Presentation to:

Rocky Mountain ASHRAE

2008 Tech Conference

Mechanical Systems Design

For

Low Energy, High Performance Buildings

April 11, 2008

by:

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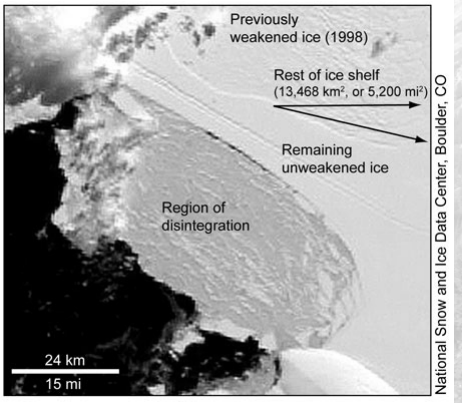
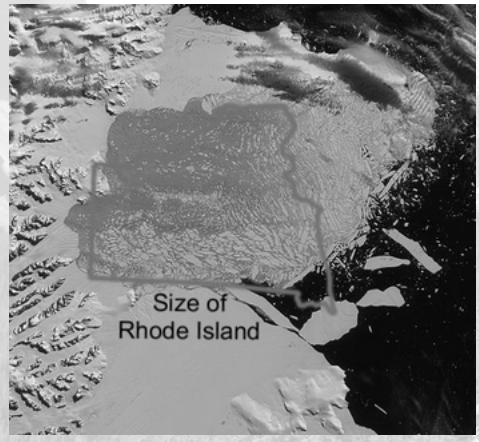
Climate Change Warnings

- 1600 sq. miles collapsed: 4% of the total Wilkins ice shelf
- 5,200 sq. miles remaining of Wilkins Ice Shelf now at risk



Wilkins Ice Shelf, West Antarctica

Larsen B Ice Shelf Collapse



Larsen B Ice Shelf Collapse

An Island Made by Global Warming
By Michael McCarthy
The Independent UK

- Sea level rise is already accelerating. Sea levels are going up around the world by about 3.1mm per year - the average for the period 1993-2003. That is itself sharply up from an average of 1.8mm per year over the longer period 1961-2003. Greenland ice now accounts for about 0.5 millimetre of the total. (Much of the rest of the rise is coming from the expansion of the world's sea water as it warms.)

Passiv Haus

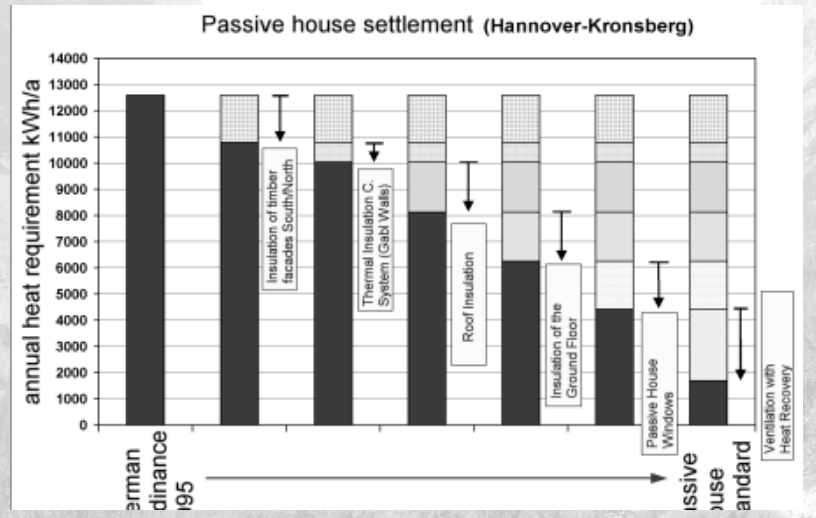
Systems in Europe Passivhaus

- See passivhaus: in C:\User_Files_02\Users_Design_Notes\Design Notes\Energy\Projects\PassivHaus
  - Superinsulation
  - Triple glazed, high performance windows
  - High eff heat recovery with supplemental heat & defroster heater (OSA)
  - Air tightness testing
  - PV
  - Solar thermal
  - Detailed sealing requirements
  - Thermal mass
  - Infrared scans
  - Detailed insulation requirements – even at roof vent penetrations
    - Minimize thermal bridging
  - Floor slab insulation
  - Efficient appliances
  - Component effect: pdf page 47
  - Performance, pdf page 93,…
  - Details, pdf page 134, …
  - Wardrobe dryer, pdf page 143

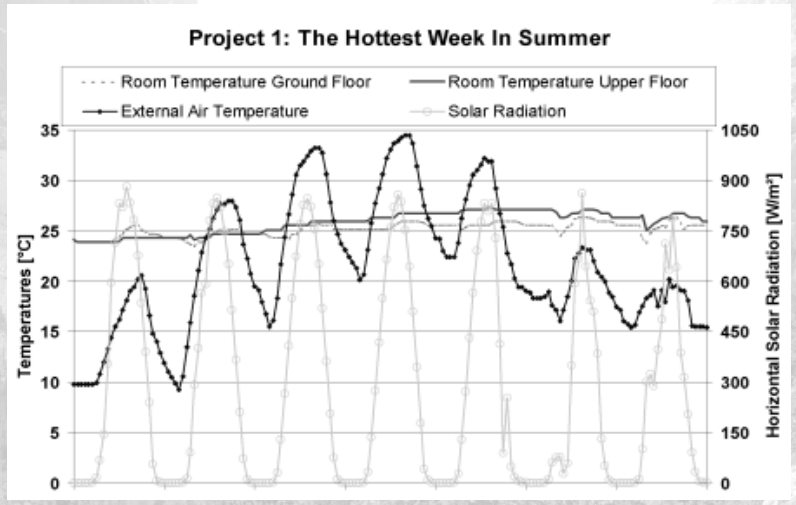
Systems in Europe Passivhaus

- Heat recovery defrost heater
- Why?
- Cool tube alternate
  - Cautions
    - Mold
    - Very high filtration requirements and sealing
    - Perhaps ultraviolet lights

Passivhaus savings increments



Passivhaus passive cooling performance



Presentation only

Client Goal: Happy, Productive Occupants

Building Energy

- Heating
  - Infiltration
  - Windows
  - Skin
  - Heating equipment
- Lighting
- Equip & plug loads
- Process

- Cooling
  - Infiltration
  - Solar
  - Skin
  - Lighting
  - Equipment
  - Process
  - Cooling equipment

HVAC System Options

- Commercial - Industrial
  - Transitional systems
  - The best efficiency will keep getting better
  - Buildings as net producers
- Residential
  - Some examples exist & more emerging
  - Net Zero
  - Net Producers

Current Sustainable Mechanical System Strategies for Colorado

- Displacement ventilation
- Natural ventilation
- Variable flow – air & water
- Heat recovery
- Ice storage
- Ground source heat pumps
- Thermal building mass
- Active & passive solar energy
- Indirect/direct evaporative cooling
- High efficiency boilers, motors, chillers, etc.
- Be proficient in these!

Current Sustainable Mechanical System Strategies for Colorado – pg 2

- Separate outside air systems
- Individual comfort control – integrated

Handout for detail

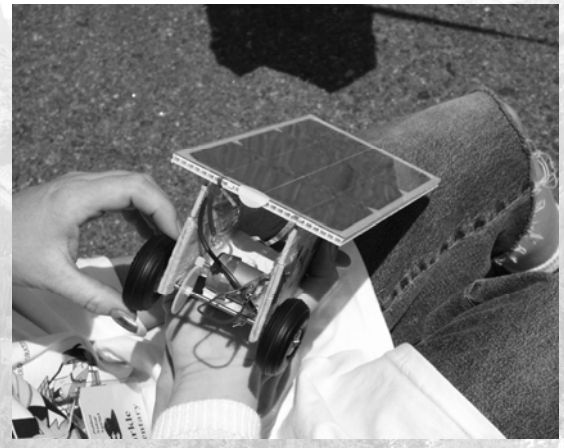
What's Next?

- Lower energy use systems
- Integration of systems & buildings
- Desiccant cooling – solar thermal regeneration
- Solar powered absorption cooling
- New, as yet imagined, mechanical/building systems
- New methods of control, TAB – Cx – M & V
- New analysis & modeling tools

Presentation only

Creativity

- Trapper stove



Handout for detail

Toward Living Buildings – What is it?

- Fully integrated mechanical, electrical, architectural, functional building components
- Building parts serve multiple functions, as the organs of a human
- Shared materials, interactive functions
- The building comes alive and responds to the needs of the occupants

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Living Buildings

- The human analogy
  - To stay warm, blood vessels constrict
  - To cool down, blood flows to the extremities, evaporation
- The living building
  - Sense and respond to your needs
  - Automatically adjust shading
  - Store heat or cool in its mass
  - Anticipate future needs
  - Clean your air, provide natural lighting
  - Needs a brain, nervous system, sensors, strong muscles, lungs, heart, …

Handout only

Living Buildings

- Living Building
  - Flexible = meets changing needs = durable
  - Anticipates occupant / zone comfort needs
  - Responds to weather / sunlight changes
  - Store solar heat per anticipations
  - Night cooling & storage per anticipations
  - Integrated into the architecture
  - Many (or all) system components are building parts

Handout only

Living Buildings - Human Analogy

- Body sweats - building evaporative cooling, roof sprays
- Body constricts blood vessels - building needs variable insulation
- Body pumps blood - building pumps hot/cold water
- Lungs filter air
- Eyes dilate - building adjusts windows, glazing shading
- Body stores fat - building mass stores heat/cool (thermal mass)

Mechanical Systems in Context

- Zero or net zero
- Building must be ultra-efficient

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Future of Buildings

- Mechanical & Electrical systems:
  - Ultra-efficient
- Processes:
  - As efficient as possible
- Buildings as whole:
  - Net energy producers
  - Solar, PV, Wind, Biomass, etc.

The Future of HVAC

- Conservation
- Efficiency
- Integration
- Living Buildings
- Warmer climate
- Higher global humidity
- Higher populations
- Expectations: healthier buildings

Zero Energy Building Critical Features

- Daylighting must work
- Mechanical sizing based on successful daylighting
- Windows
  - Weather protection
  - Let light in
  - Winter: let heat in
  - Summer: keep heat out
  - Passive or active controls

Integrated Design
Load Reduction

- Window shading, reduced loads & mechanical cost
- View
- Optimize use of natural light
- Daylighting
- Corner lighting minimizes contrast

Daylighting Success

- Upper, daylight: shaded, clear
- Lower, view: low SHGF, low e

- Upper vs. Lower windows

Handout for detail

Load Reduction - Daylighting

- Healthy, Comfortable Lighting
  - Diffuse, even, low glare
- Reduced Mechanical Loads
  - Occupancy sensors: open offices
  - Daylight control system - photocells
  - Low energy: Reduced Mechanical & Electrical Costs

Integrated Design - Daylighting

- Old days: 2.5 W/SF
- Now: 0.8 W/SF
- Better:
  - Daylight
  - Night or heavy clouds: Background: controlled +/- 0.2 W/SF
  - Task lighting
- Daylight MUST work
  - Mech sizing depends on effective daylighting
  - Minimal or no glare
  - Uniform lighting
  - Independent daylight design peer review
  - Contract req't

Handout for detail

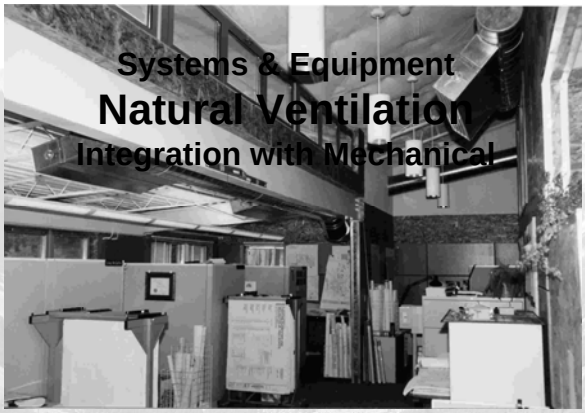
Load Reduction

Daylighting Success

- Fully Commit to the Goal
  - Sufficient Controls
  - **Integrate with Mechanical**
- Lighting Control - Tools for Success!
  - Occupancy Sensors
  - Photocell Control (Exterior, non-tamperable)
  - Multiple Lighting Zones per room
  - Independent Zone Dimming
- Commissioning
  - Assure cooling loads reduced - **Integrated Performance Test** - team commitment, not one fall guy (person)

Integrated Design – Natural Ventilation

- System monitoring/control input
  - Window bugs and other sensors
  - Outside air temperature – roommate effect
  - Solar intensity
  - Building energy balance
- Occupant feedback
  - Mode lights, message boards
  - Open/close window recommendations
  - System lockouts (from window bugs)

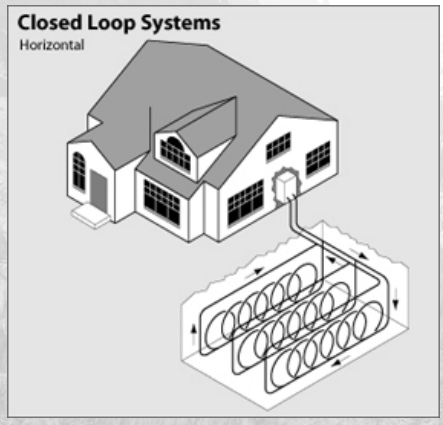


- Manual window operation vs. mechanical energy consumption
- Window sensors (“bugs”)
- Feedback to Occupants
- Mechanical lock-outs
- Commissioning
- Automatic or Manual?

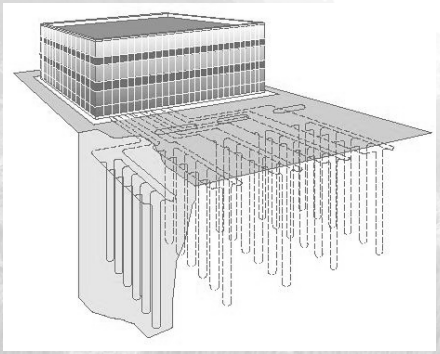
Ground Source Heat Pumps (GSHP)

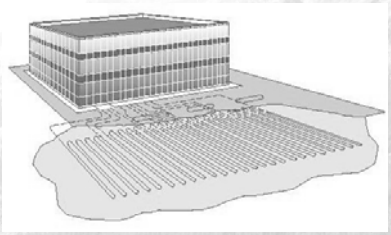
- Ground
  - thermal sink
  - or thermal source
- Surface contact area in ground
  - More = + efficiency
  - More = + cost
- Many kinds
  - Vertical bores
  - Horizontal tubes
  - Slinkies
  - Ponds
  - Ground water

Slinky

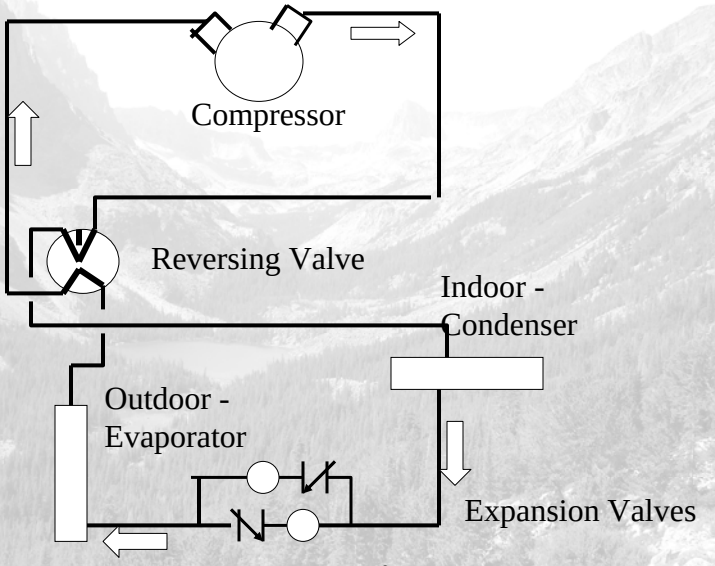


Vertical & Horizontal systems

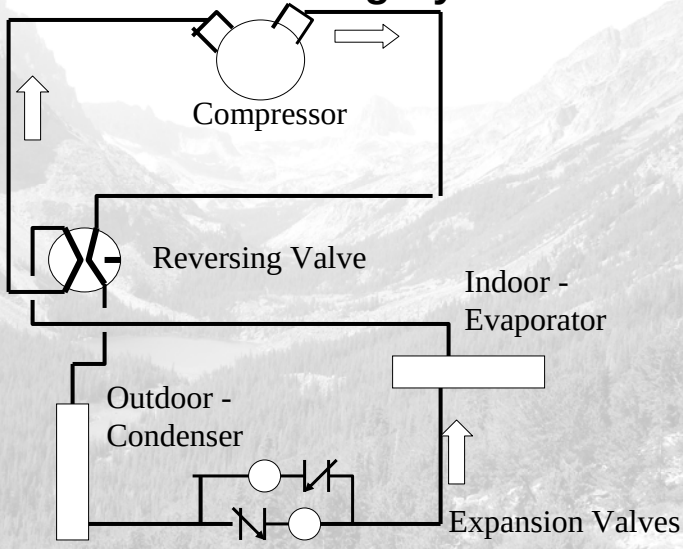




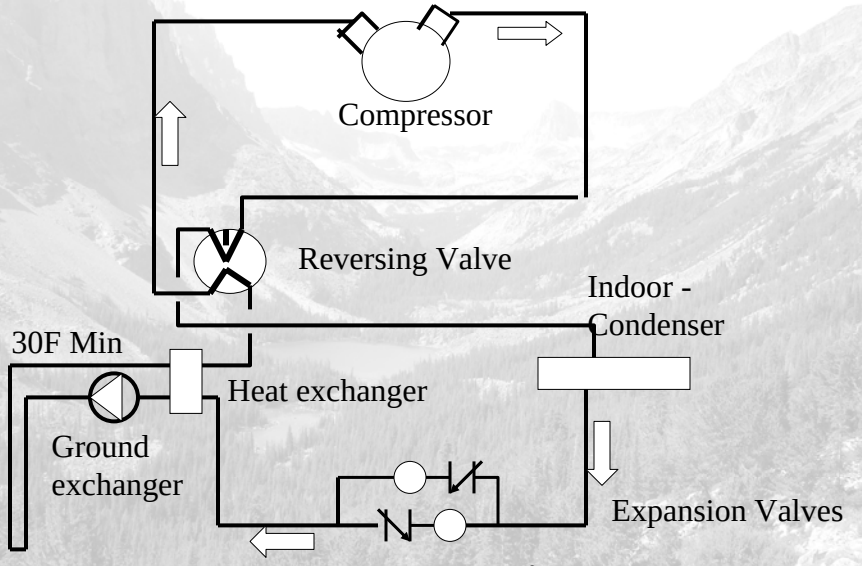
GSHP Basic Heating Cycle



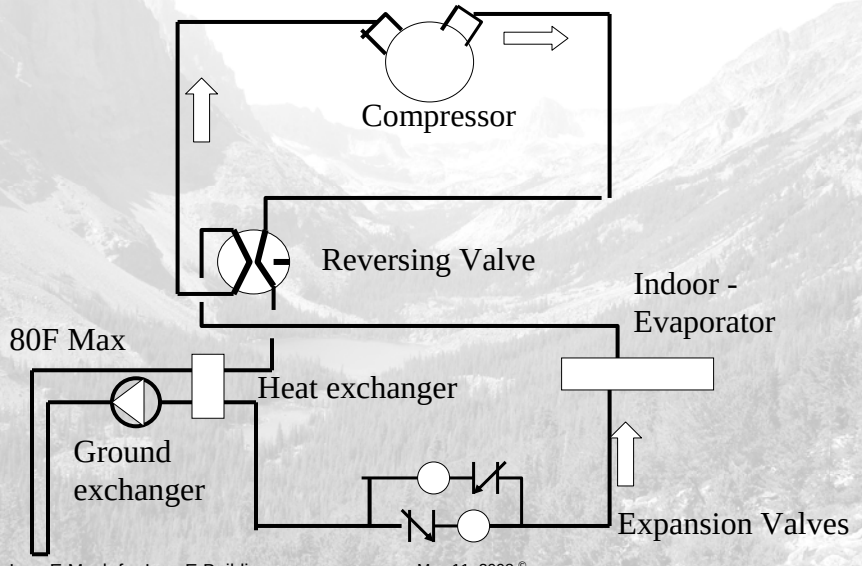
GSHP Basic Cooling Cycle



Ground Source Heat Pumps - Heating

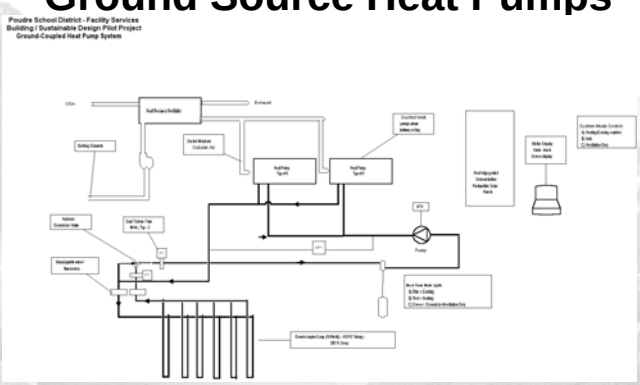


Ground Source Heat Pumps - Cooling



Ground Source Heat Pumps

Handout only



- Heat rejection/absorption from earth
- Design, heating 30F EGT; cooling 80F EGT

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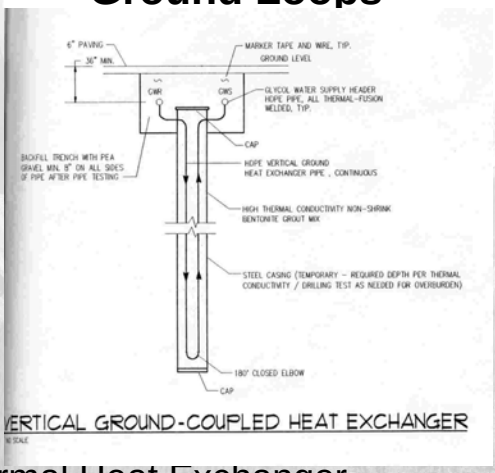
Ground Loops



- Geothermal Heat Exchanger
  - 1” HDPE, High conductivity grout

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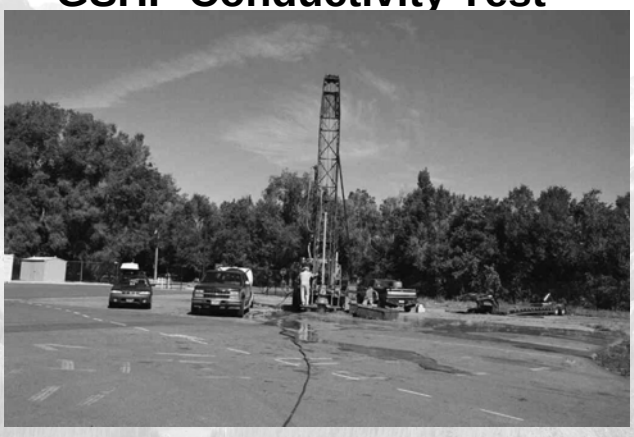
Ground Loop Sizing

- Heat Exchange
- Temperatures
- Conductivity
- Factors (soil, water, …)
- Criteria
  - Heating: 30F EWT to 22F LWT, ideally stable down to 15F EWT
  - Cooling: 80F EWT to 88F LWT, sized for 70F

Ground Loop Efficiency – Project example

- Base (example)
  - 80F EWT and 19.2 EER
  - Less cost
- Efficient (example)
  - 70F EWT and 22.2 EER
  - 15.6% more efficient
  - More ground piping

GSHP Conductivity Test



- Conservative design for bidding
- Unit price bid alternates per test

Displacement Ventilation & Underfloor Air

From: "Models for Prediction of Temperature Difference and Ventilation Effectiveness with Displacement Ventilation Xiaoxiong Yuan, Ph.D. Qingyan Chen, Ph.D. Leon R. Glicksman, Ph.D."

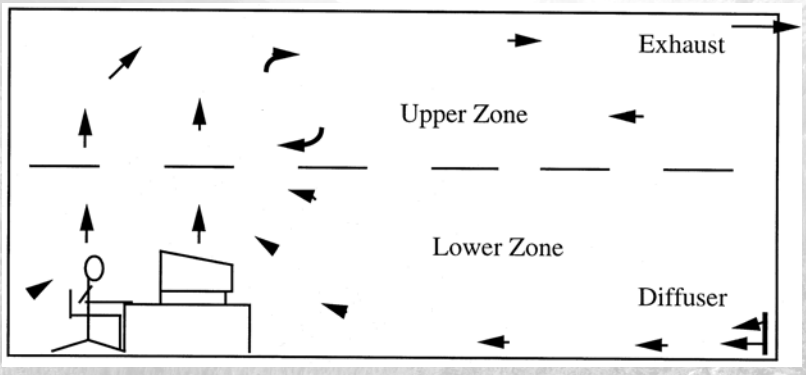


Figure 1 *Sketch of displacement ventilation.*

Basic equation for heat to zone, smaller spaces, per previous study

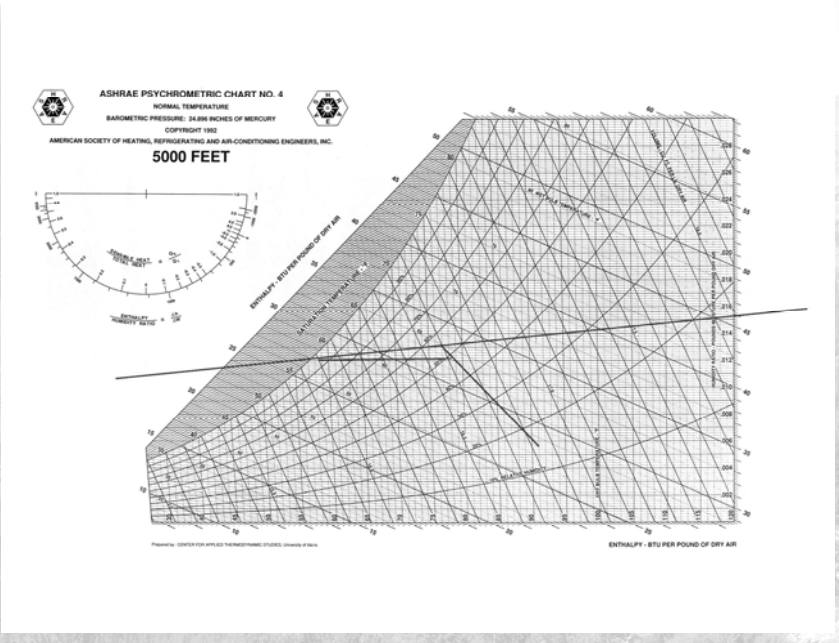
- $D T_{hf}\, r C_p V = a_{oe} Q_{oe} + a_l Q_l + a_{ex} Q_{ex}$
- where
  - *Qoe* = heat generated by occupants, desk lamps, and
  - equipment, (*Qo*+*Qdl*+*Qe*);
  - *Ql* = heat generated by overhead lighting;
  - *Qex* = heat from the exterior wall and window surfaces and
  - the transmitted solar radiation;
  - a_{oe}, a_l, and a_{ex} = weighting coefficients for the contribution of the convective heat to the air between head and foot
  - a_{oe} = 0.295; a_l = 0.132; a_{ex} = 0.185

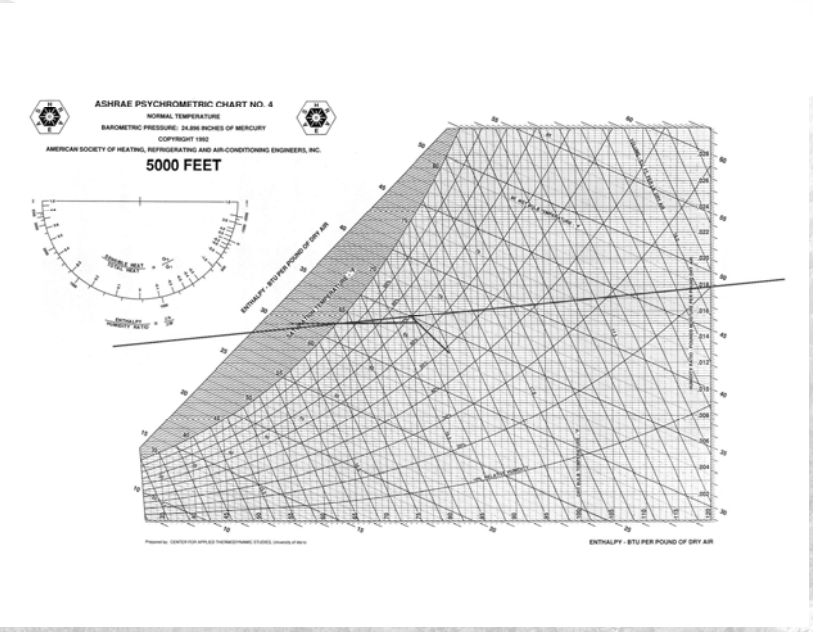
Mark Hogan, Tom Webster, Fred Bauman
Center for the Built Environment (CBE)
University of California, Berkeley

- Underfloor issues in order
  - Supply air leakage
  - Airflow temp decay
  - Air leakage, floor
  - Dust & dirt in plenum
  - Stratification
  - Moisture issues

Displacement Ventilation

- Humidity
  - Higher SAT: 62 to 65
  - Less inherent dehumidification
  - Bypass return air to mix with coil air
  - Desiccant dehumidification
  - Mix dual air streams
- Supply air temp control
  - Good mixing
  - Modulation to control to desired supply temp





Plenum leakage – construction details

Leakage Rates

- **Construction quality leakage**
  - Not to exceed 0.05 cfm/ft2 at 0.05 in H2O
  - (e.g., 1,000 cfm for a 20,000 ft2 floor plate at 1 cfm/ft2)
- **Floor leakage**
  - Not to exceed 0.10 cfm/ft2 at 0.05 in H2O
  - (e.g., 17% leakage for an interior zone with 0.6 cfm/ft2 design airflow)
- **Test a full-scale mock-up at first stage of construction.**
  - **Fix bypass openings**
  - **Seal leaks**
  - **Test again.**

Underfloor air mixing within stratification zone

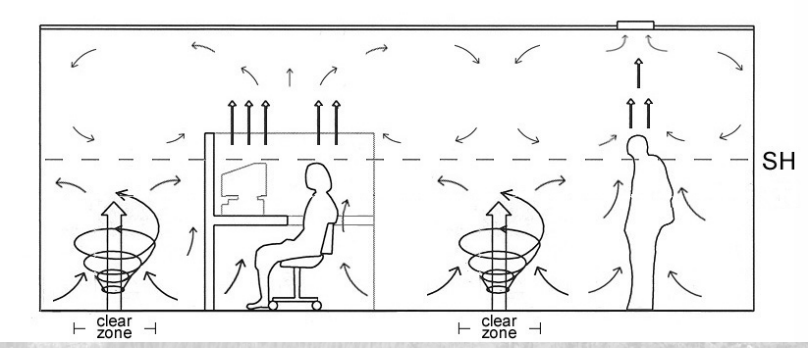
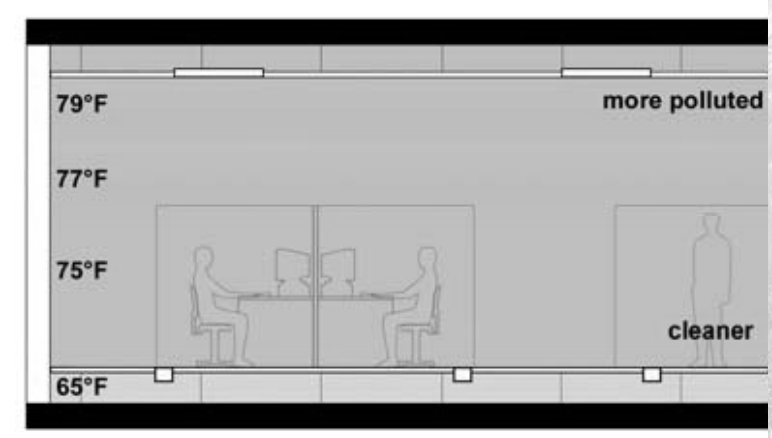


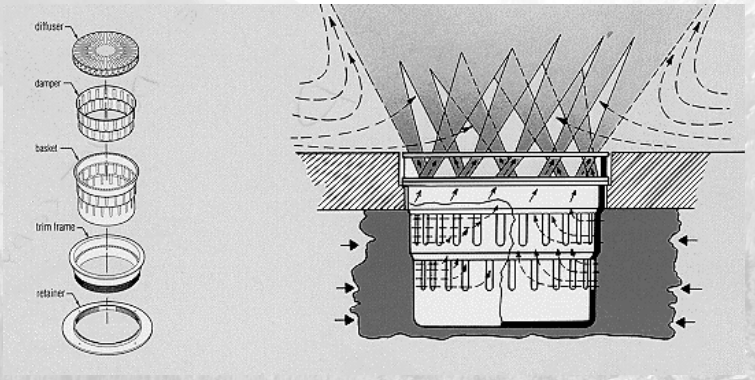
Image: CBE

Room Air Stratification (cooling operation)

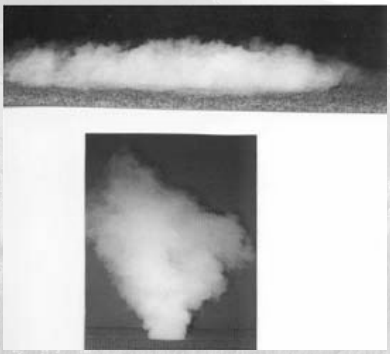


Underfloor HVAC Concept

Swirl Diffusers
Individually adjustable



Air Patterns



- Displacement
- swirl

Circular outlet

Same Energy for All? Basic Math

- Current energy use, if everyone uses the same:
  - 15% uses 53% of world energy
  - The 15% need to reduce by 72%
  - The 85% could increase by 81%
- If everyone (at 0 population growth) combined must use 12% of present total to maintain present CO2, :
  - **The 15% need to reduce by 97%!**
  - The 85% need to reduce by 78%

Handout only

Starting with Equality - A Little (Simplified) Math

- Same Energy Use for Everyone:
  - 15% uses 53% of world energy
  - 15% x 53% + 85% x 47% = 100% E
  - 15/53 = 0.28
  - 85/47 = 1.81
  - The 15% need to reduce by 72%
  - The 85% could increase by 81%
- If everyone combined must use 12% of present total to maintain present CO2, :
  - **The 15% need to reduce by 97%!**
  - For buildings, the goal should be:
    - Zero, or perhaps Net Zero

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What Do We Need to Save?

- To maintain, but for all peoples, 90% to 100%
- Even LEED Platinum doesn't promise 90% savings
- Assumes world population stabilizes at present level!
- LEED projects average 30% energy savings above ASHRAE standards

What is being done?

- A little Internet search:

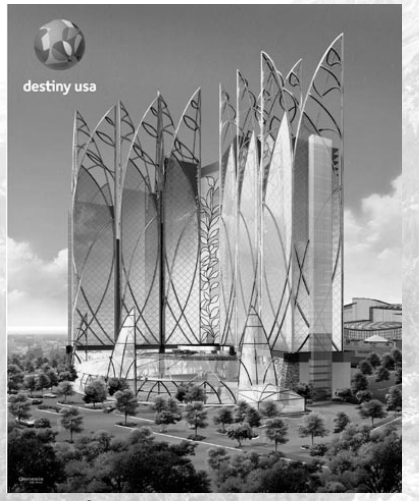
Ocean One Tower
Thailand

Ocean One Tower
Thailand

- Asia generally lags behind the U.S. and Europe as far as the green-buildings movement goes. But there are signs that green architecture is starting to move more into the mainstream.
- 91-story beachfront residential high-rise in the Thai resort town of Pattaya. The building (set to be completed in 2010) will be the first eco-friendly high-rise and tallest building to be built in Thailand.

Destiny Hotel Complex
Syracuse

- $450 million high rise will be situated to the west of the Carousel Center, facing Onondaga Lake. With more than 1,300 guest and conference rooms, the facility will be the largest hotel in the state outside of New York City.



Destiny Hotel Complex
Open schedule: 2012

- The 39-story, 1,342-room structure is to assume the shape of six towering blades of brilliantly green grass.
- The hotel's sky-scraping, grass-blade facade will be roofed with solar and photovoltaic panels that could save energy costs by $266,000 annually.
- A biomass gasification power plant will utilize agricultural and solid waste from the hotel to produce electricity, steam and chilled water.
- Developers hope to turn the area into a purpose-built environment free of fossil fuels. The types of sustainable tools and technologies used to create the hotel grant that at its completion, Destiny USA will be the largest facility of its kind powered by renewable energy.

Living Buildings

- Flexible = meets changing needs = durable
- Anticipates occupant / zone comfort needs
- Responds to weather / sunlight changes
- Store solar heat per anticipations
- Night cooling & storage per anticipations
- Integrated into the architecture
- Many (or all) system components are building parts

The Building as Mechanical System

- Natural Ventilation - Cross Ventilation
  - Stack Effect
- Cool Towers
- Ground fresh air heat exchangers
- Built-in photovoltaics
- Active Walls
- Wind turbines built into natural ventilation systems
- Creativity = new technologies

Building Mass "Timing"

- Mass "Timing" for sizing - Thermal lag timed with load
- TAB – Cx – M & V Challenges?
- If Cooling Peak is 2 PM
  - Enough mass to time "coolness" to reach inside at 2 PM
  - If arrives too early, spent by 2 PM - no peak cooling reduction - no mechanical downsizing

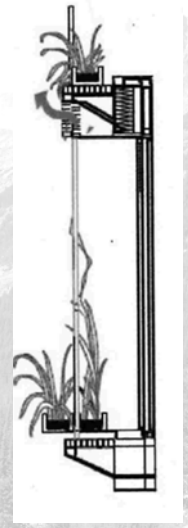
Recap

- Super-tight building
- Natural building systems
- Solar PV and solar thermal

- HVAC Systems
  - Find renewable source, waste biomass
  - Low energy systems
  - Separate OSA with Heat recovery
  - Solar source desiccant dehumidification
  - Solar source AC

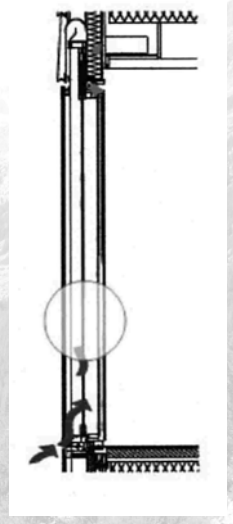
Double Skin Wall Systems (High Performance Facades)

- Externally Shaded Wall
- Plant shade Summer
- Defoliate in Winter



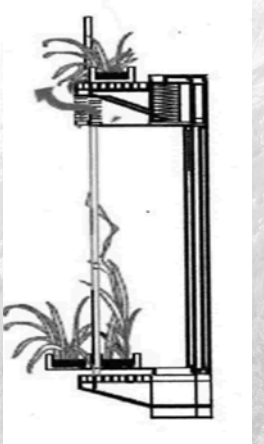
Interactive Wall

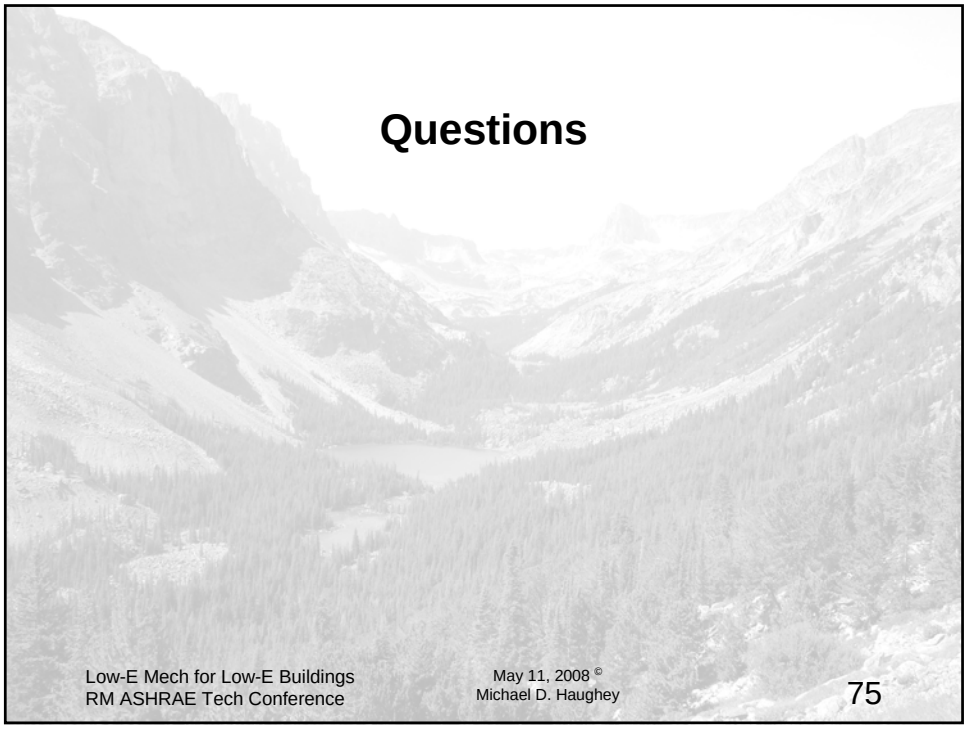
- Vent with OSA
- Microfans, variable speed
- Operable windows



Vegetation Conditioning

- From filters – to Spec plants
- Transpiration cooling
- Air filtration
- Pollution absorption




Questions
Low-E Mech for Low-E Buildings
RM ASHRAE Tech Conference
May 11, 2008 ©
Michael D. Haughey
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