THE HONG KONG
POLYTECHNIC UNIVERSITY
香港理工大學

Sustainable Building Design and Renewable Applications

Dr. Lu Lin, Vivien

Associate Professor

Department of Building Services Engineering
The Hong Kong Polytechnic University

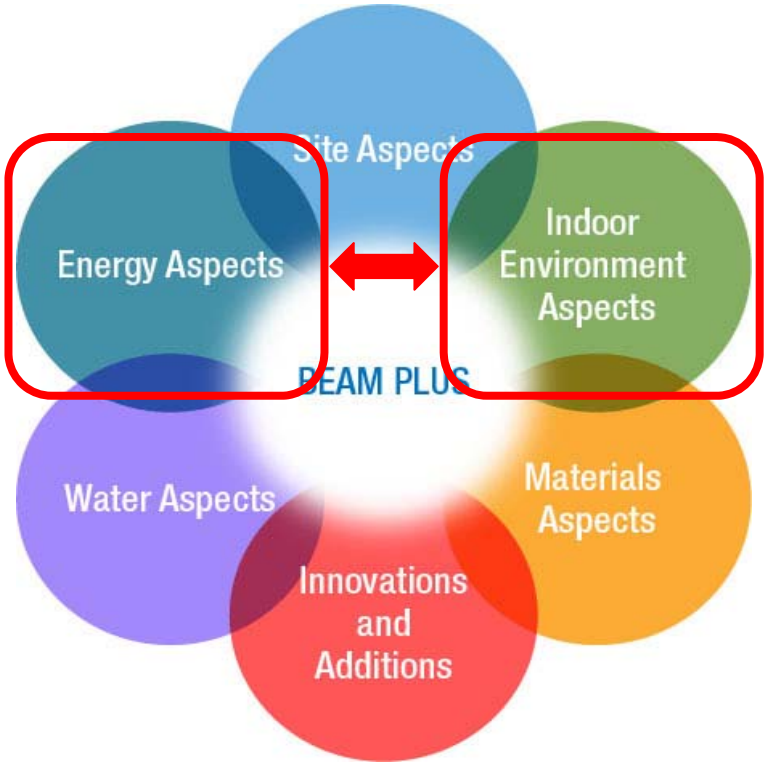
Overview

- Introduction of building sustainable design
- Passive architectural design sensitivity analysis and optimization
- Green building nanomaterial development
- Building energy efficient systems (Fluid mechanics and heat/mass transfer)
- Renewable energy applications

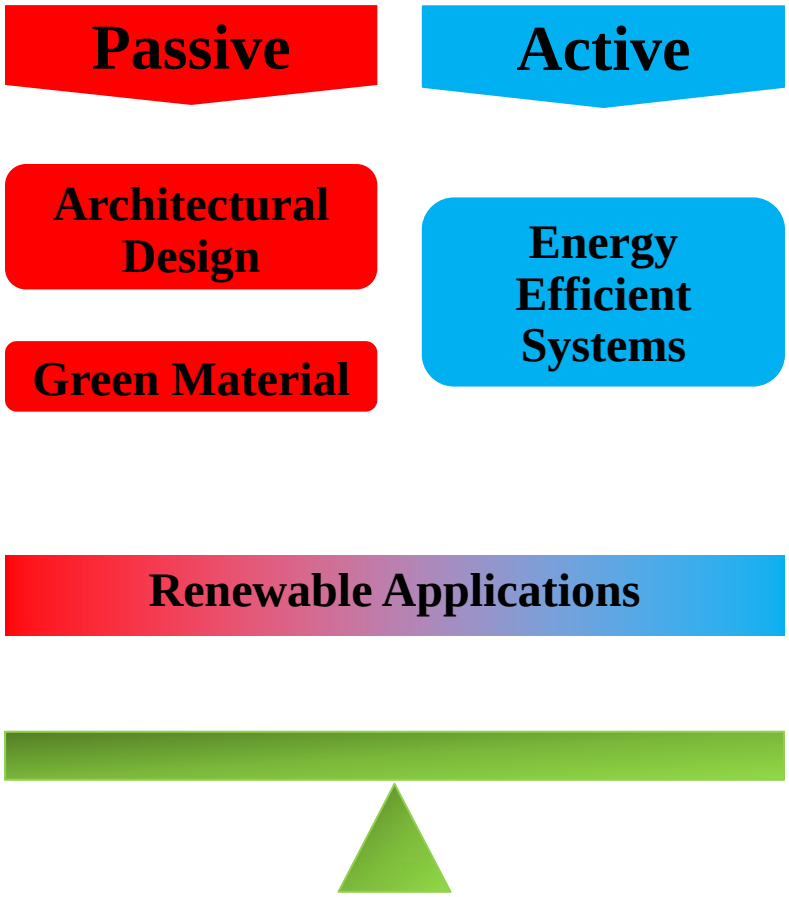
- **Introduction of building sustainable design**
- **Passive architectural design sensitivity analysis and optimization**
- **Green building nanomaterial development**
- **Building energy efficient systems (Fluid mechanics and heat/mass transfer)**
- **Renewable energy applications**

Building sustainable design background

- Energy use in buildings accounts for about ***92.7%*** of all electricity consumption according to statistics published in 2013
- People spend about ***80% to 90%*** of the time on indoor activities

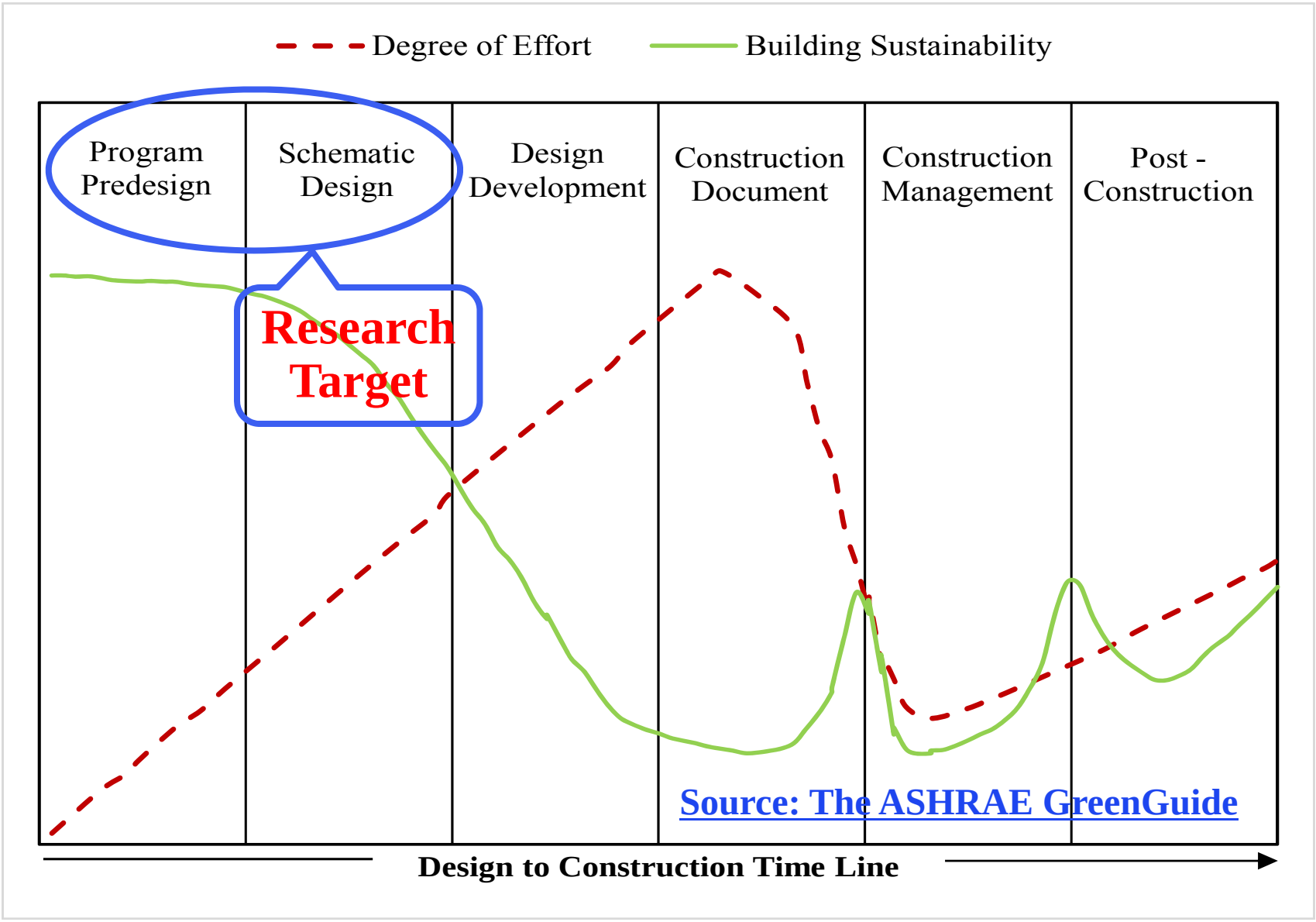


Building sustainable design technologies



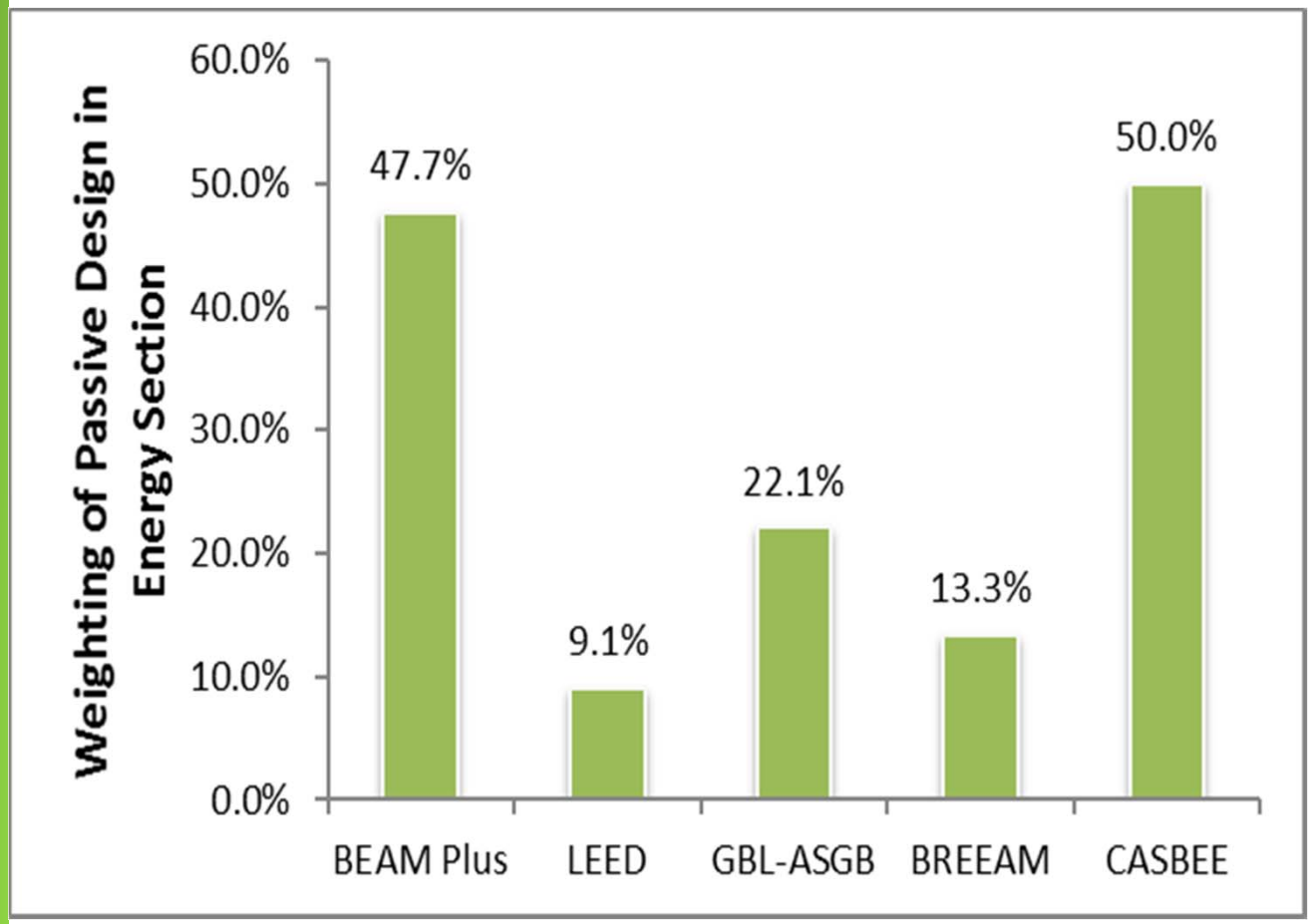
- To keep indoor environment comfortable while achieve energy saving, passive or active building designs can be adopted:
- ***Passive design*** use ambient energy sources, including daylighting, natural ventilation, and solar radiation.
- ***Active design*** use or create purchased energy to keep the building comfortable.
- ***Hybrid design*** use both energy sources

Building sustainable strategies from early design stages



- **Introduction of building sustainable design**
- **Passive architectural design sensitivity analysis and optimization**
- **Green building nanomaterial development**
- **Building energy efficient systems (Fluid mechanics and heat/mass transfer)**
- **Renewable energy applications**

Passive architectural design in green building rating tools



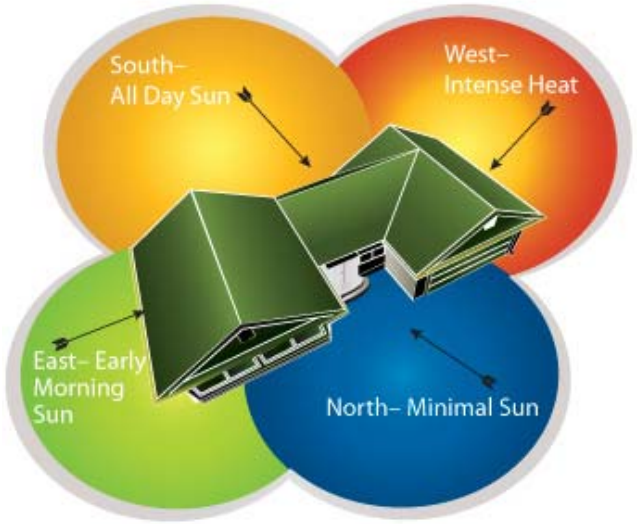
BREEAM®

LEED

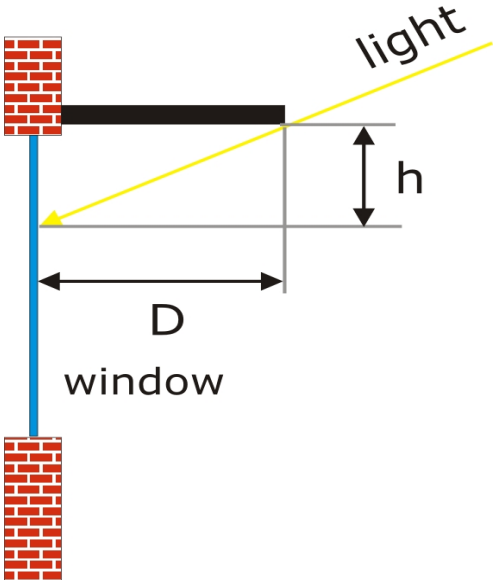
CASBEE®

BEAM

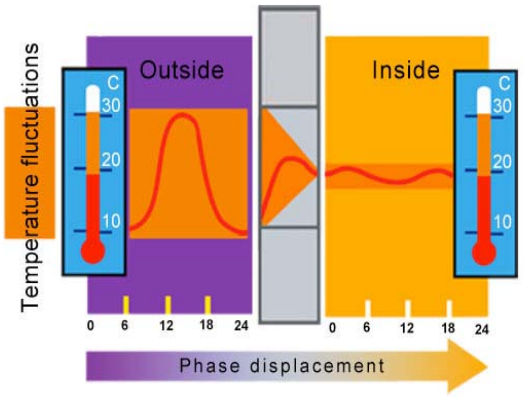
Building Passive architectural design classification



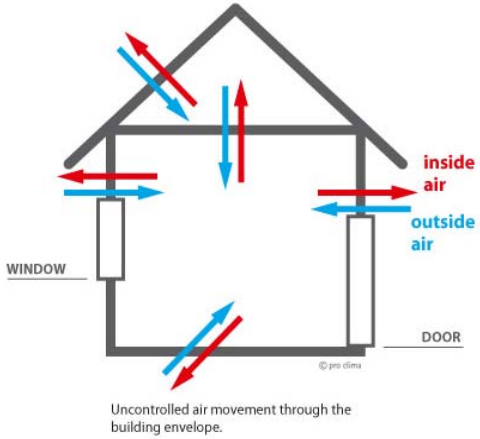
Building Layout: Building orientation and external obstructions



Building Geometry: structural ratios and external shadings



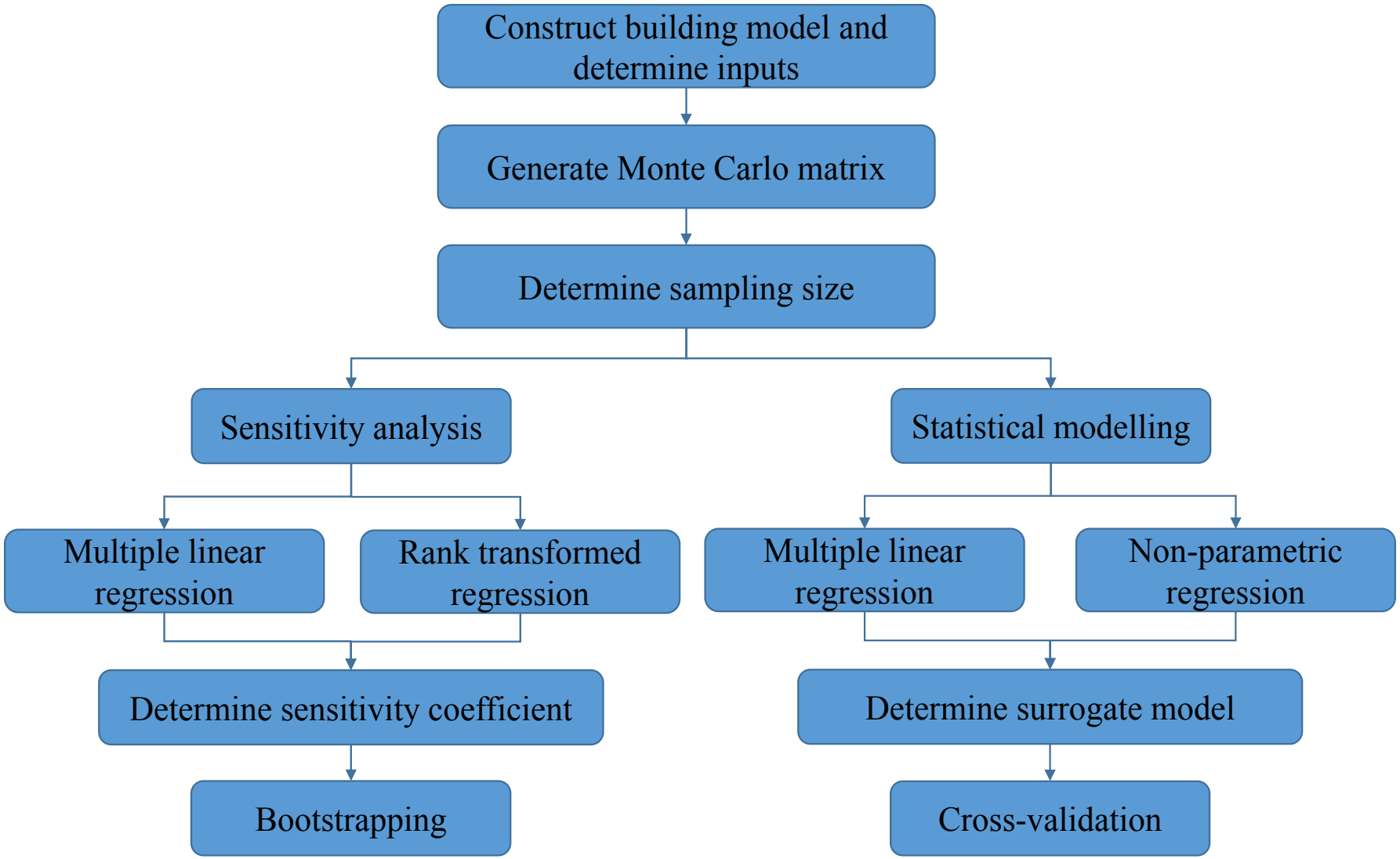
Thermal Physics: Envelope physical properties



Uncontrolled air movement through the building envelope.

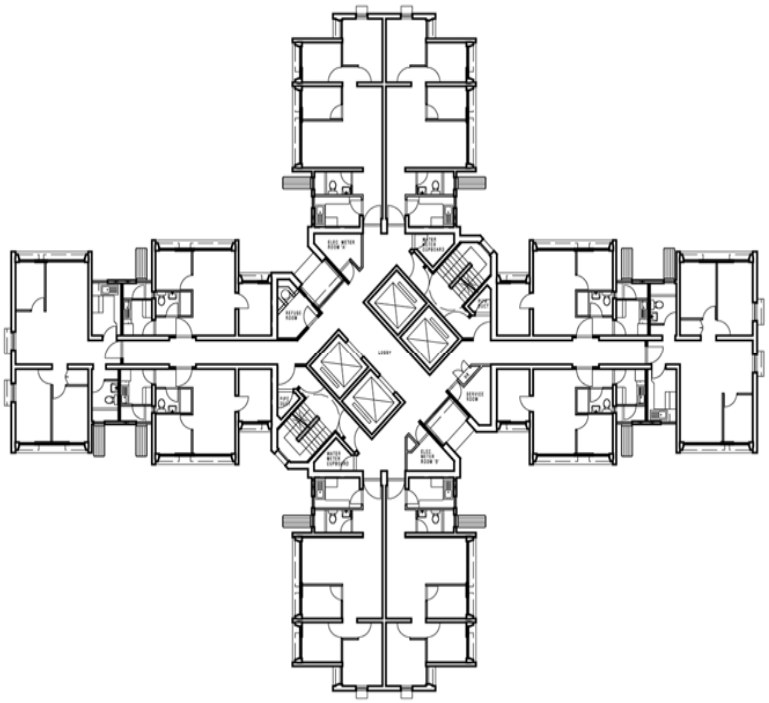
Infiltration: Air-tightness criteria

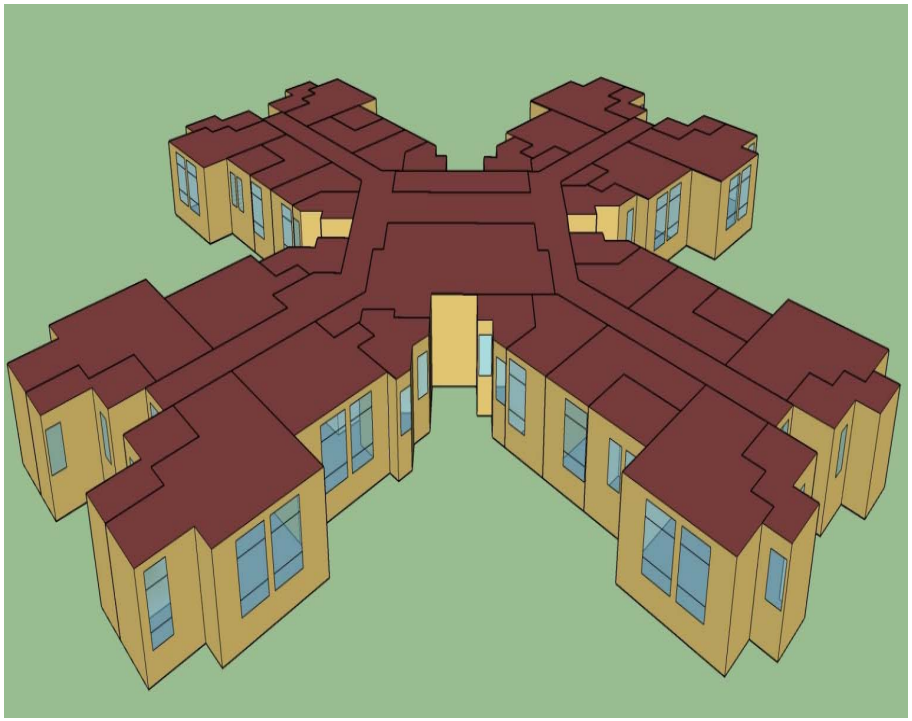
Statistical analysis of Passive architectural design strategies



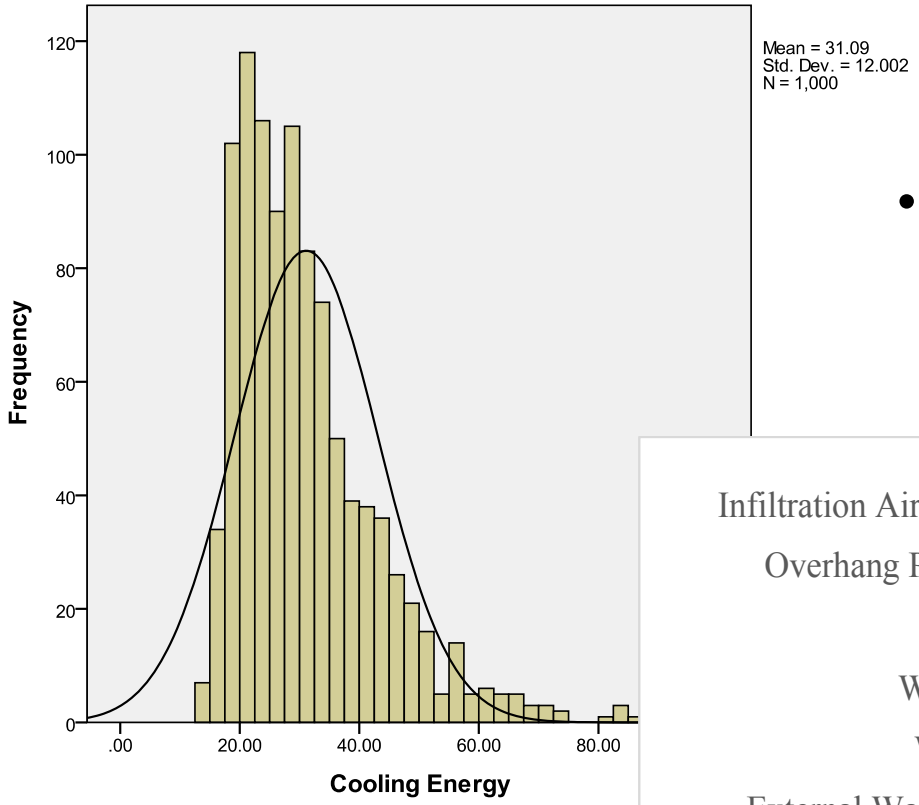
Passive architectural design case study buildings

- Over ***90%*** of the population in HK lives in ***high-rise domestic*** buildings of 10 to 40 floors
- Public Rental Housing (***PRH***) provided accommodations for over ***30%*** the local residents



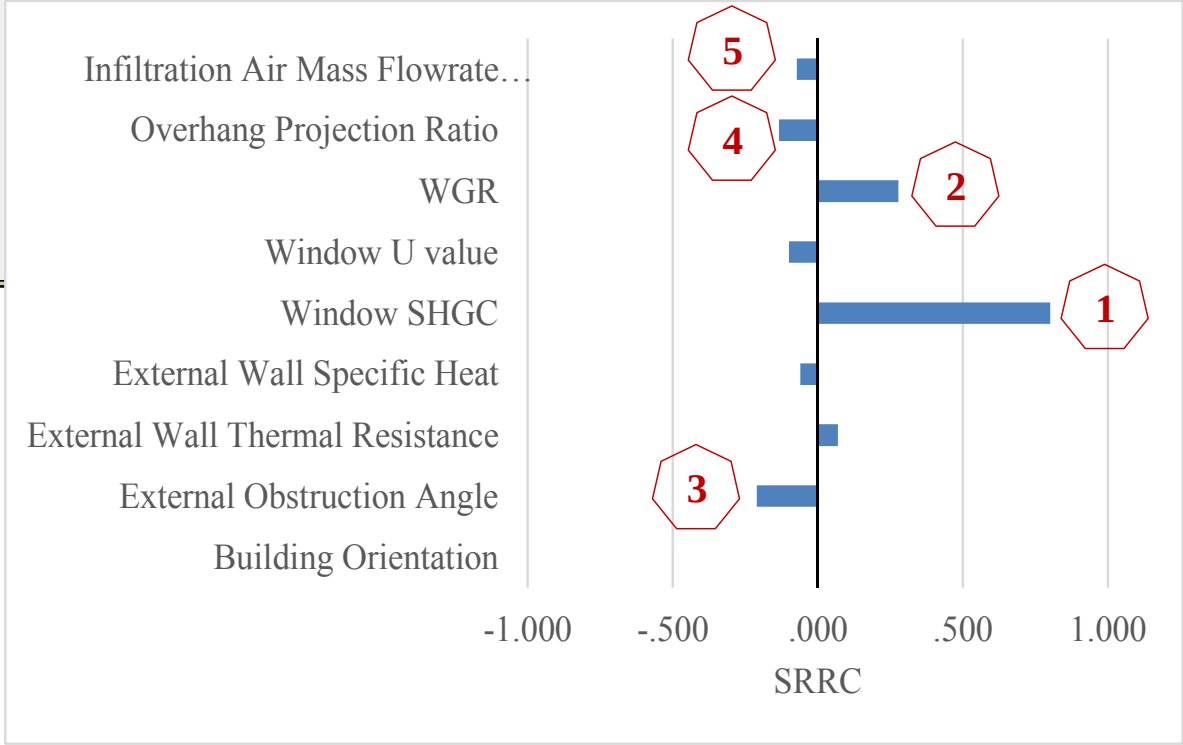


Importance of different building design factors on building energy consumption

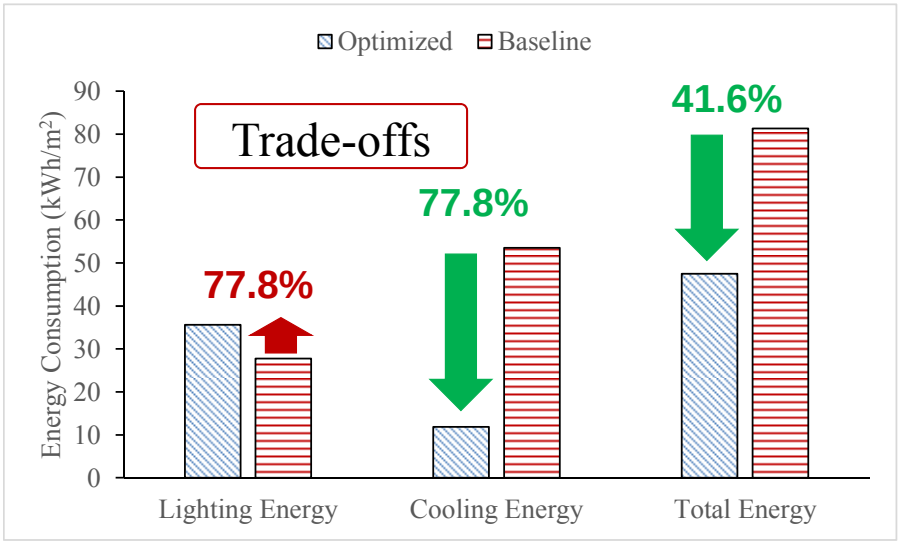


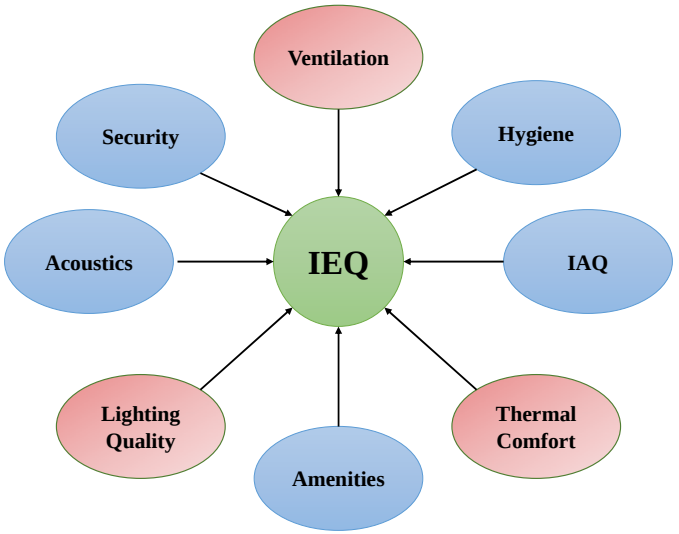
- To estimate the uncertainty of annual energy consumption

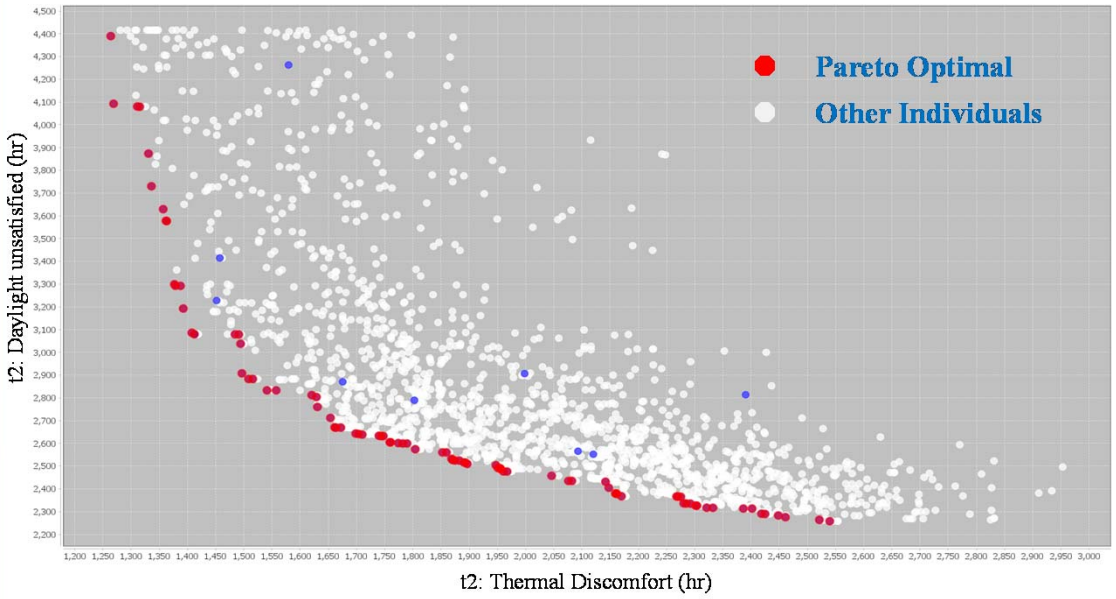
- To determine the ranking of various design strategies



Multi-objective building optimization



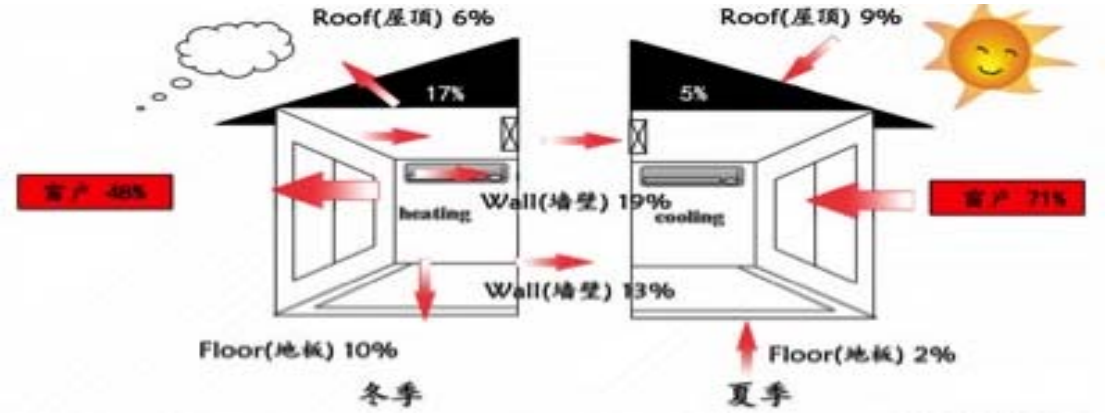




- Energy performance including cooling and lighting
- Indoor environmental quality including thermal comfort, lighting quality and ventilation.
- Non Sorting Genetic Algorithm II (NSGA-II) adopted to obtain Pareto frontier

- **Introduction of building sustainable design**
- **Passive architectural design sensitivity analysis and optimization**
- **Green building nanomaterial development**
- **Building energy efficient systems (Fluid mechanics and heat/mass transfer)**
- **Renewable energy applications**

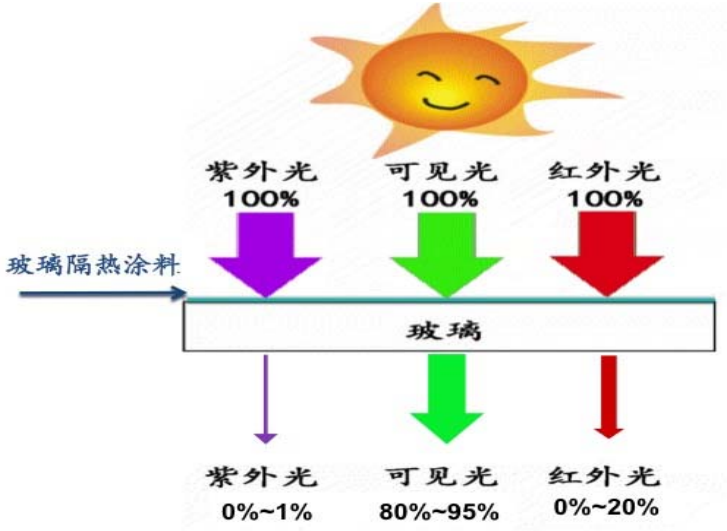
Nano-paints for window heat insulation



Buildings emitted 8.3 Gt carbon dioxide each year accounting for more than 30% of the greenhouse gas emissions in many developed countries.

- 2015/16 HKSAR Government ITF (UICP): Development of Novel High Dispersed Transparent Heat Insulation Paints for Glass (UIM/265)

Windows or curtain walls, taken as the day-lighting structure of a building, is still suffering from the balance of thermal insulation and visible transparency.



Our ongoing ITF project

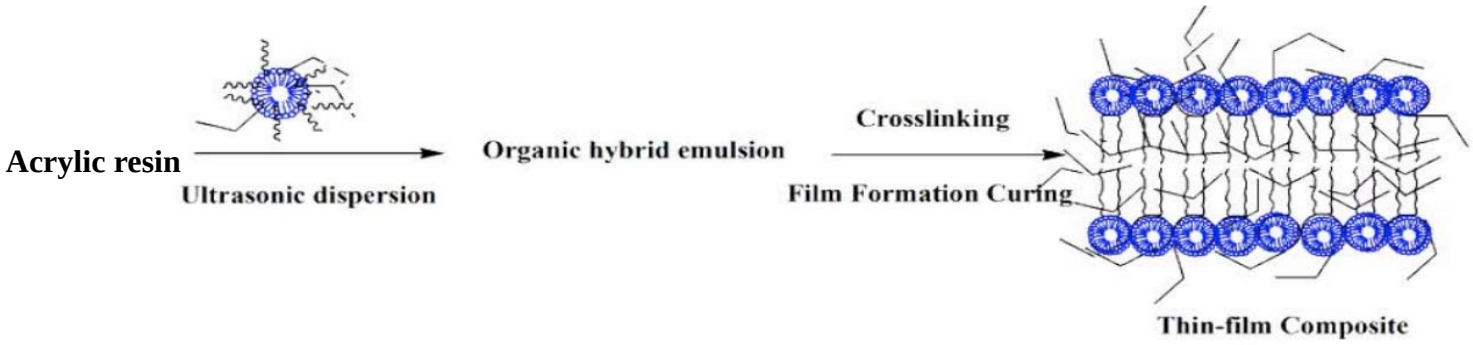
Novel High Dispersed Transparent Heat Insulation Paints for Glass

Problems for traditional coating

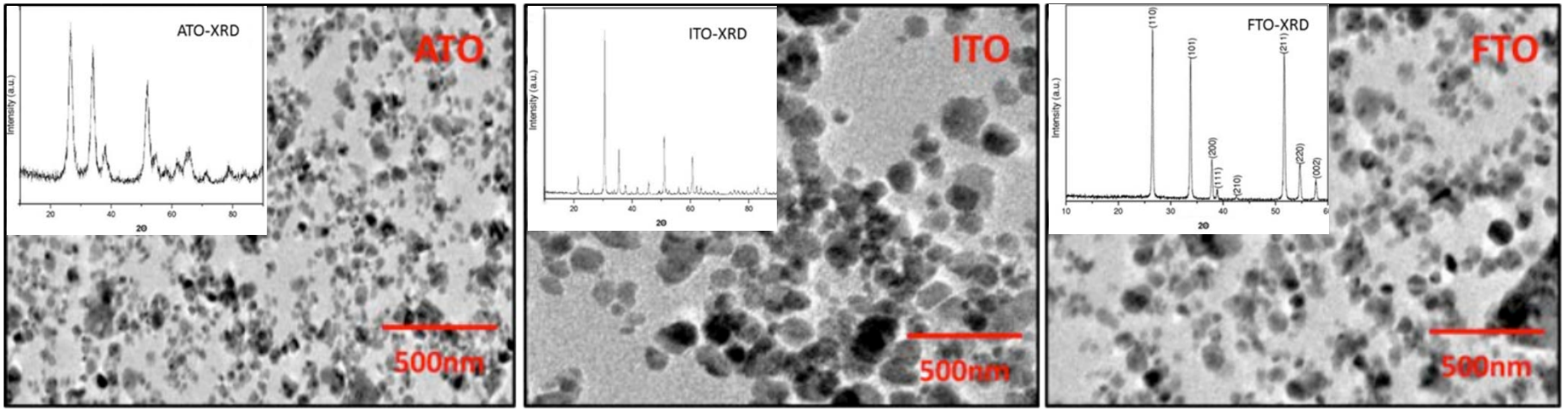
1. High cost (Foreign monopoly)
2. Bad transparence (Poor dispersion)
3. Solvent based coating (Environmental problems)

Project Objective

1. Independent research to reduce the cost (Break up foreign monopoly)
2. Good transparence (Stable colloid)
3. Water based coating (Environmentally friendly)



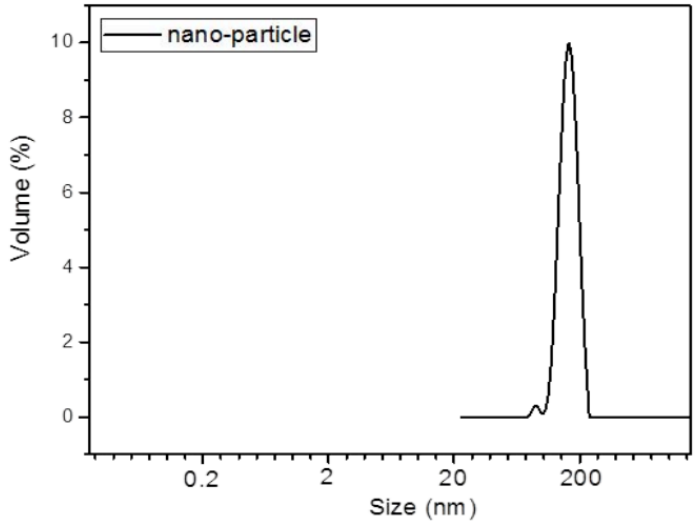
Thermal insulation coating



Size of ATO: 5nm

Size of ATO: 50nm

Size of FTO: 20nm



secondary particle size (in water): <200nm

Thermal insulation coating

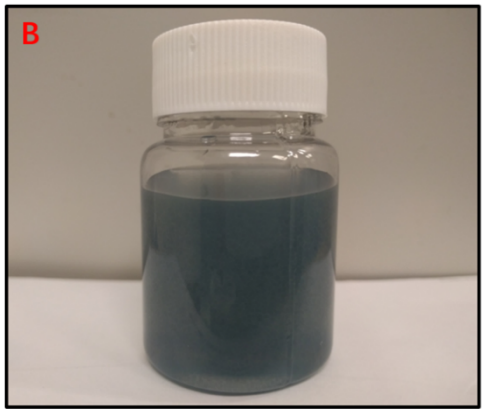
Graphene

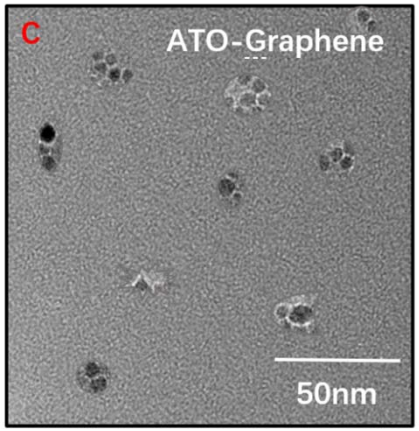
Precursor of ATO

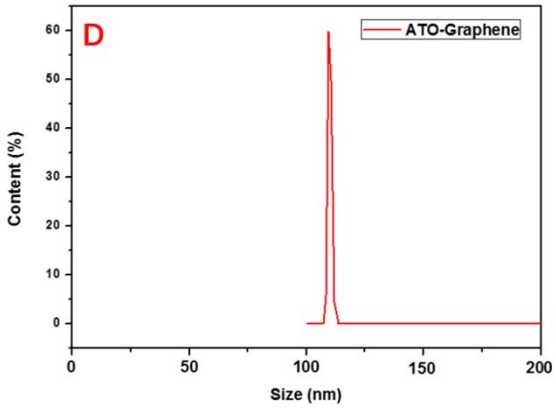
Hydrothermal reactor

Ball mill

ATO-Graphene







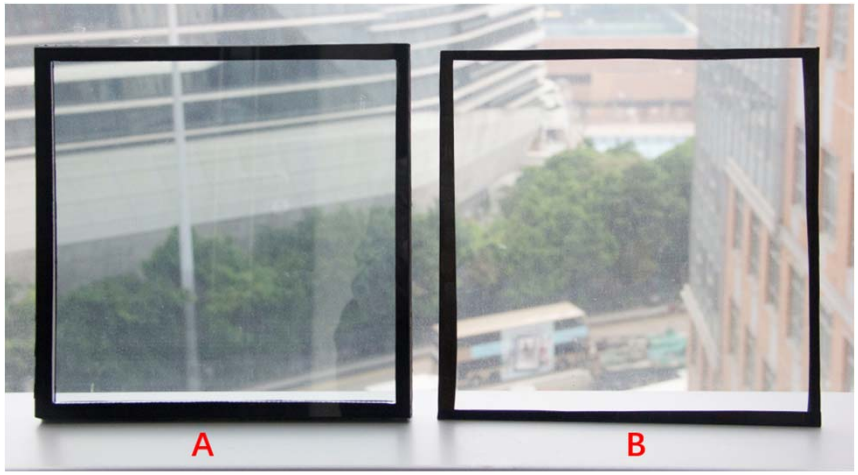
1. **Good dispersion, no sediment**
2. **Secondary particle size (in water): <150nm**
3. **Primary particle size: <30nm**

Thermal insulation coating

Number of samples	Vis-Light Transmission	IR-Light Transmission	UV-Light Transmission
1	73	28	13
2	85	24	8
3	70	30	14
4	83	27	11
6	75	25	9
7	87	22	7
9	82	22	12

Insulation Performance of the Coating:

- Vis-Light Transmission: >75%
- IR-Light Transmission: <30%
- UV-Light Transmission:<15%

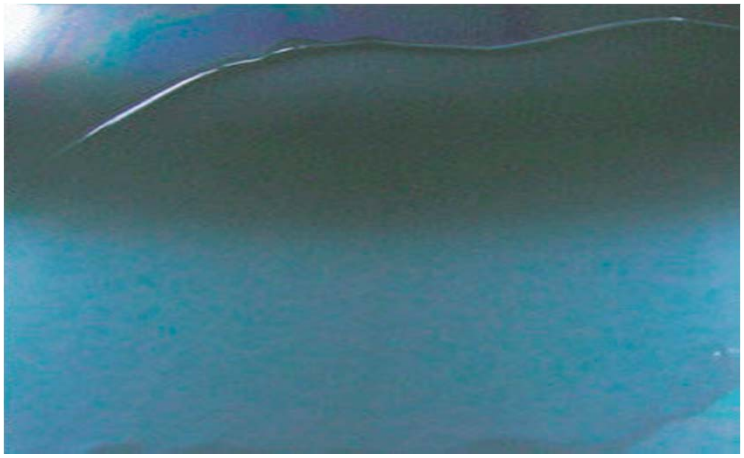


Self-cleaning coatings

Super-hydrophobic , θ(Lotus leaf)>150°

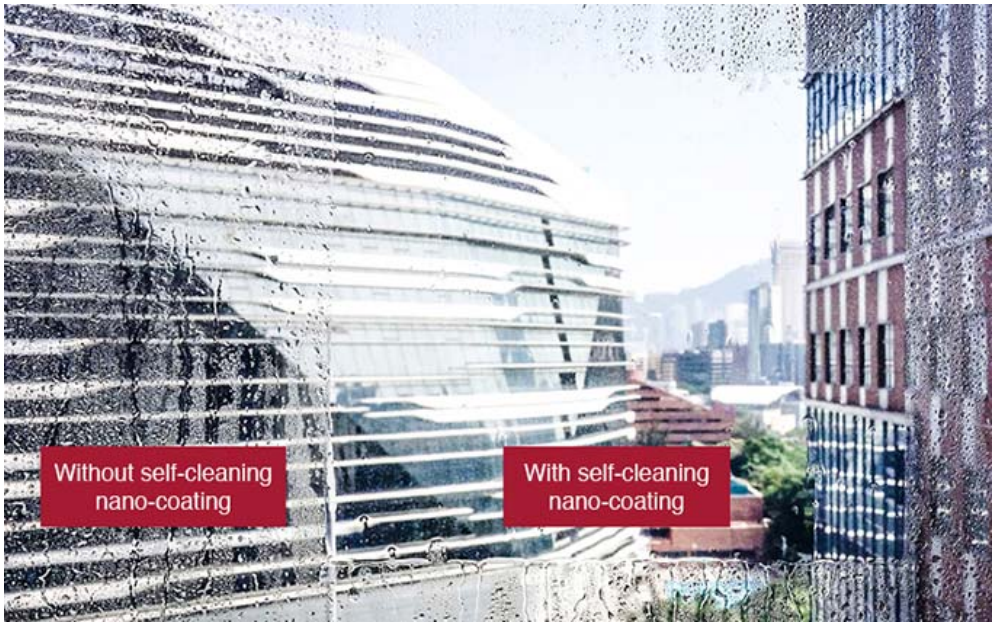
Super-hydrophobic self-cleaning glass

Super-hydrophilic，θ（clean glass）<10°



Super-hydrophilic self-cleaning glass

Low-cost self-cleaning nano-coating for curtain walls



Conventional self-cleaning glass curtain wall involves chemical vapour deposition and sputtering technologies.

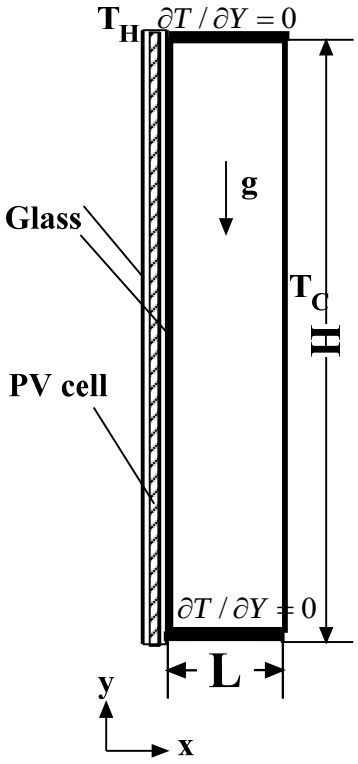
A comparison between PV modules with and without self-cleaning coatings after one month's outdoor exposure.

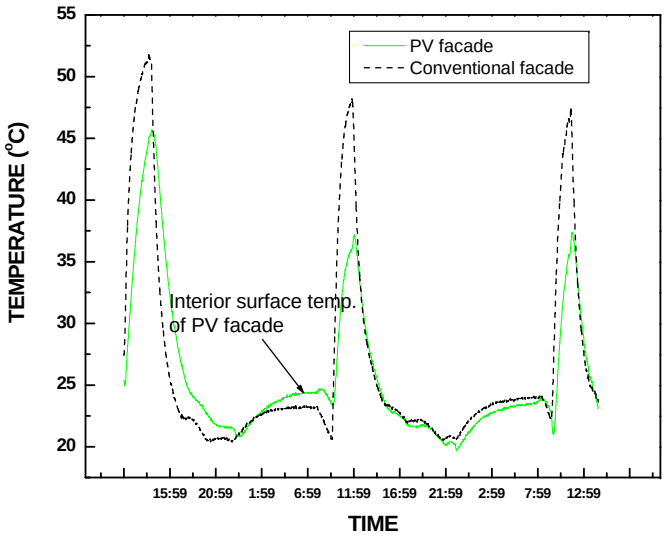
- **Introduction of building sustainable design**
- **Passive architectural design sensitivity analysis and optimization**
- **Green building nanomaterial development**
- **Building energy efficient systems (Fluid mechanics and heat/mass transfer)**
- **Renewable energy applications**

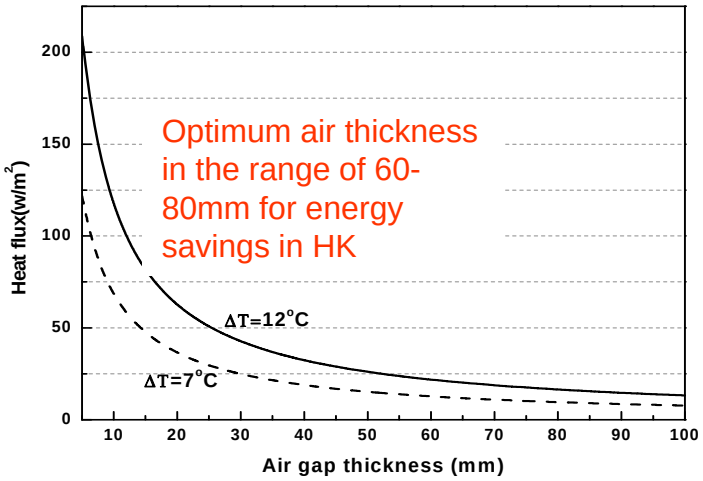
- **Introduction of building sustainable design**
- **Passive architectural design sensitivity analysis and optimization**
- **Green building nanomaterial development**
- **Building energy efficient systems (Fluid mechanics and heat/mass transfer)**
- **Renewable energy applications**

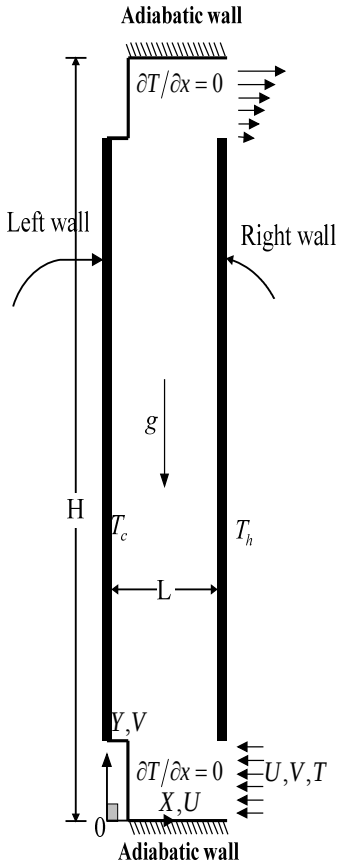
Building-integrated solar PV systems

- ***Natural ventilated PV façade (experimental and numerical)***



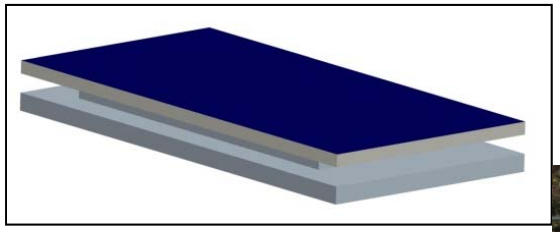




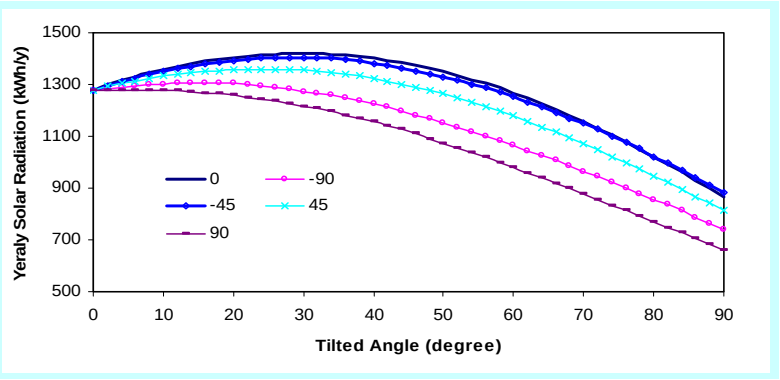


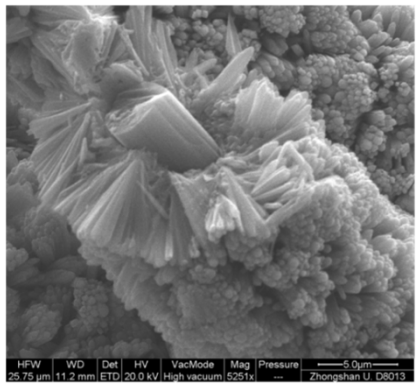
Solar cell development and installation orientation optimization

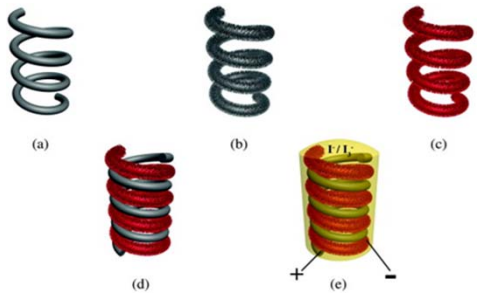
- Optimal installation orientation of PV modules
- Development of solar cells and PV product, etc.



Direct-Integrated PV Roof Claddings

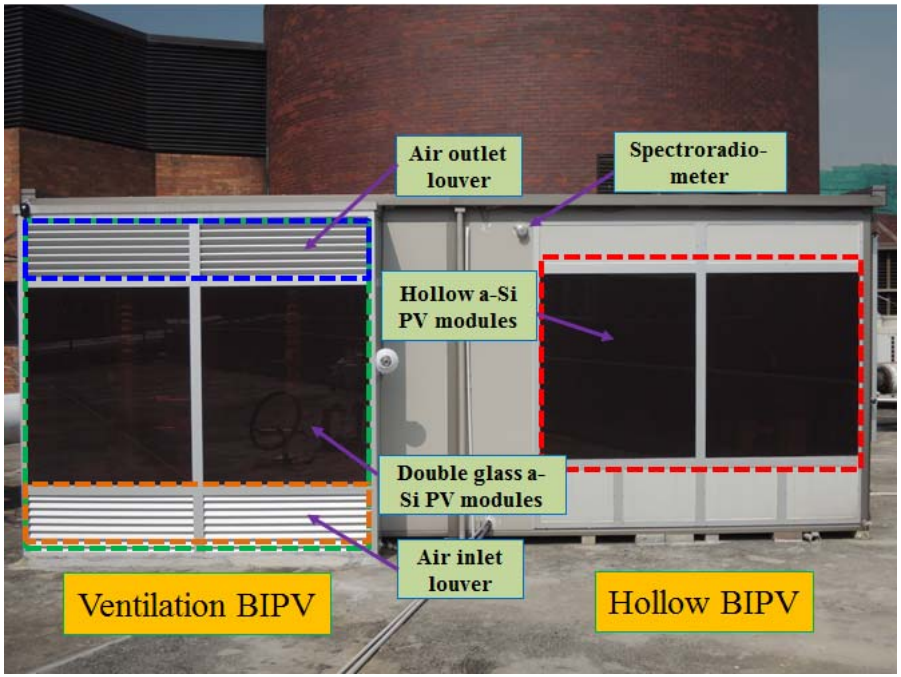


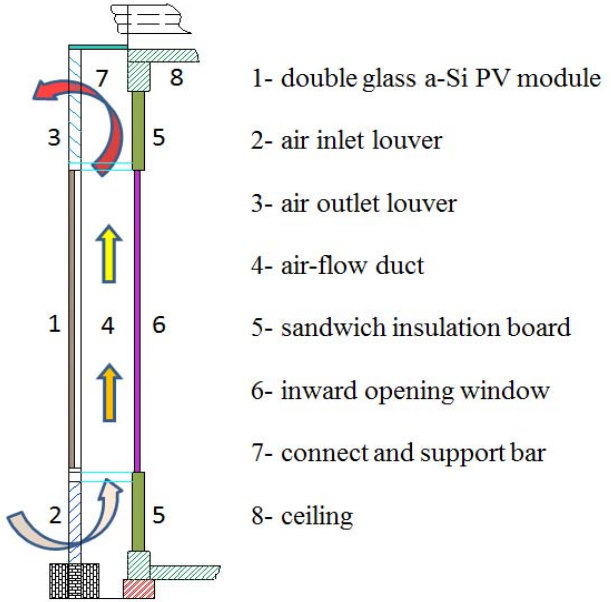




Dye-sensitized solar cells based on graphite fibers

Ventilated BIPV and new modules

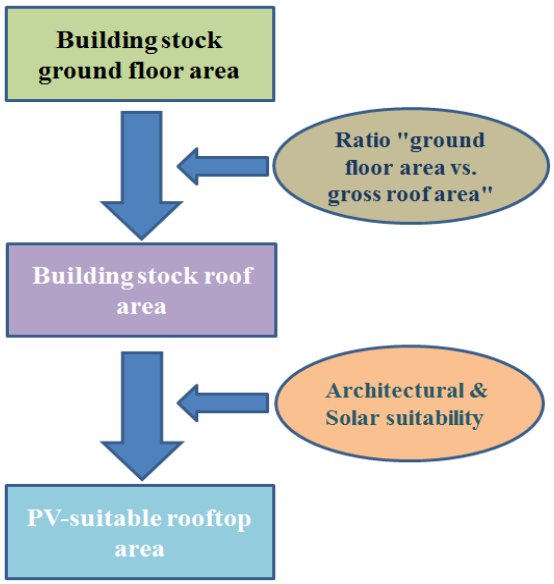


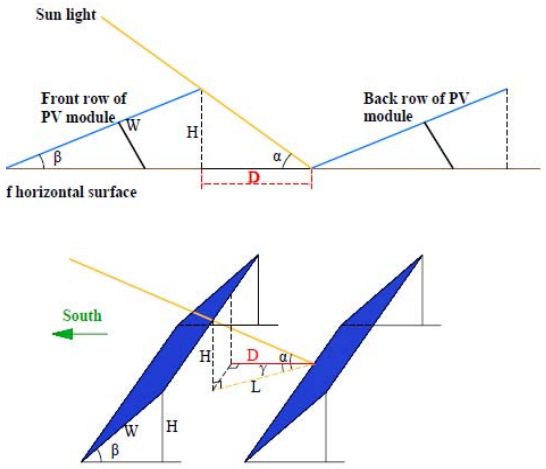


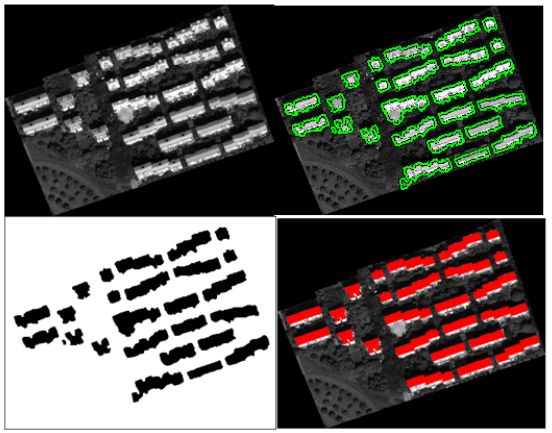
The overall energy performance of BIPV facade:

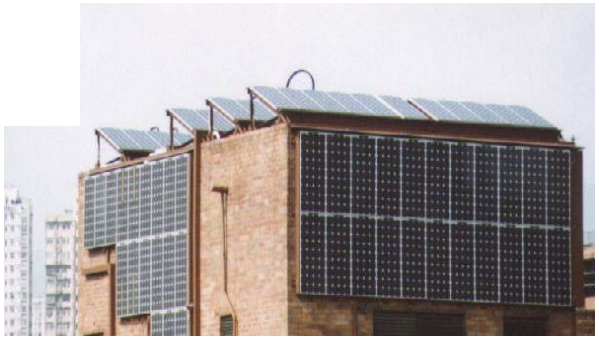
- real-time power generation performance
- thermal performance
- natural lighting performance

Rooftop solar photovoltaic applications in Hong Kong





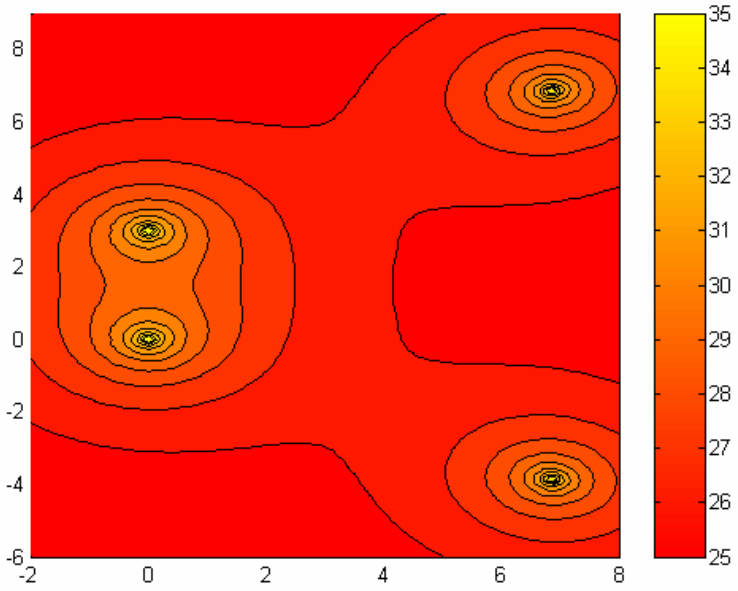




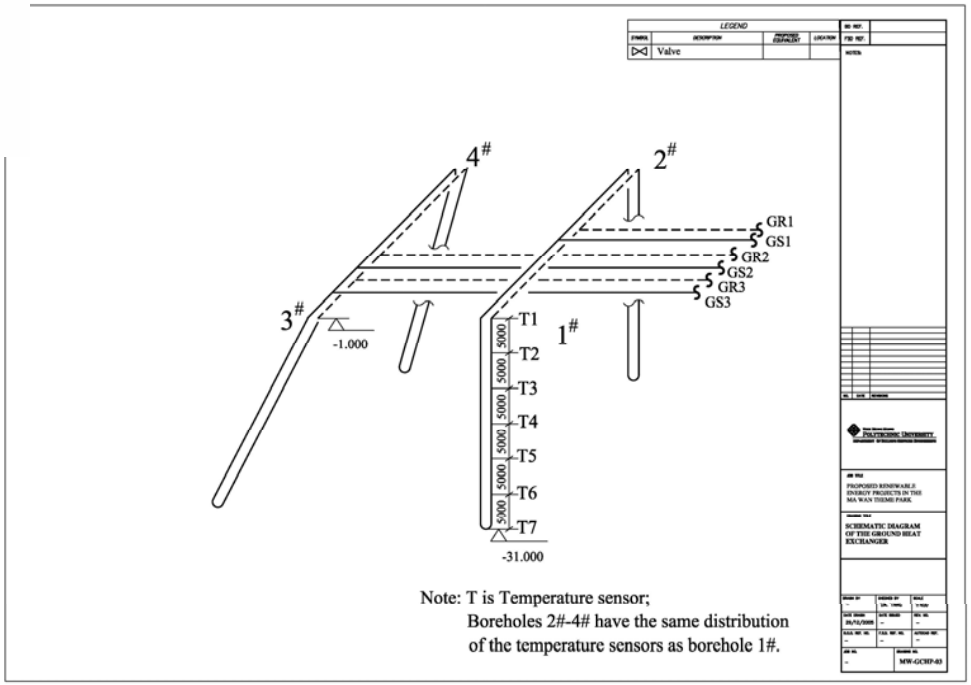
- Evaluating the PV-suitable roof-top areas by using remote sensing imagery;
- Rooftop extraction from remote sensing imagery is employed to estimate the utilization rate of urban roofs

The potential PV electricity output is about 4674GWh, accounts for 10.7% of the total electricity use in 2014.

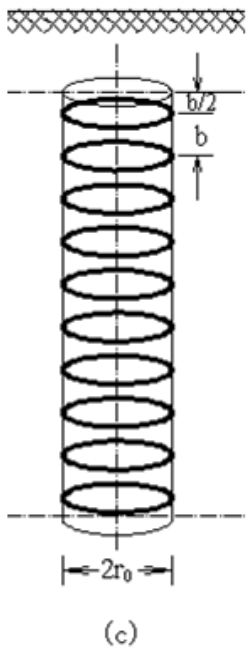
Thermal performance of ground-source heat pumps



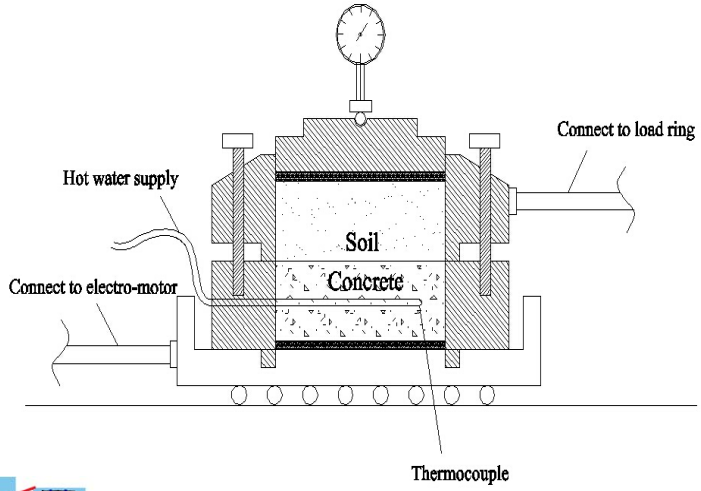
Simulation and experiments of vertical and inclined boreholes

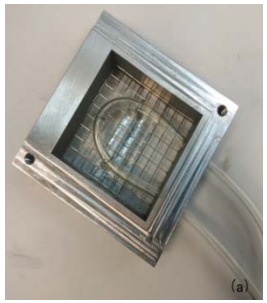


Development of heat exchanger foundation pile considering its thermo-mechanical behaviour

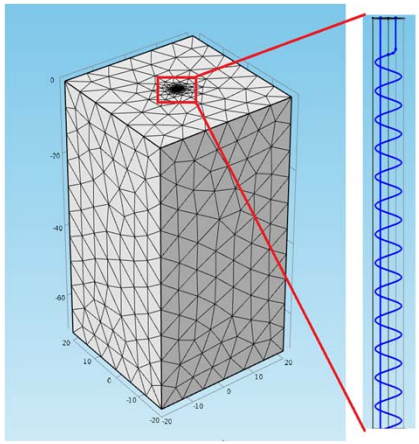


We firstly proposed a reliable analytical solution both considering the finiteness of heat source and difference of thermal property in the molding process.

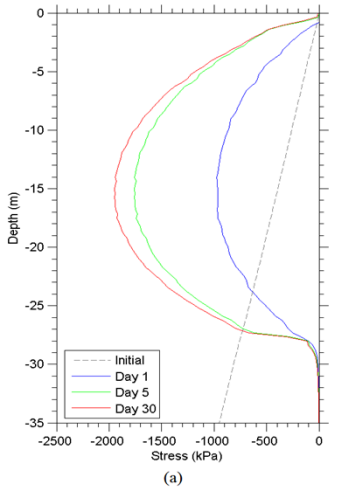


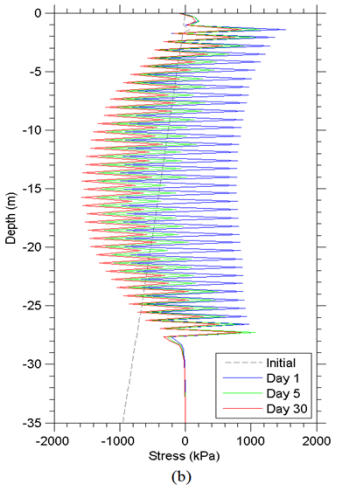


Thermal vertical stresses distributions

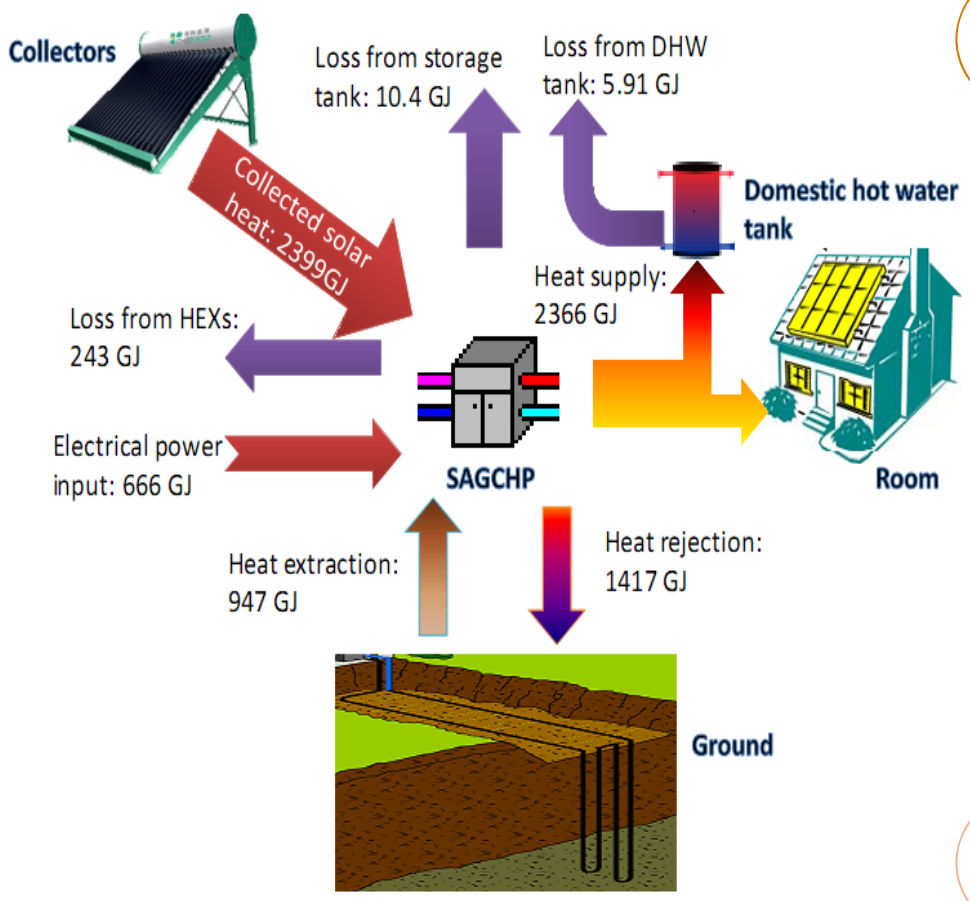


Cracks may occur for long-term operation, and we need to explore its long-term operation with fatigue test to know its ultimate bearing capacity in the whole life-cycle.





Solar-assisted ground source heat pump system



1. **Solar direct heating**
2. **Solar heat pump heating**
3. **Ground-source heating**
4. **Solar coupled ground source heating**
5. **Solar energy storage and recharging**
6. **DHW production**

Thank you!