IEA-Annex 68 IAQ Design and Operation Strategies for Low Energy Residential Building

A Proposed Framework for Modeling and Benchmarking (draft for discussion)

By
Jensen Zhang, John Grunewald, Menghao Qin, and Carsten Rode

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Outline

☐ Introduction
  ◆ Objectives of IEA-Annex 68 Task 3 Modeling
  ◆ Potential IAQ problems in low-energy buildings
  ◆ IAQ control concepts and principles
  ◆ Role of modeling and benchmarking

☐ A proposed framework for modeling and benchmarking
  ◆ A single zone model for load analysis
  ◆ Multizone whole building models
  ◆ Definition of reference buildings

☐ Next steps and challenges
Objectives of Annex-68 Task 3: Modeling

- Review, analyze knowledge gaps, and categorize existing models and simulation methods
- Collect and develop validated reference cases for modeling and simulations
- Use contemporary whole building analysis tools and methods to predict the hygrothermal conditions, sorption and transport of humidity and chemical substances, and energy consumption within buildings

CHAMPS --- Combined Heat, Air, Moisture and Pollutant Simulations

*Design or Control Parameters

*Shared databases*

*Envelope model

*Room model

*Predicted Building Performance & Dynamics

*Databases: Material Properties; Pollutant Properties; Sources & Sinks; Weather*
Low-Energy Buildings and IAQ

- Energy efficiency measures
  - Air-tight construction
  - Super insulation
  - Heat recovery ventilation
  - Natural or hybrid ventilation
  - Wind energy harvesting
  - Solar heat and solar PV
  - Thermal storage
  - Efficient lighting

- Potential IAQ problems
  - Low tolerance for error in construction and operation
  - Inadequate control of indoor pollution sources
  - Introduction of pollutants from outdoors and building enclosure
  - Insufficient outdoor air for pollutant dilution
  - Inadequate moisture control
Air Pollution Processes and Control

Pollutant Sources

Outdoor
Indoor

People
Materials & equipments
Reactive compounds

Transport

Inhibitors & Sinks

Source controls
• Remove or prevent sources
• Lower source emissions
• Exhaust pollutants locally

Ventilation
• Delivery clean air
• Dilute pollutants

Air purification
Source Control, Ventilation or Air Purification?

Normalized Airflow Rate vs. $C_{\text{criteria}}$

- Target pollutant (e.g., formaldehyde)
- Particulates
- Bio-effluent

Minimum ventilation rate for unknown pollutants

Ventilation Rate Requirement

Acceptable Air Pollution Level

$\Delta Q$

Typical load

50% reduction
Integrated IAQ Strategies

1) Source control to the extent possible
   - *Removal and prevention of pollutant sources*
   - *Emission reduction*
   - *Local exhaust/suction*

2) Ventilation
   - *Dilution for all pollutants (known or unknown)*
   - *Personal air delivery*

3) Air cleaning/purification
   - *Active or passive*
   - *For target pollutants*
   - *No harmful byproducts allowed*

The goal of integration is to improve IAQ in a most energy-efficient and cost-effective manner.
Role of Modeling and Benchmarking

- Physical, chemical and biological processes affecting IAQ
  - *Sources and sinks, ventilation, and air purification*
- Interactions between energy efficiency and IAQ strategies
  - *e.g., Energy recovery and ventilation, Solar heating and material emissions, Natural ventilation and air cleaning*
- Performance evaluation of energy efficiency and IAQ strategies
  - *How do the proposed strategies compare to reference buildings?*
- Recommendations of optimal IAQ strategies in low-energy buildings
A Framework for Modeling and Benchmarking

- A single zone model
  - Pollution load and “budget” analysis comparing to the established IAQ targets
    - Sources and sinks, and their interactions
    - Indoor and surface chemistry
    - Effects of temperature and humidity
  - Validation by full-scale chamber test data
  - Evaluation of IAQ strategies for the reference house and extrapolation to other houses

- Multizone whole building models
  - CHAMPS-MZ, CONTAM, DesignBuilder/E+, VDS/E+/CHAMPS-MZ
  - Energy and IAQ performance evaluation against the reference house

- Definition of reference buildings for benchmarking
  - Different references for dissimilar type of residences - Single family house, semi-detached, townhouse, low-rise apartment, high-rise apartment
  - Different references for dissimilar climate zones
A Single Family House Example

- **Definition of a reference house for single family houses**
  - **Climate zone:** 6A
  - **Size and occupancy:** 1500 SQFT, two stories with a basement, 3 bedrooms, two bathrooms, a kitchen/dinning room, a living/family room
  - **Design specifications:** Building America practice, ASHRAE 62.2, and 90.2
  - **Design Builder/E+ simulation to determine baseline energy consumptions**

- **Single zone model representation**
  - **Indoor sources and sinks**
  - **Infiltration**
  - **Ventilation**
  - **Air purification**

- **Whole building model representation**
  - **DesignBuilder/E+ and CONTAM**
  - **VDS (CHAMPS-MZ and E+)**
  - **Modelica + GUI**


Source: Tim Stenson, Syracuse University
Next Steps and Challenges

- Develop an approach for scaling and extrapolation
  - Dimensional analyses and reference scales
  - Design and operating conditions
  - Performance indices
- Develop a method to quantify the uncertainties in the simulation results
- Develop a protocol for reliable modeling and simulations – quality assurance
  - Comparison between different tools for reference buildings
  - Parametric studies for trend analysis
  - Comparison with field measurements (e.g., NIST Net-zero energy house)
Thank you.