Smart Building Facilitated by Wireless Sensor Networks and Integrated Terminal Control

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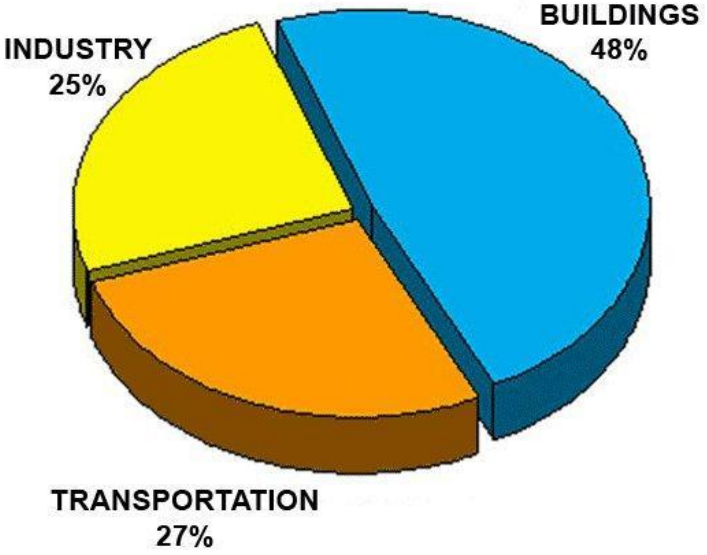
Why Smart Buildings? – U.S.



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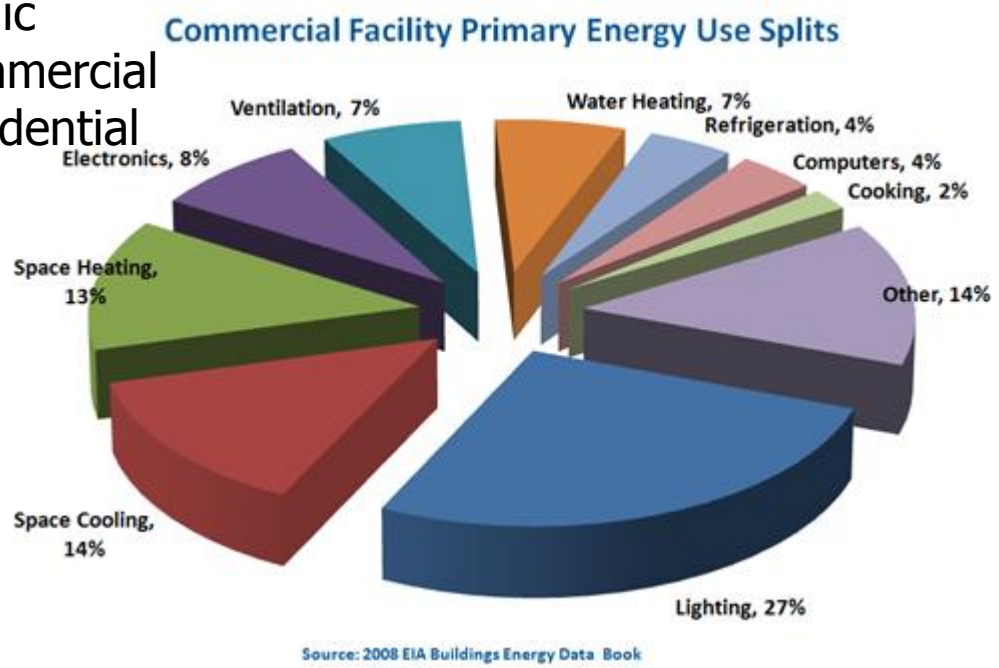


US ENERGY CONSUMPTION

In the US, buildings are responsible for

- 38% of CO2 emissions
- 71% of electricity consumption
- 39% of energy use
- 12% of water consumption
- 40% of non-industrial waste
- **90%** of our time indoors.

Why Smart Buildings? – China

Year 2012, 430 Bm^2

Construction Cost
16.7% of
total energy
consumption

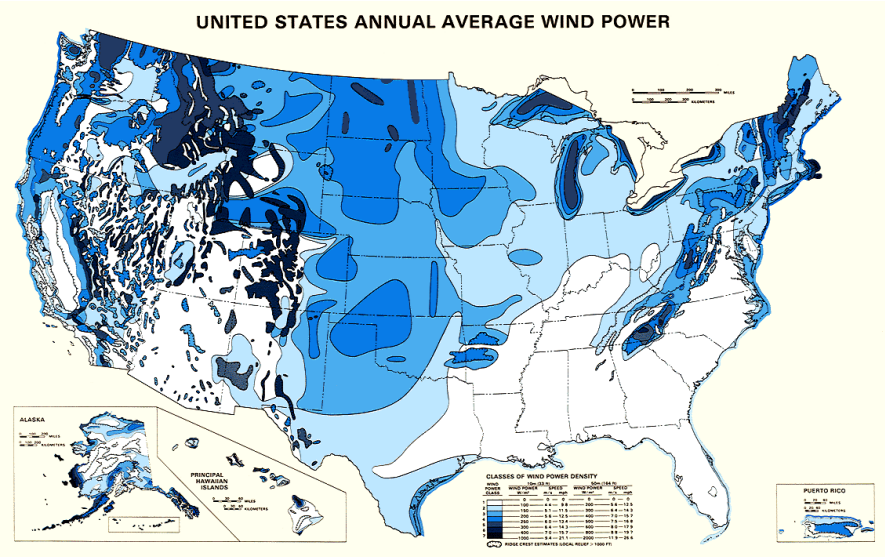
Operational Cost
30%
(20% by HVACs)

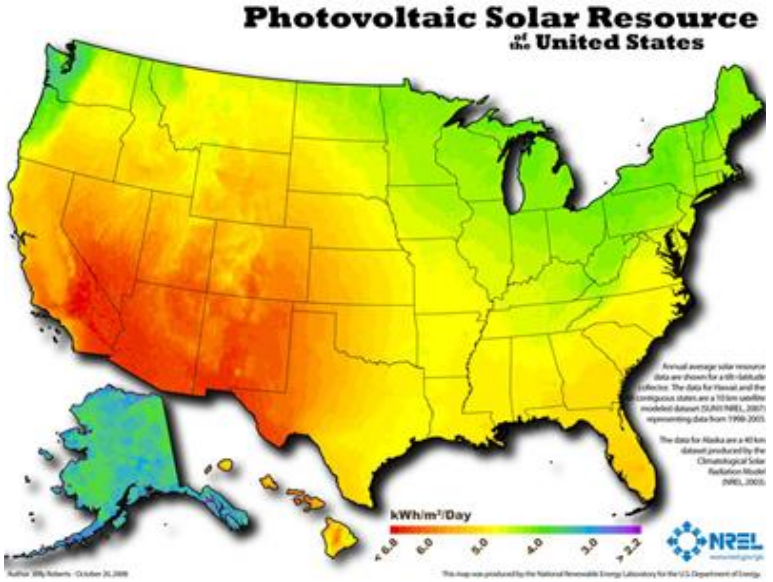
Year 2020

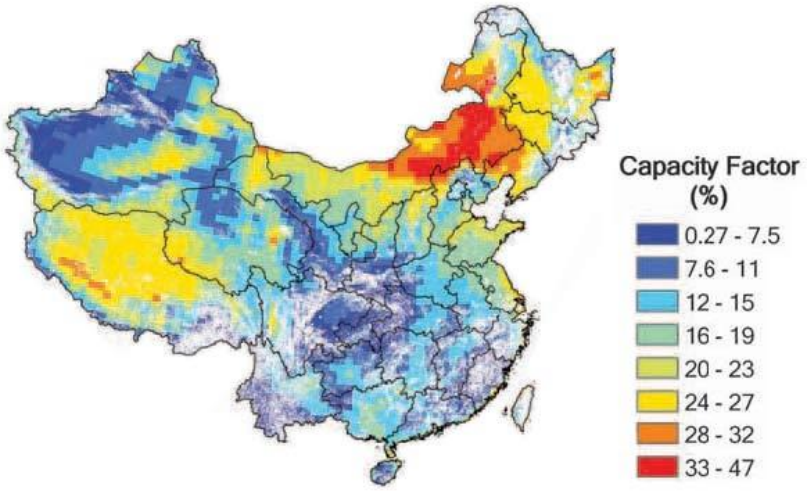
3 times of yr 2012
1.09 BTEC
2,943 BkWh
15 three gorges

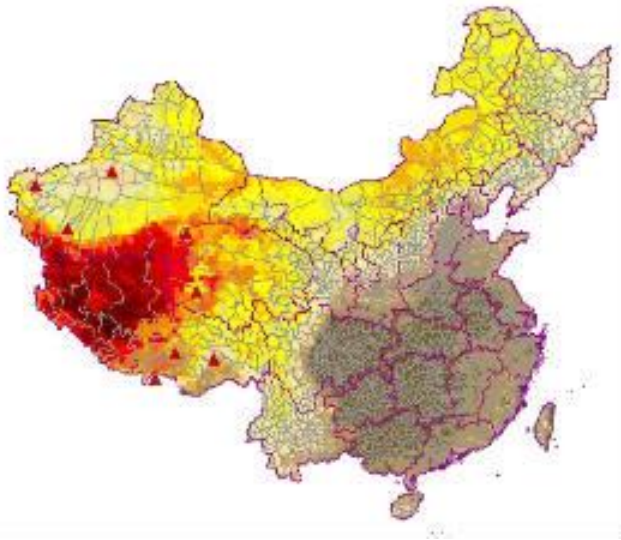
- If no actions are taken, China will become No. 1 CO2 emissioner by 2020.

Renewable Energy?









Why Smart Buildings? – Big Potential

Actual utilization of coal fired electrical energy in China

Coal mining loss

Thermal turbine loss

magnifying effect of saving energy

Actual utilization

70%

20%

8%

1%

1%

Coal shipping loss

Transmission &distribution loss

1 penny saved is 12.5 pennies earned.

We need

Green, Comfort, Secure, and Safe Buildings!!

The Only Formula in This Talk

Energy Cost (**E**) = Cost per unit of load (**C**) × Load (**L**)

Energy efficiency

Better envelope
Smart materials
Smart controls
New HVACs
PV panels
E-cars
…

Control the Demand

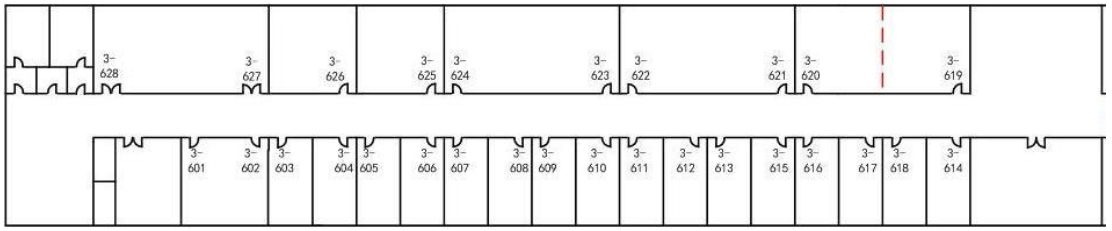
Why Controlling the Demand?

- There are limits of improving building energy efficiency (i.e., reducing **C**)
  - Most of the new devices and materials are suitable for new buildings
  - Better control can be used for both new and existing buildings, but no magic in energy saving, 10-20% saving.
- Without control, the demand in buildings will rise up very sharply! (i.e., fast growing **L**)
  - E.g., modern buildings, fancy, energy monsters
  - Examples around us

A Case Study in Tsinghua

Tsinghua National Lab for Information Science and Technology
(FIT building)

- 10,000 m^2
- Electricity cost: 3M RMB/yr



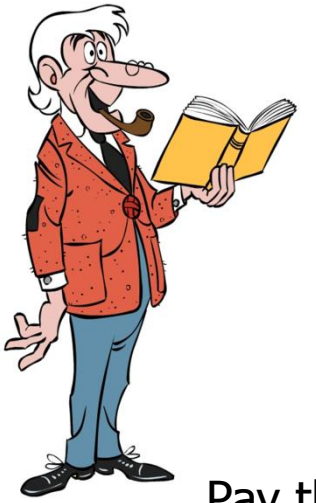
Layout of CFINS (FIT-3-6xx)

- Pick two labs
- 36 students, 52 desktops
- Electricity cost: 105,120 RMB in yr 2010
- Educate the students
- One year later
- Electricity cost ***increased!***

Why Increased?

Consume power.
Don't pay the bill.

The students don't have the motive to reduce the demand.



Pay the bill.
Don't control the building

Control the building.
Don't control the demand.

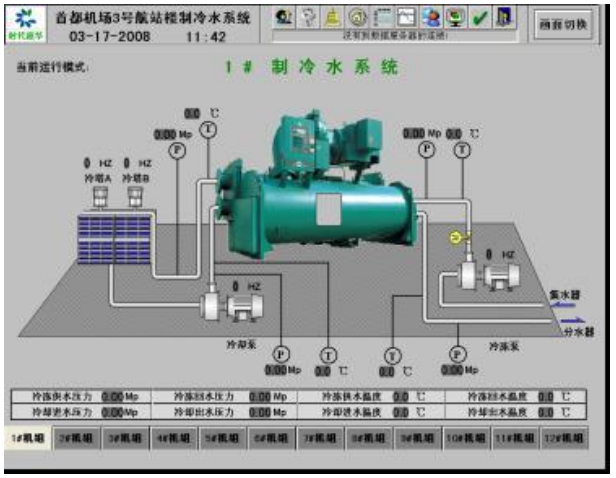
How to Control the Demand?

Information Systems - Environment

- Temperature
- Humidity
- CO2 level
- Luminance
- Wind speed
- Noise level
- Radiant temperature

Information Systems - Devices

- HVAC
  - Chilled water temperature
  - Water pump
  - Fan speed of Fan-Coil-Unit (FCU)
  - Fan speed of Fresh-Air-Unit (FAU)
  - Valve
  - Output air temperature
- Lights, blinds, windows
- Energy consumption
  - Traditional power meters
  - Plug-in loads
  - ***MAC addresses*** (Zhang et al. 2010)



Information Systems - Occupants

Systems		Cost (RMB)	Approach	Accuracy	Disadvantage
Active sensors	WSN/RFID	200	Localization	2m-5m	Multipath effect
	RFID	3,000(r) 200(t)	Localization	2m-5m	Multipath effect
	UWB	30,000(r) 200(t)	Localization	0.30m	High cost
	Cricket	2,000	Localization	0.10m	Ultrasonic, orientation constrained
Passive sensors	Video	5,000~ 200	Image Processing	90%~95%	Privacy, cost
	CO2	2,000~ 100	Signal Processing	50%~80%	Drift
	Infrared	100	Counting	80%~95%	No identity

Fusing cheap sensors to get high accuracy. (Wang et al. 2012, Jia et al. 2012)

Information Systems - HMI

- Multi-dimensional satisfaction feedback
- System state query
- Comfort profile learning
  - (Zhao et al. 2010)
- Energy consumption prediction
  - (Wang et al. 2011)
- Group dynamics
  - A single HMI
  - Multiple HMIs
  - No HMIs

Thermostat

NEST Learning Thermostat

Tsinghua HMI (Jiang et al. 2011)

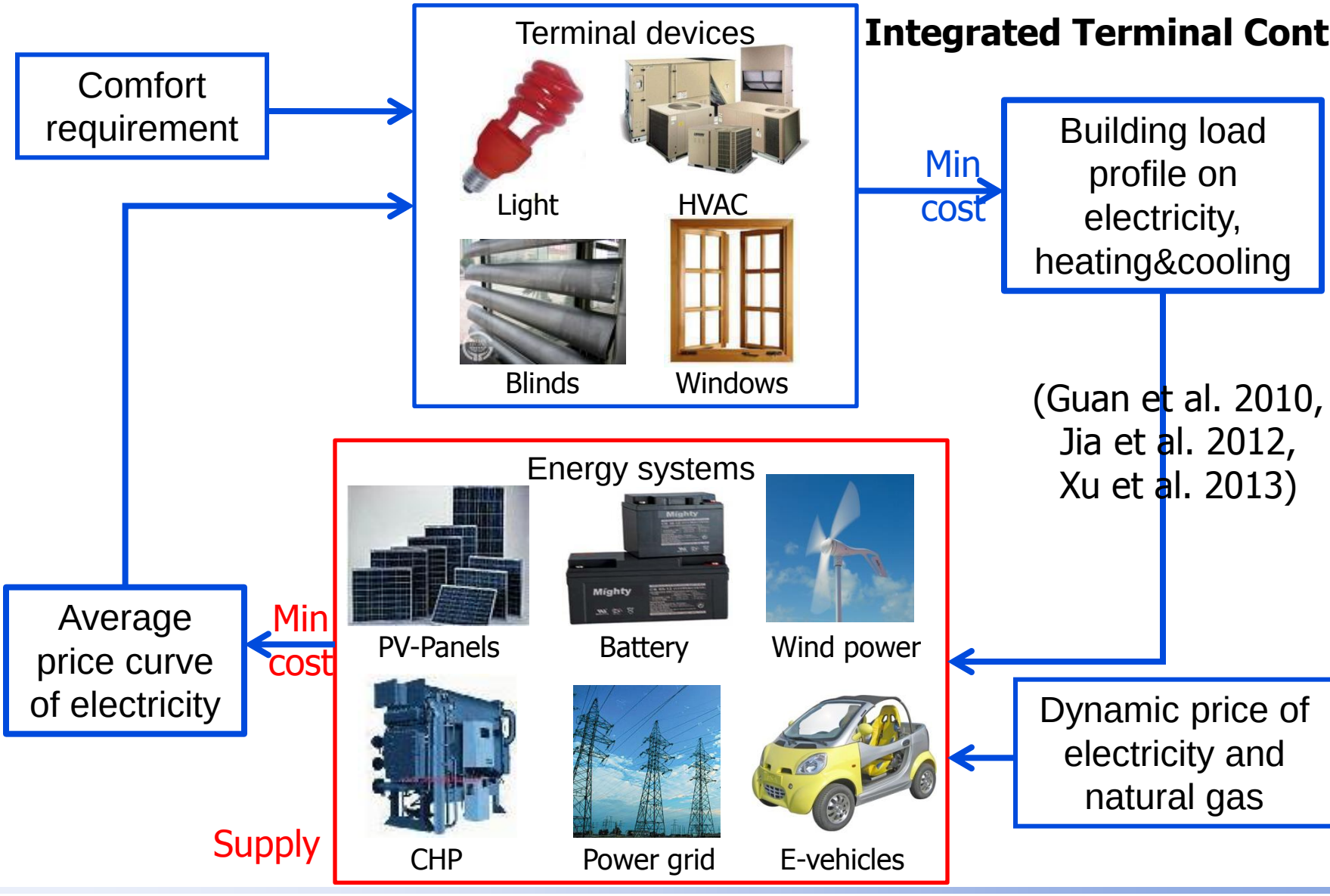
Integrated Terminal Control

- To improve the energy efficiency (reducing **C**)
  - 10-20% energy saving using natural ventilation, sun shine

  (Sun et al. CASE 2010, T-ASE 2012)
- To reduce the load (i.e., **L**)
  - ***Respond***: to complaint
  - ***Responsive***: guaranteed service
  - ***Prioritized***: differentiate different needs
  - (Wu et al. 2013)

Low Energy Demo (LED) building @ Tsinghua

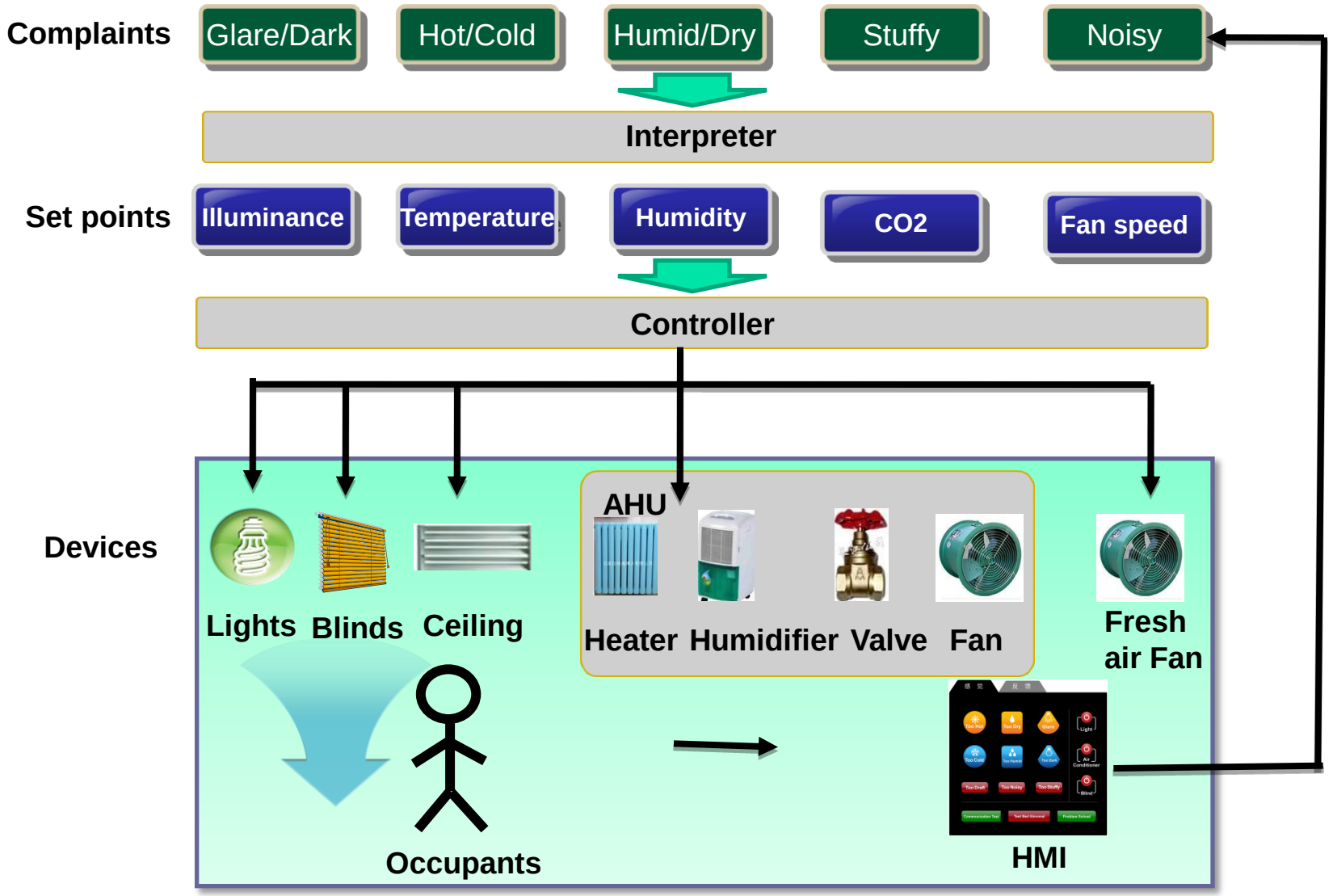
Integrated Control to Improve Energy Efficiency



Motivation Mechanism

- Meter/Estimate the energy consumed by each student (Zhang et al. 2010, Lei 2012)
  - Individual cost (desktop, laptop, other plug-ins)
  - Shared cost (HVAC, lights, etc.)
- Feedback (Lei 2012)
  - Relative rank (peer pressure)
  - Suggested actions
- ***Give each student a budget (200RMB/month). Then let them pay the bill.*** (on going research…)
- ***Location-based pricing*** (Xu et al. 2013)

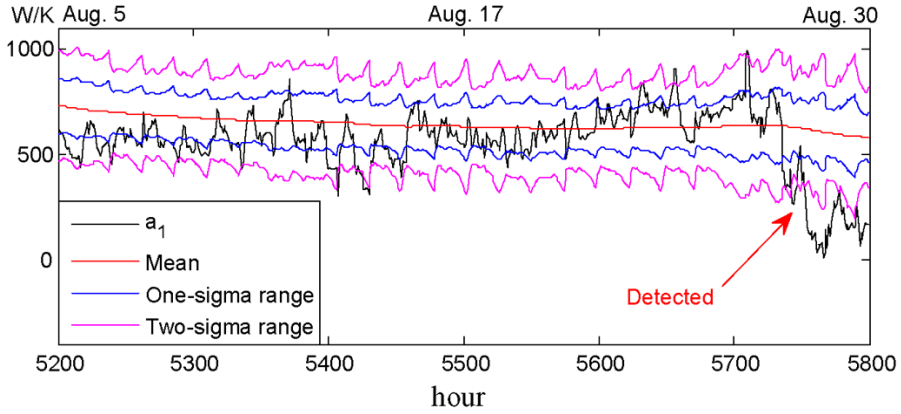
iBuilding


Complaints
Glare/Dark
Hot/Cold
Humid/Dry
Stuffy
Noisy
Interpreter
Set points
Illuminance
Temperature
Humidity
CO2
Fan speed
Controller
Devices
Lights
Blinds
Ceiling
AHU
Heater
Humidifier
Valve
Fan
Fresh air Fan
Occupants
HMI

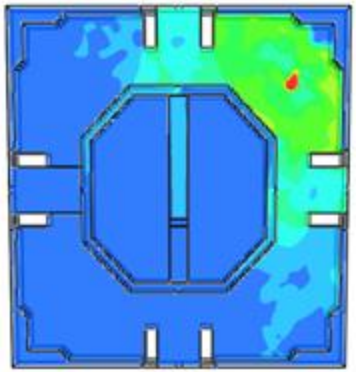
Conclusion

- Building energy saving is of great practical interest.
- ***Control the demand*** is important.
  - Information systems supported by wireless sensor networks save energy by 10%.
  - Integrated terminal control saves energy by 10%.
  - Mechanism changes are predicted to ***save 30%***.
- And …

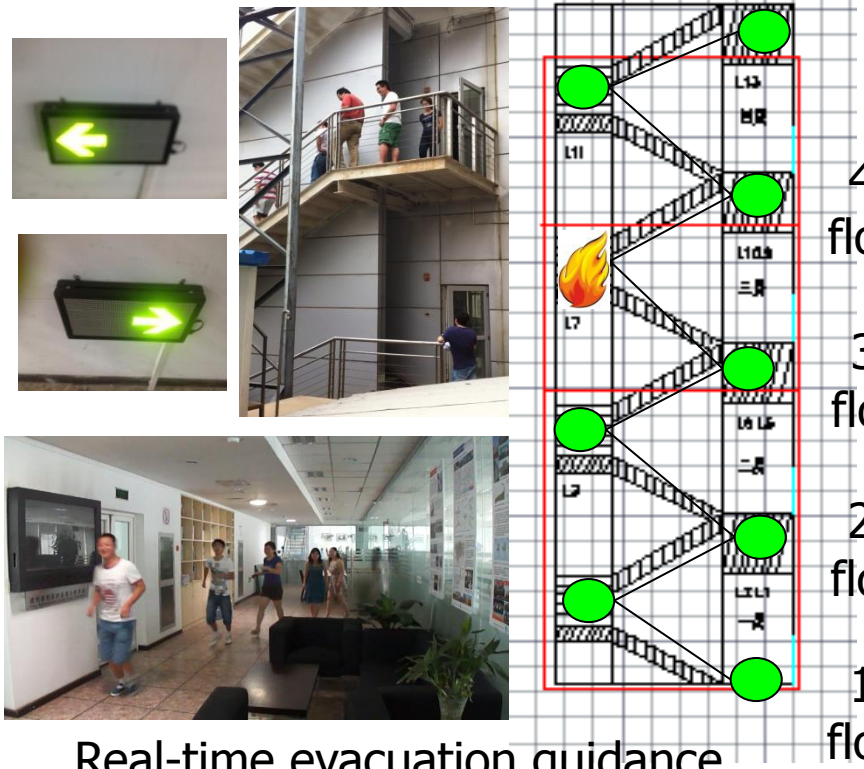
Some Other Applications



Building fault diagnosis
(Sun et al. T-ASE 2012)



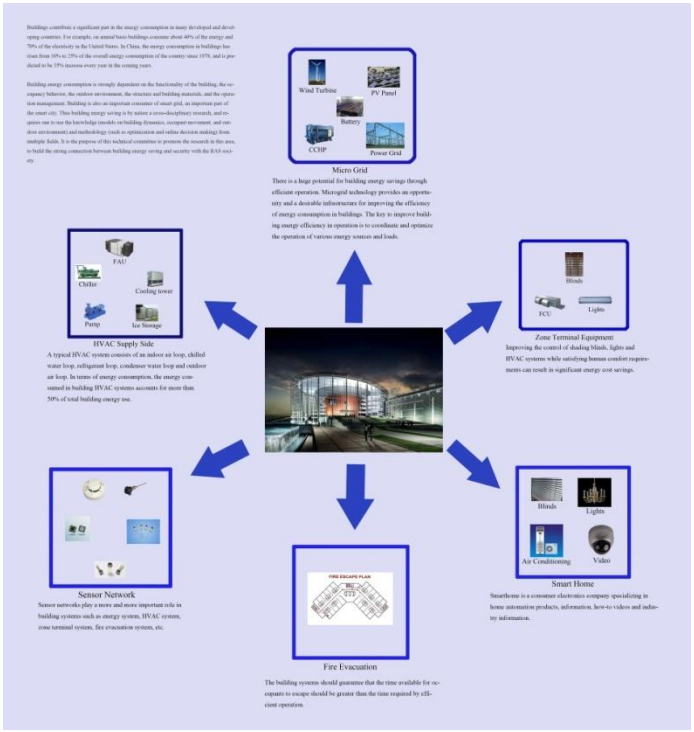
Real-time fire source identification and risk map calculation
(Qiao et al. 2010, Yang et al. 2012)



Real-time evacuation guidance
(Zhang et al. 2012)

Reservation-based HVAC control (Xu et al. 2010, 2013)
Storage devices analysis (Xu et al. 2011)

Smart Buildings TC in IEEE RAS



- http://cfins.au.tsinghua.edu.cn/sbtc/
- http://www.ieee-ras.org/technical/committees.html
- Smart Building special sessions in CASE 2013

Thank you!

Any questions?

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