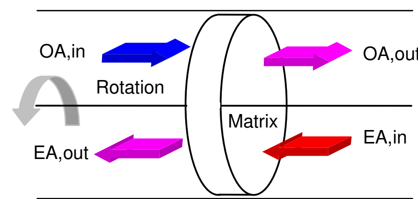
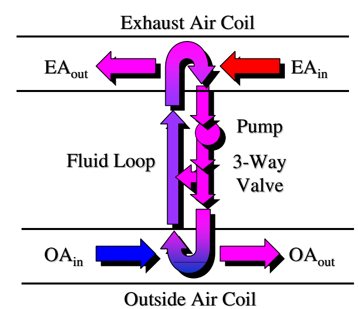
New TRNSYS Types to simulate Air-To-Air Energy Recovery

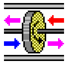


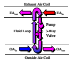


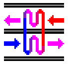
Sebastian Freund, Michaël Kummert

Presentation Overview

- Why Air-To-Air Energy Recovery?
  - Heat recovery
  - Humidity Recovery
- 2 different approaches
  - Enthalpy Exchanger
  - Runaround Loop
- New Types
  - Modeling
  - Integrated Controls
- Application Example





Why Air-To-Air Energy Recovery?

- Modern buildings:
  - Well insulated
  - IAQ becomes more important
    - Strict ventilation standards
    - Often more than 30 $m^3\ h^{-1}\ pers^{-1}$
    - Comfort → Temperature AND humidity

  → Ventilation is responsible for a large fraction of HVAC energy use
- Solution: Energy recovery
  - Heat exchanger between inlet air and exhaust air
  - Humidity and Temperature: Enthalpy exchanger

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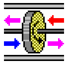
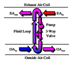
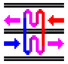
2 Different approaches

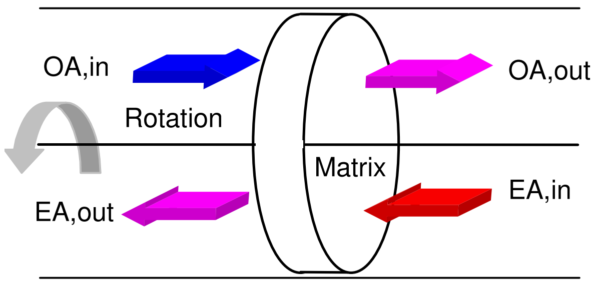
- **Enthalpy exchanger**
  - Rotary heat and mass exchanger (regenerative)
  - Requires exhaust and inlet flows to cross each other
  - Well adapted to new buildings
  - “Total solution”: Heat and mass transfer
- **Runaround loop**
  - Two air/water heat exchangers + water loop
  - Well adapted to existing building where ventilation ducts cannot be modified
  - No “humidity recovery”
  - No cross-contamination is possible





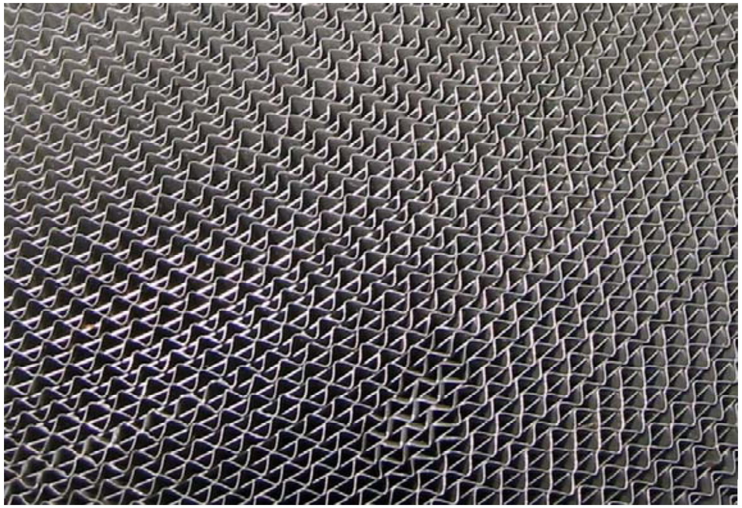


Rotary Enthalpy Exchanger



- Cylindrical Wheel
  - Numerous parallel channels
  - Each half works intermittently in each flow (regenerative)
- Matrix:
  - Desiccant coated Aluminum foil
  - Polymer membrane with desiccant substance (e.g. silicagel or molecular sieve)

The Enthalpy Exchanger Matrix



- corrugated aluminum coated with a molecular sieve

- Polystyrene membrane coated with silicagel

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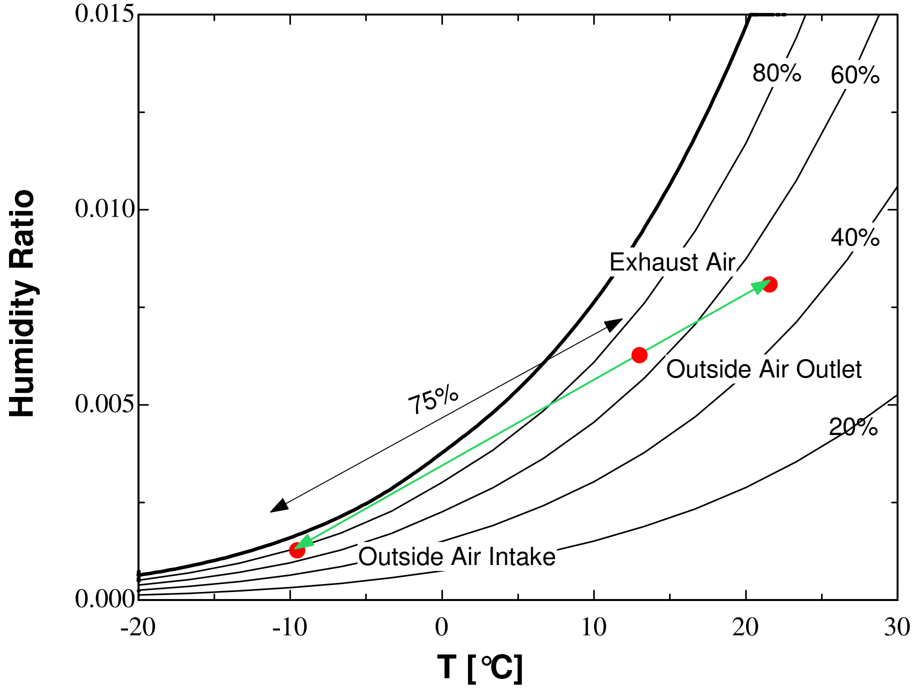
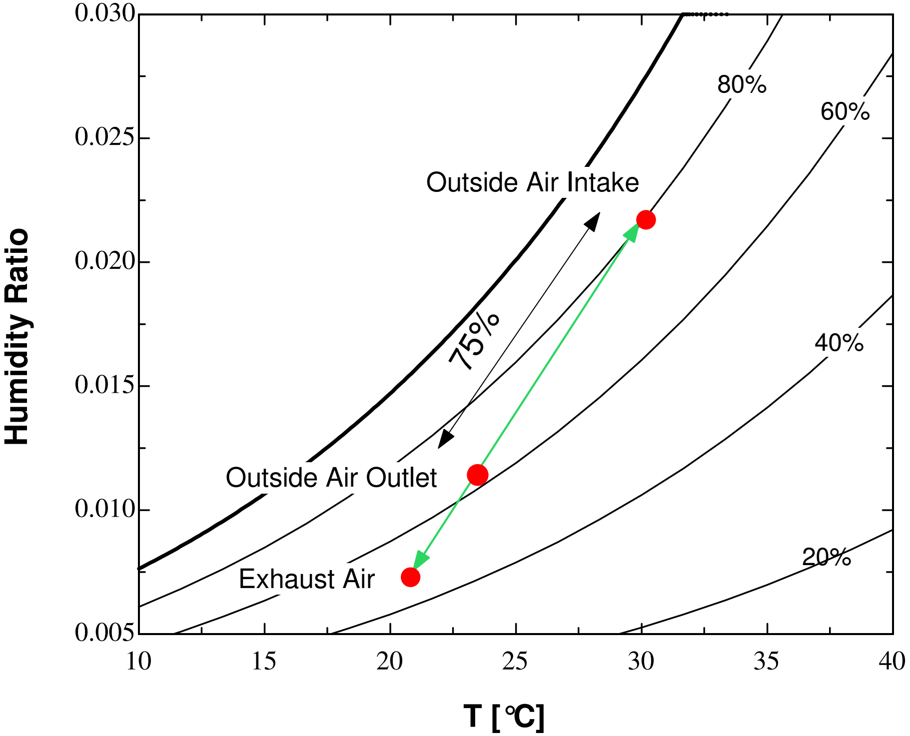
Some psychrometric charts



Heating ↑

Cooling ↓



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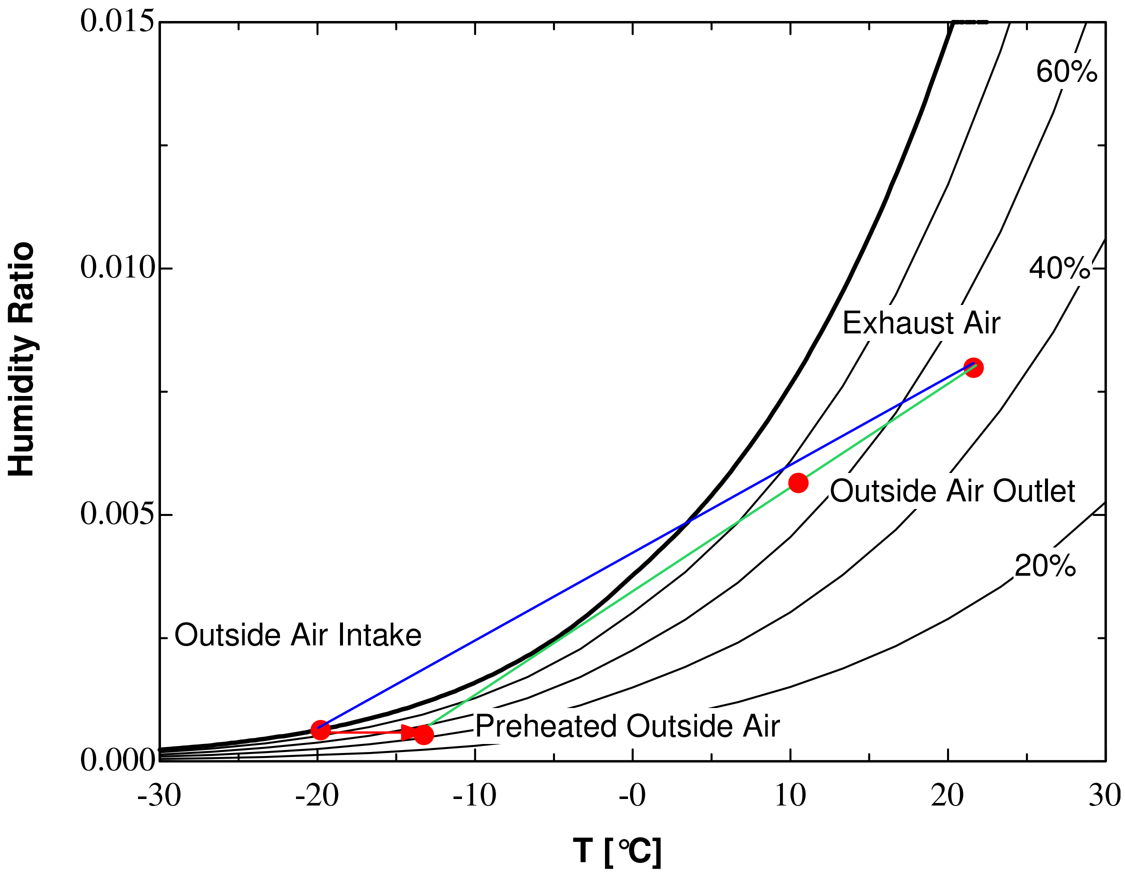
An interesting problem: freezing



- Solutions
  - Lower rotation speed (lower effetiveness)
  - Preheat outside air (preferred option)
- Usually happens for Tamb < -10°C

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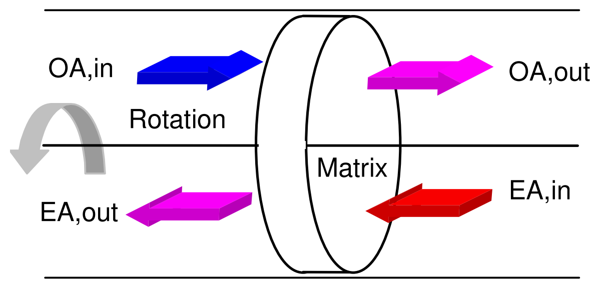
Modeling

- Effectiveness (Heat and Mass transfer)

$$\varepsilon_T = \frac{T_{OA,\,in} - T_{OA,\,out}}{T_{OA,\,in} - T_{EA,\,in}}$$

$$\varepsilon_w = \frac{w_{OA,\,in} - w_{OA,\,out}}{w_{OA,\,in} - w_{EA,\,in}}$$



- Counter-flow Heat exchanger with a correction factor

$$\varepsilon = c\,\frac{1 - e^{(-NTU\,(1-C_r))}}{1 - C_r\,e^{(-NTU\,(1-C_r))}}$$

c: correction factor

Note: one effectiveness for Temperature, one for humidity

Model parameters / limitations

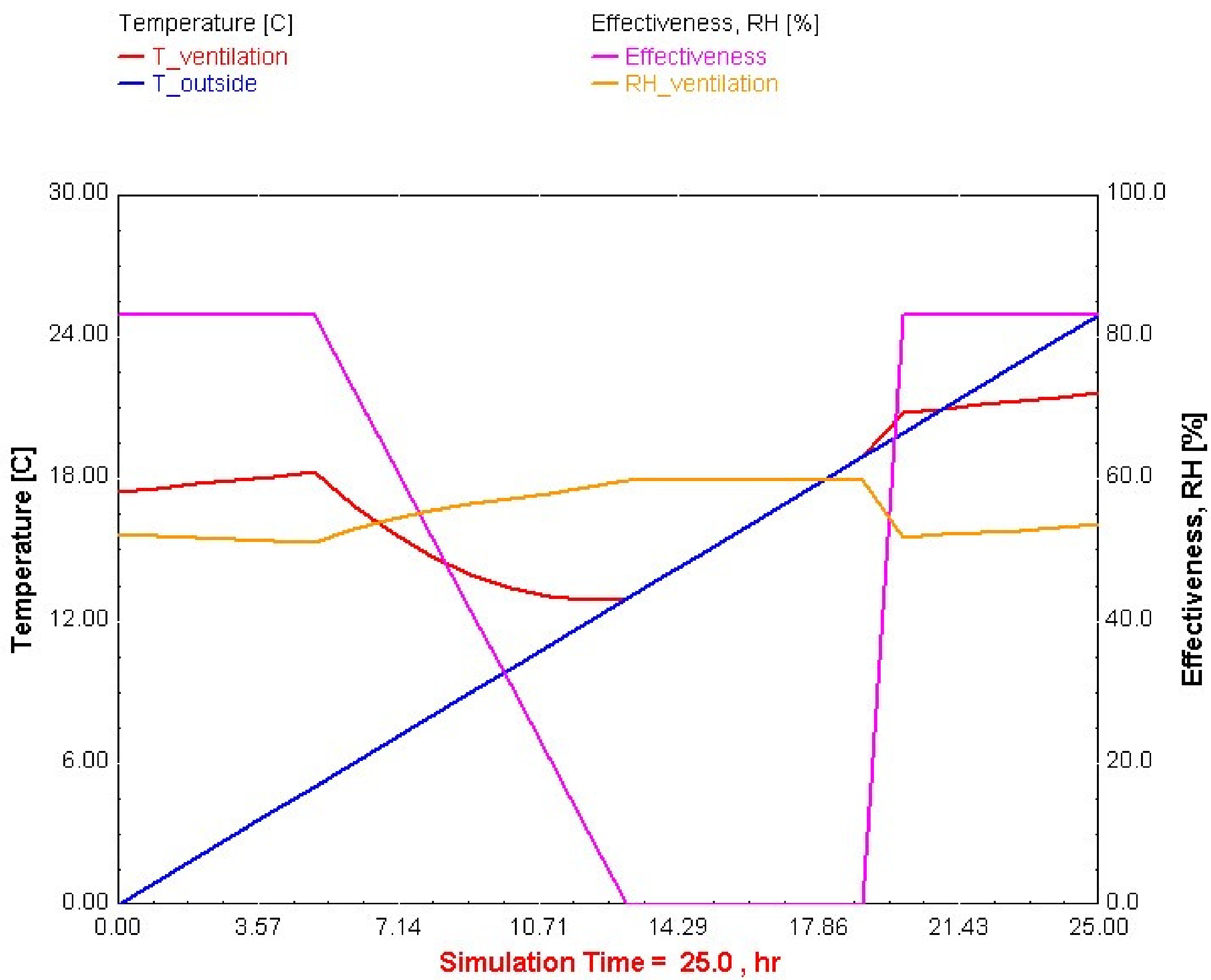
- What do you need?
  - 2 experimental data points
    - catalog data
    - ARI tests (Air Conditioning and Refrigeration Institute)
    - Not “just” a curve fit (c is adapted for unbalanced flows)
- Limitations
  - Not usable to design an enthalpy exchanger
  - Flow rates close to experimental data range
    - Implicit assumption that UA is constant (laminar flow rate at all times)
  - Sufficient rotation speed
    - Recommended rotation speed for enthalpy exchangers
    - Lower speed would significantly decrease ε

Integrated controls

- 2 problems
  - When cooling is required with Tamb < Tbldg
    - “Economizer” mode (bypass the enthalpy exchanger)
    - Take humidity into account!
  - Freezing
    - Preheating or reduced effectiveness (choice in the model)
- Extra inputs for economizer mode
  - Building “heating point”
  - Building “balance point”

  (see manual and proforma for details!)
- Other output: pressure drop
  - based on 2 data points

Economizer operation



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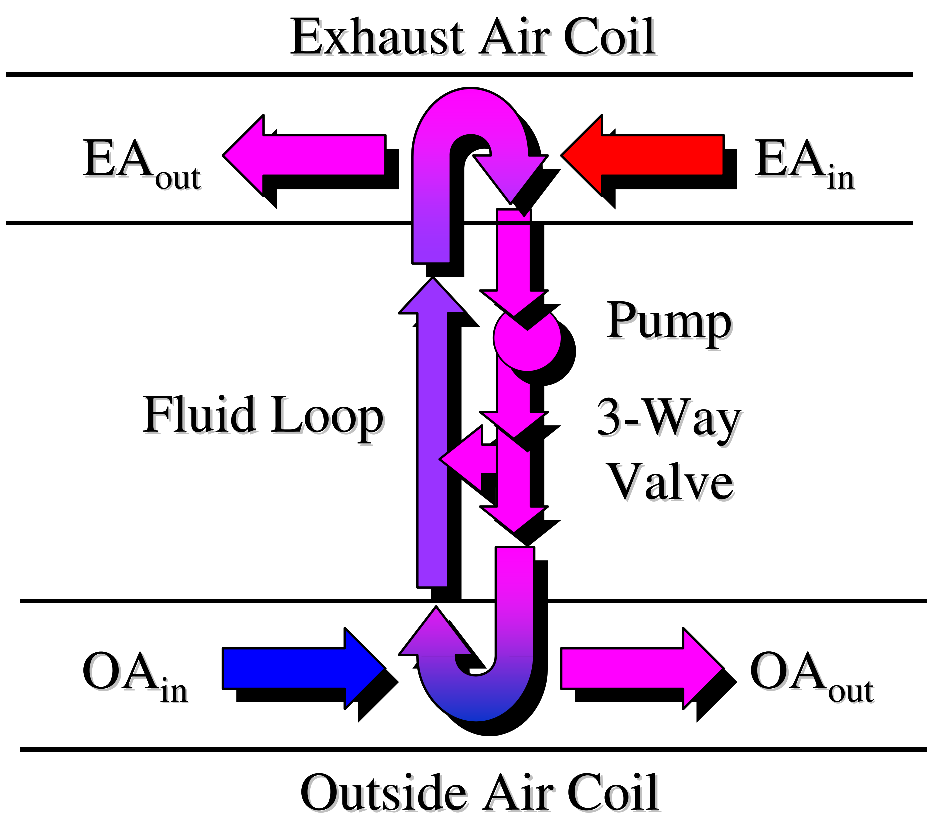
Runaround Loop



- Heat exchange only
  - Preheating (wintertime)
  - Precooling (summertime)
  - Reheat (summertime)
- Replaces long air ducts by long water pipes (more efficient)
- 2 Heating / Cooling coils
- Control variables
  - Water flow rate (pump or bypass)
  - Air bypass

Runaround Loop Model

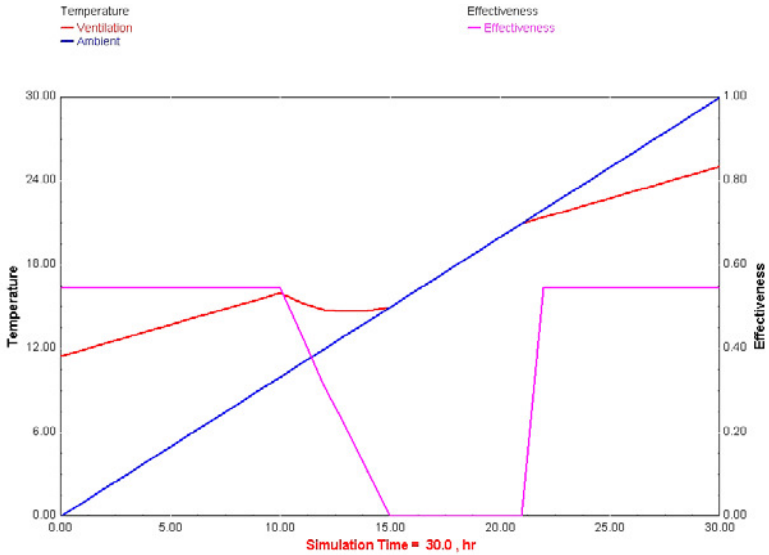
- Effectiveness approach

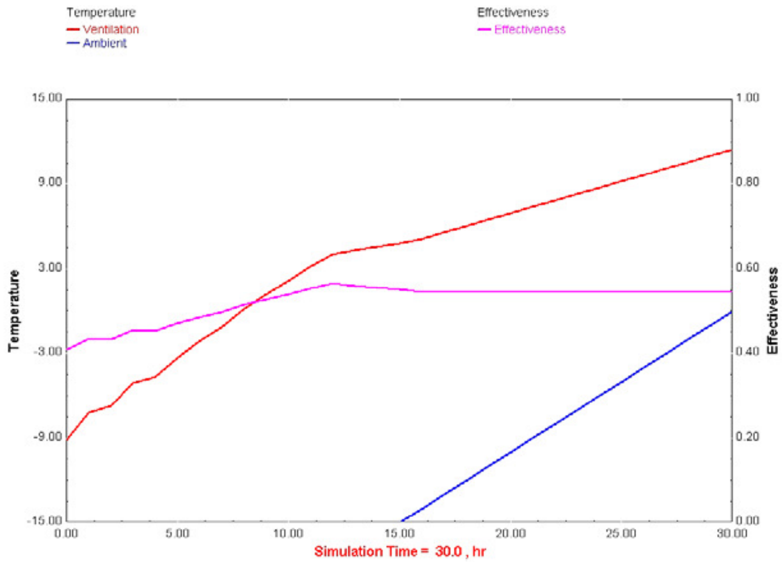
$$\varepsilon_o = \frac{1}{\frac{\dot{C}_{\min}}{\dot{C}_{\min,1}\varepsilon_1} + \frac{\dot{C}_{\min}}{\dot{C}_{\min,2}\varepsilon_2} + \frac{\dot{C}_{\min}}{\dot{C}_{liq}}}$$

- ε1, ε2: effectiveness of each coil
- Model data:
  - Geometrical coil data
  - Design conditions
- The model
  - Computes heat exchange coefficients (air / liquid)
  - Takes condensation into account: wet coil operation
  - Computes Pump and fan power (needs 1 data point)

Integrated controls

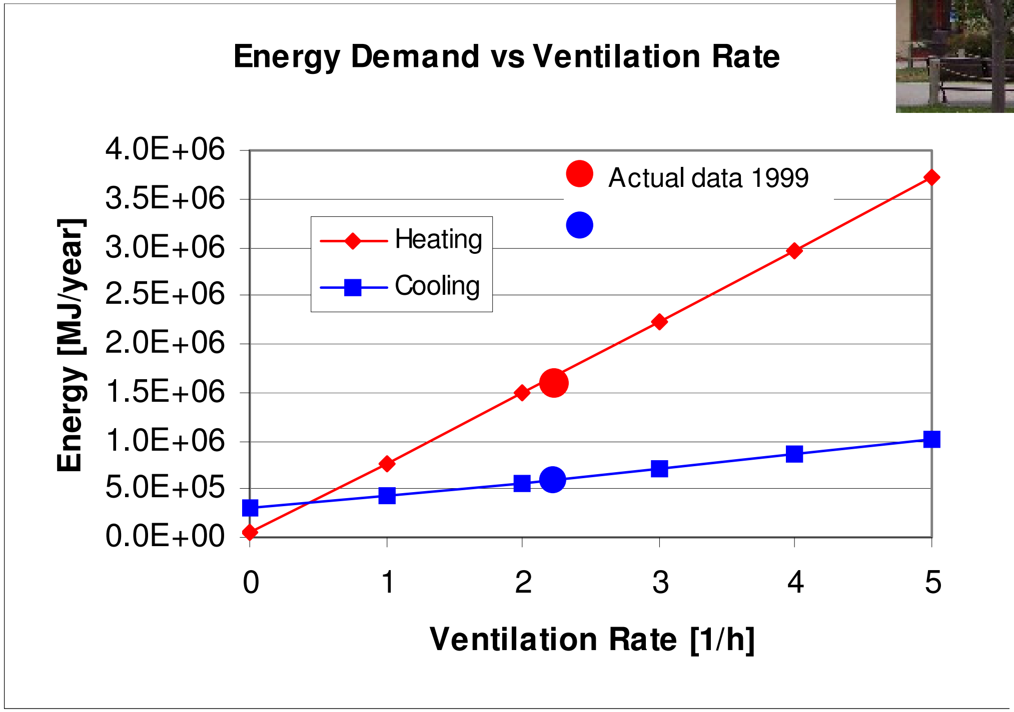
- Economizer mode and frost protection
  - Similar to Enthalpy exchanger controls



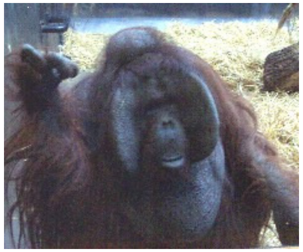


Application example

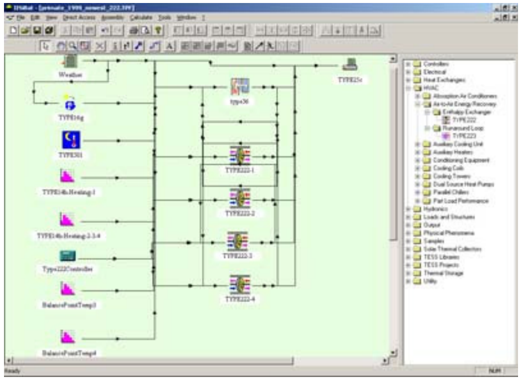
- Madison zoo

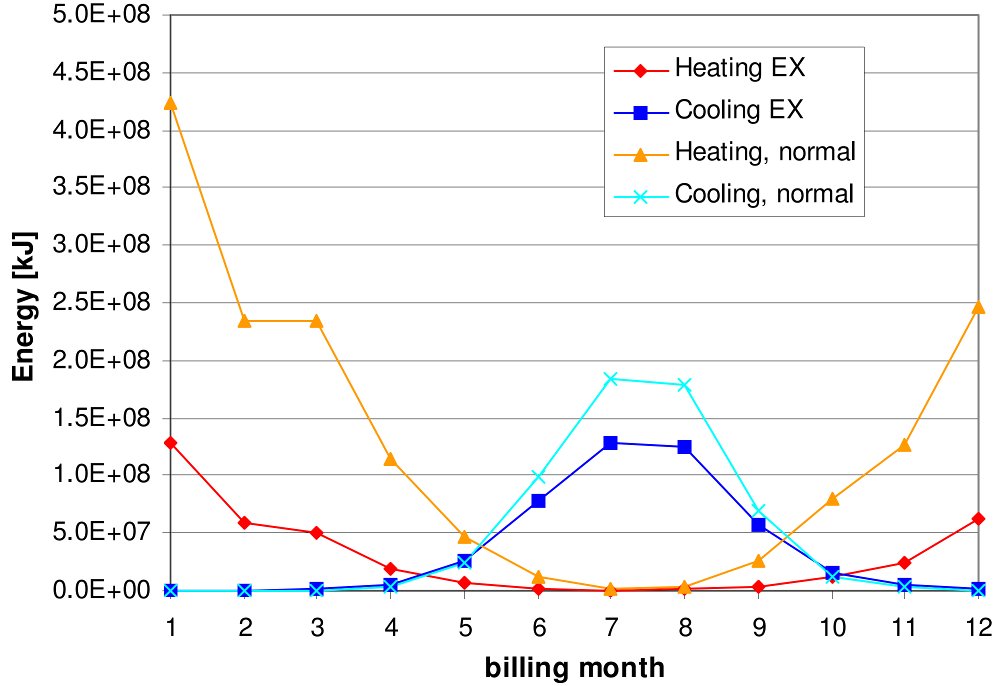


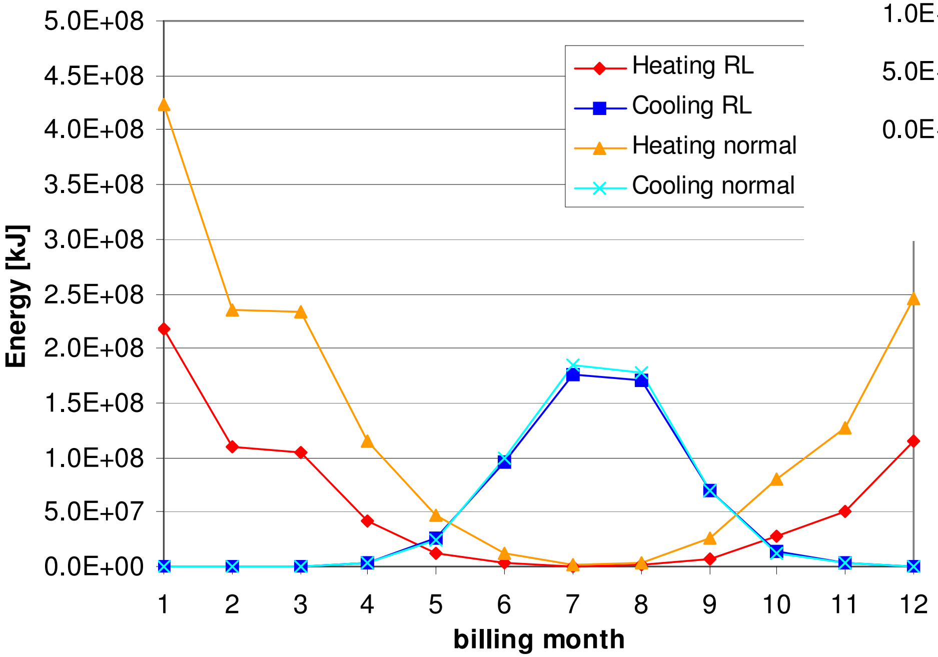
- High ventilation rate
- 4 zones
- Unusual internal gains (sensible and latent)



Enthalpy Ex vs. Runaround Loop







Savings

EEx: 75% Heat, 25% Cooling

RL: 55% Heat, 5% Cooling

EEx also reduces Peak Power from 65% (H) and 45%(C)

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Conclusions

- 2 Types are included in TRNLIB
  - Available on the website: http://sel.me.wisc.edu/trnsys (Go to TRNLIB)
  - Code, Manual + IISiBat Proforma

- More details?
  - Sebastian Freund's MS (available on the SEL website) http://sel.me.wisc.edu/ (Go to "Publications")