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Smart Green Building Initiative at HKUST

Prof. Lionel M. Ni





Forging the Future
Young and Promising
Technology Oriented
Global Talents
Stimulating Environment
Building Excellence on Excellence 1



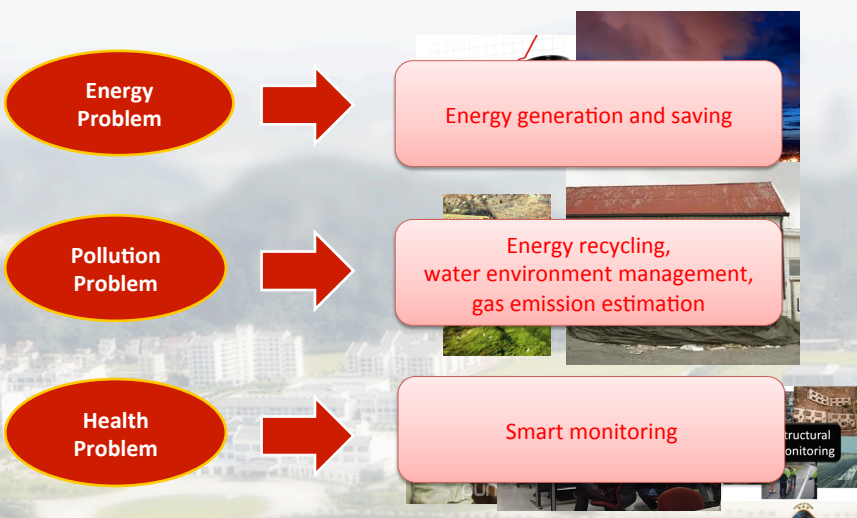
HKUST FYTGS | **Impact of Buildings**

- Up to 40% of the world’s energy each year is used to heat, cool, and light buildings
- In China, 30% of energy consumption is from buildings. Among 43B m² buildings areas, 95% are high energy consumptions.
- The buildings have to be as sustainable as possible at every stage of their lifetime – from construction, renovation to demolition
- Green buildings require efforts from many aspects including energy carbon emission, waste management, water usage, construction materials, recycling, etc.
- Different approaches will be needed for various constraints, such as type of buildings, site restrictions, cost, external air quality, noise pollution, etc.
- Sustainable and energy-efficient buildings must subject to reduced risk, greater usability, and greater comfort.

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HKUST FYTGS | **Why Smart Green Buildings?**




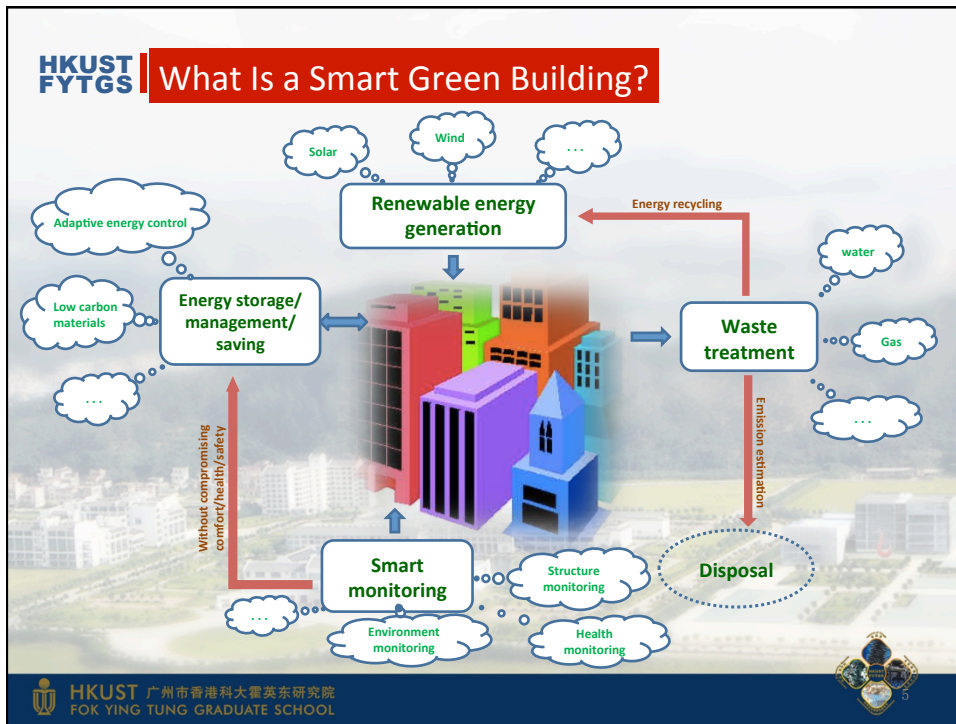
Energy Problem → Energy generation and saving

Pollution Problem → Energy recycling, water environment management, gas emission estimation

Health Problem → Smart monitoring

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HKUST FYTGS | Green Net Zero Building

- A building with **zero net energy** consumption and **zero net carbon emissions** annually
- The amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building.
- The carbon emissions generated must be balanced by the equal amount of carbon emissions reduced (**carbon neutrality**)
 - by the amount of equivalent renewable energy production
 - by buying enough carbon credits to make up the difference

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HKUST FYTGS | **Achieving Sustainable Buildings**

- Self-sufficient by collecting and re-using **waters**
 - Usage reduction and recycling of valuable potable water
- Built using sustainable **materials**
 - Building materials are a finite resource. Buildings can be designed to be reused or recycled in whole or in part.
 - Consider the energy cost of construction materials
- Efficient use of **natural resources** (e.g., land)
- Able to cope with future **climate changes**
 - How buildings can adapt to future changes
- A positive contribution to the community and **built environment**
 - Help achieve positive social, economic, and environmental effects
- Sustainable in **operation**
 - Buildings can be operated easily and efficiently

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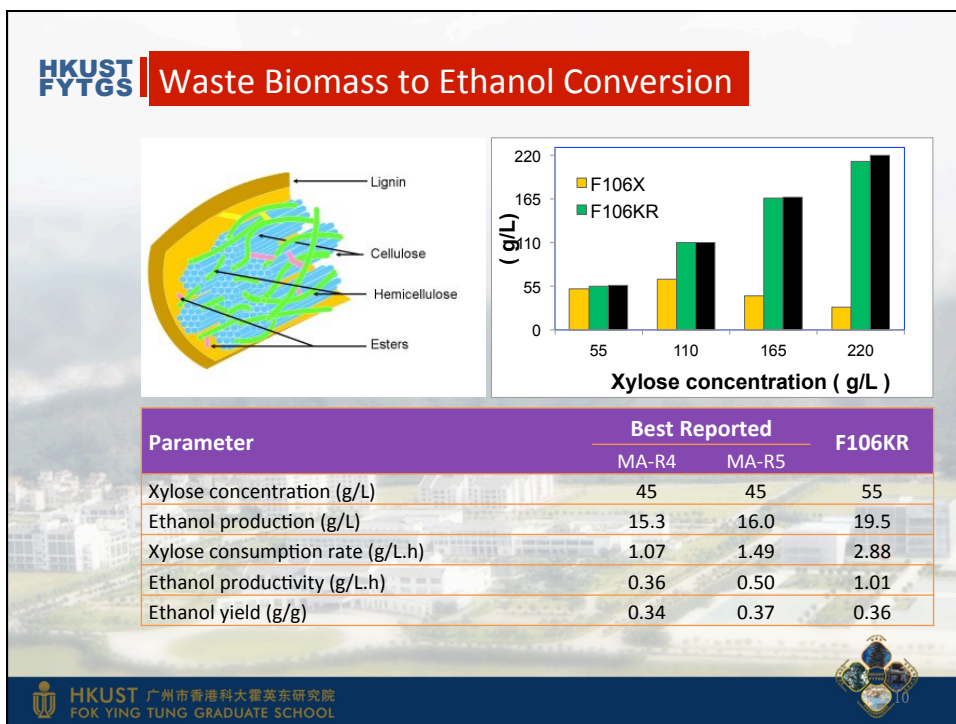
HKUST FYTGS | **Energy Generation**

Powering a house by solar photovoltaic (PV) and wind turbine


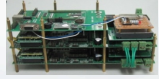
Organic film photovoltaic cells: low power conversion efficiency

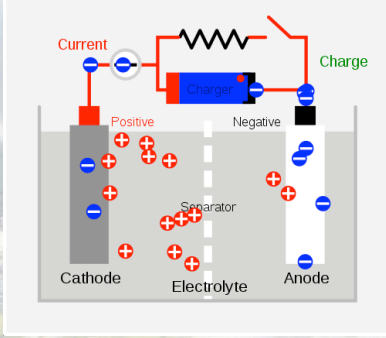
- Roof/wall
- Crafts
- Sun umbrella
- Phone booth
- Back pack

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HKUST FYTGS Battery Storage and Management


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Rechargeable Battery

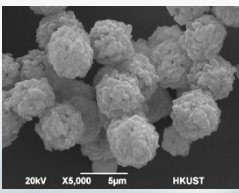
- Battery Management System (BMS)
 - Protect the cells or the battery from damage
 - Prolong the life of the battery
 - Maintain the battery in a state in which it can fulfill the functional requirements of the application for which it was specified.



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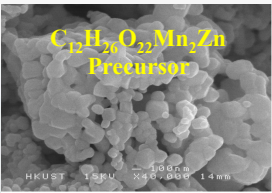


HKUST FYTGS Lithium Ion Battery



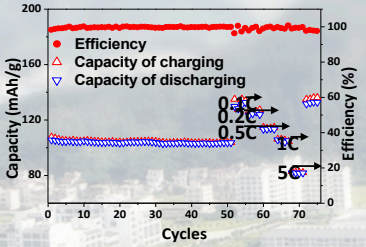
20kV X5,000 5µm HKUST

$C_{12}H_{16}O_{22}Mn_3Zn$
Precursor



Spinel
 $ZnMn_2O_4$

HKUST 15kV X4,000 1.4µm




Cycles

Volume ~20% ↓


Weight ~20% ↓

New **cathode** material: Lithium ferrous phosphate prepared with novel procedures (Uniform particle size, nearly 100% current efficiency)

New **anode** material: Capacity is 75% larger than the theoretical value of graphite (372 mAh/g)



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HKUST FYTGS | Energy Saving Technologies

- Major energy consumption devices
 - Water heater
 - Air conditioner
 - Lighting lamps
- Saving energies
 - Better energy insulation materials
 - Do more for less

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HKUST FYTGS | Water Heater from Heat Recovery System

Possible heat sources:
shower water, refrigerator, and air conditioner.

CHALLENGES: Why not in the market:
 (1) Shower water heat recovery system is usually only compatible with the instant water heater because the time lag between water heating and heat recovery would make the system not effective.
 (2) Refrigerants of air-conditioners and refrigerators keep flowing no matter whether hot water is required at a certain period. Since heat pump water heater takes a long time to heat up water, it is not easy to decide whether the heater should run.

SOLUTION: A smart control system integrating the algorithm of process control is employed to calculate the optimal action of the water heater based on information retrieved from temperature sensors, flow sensors, and input preferences.

Heat Exchanger

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HKUST FYTGS | Solar Adsorption Cooling System

Solar adsorption cooling system:

- Utilize solar energy (or industrial waste heat) for cooling, low power consumption
- High energy efficiency
- Material used in the cooling system is environmentally friendly, non-toxic, and recyclable
- No compressor, the system is safer and quieter

Compare to existing adsorbents, our new composite adsorbent enables greater cooling and lower regeneration temperature.

New composite adsorbent

First generation prototype

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HKUST FYTGS | High Brightness LED Packaging

Developing transparent nanocomposite LED encapsulants with HIGH reflective index, thermal conductivity, thermal/UV stability and light extraction efficiency for next generation of LED packaging with good reliability

Low electric-light conversion rate, high energy consumption, high temperature

Thermal failure leads to short application life with low reliability

Technical bottleneck of high brightness LED

High Brightness LED

Multilayer Phosphor Nanoparticles


- Improved electric-light conversion efficiency
- Improved thermal and UV stability

Nanocomposite encapsulants with

- Gradient-RI for high light extraction efficiency
- Nanoparticles for high thermal conductivity

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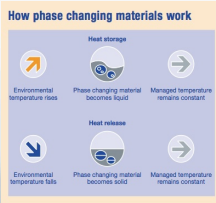
HKUST FYTGS | Smart Wall: Phase Change Material (PCM)



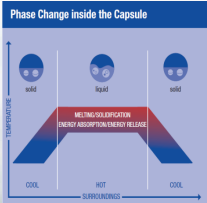
Ice-to-water phase change keeps the drink at 0°C

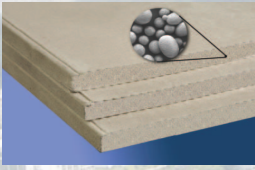
Phase change materials keep the building material at their melting temperatures

How phase changing materials work




Phase Change inside the Capsule

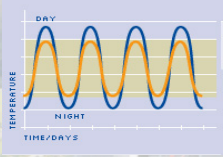





Construction materials with PCM capsules



A house with PCM Building materials



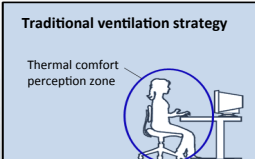
Internal temp of the house with PCMs (orange curve)



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HKUST FYTGS | Personalized Ventilation

Traditional ventilation strategy



Thermal comfort perception zone

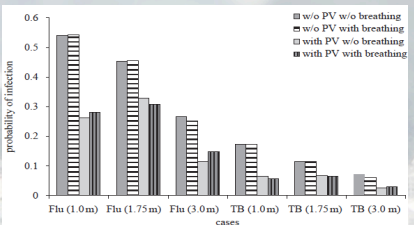
Personalized ventilation strategy



Air terminal device

Personalized ventilation (PV) strategy:


- supplies conditioned fresh air directly to the occupants
- able to integrate sensor technology to consider individual comfort need
- energy saving and enhance health and comfort



probability of infection

cases: Flu (1.0m), Flu (1.75m), Flu (3.0m), TB (1.0m), TB (1.75m), TB (3.0m)


Legend: w/o PV w/o breathing, w/o PV with breathing, with PV w/o breathing, with PV with breathing



Air terminal part of the PV system

PV can reduce the health risk toward indoor air contaminant

Our personalized ventilation system uses sensors to control the system operation, and applies computational fluid dynamics simulation to further enhance thermal comfort and energy efficiency.



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HKUST FYTGS | **How IT Can Help in Green Buildings**

Making Green Buildings SMART!

- Occupants should not compromise the comfort they have enjoyed
- Occupants should spend minimal efforts in operating the building
- Smart resource management system
 - Sensors: monitor various building conditions, environments, etc.
 - Actuators: control various devices in the building
 - Control System: based on collected sensory data and other historical data to provide customized service through actuators
 - Wired and wireless networking
 - Storage of relevant data (cloud computing)
 - Energy-efficient design and operation

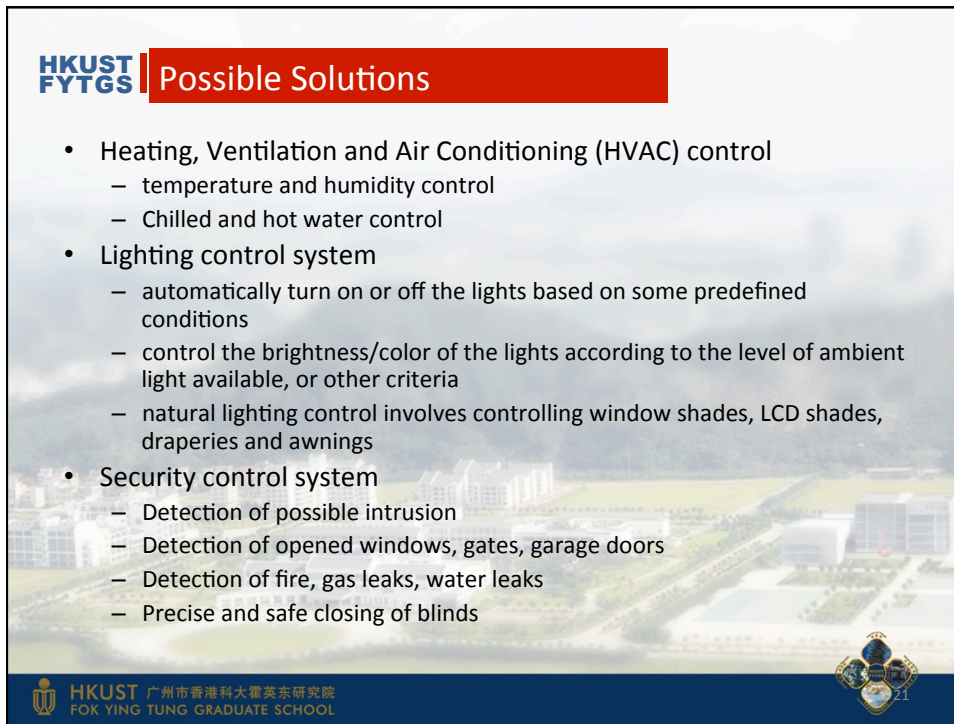
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HKUST FYTGS | **Smart Sensing and Monitoring**

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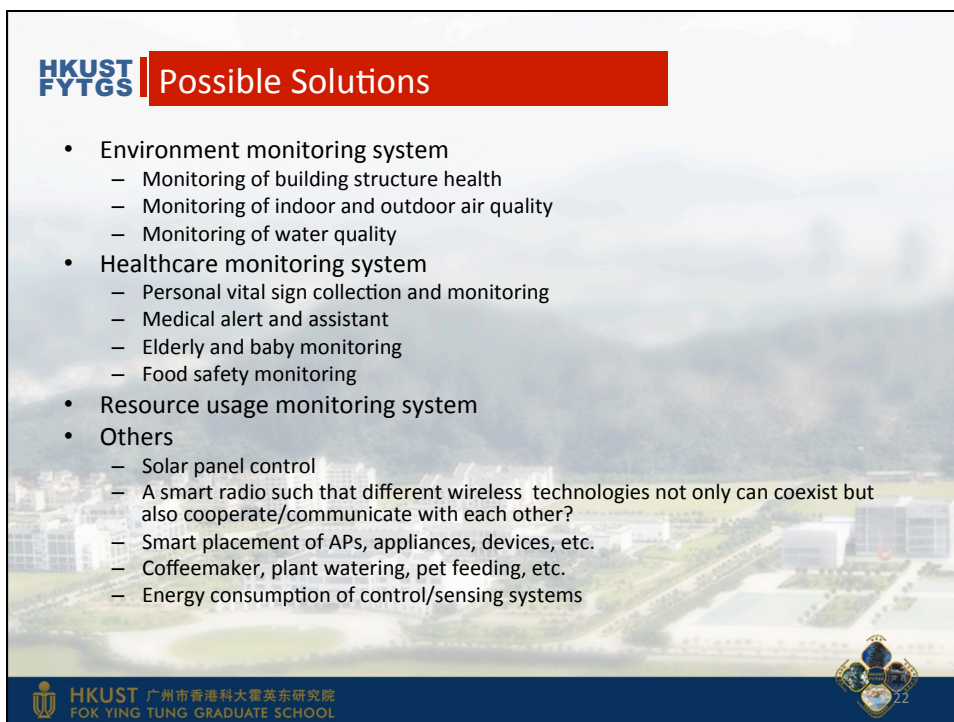
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HKUST FYTGS Possible Solutions

- Heating, Ventilation and Air Conditioning (HVAC) control
 - temperature and humidity control
 - Chilled and hot water control
- Lighting control system
 - automatically turn on or off the lights based on some predefined conditions
 - control the brightness/color of the lights according to the level of ambient light available, or other criteria
 - natural lighting control involves controlling window shades, LCD shades, draperies and awnings
- Security control system
 - Detection of possible intrusion
 - Detection of opened windows, gates, garage doors
 - Detection of fire, gas leaks, water leaks
 - Precise and safe closing of blinds



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HKUST FYTGS Possible Solutions

- Environment monitoring system
 - Monitoring of building structure health
 - Monitoring of indoor and outdoor air quality
 - Monitoring of water quality
- Healthcare monitoring system
 - Personal vital sign collection and monitoring
 - Medical alert and assistant
 - Elderly and baby monitoring
 - Food safety monitoring
- Resource usage monitoring system
- Others
 - Solar panel control
 - A smart radio such that different wireless technologies not only can coexist but also cooperate/communicate with each other?
 - Smart placement of APs, appliances, devices, etc.
 - Coffeemaker, plant watering, pet feeding, etc.
 - Energy consumption of control/sensing systems

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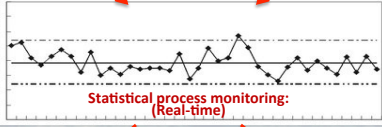



HKUST FYTGS | Smart Resource Management System




Perform real-time statistical monitoring on various building parameters, such as water, electricity, and greenhouse gas emission.


- Optimal strategy to use the resources will be obtained
- Abnormal state will be detected
- Excessive resource wastage can be prevented




Statistical process monitoring:
(Real-time)




Excessive resource and money wastage can be prevented!




Optimal strategy to use the resources



Abnormal detection

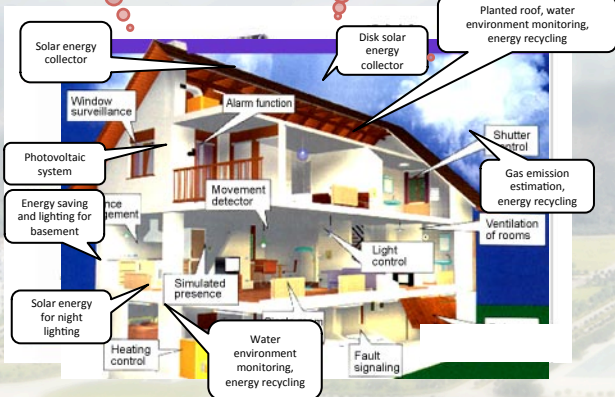


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HKUST FYTGS | Smart Green Building: A Big Picture

Energy generation and saving Smart monitoring Energy recycling, water environment management, gas emission estimation



The diagram illustrates a multi-story smart green building with various integrated systems:

- Energy generation and saving:** Solar energy collector, Photovoltaic system, Energy saving and lighting for basement, Solar energy for night lighting, Heating control.
- Smart monitoring:** Window surveillance, Alarm function, Movement detector, Simulated presence, Water environment monitoring, energy recycling, Fault signaling, Light control.
- Energy recycling, water environment management, gas emission estimation:** Disk solar energy collector, Planted roof, water environment monitoring, energy recycling, Gas emission estimation, energy recycling, Ventilation of rooms, Shutter control.



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