Energy Modeling

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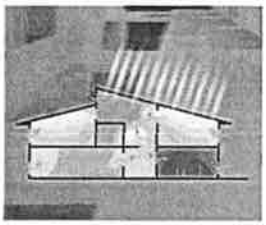


Agenda

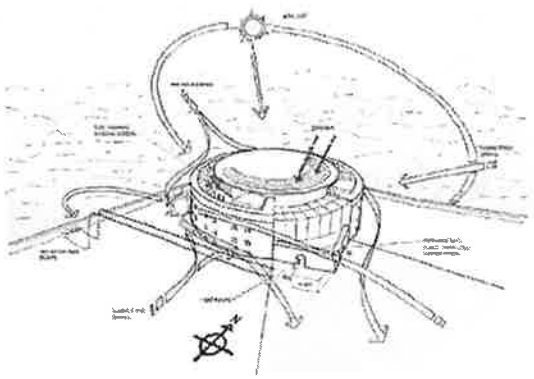
- Introduction to energy modeling
- Energy Modeling and GMIS
- Case Study

Objectives

Understand

- Building energy modeling and its use
- Software tools – their structures, solution method and features
- Energy modeling and GMIS

Introduction to Energy Modeling



What?

Building Energy Model

- A computer model to simulate the way a building consumes energy to meet the demands of services to maintain the temperature, humidity within the building.
- It provides users with the key performance indicators of energy use, space conditions and costs
- An important building energy management tool.

Why?

- Informed decisions
- Understand design decision implications
- Saves energy and $
- Improve building performance
- Resolves complicated questions
- Reduces risk

"Modeling allows you to play "what if" on a scientific basis."

When?

early, early, early

"When just 1% of a project's up front cost are spent....
Up to 70% of its life-cycle costs may already be committed."

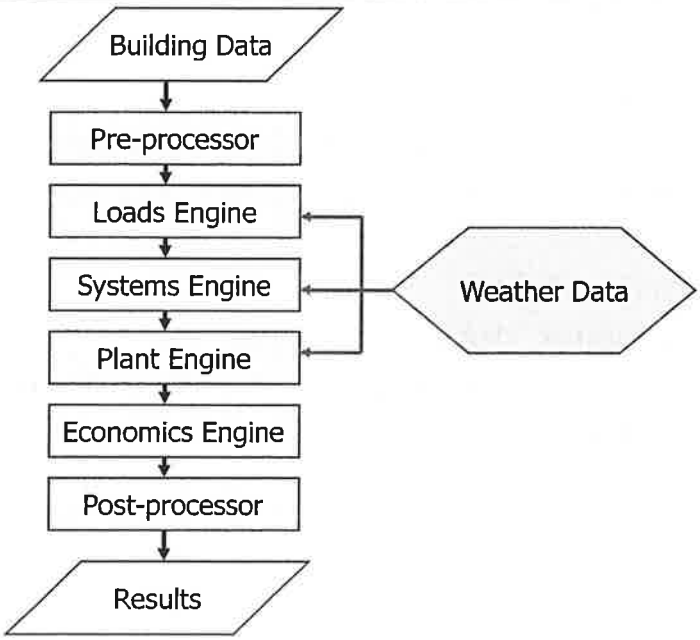
How?

Pre-Design	•Climatic analysis; •Identify strategies; •Goal setting
Schematic Design	•Shape, Massing, Building Envelope; •Daylighting, HVAC options; •Load reduction iterations
Design Development	•HVAC systems comparisons; •Fine-tune details – system optimization
Construction/ O&M	•Calibrate model; •Troubleshoot operation; •Measurement and verification

EM as a design tool

- Thermal insulation
- Thermal capacity ("thermal mass")
- Glazing properties
- Built form and orientation
- Shading from nearby buildings and self-shading
- Solar heat gain & Cooling Load
- Gains from lights, occupants and equipment (both sensible and latent)
- Air conditioning system design & optimization
- Mechanical ventilation system design & optimization
- Available plant capacities for heating and cooling
- Artificial lighting system design

Energy Software Structure



Energy Software Structure

Loads engine

- Calculates heating and cooling loads for each space taking account of weather and building use schedules.
- For each period simulated, a heat balance of space surfaces and room air is performed.

Systems engine

- Based on the system described for building model, calculates the energy and utilities demand to satisfy the space loads computed in Loads Engine

Energy Software Structure

Plant engine

- Calculates the central plant energy needed to supply the utilities demand computed in Systems.

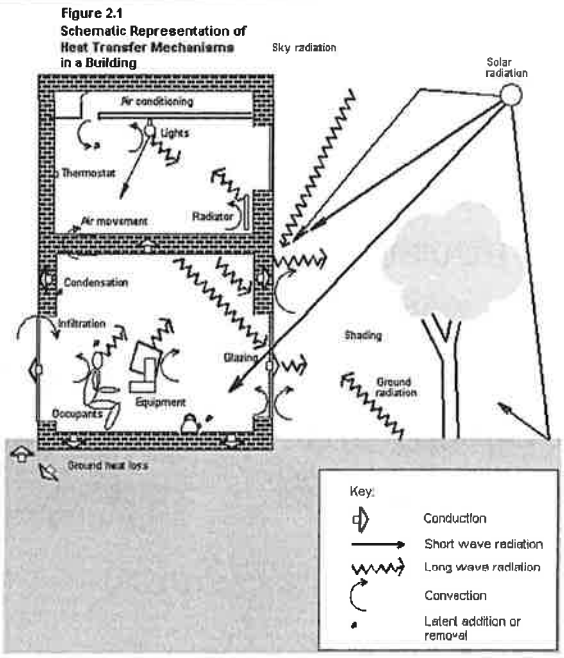
Economics engine

- Calculates the energy cost
- Calculates cost benefit of various building systems design

Understand the loads

Building loads:

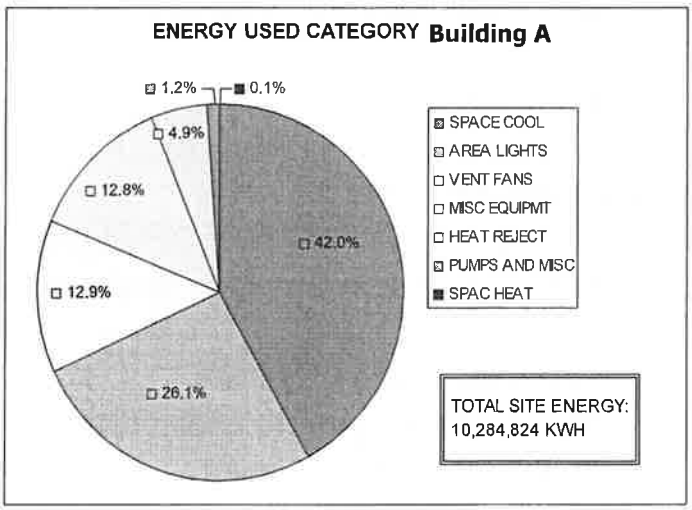
- Solar heat gains
- Human
- Lighting
- Equipment
- Receptacle
- Infiltration
- Others



Understand the Consumptions

Energy Consumption by End Use

- Space Cooling
- Lighting
- Ventilation
- Misc Equipment
- Pump & Misc
- Others



Reduce the loads

- Size
- Orientation
- Envelope
  - Insulation
  - Fenestration
  - Shading
- Lighting Systems
- Internal Loads



Some Strategies

Take Advantage of Climate

- Solar exposure
- Daylighting
- Natural Ventilation

Optimize Systems

- Lightings – Lighting Power Density, Lighting control
- HVAC – Air-side, water-side Systems

Use on-site Energy System

- Renewable energy – PV, Solar thermal
- Combined Heat and Power

Understanding the limitations

Energy models can't directly model everything

- Air flows study
- Light Quality
- Certain Technologies – Strategies
  - Natural ventilation
  - Phase-change materials
  - Electro-chromic window

Work Arounds...

Energy Modeling & Green Mark



BCA GREEN MARK

Background

- Nov 2006 – Learning experience from USGBC's GreenBuild Conference at Denver.
- Formation of Energy Modeling Technical Committee to draw up the EM frame work and guidelines.
- Members from private sector, public agencies and tertiary institutes.
- Final EM frame work come effective 15 March 2007.
- Second revision launched Aug 2010, together with Green Mark version 4.0.
- Minor revision of requirements with effective from 15 Jan 2013, in line with Green Mark v4.1

Energy Modeling & Green mark

- Models
  - Reference Model
  - Proposed Model
- Reference model: Building that complies to all minimum requirements prescribes in codes and standards.
- Proposed model: Building that being designed for – more than meets code requirements, incorporating innovative energy efficient systems.

Energy Modeling & Green mark

- Total annual energy consumption between proposed and reference model must
  - Achieve > 25% savings for Gold Plus award.
  - Achieve > 30% savings for Platinum award.
- Use of accredited software and endorsement by QP (Mechanical & Electrical).

Energy Modeling & GMIS

Compliance with BC & SS

- SS530:2006 – Energy efficiency standard for building services and equipment.
- SS 553:2009 -Code of Practice for Air-conditioning and mechanical ventilation in buildings. *(replaced CP 13)*
- SS 531: Part 1: 2006 - Code of Practice for Lighting of work places *(replaced CP 38)*
- ETTV requirements: Guidelines on Envelope Thermal Transfer Value for Buildings.

Others references: ASHRAE std 90.1, std 62.1

V 4

SS530

Energy efficiency standard for building services and equipment.

Provides minimum energy efficiency requirements for:

- Air Conditioning equipment
- Heat rejection equipment
- Water Heaters
- Electric Motor Drives
- High Efficiency Lighting

SS530

Energy efficiency standard for building services and equipment.

Air Conditioning equipment

- Unitary air conditioners and condensing units
- Water chilling packages

Equipment Type	Size category	Min Efficiency
Air-conditioners, Air cooled	> 40 kW & < 70 kW	2.85 COP
Air-conditioners, water cooled	> 40 kW & < 70 kW	3.22 COP
Water-cooled, electrically operated, Rotary screw	< 528 kW	4.45 COP
	> 528 kW & < 1055 kW	4.90 COP
	>1055 kW	5.50 COP
Water-cooled, electrically operated, centrifugal	< 528 kW	5.00 COP
	> 528 kW & < 1055 kW	5.55 COP
	>1055 kW	6.10 COP

SS530

Energy efficiency standard for building services and equipment.

Max Lighting Power Budget (including ballast loss)

Type of usage	Max Lighting Power Density (W/m2)
Office	**15**
Shops	**25**
Restaurants	**15**
Car parks	**5**
Corridors	**10**
Lobbies	**10**
Stairs	**6**
...	**...**

Design service illuminance, lamp efficacies, light output ratios of luminaries in accordance with SS531

SS530

Energy efficiency standard for building services and equipment.

Permanently wired electric motor (1.1 ~ 90kW)

	Minimum nominal full-load efficiency (%)		
	Continuous use [a]		Occasional use [b]
Number of poles	2	4	2 and 4
Motor power (kW)			
15.0	91.3	91.8	89.4
18.5	91.8	92.2	90.0
22.0	92.2	92.6	90.5
30.0	92.9	93.2	91.4
37.0	93.3	93.6	92.0

Continuous use: at least 2900hrs/ year

SS 553

CP for air conditioning and mechanical ventilation in buildings.

Air-Conditioning Hydronic Systems	SS 553 : 2009 – Code of Practice for Air-conditioning and mechanical ventilation in buildings (cl 10.5.1 – Pumping system design criteria)	For air-conditioning hydronic systems having a total pump system power exceeding 7.5 kW, the pump power limitation for chilled water systems shall be 349 kW/m^3/s. The pump power limitation for condensing water systems is 301 kW/m^3/s. Motors exceeding 15 kW shall have controls/ and/or devices that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow.

SS 553

CP for air conditioning and mechanical ventilation in buildings.

Option 1 – Fan System Motor Nameplate Power

Baseline : SS553:2009 Table 2 – Fan power limitation and as prescribed below :

Baseline Air Distribution System Type	Allowable Motor Nameplate Power	
	(kW/m^3/s)	(W/CMH)
AHUs/FCUs ≥ 4kW (Constant Volume)	1.7	0.47
AHUs ≥ 4kW (Variable Volume)	2.4	0.67
Fan systems with nameplate motor power < 4 kW	No baseline	

(b) Individual VAV fans with motors 11 kW and larger shall meet one of the following requirements:

(i) Be driven by a mechanical or electrical variable speed drive or the fan shall be vane-axial fan with variable pitch blades;

(ii) Have other control and devices for the fan that will result in fan motor demand of less than 30% of design wattage at 50% of design air volume when static pressure setpoint equals one-third of the total design static pressure based on manufacturer's certified fan data.

SS 553

CP for air conditioning and mechanical ventilation in buildings.

V 4.1

Option 2 – Fan System Input Power

Baseline : ASHRAE 90.1:2010 Clause 6.5.3.1 and as prescribed below :

Baseline Air Distribution System Type	Allowable Fan System Input Power*	
	($kW/m^3/s$)	(W/CMH)
AHUs/FCUs ≥ 4kW (Constant Volume)	1.5	0.42
AHUs ≥ 4kW (Variable Volume)	2.1	0.58
Fan systems with nameplate motor power < 4 kW	0.6	0.17

* Applicable pressure drop adjustments can be considered based on ASHRAE 90.1 Table 6.5.3.1.1B and are subject to BCA's evaluation

Option 1 – Fan System Motor Nameplate Power

Baseline : SS553:2009 Table 2 – Fan power limitation and as prescribed below :

Baseline Air Distribution System Type	Allowable Motor Nameplate Power	
	($kW/m^3/s$)	(W/CMH)
AHUs/FCUs ≥ 4kW (Constant Volume)	1.7	0.47
AHUs ≥ 4kW (Variable Volume)	2.4	0.67
Fan systems with nameplate motor power < 4 kW	No baseline	

Energy Modeling & Green mark

V 4

Add in DCS energy modeling methodology

- If proposed model is supplied with District Cooling System (DCS) for which plant data is not available,
  - Energy modelling may exclude the energy consumption on DCS plant, but shall include those on the ACMV components dedicated to the design building; and
  - energy modelling shall demonstrate compliance with the 2 following criteria.

S/N	Criteria	Gold Plus	Platinum
1	Cooling Load Savings	10%	15%
2	Energy Consumption Savings (excluding the Air-Conditioned Plant);	27%	33%

Energy Modeling & Green mark

Building development with more than 30% Non AC Spaces

V 4.1

Aggregate Non Air-Conditioned Spaces (m^2)	Aggregate Air-Conditioned Spaces (m^2)	Ventilation Simulation Requirement See Note (a)	Energy Modeling Requirement See Note (b)	Justification on Energy Savings See Note (c)
≥ 2000	≥ 5000	Yes	Yes	No
< 2000	≥ 5000	No	Yes	No
≥ 2000	< 5000	Yes	No	Yes
< 2000	< 5000	No	No	Yes

Important Notes :

(a) Ventilation requirement stated paragraph (12) is a pre-requisite requirement to attain Green Platinum rating.

(b) The stipulated energy savings and Design System Efficiency (DSE) of cooling system stated in paragraph (7) and (8) are pre-requisites to attain Green Mark Gold^{Plus} and Platinum rating.

(c) Detailed calculations to be provided to justify the savings in energy consumption from the use of salient energy efficient features /equipment. Energy savings will be based on the energy efficiency measures and improvements over the reference model established for similar building types. The reference ACMV system will be of the same type as the proposed system. The baseline used for the equipment will be in accordance with the minimum efficiency requirement stipulated in SS 530. For VRF system, the baseline COP of 3.37 shall be adopted. The stipulated energy savings stated in paragraph (7) are pre-requisites to attain Green Mark Gold^{Plus} and Platinum rating.

Energy Modeling & Green mark

V 4.1

Reference system to be used will be based on the peak building cooling load :

(i) For buildings with peak building cooling load of 500 RT or more, the reference system will be centrifugal chiller.

(ii) For buildings with peak building cooling load of less than 500RT, the reference system will be screw chiller.

Energy Modeling & Green mark

V 4.1

Move towards Passive Design approach

- Passive Design Enhancement

For projects that demonstrate considerable efforts to reduce air-conditioned spaces, a cap of 2% additional energy savings over its referenced model can be considered. This would not apply to areas that would normally be non air-conditioned such as warehouses, carparks, school classrooms, staircases, toilets and pantries. Circulation spaces such as atria, plaza and corridors can be considered if these spaces are largely designed to be nonair-conditioned and sizeable.

Energy Modeling & Green mark

V 4.1

Move towards Passive Design approach

- Passive Design Enhancement

For savings to be justified, design strategies that enhance the ventilation and thermal comfort of the designated non air-conditioned spaces must be demonstrated. A written justification detailing the design strategies used and the energy saving estimate would be required for evaluation.

Energy Modeling & Green mark

V 4.1

- Where no Baseline Standard is available, the basis for deriving the overall energy consumption and potential savings must be made clear and justifiable for consideration.
- Notwithstanding this, the potential energy savings for the following system/devices are subject to the cap based on the following norm:

List of Systems/Devices		Energy Savings Cap
Escalator		30%
Lifts	With VVVF and Sleep mode	10%
	Regenerative features	18%
CO sensors		15%
Occupancy Sensors		15%
Photo Sensors		15%

Energy Modeling & Green mark

Software selection:

- The software must be able to model the thermal performance of buildings in a multi-zone format and calculate the building's total energy consumption over a continuous 12-months period.
- The software must be tested by a recognized institution in accordance to the Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs - **ANSI/ASHRAE STD 140** or other international equivalent, such as **IEA HVAC BESTEST**.

Software Options

- DOE-2*
- Energy-10
- EnergyPlus*
- eQUEST* Foc
- ESP-r*
- HAP
- HEED*
- IDA ICE
- IES VE
- PowerDOE
- SUNREL
- TAS
- TRACE
- TRNSYS
- VisualDOE 4.1

Note: * Free software

Methodology

Create massing model ← Layout, shape, size, orientation

⇩

Define roof, windows, floors, openings, shading, walls, etc ← U-value, color, dimensions, transmission, etc

⇩

Define zones having different ACMV ⇨ **For each zone, define heat loads, lighting systems, operating schedules, etc** ⇨

Methodology

Define ACMV details for each zone

COP, flow rates, set-points, etc for pumps, fans, dehumidifiers, chillers, etc

Sensors & other efficient features may reduce operating times, energy consumptions

Run simulation

Local weather data files

Peak load, Part load, Annual power consumption data

Energy Modeling Methodologies

- Extract relevant data from the building plans or other project documentations as inputs for **Proposed Model.**

  - Building design layout in terms of shape, size and orientation.

  - Materials for walls, windows, roofs, floors, doors and permanent shading devices.

  - Internal loads such as levels and schedules for occupancy, lighting systems, equipment, appliances and machinery within the building.

  - HVAC equipment, controls and other associated components selected for use in the building.

Energy Modeling Methodologies

- Perform hourly simulation for **proposed model.**
- Compute the overall energy consumption of the model, using the building envelope and all energy-consuming equipment that are selected during the design stage.
- These include chillers, air handling systems, plant equipment, and non-HVAC systems such as lightings, lifts, escalators, and receptacle loads from equipment.

Energy Modeling Methodologies

- Extract relevant data from the Codes and Singapore standards or other project documentations as inputs for **reference model.**

  - Building design layout in terms of shape, size and orientation.

  - Materials for walls, windows, roofs, floors, doors and permanent shading devices.

  - Internal loads such as levels and schedules for occupancy, lighting systems, equipment, appliances and machinery within the building.

  - HVAC equipment, controls and other associated components selected for use in the building.

Energy Modeling Methodologies

- Perform hourly simulation for **reference model.**
- Compute the overall energy consumption of the model, using the building envelope and all energy-consuming equipment that are selected during the design stage.
- Compare the overall energy consumption of the Reference Model against the Proposed Model.

Energy Modeling Methodologies

The simulations for both the Proposed Model and Reference Model shall use:

- the same software,
- the same weather data,
- the same operating schedules,
- the same occupancy rates,
- the same building design in terms of shape, size and orientation,
- the same receptacle loads,
- the same indoor environmental conditions in terms of thermal comfort level, and
- the same internal illuminance levels (lux) for space lightings.

Energy Modeling & Green mark

- Completed building

  - Compile monthly whole-building energy use utility data for 12 months.

- Reference building model

  - Revise schedules and occupancy data

  - Simulate annual energy consumption and compare with actual performance

  - Explain any differences

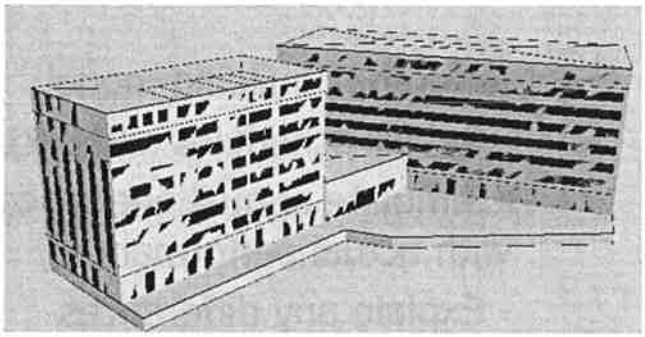
Case Study – Tampines Grande



Proposed Erection of 2 Blocks of **8-Storey** Office Building with One Level of **Basement Carpark** on HDB Land Parcel P15 Lot 2559K Mk 29 at Tampines Grande (Tampines Planning Area)

3 D Model

- 2 Blocks of 8-Storey Office Building connected with an atrium at L1 & L2
- One Level of Basement Carpark
- L3 to L8 – typical floors
- GFA of 35,000m2
- ETTV =39 W/m2



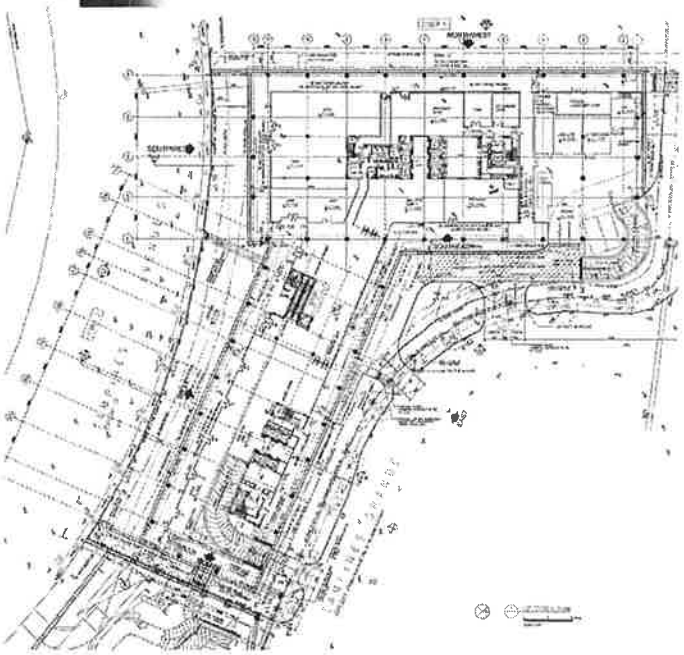
METHODOLOGY

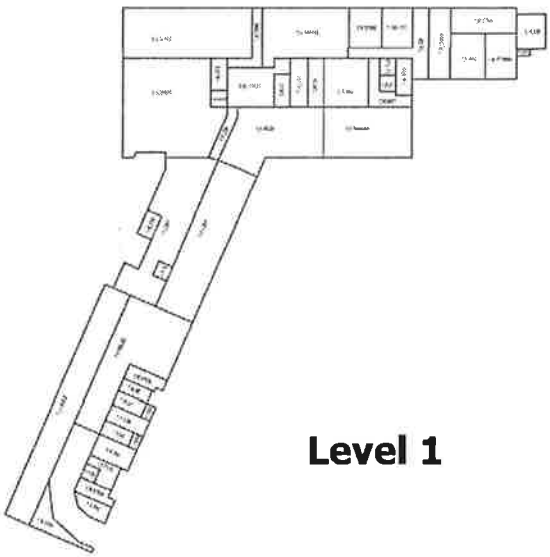
Simplified Floor Plans

➢ The building thermal zones had been modified into **Simple Zones** based on the occupancy type, operating hours and ACMV system

➢ Ensure that no significant differences in
- ✓ Floor Area,
- ✓ Exterior Wall Area,
- ✓ Window area &
- ✓ Orientation.

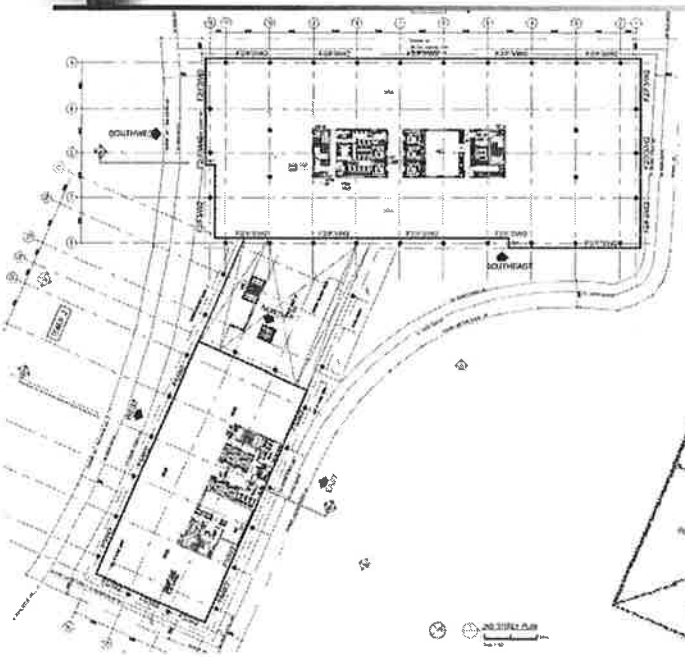
METHODOLOGY
Simplified Floor Plans

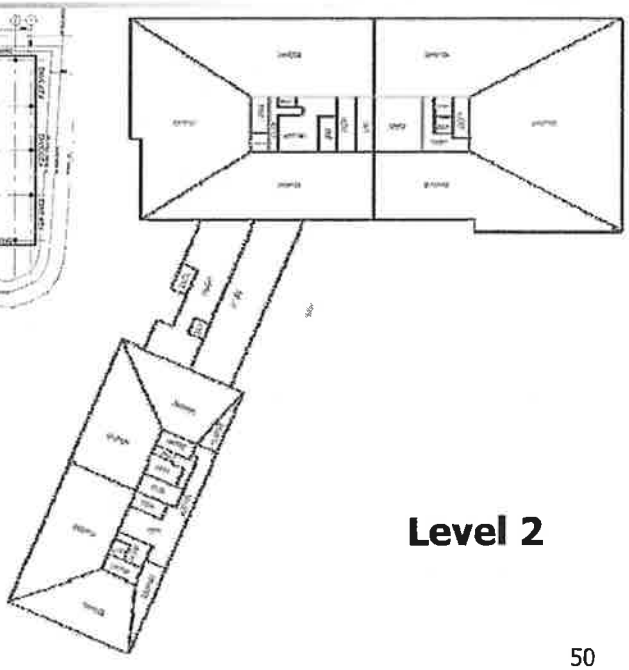




Level 1

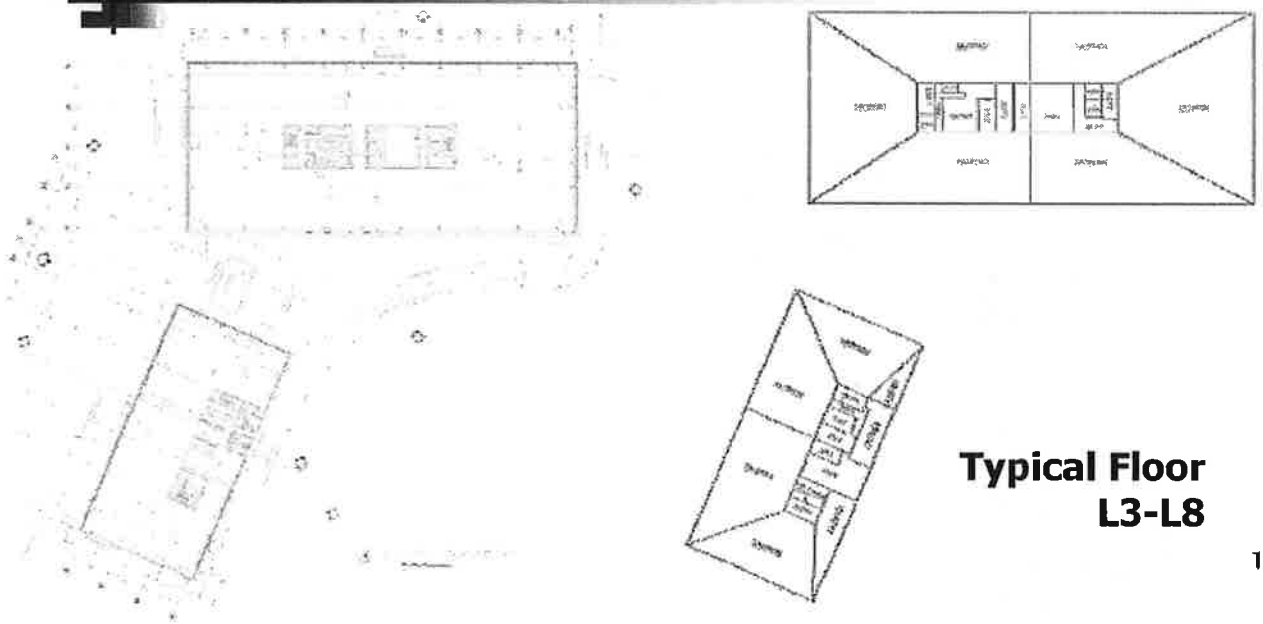
METHODOLOGY
Simplified Floor Plans





Level 2

METHODOLOGY
Simplified Floor Plans



Typical Floor
L3-L8

SIMULATION INPUTS
Building Envelope (example)

BUILDING ELEMENT	REFERENCE MODEL	PROPOSED MODEL
Wall Construction	Glass, Air gap, cement plaster, light weight wall, Rockwool insulation, Alum Cladding; U = 2.72 W/m2K	Glass, Air gap, cement plaster, light weight wall, Rockwool insulation, Alum Cladding, U = 0.83 W/m2K; south façade U=0.54 W/m2K
Windows	Same as Proposed Model	12mm Single glaze U = 4.1, SC = 0.7 Double glaze U = 1.7, SC = 0.32
Skylight	Same as Proposed Model	RC slab
Floor	Medium construction, U = 0.8 W/m2K	RC roof , U = 0.49 W/m2K
Roof	Same as Proposed Model	0.54
Window to Wall Ratio (WWR)	ETTV = 50 W/m2	ETTV = 39.5 W/m2

SIMULATION INPUTS
Lighting Power Budget (example)

BUILDING ELEMENT	REFERENCE MODEL	PROPOSED MODEL
Lighting Power Density (W/m^2)	Office = 15 W/m2 Circulation = 10 W/m2 Main Lobby = 10 W/m2 Mgt Office = 15 W/m2 Restaurant = 15 W/m2 Retail = 25 W/m2 Stairs = 6 W/m2 Car Park = 5 W/m2 Utilities = 10 W/m2 Toilet = 10 W/m2	Office = 10 W/m2 Circulation = 8 W/m2 Main Lobby = 10 W/m2 Mgt Office = 10 W/m2 Restaurant = 15 W/m2 Retail = 25 W/m2 Stairs = 4 W/m2 Car Park = 3 W/m2 Utilities = 10 W/m2 Toilet = 10 W/m2

SIMULATION INPUTS
HVAC System (example)

BUILDING ELEMENTS	REFERENCE MODEL	PROPOSED MODEL
AHU Fan Properties	AHU VAV Fan with 0.74 W/cmh	AHU Fan with average 0.36W/cmh
Central Plant Efficiency	2 x 600 Rton Cent Chillers, COP = 6.1 2 x 300 Rton Screw Chillers, COP = 5.5 CHW pump = 0.117 kW/ton CW pump = 0.088 kW/ton Cooling Tower = 0.06 kW/ton	2 x 600 Rton Cent Chillers, COP = 7.25 2 x 300 Rton Screw Chillers, COP = 6.94 CHW pump = 0.05 kW/ton CW pump = 0.03 kW/ton Cooling Tower = 0.03 kW/ton
HVAC Circulation Properties	CHW pump 2.85 (l/m)/ikW, head: 35 m CHW pump efficiency = 51.93 x 94.2 CW pump 3.23 (l/m)/ikW, head: 15m CW pump efficiency = 29.2 x 93.2	CHW pump 2.85 (l/m)/ikW, head: 35 m CHW pump efficiency = 89.42 x 94.5 CW pump 3.23 (l/m)/ikW, head: 15 m CW pump efficiency = 85.19 x 93.9

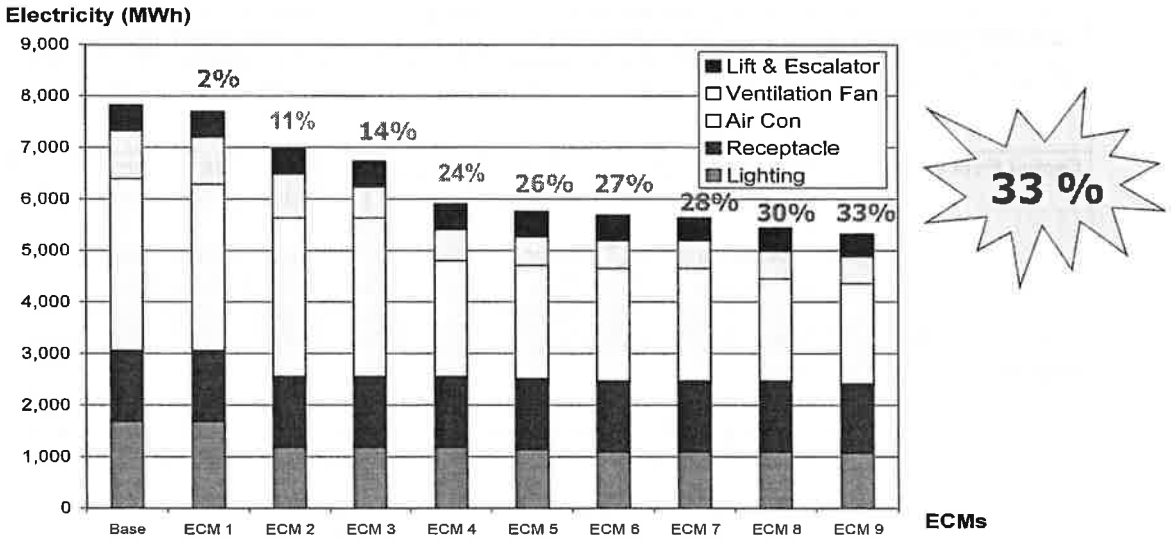
Energy Conservation Measures (ECM)

BASE: Building design to comply with Code of Practices & BCA approved documents.

ECM1: Improve ETTV from 50 W/m2 to 39 W/m2
ECM2: Select T5 lighting solution that reduces 30% from BASE case.
ECM3: Improve air ventilation efficiency by 45% from BASE case.
ECM4: Chilled water plant Optimization and efficiency improvement by 25%.
ECM5: Incorporate motion sensor & CO2 sensor in building design.
ECM6: Introduce perimeter lighting control with photo sensor.
ECM7: Energy Efficient AC VVVF lift & escalator with slow down feature.
ECM8: Incorporate energy recovery solution for fresh air pre-cool AHU
ECM9: Integrate Solar Photovoltaic Panel at roof top of development.

Annual Energy Consumptions

Annual Energy Consumption Comparison for ECMs




Thank You
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