Why is IEQ so important?
- Quality of life: Health risks of degraded IEQ
- Economy: huge capital stock; IEQ affects performance
- Energy/climate: Buildings must become sustainable

What will SinBerBEST do?
- Advance knowledge and insight on human-building interactions, focusing on tropical climates, so that
  - IEQ goals are achieved, even as
  - Buildings become more energy & resource efficient

Mission
To acquire information, create knowledge, and convey understanding to ensure that indoor environmental quality provided for building occupants is maintained or improved while energy efficiency gains are achieved.

Sustainability and Human/Building Interactions
- Buildings: major energy end use; large CO₂ emissions
- Energy needed for indoor environmental quality (IEQ)
- Good IEQ required for high performance buildings
- Knowledge gaps are large for attaining good IEQ with high efficiency in buildings in tropical climates

Why is achieving good IEQ so difficult?
- Overlapping domains: buildings, environment, health
- Inherent complexity: 10⁸ buildings × 10¹⁰ people
- Many IEQ parameters that vary with time
- Influencing factors are physical and psychosocial

Energy Use in Singapore Offices
- Energy index: 12-55 kWh m⁻² month⁻¹
- For 10 m² of office space with electricity cost of $0.28/kWh, electricity cost = $0.34-$1.5/month. This is a small fraction of the typical wage of an office worker.

Principles of effective IEQ control
1. Source control: Limit E
2. Protect from outdoor pollutants: Reduce f
3. Provide adequate ventilation: Sufficient Q
4. Apply air cleaning when necessary: Use k

Energy Use in Singapore Offices
- Energy index: 12-55 kWh m⁻² month⁻¹
- For 10 m² of office space with electricity cost of $0.28/kWh, electricity cost = $0.34-$1.5/month. This is a small fraction of the typical wage of an office worker.

Ventilation and Sick-Building Syndrome (SBS)
... as the ventilation rate drops from 10 to 5 liters per second per person, relative SBS symptom prevalence increases approximately 23% and as ventilation rate increases from 10 to 25 liters per second per person, relative prevalence decreases approximately 29%.

Emerging IEQ Topics
- Understanding is not yet adequate to ask incisive questions for all important aspects
  - Example 1: Indoor microbiome
  - Example 2: Climate change & IEQ

Simple model for indoor pollutants
\[ C = f \times C_{out} + \frac{E}{Q + kV} \]
- C = indoor pollutant concentration (µg/m³)
- F = infiltration factor (-)
- E = indoor emission rate (µg/h)
- Q = ventilation rate (m³/h)
- k = indoor removal loss coefficient (h⁻¹)
- V = indoor volume (m³)

Performance and maintenance of buildings
- Energy Use in Singapore Offices
- Ventilation and Sick-Building Syndrome (SBS)
- Energy Use in Singapore Offices
- Ventilation and Sick-Building Syndrome (SBS)

Summary
- High-performance buildings must have good indoor environmental quality to achieve their purpose
- Energy efficiency and good IEQ requires improved understanding of key issues
- IEQ knowledge gaps in tropical climates include HVAC hygiene, thermal comfort, bioaerosols, and temperature/humidity effects on pollutant dynamic behavior
- SinBerBEST will enhance knowledge that will advance IEQ science and improve building practice

Priorities for improved IEQ in (US) offices
- Increase ventilation rate to 10 L/s per person
  - $5.6 b/y
- Further increase ventilation rate to 15 L/s per person
  - $13.5 b/y
- Add air cleaner when absent
  - $11.9 b/y
- Eliminate winter indoor T > 23°C
  - $3.4 b/y
- Reduce dampness and mold 30%
  - $0.5 b/y

(*) Benefits account for performance improvements, decreased SBS symptom prevalence, reduced short-term absence, and include effects of increased energy consumption. Actions in blue have potential relevance for tropical climates.

Source: WJ Fisk et al., Indoor Air 21, 357-387, 2011.

Ozone (O₃) and its byproducts
- Respiratory irritant, association between ambient O₃ levels and acute morbidity and mortality.
- Ozone indoors is typically 20-70% of outdoor level.
- Byproducts of ozone-surface chemistry are a health concern.


Human-Building Interactions and the Environment
William W Nazaroff, University of California, Berkeley, California USA
Wei-Chung Victor Chang, Nanyang Technological University, Singapore

Work Packages
WP4.1 – Heating, ventilating, and air-conditioning system hygiene
WP4.2 – Human factors for thermal comfort
WP4.3 – Bioaerosols in tropical buildings
WP4.4 – Temperature & humidity effects on indoor pollutant dynamics
WP4.5 – Critical reviews
WP4.6 – Coordination and outreach

WP4.1
Temperature & humidity effects on indoor pollutant dynamics
- 3.1 Heating and cooling system design
- 3.2 Airflow and mixing patterns
- 3.3 Indoor air pollutants
- 3.4 Ventilation effectiveness
- 3.5 Building materials and emissions

WP4.2
Human factors for thermal comfort
- 2.1 Human thermal comfort
- 2.2 Building energy use
- 2.3 Building materials
- 2.4 Indoor air quality
- 2.5 Building design

WP4.3
Bioaerosols in tropical buildings
- 1.1 Bioaerosol generation
- 1.2 Bioaerosol transport
- 1.3 Bioaerosol deposition
- 1.4 Bioaerosol fate
- 1.5 Bioaerosol impact

WP4.4
Temperature & humidity effects on indoor pollutant dynamics
- 4.1 Indoor pollutant dynamics
- 4.2 Indoor pollutant sources
- 4.3 Indoor pollutant sinks
- 4.4 Indoor pollutant transport
- 4.5 Indoor pollutant fate

WP4.5
Critical reviews
- 5.1 Critical review of existing knowledge
- 5.2 Critical review of methodology
- 5.3 Critical review of data
- 5.4 Critical review of models
- 5.5 Critical review of policies

WP4.6
Coordination and outreach
- 6.1 Coordination across work packages
- 6.2 Outreach to stakeholders
- 6.3 Outreach to the public
- 6.4 Outreach to policymakers
- 6.5 Outreach to researchers

Summary
- High-performance buildings must have good indoor environmental quality to achieve their purpose
- Energy efficiency and good IEQ requires improved understanding of key issues
- IEQ knowledge gaps in tropical climates include HVAC hygiene, thermal comfort, bioaerosols, and temperature/humidity effects on pollutant dynamic behavior
- SinBerBEST will enhance knowledge that will advance IEQ science and improve building practice

Source: WJ Fisk et al., Indoor Air 19, 159-165, 2009.