecture in Singapore

BIPV Example in Germany





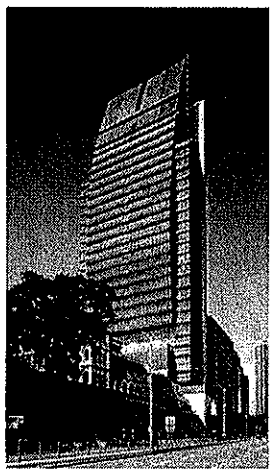
- *Building name : House of Fashion Zara*
- *Location : Germany, Cologne*
- *Building type : Commercial*
- *PV application : Façade integration*
- *Type of PV : Polycrystalline*

PVs are not connected. PVs are function only as aesthetic elements.

Source : www.solon-pv.de;
Solon Presentation (2004)

Towards Solar Architecture in Singapore

BIPV Example in Hong Kong



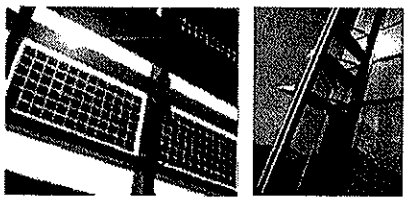
- *Building name : One Peking Road*
- *Location : Hong Kong, One Peking Road, Tsim Sha Tsui, Kowloon Hong Kong*
- *Building type : Commercial building (mix use)*
- *Completion : March 2003*
- *PV application : Upper façade*
- *PV type : Polycrystalline Silicon*
- *Quantity : 7.2kWp (total PV area of 200m²)*
- *Estimated : 10344 kWh/year*

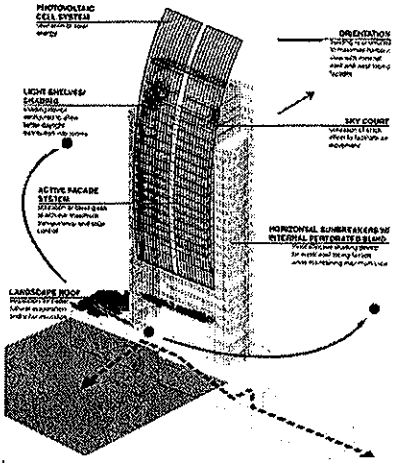
This off-grid PV is the first large scale commercial BIPV in Hong Kong and China. The building won the HKIA (Hong Kong Institute of Architect) Award due to its aesthetics and environmentally friendly design.

Source :http://www.architecturechina.cn/en/issue1/article16.htm; http://hkci.org/upload/bank/onepekingrd_innov.pdf; http://www.pabhk.com/blogs/2004/04/profile-building-integrated-solar-pv.html

Towards Solar Architecture in Singapore

BIPV Example in Hong Kong





Besides Photovoltaic, the building implements Active Façade System :

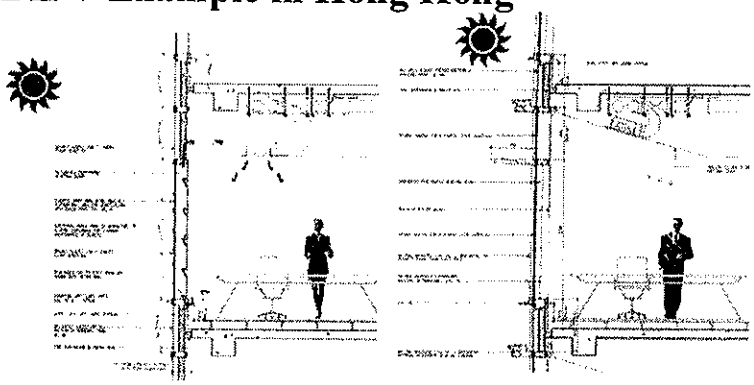
- *Triple glazed walling system*
- *Low-e clear glass*
- *Ventilated cavity*
- *Automated sun tracking blind in the cavity*

Source : http://www.hk-beam.org.hk/fileLibrary/One%20Peking_GCPL_C1071.pdf; http://www.architecturechina.cn/en/issue1/article16.htm

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Towards Solar Architecture in Singapore

BIPV Example in Hong Kong



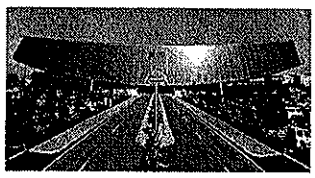
The cavity in the glass is ventilated from the interior cooler air. South facade has some sun shade and reflective interior ceiling that function as Daylight Directing Device.

Source : http://www.hk-beam.org.hk/fileLibrary/One%20Peking_GCPL_C1071.pdf

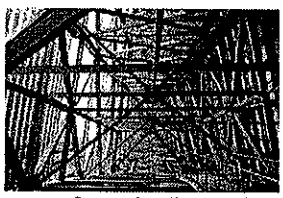
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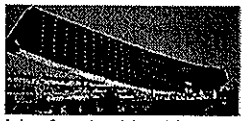
Towards Solar Architecture in Singapore

BIPV Example in Japan



- *Building name : Solar Ark*
- *Location : Japan, Ogaki city, Gifu*
- *Building type : Commercial*
- *Completion : December 2001*
- *PV application : Façade integration*
- *Type of PV : Monocrystalline*
- *Quantity : 630 kWp*
- *Estimation : 530000 kWh output/year*





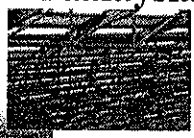


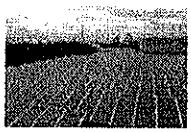
Source : http://www.asahi-net.or.jp/~ap8n-tn/sun/photo/photorsa/sanyo/esanyo.html; http://www.japan-photo.de/e-mul-15.htm; http://www.solar-ark.com.data-hotel.net/english2/ark/index.html

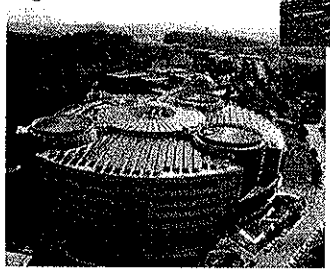
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BIPV Example in Malaysia

The largest PV rooftop system in Asia Pacific in 2001, now is the 2nd largest in South East Asia.







- *Building name : Technology Park*
- *Location : Malaysia, Kuala Lumpur*
- *Building type : Commercial*
- *Completion : 2001*
- *PV application : Roof integration*
- *Type of PV : Monocrystalline*
- *Quantity : 362 kWp*

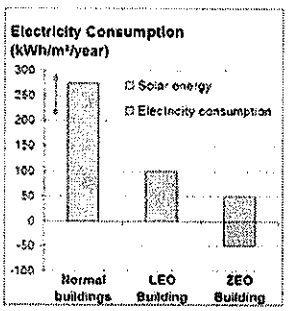
Source : http://www.sebastianselmitt.de/Welt/Malaysia/TPM/; http://www.ptm.org.my/BIPV/pdf2/web%20info/database/BIPV-installation%20list.pdf





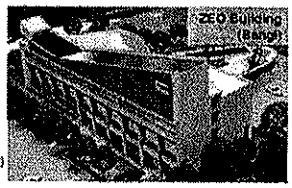
Towards Solar Architecture in Singapore

National BIPV Program in Malaysia





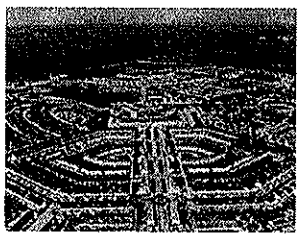




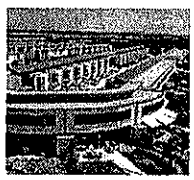
Source:
http://www.nhgade3.dk/zeroenergyoffice building/

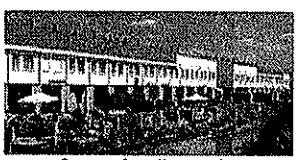
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BIPV Example in Netherlands





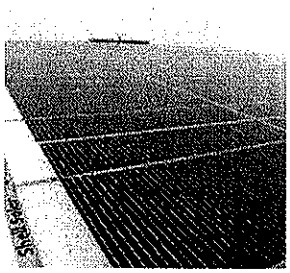




Source : http://www.oja-services.nl/iea-pvps/cases/nld_01.htm

- *Building name : Housing Area of Amsterfoot*
- *Location : Netherland, Amsterfoot*
- *Building type : Residential*
- *Completion : 1999*
- *PV application : Roof integration*
- *Type of PV : Polycrystalline*
- *Quantity : 1323 kWp on 500 houses*

BIPV Example in Thailand

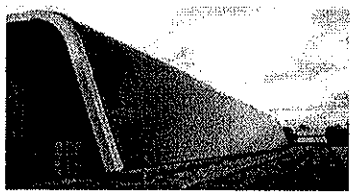


Source :
http://www.renewableenergyaccess.com/rea/market/business/viewstory;jsessionid=a841RoLUMN8a?id=17203

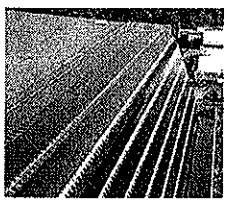
- *Building name : The Tesco-Lotus Hypermarket*
- *Location : Thailand, Bangkok*
- *Building type : Hypermarket*
- *Completion : 2004*
- *PV application : Roof integration*
- *Type of PV : Polycrystalline*
- *Quantity : 460kWp*
- *Estimation : 600000 kWh/year output. 12.5% of building annual consumption.*

It is the largest in South East Asia. The system will reduce peak demand on the grid with the added benefit of annually offsetting 400 tons of carbon dioxide emission from Bangkok fossil-fuel power plant.

BIPV Example in United Kingdom







Source :
http://www.jxj.com/magsandj/rew/2004_02/optic.html

- *Building name : OpTIC centre*
- *Location : UK, North Wales*
- *Building type : Technology Business Centre*
- *Completion : 2003*
- *PV application : Facade integration*
- *Type of PV : Copper indium diselenide*
- *Quantity : 85 kWp*

Building Integrated Photovoltaics:

- common
- aesthetical
- affordable

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BIPV Example in Singapore



Source :
www.interlinkpower.com.sg

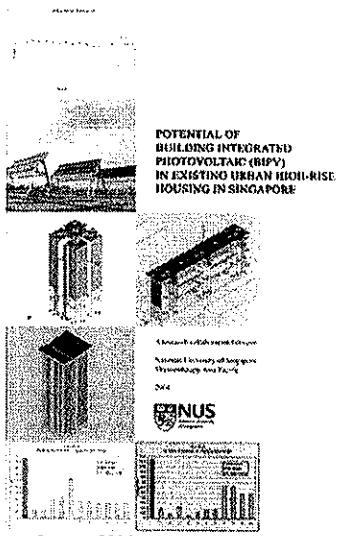
http://www.bouyguesasia.com/pages/fsetc1.htm

- *Building name : Savannah Park Condominium*
- *Location : 31 Simei Rise, Singapore*
- *Building type : Residential*
- *PV application : Roof integration (at club house*
- *Quantity : 5.1 kWp*





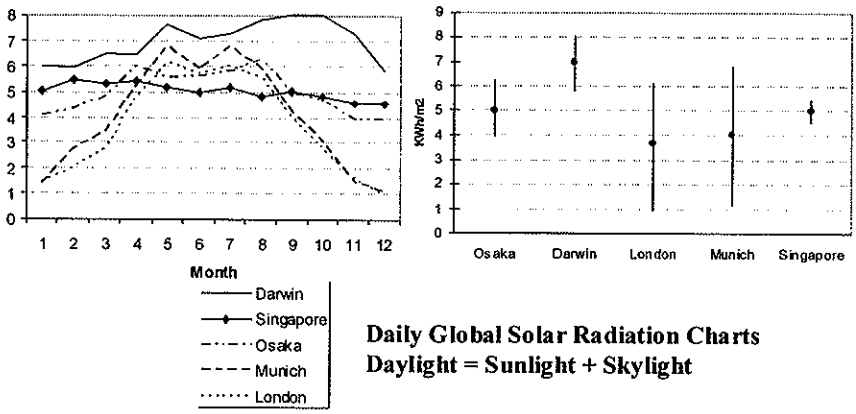
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Research Project

- *Title*
  - **Potential of Building Integrated Photovoltaic (BIPV) in existing urban high-rise housing in Singapore**
- *Collaboration*
  - **NUS, Department of Architecture**
  - **ThyssenKrupp Asia Pacific**
- *Status*
  - **Completed 2004, research report**

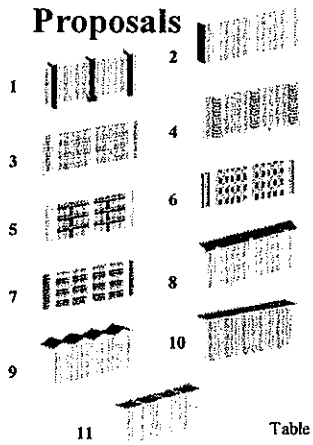
Singapore: Plenty of Daylight



Daily Global Solar Radiation Charts
Daylight = Sunlight + Skylight

Towards Solar Architecture in Singapore

Overview of Slab Block Design Proposals



No	Design description	PV location	PV integration	PV appearance
1	PV on staircase core	Vertical walls	Rainscreen cladding	Strong vertical from front, accentuates the vertical circulation
2	PV on end walls	Vertical walls	Rainscreen cladding	Strong vertical from side
3	PV over windows	Vertical walls, glazing	Fixed sun shades	Thin horizontal strips from front
4	PV along protruding elements (staircase and bedrooms)	Vertical walls with inclined PV	Rainscreen cladding (PV efficiency improved)	Distinctive horizontal strips from front and back
5	PV along corridor	Vertical wall (parapet) and shelter	Rainscreen cladding and fixed sun shades	Distinctive horizontal strips; accentuates the horizontal circulation
6	PV vertically between windows	Vertical walls	Rainscreen cladding	Distinctive vertical strips narrowing the building
7	PV horizontally between windows	Vertical walls	Rainscreen cladding	Distinctive vertical strips widening the building
8	PV on long hip roof	Inclined roof	Roof panels	Thin continuous strip floating over the building
9	PV on short hip roofs	Inclined roof	Roof panels	Strong zig-zag as series of connected gable boards
10	PV on long butterfly roof	Inclined roof	Roof panels	Thin continuous underside of roof floating over the building
11	PV on short butterfly roofs	Inclined roof	Roof panels	Light zig-zag as series of connected gable boards

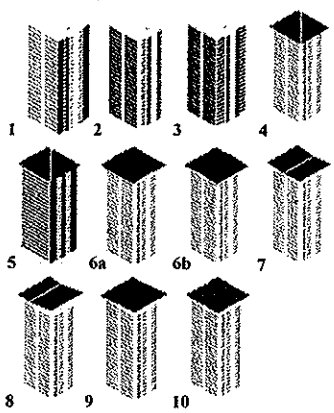
Table 3.4.

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Towards Solar Architecture in Singapore

No	Design description	PV location	PV integration	PV appearance
1	PV vertically along west and east facade	Vertical walls	Rainscreen cladding	Strong vertical from west and west, accentuates the edges
2	PV horizontally along window sills	Vertical walls	Rainscreen cladding	Strong horizontal, accentuates the windows
3	Inclined PV all over	Vertical walls, glazing	Rainscreen cladding and fixed sun shades (PV efficiency improved)	Strong horizontal reads opening up the solid block
4	PV at pitch roof	Inclined roof	Roof panels	Strong vertical ending of block
5	Design 1 4 combined			
6	PV hip roof north south	Inclined roof	Roof panels	Light horizontal strips, almost same as flat roof
6a	PV on hip roof east west	Inclined roof	Roof panels	Light horizontal strips, almost same as flat roof
7	PV on butterfly roof, symmetrical	Inclined roof	Roof panels	Thin continuous underside of roof floating over the building
8	PV on asymmetrical butterfly roof, bigger surface facing west	Inclined roof	Roof panels (PV efficiency improved)	Strong zig-zag and thin continuous underside of roof floating over the building
9	Mono-pitched roof facing west	Inclined roof	Roof panels (PV efficiency improved)	Thin continuous underside of roof floating over the building
10	PV on east-south roof facing west	Inclined roof	Roof panels	Light zig-zag roof line

Overview of Point Block Design Proposal



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Percentage of PV Supply to Total Electrical Demand

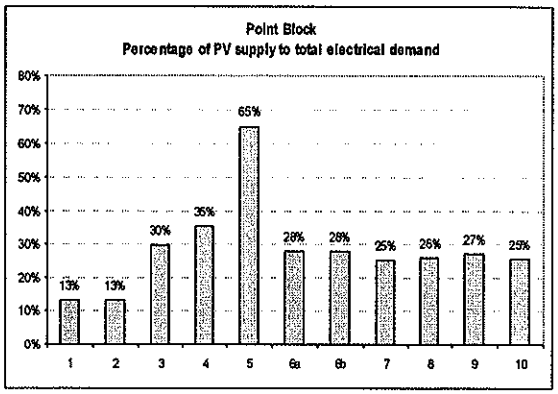


Figure 3.31

Percentage of PV Supply to Total Electrical Demand

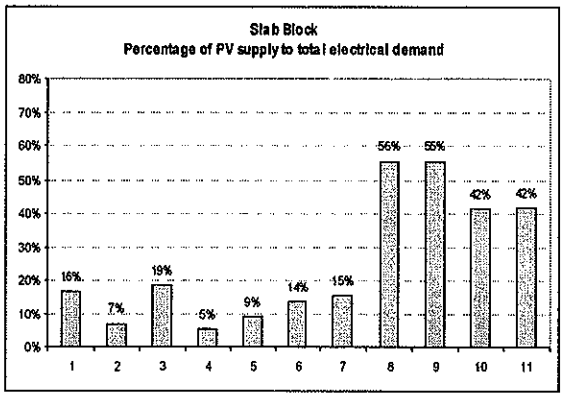
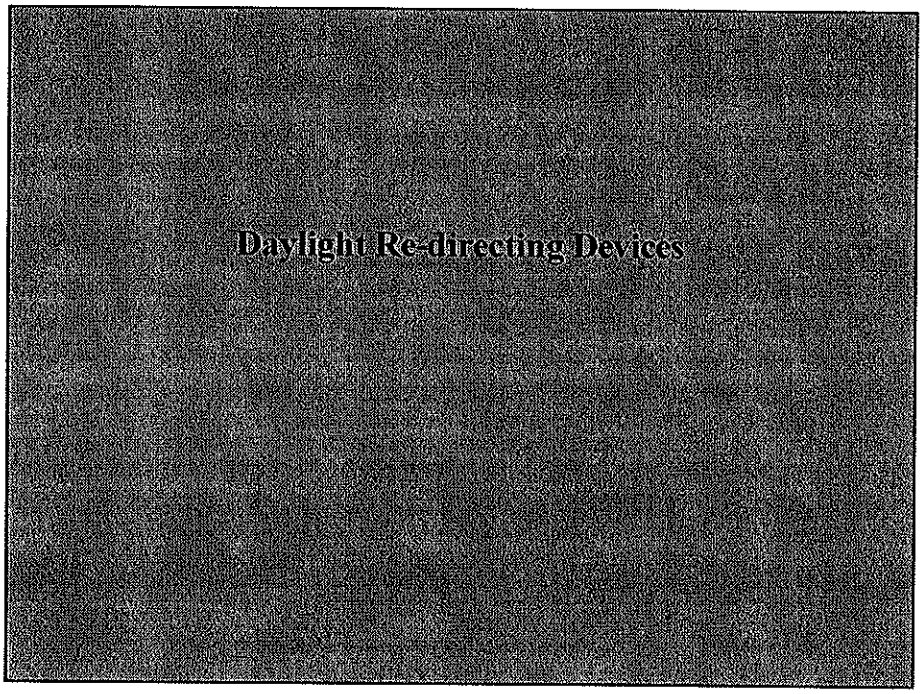
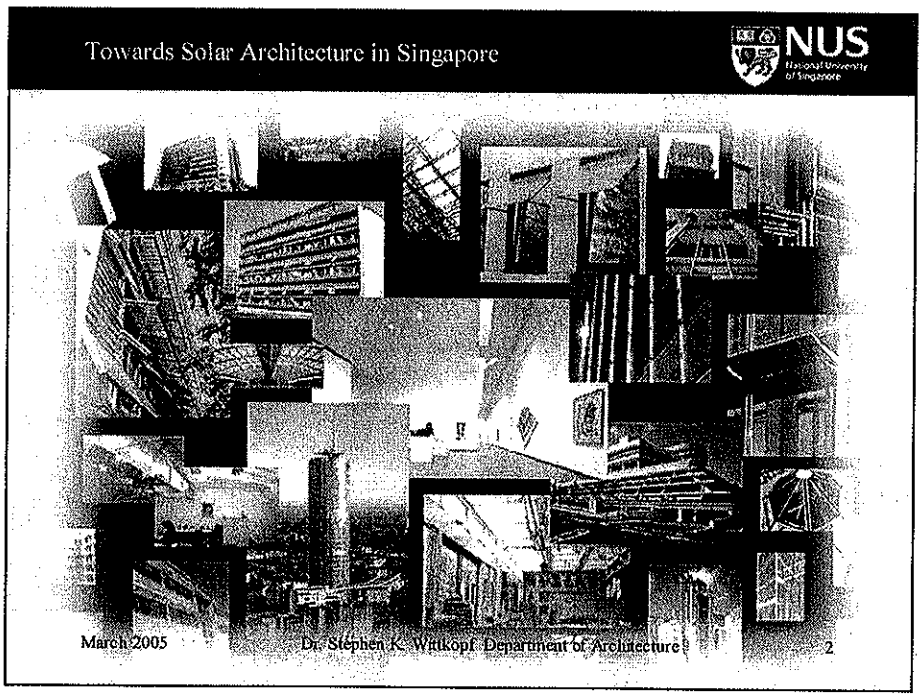


Figure 3.32

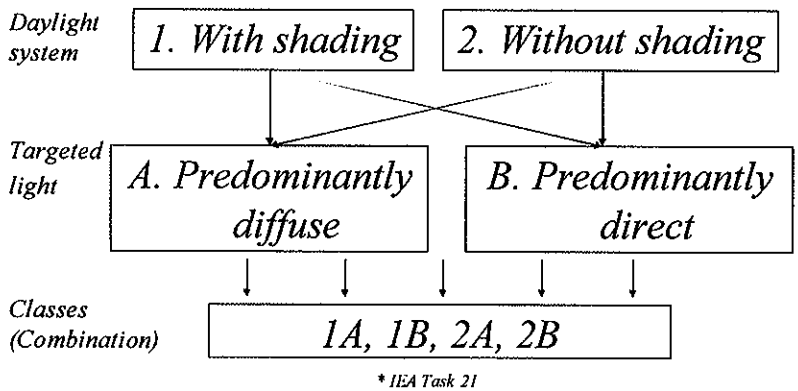

Daylight Re-directing Devices


Towards Solar Architecture in Singapore
NUS
March 2005
Dr. Stephen K. Wittkopf, Department of Architecture
2

Programme Task 21

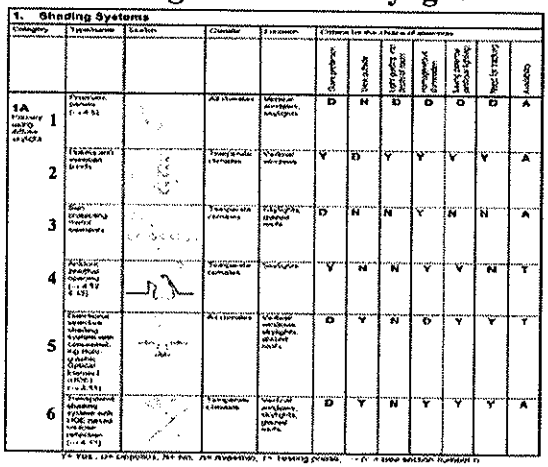
- *Main objective: to advance daylighting technologies and to promote daylight-conscious building design*
- *Subtasks:*
  - **A** : *Performance Evaluation of Daylighting System*
  - **B** : *Daylight Responsive Controls*
  - **C** : *Daylighting Design Tools*
  - **D** : *Case Studies*
- *Publication : Daylight in Buildings*

System Matrix for Daylight System (Overview)



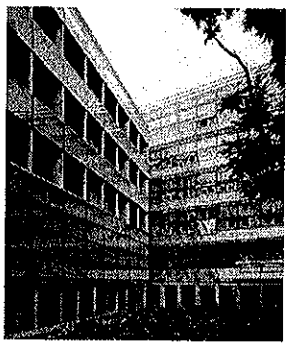
* *IEA Task 21*

1.A. Daylight Systems with Shading for Diffuse Skylight



1A	1				D	N	D	D	O	D	A
	2				Y	D	Y	Y	Y	Y	A
	3				D	N	N	Y	N	N	A
	4				Y	N	N	Y	Y	N	Y
	5				D	Y	N	D	Y	Y	Y
	6				D	Y	N	Y	Y	Y	A

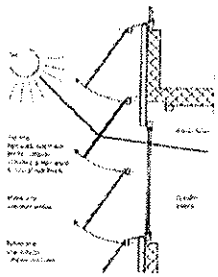
1.A.1. Prismatic Panels (as A Shading), Example 1



Source : Wigginton, Michael and Harris, Jude. (2002). Intelligent Skins. Woburn : Butterworth-Heinemann

- *Building name : SUVA Building*
- *Location : Switzerland, Basel*
- *Building Type : Office*
- *Completion : 1993*
- *LDD location : External Facade*
- *Type of LDD : prismatic panels*





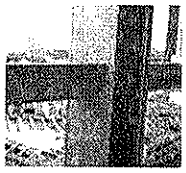
Towards Solar Architecture in Singapore

1.B.2. Louvres and Blinds, Example 9



Source : www.streetdirectory.com.sg

- *Building name : One George Street*
- *Location : Singapore*
- *Building Type : Office*
- *Completion : 2004*
- *LDD location : External Facade*
- *Type of LDD : Louver Cladding*





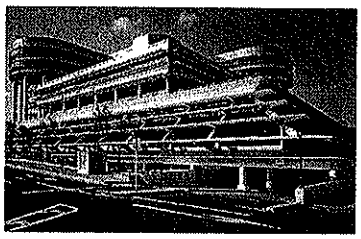


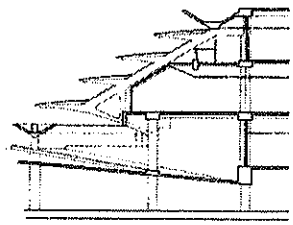
Source : Aung Aung La Win, BS5216

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Towards Solar Architecture in Singapore

2.A.1. Light Shelf, Example 4





Source : www.akitektenggara.com; Powell, Robert. (1997). Line, Edge and Shade: The Search for a Design Language in Tropical Asia. Singapore: Page One.

- *Building name : Kandang Kerbau Hospital*
- *Location : Singapore, 100 Bukit Timah Road*
- *Building type : Hospital*
- *Completion : 1997*
- *LDD location : Facade at Podium*
- *Type of LDD : Light shelves*

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Towards Solar Architecture in Singapore

2.A.1. Light Shelf, Example 5





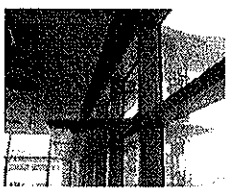
Source : Steve Kardinal Jusuf, BS5216

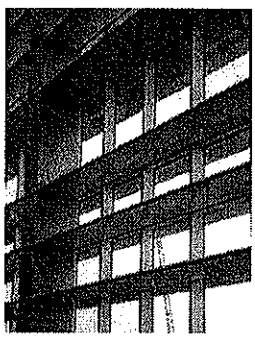
- *Building name : National Library*
- *Location : Singapore, Victoria St*
- *Building Type : Library*
- *Completion : Expected June 2005*
- *LDD location : Facade*
- *Type of LDD : Light Shelves*

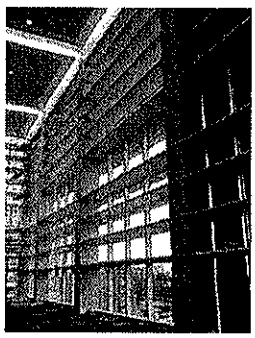
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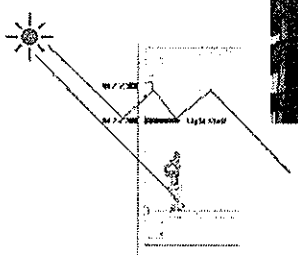
Towards Solar Architecture in Singapore

2.A.1. Light Shelf, Example 5









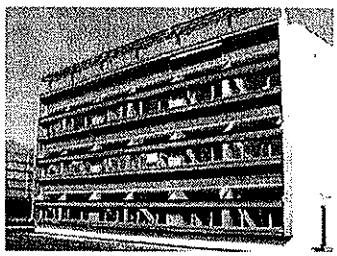
Source : Steve Kardinal Jusuf, BS5216

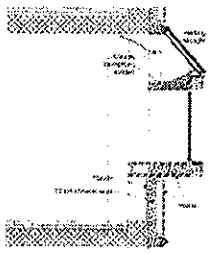
Light shelf provides deeper daylight depth of penetration into the building. Multiple light shelves help to distribute daylight for high ceiling.

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Towards Solar Architecture in Singapore

2.A.2. Anidolic Integrated System, Example 1





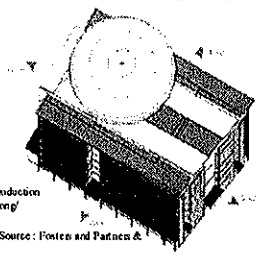
Source:http://lesoww.epfl.ch/anglais/Leso_a_recherche_DL_anidolics_design.html#Sustainable%20Anidolic%20Facade ; http://hope.epfl.ch/guidelines/HOPEGuidelines7.pdf

- *Building name : LESO solar experimental building*
- *Location : Swiss, Lausanne*
- *Building type : Experimental building*
- *Completion : 1999*
- *LDD location : Above windows*
- *Type of LDD : Anidolic integrated system*

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Towards Solar Architecture in Singapore

2.C.1. Scattering System, Example 4

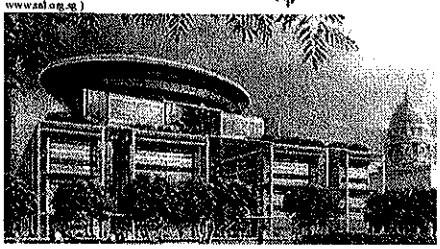


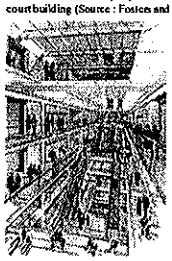
Simplified daylight introduction diagram (Ong Swee Heng/ BS5216)

Rendered perspective (Source : Foster and Partners & www.sal.org.sg)

- *Building name : New Supreme Court*
- *Location : Singapore*
- *Building Type : Government*
- *Completion : 2005*
- *LDD location : External Façade, Sunshade canopies*
- *Type of LDD : Translucent stone cladding and lamellas (scattering system & fix lamellas)*

Main atrium sectional perspective & exterior view from old supreme court building (Source : Foster and Partners & www.sal.org.sg)



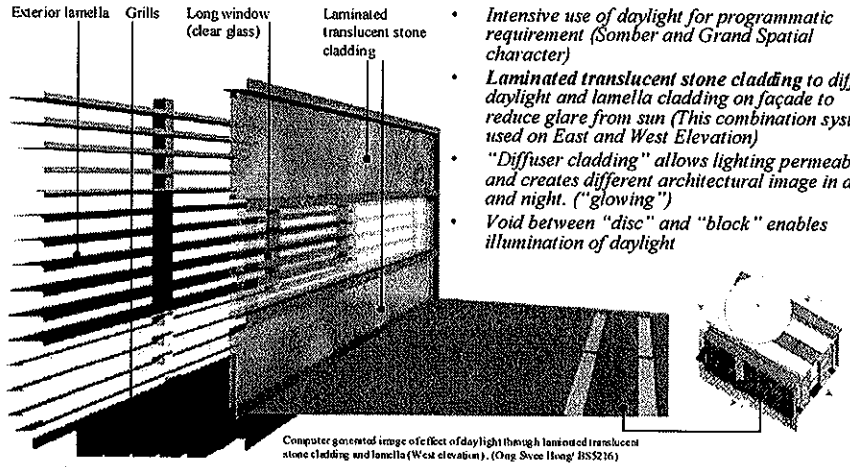




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Towards Solar Architecture in Singapore

2.C.1. Scattering System, Example 4

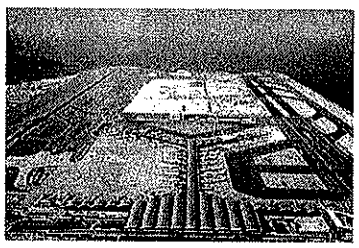


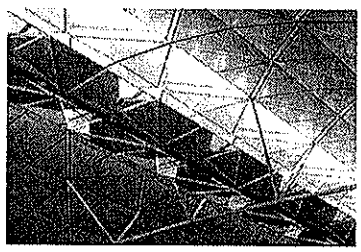
Computer generated image of effect of daylight through laminated translucent stone cladding and lamella (West elevation). (Ong Swee Hong/ BSS216)

- *Intensive use of daylight for programmatic requirement (Somber and Grand Spatial character)*
- ***Laminated translucent stone cladding** to diffuse daylight and lamella cladding on façade to reduce glare from sun (This combination system used on East and West Elevation)*
- *"Diffuser cladding" allows lighting permeability and creates different architectural image in day and night. ("glowing")*
- *Void between "disc" and "block" enables illumination of daylight*

Towards Solar Architecture in Singapore

2.D.6. Light Guiding Ceiling, Example 3





Source : http://www.sasint.co.uk/sas/literature/download/airport_brochure.pdf; http://www.fosterandpartners.com/InternetSite/html/simple.html; Dobney, Stephen. (1997). The Master Architect Series II : Norman Foster. Victoria: The Images Publishing Group Pty Ltd.

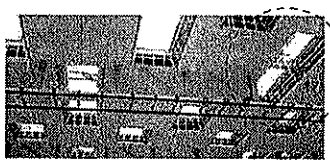
- *Building name : Chek Lap Kok Airport*
- *Location : Hong Kong*
- *Building type : Airport*
- *LDD location : Ceiling*
- *Type of LDD : Reflector under skylight (light guiding ceiling)*

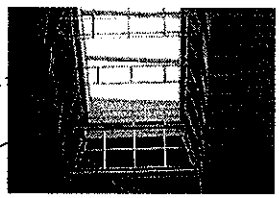
Towards Solar Architecture in Singapore

2.D.6. Light Guiding Ceiling, Example 6

- *Building name : Terminal-3*
- *Location : Singapore*
- *Building type : Airport*
- *Completion : 2006 (Expected)*
- *LDD location : Roof*
- *LDD type : Butterfly & Parabolic anti glare system (light guiding ceiling)*





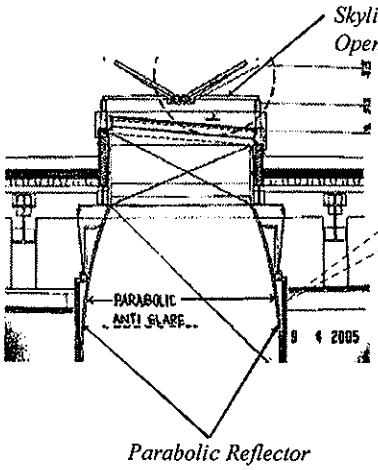


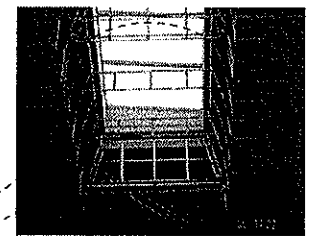
Frame for Parabolic Anti Glare Reflector

Source : Khin Maung Lin (BS5216)

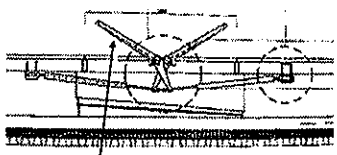
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2.D.6. Light Guiding Ceiling, Example 6





Source : Khin Maung Lin (BS5216)

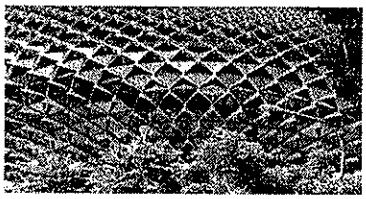


Parabolic Reflector

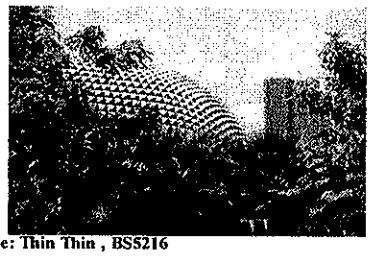
Butterfly

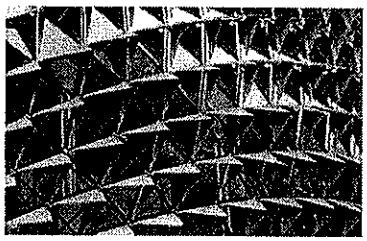
Towards Solar Architecture in Singapore

2.D.6. Light Guiding Ceiling, Example 8



- *Building name : Esplanade*
- *Location : Singapore*
- *Building Type : Commercial*
- *LDD location : Ceiling*
- *Type of LDD : Triangular reflective fins as roof and ceiling (light guiding ceiling)*



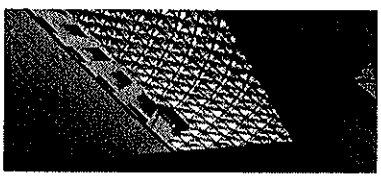


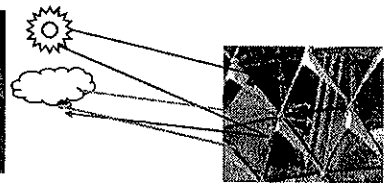
Source: Thin Thin , BS5216

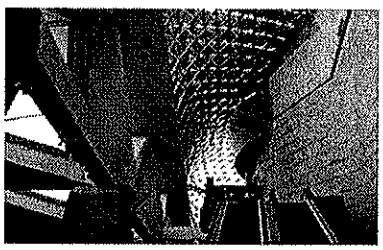
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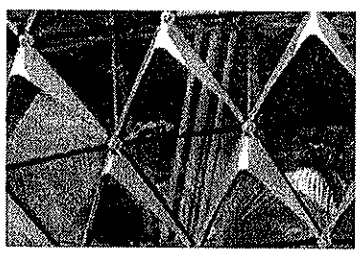
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2.D.6. Light Guiding Ceiling, Example 8





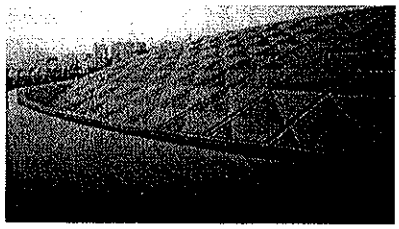


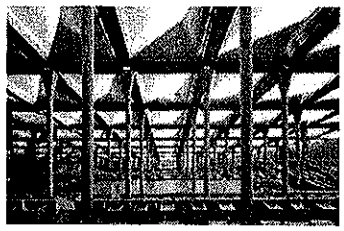


Source: Thin Thin , BS5216

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2.D.6. Light Guiding Ceiling, Example 9





Source : Roof and Façade Asia, December 2004 (Page 2)

- *Building name : Bibliotheca Alexandrina*
- *Location : Egypt, Alexandria*
- *Building Type : Library*
- *Completion : October, 2002*
- *LDD location : Ceiling/roof*
- *Type of LDD : Diagonally half concave square roof (light guiding ceiling)*

The concave part of the square roof module reflect the light through the glass (opening) in between the plane and concave portion

Solar Architecture

Integrated Design Approach

Example

Design Example (1)

Solar Architecture - Design Proposals for Elevated Train Station

Design Strategies

Solar Architecture refers to Architecture harnessing Solar Energy by means of integrated solar cells and daylight re-directing devices. In this case solar cells produce energy for cooling (mechanical ventilation) and daylight re-directing devices ensure sufficient daylight in the interior to reduce electrical lighting loads. Thus Solar Architecture contributes to an energy efficient sustainable built environment.



Design Example (1)

1. Direct Daylighting

Semitransparent Solar Roof

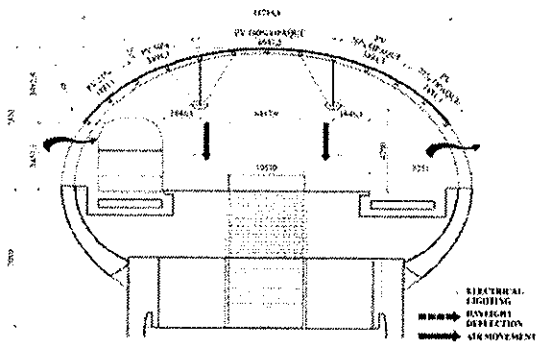
Architectural Strategy

Daylight Strategy

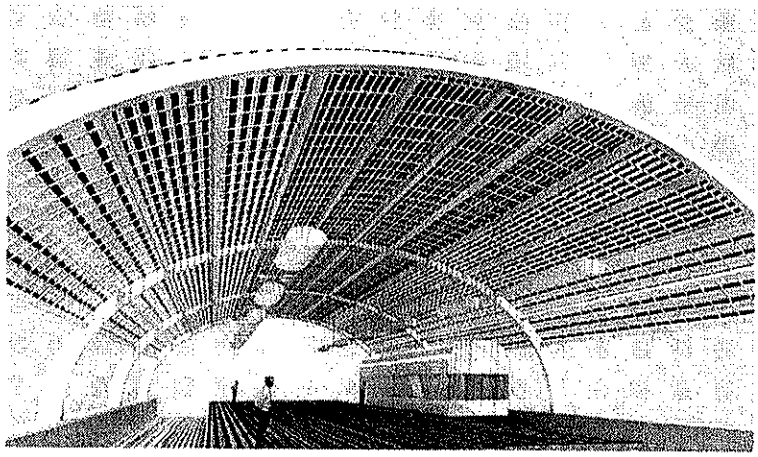
Solar Cell Strategy

Solar Heat Reduction Strategy

Electrical Lighting Strategy



Design Example (1)



A New Design Language?

