Presentation to:

Rocky Mountain ASHRAE

2009 Tech Conference

April 17, 2009

Mechanical Systems Response to Current Climate Change Data –

for High Performance Buildings

by:

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Silvertip

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Climate Change Data & Mechanical Systems Response

- Recent Climate Data
  - ❖Ice melting
  - ❖East Antarctica
  - ❖Methane
  - ❖CO_2
- Implications on future climate
- Mechanical impacts
  - ❖Mechanical Efficiency needs
  - ❖Integration with Buildings needs
  - ❖Climate data for load calcs & energy models
  - ❖New systems and concepts

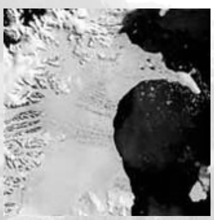
What Are “WE” Trying to Accomplish?

- Avoid climate change and global warming impacts
  - ❖Sorry – too late
    - ➢Already happening
    - ➢More is locked into system “momentum” (heat imbalance)
- Avoid catastrophic climate change and global warming impacts?
  - ❖Maybe we can deal with that

Climate Change Indicators

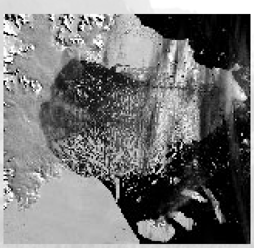
- Global Warming
- Humidity rising
- More severe storms
- More frequent storms
- Sea level rise
- Animal and vegetation migration
- Arctic ice melting
- Greenland ice melting
- West Antarctica ice sheets collapsing
- Tundra thawing
- Sub-sea permafrost
- East Antarctica ice starting to melt
- And lots more

Larsen B Ice Shelf Collapse



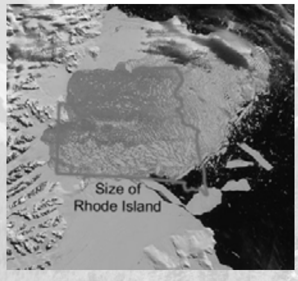
- January 31, 2002

Larsen B Ice Shelf Collapse



- March 5, 2002
  - ❖35-day collapse

Larsen B Ice Shelf Collapse



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Larsen B Ice Shelf Collapse

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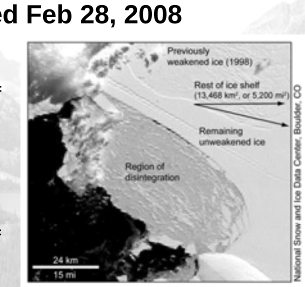
Wilkins Ice Shelf partial Collapse Started Feb 28, 2008

- 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

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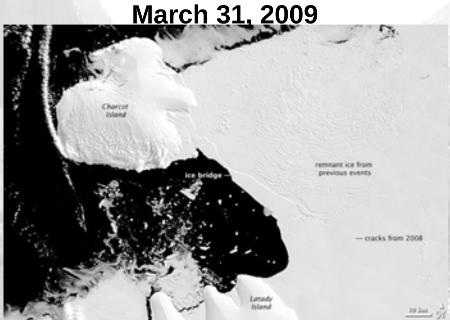
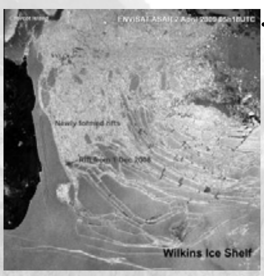
Wilkins Ice Shelf bridge Pre-collapse March 31, 2009

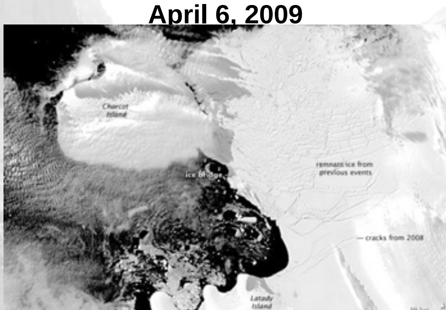


Wilkins Ice Shelf bridge Collapsing April 4, 2009

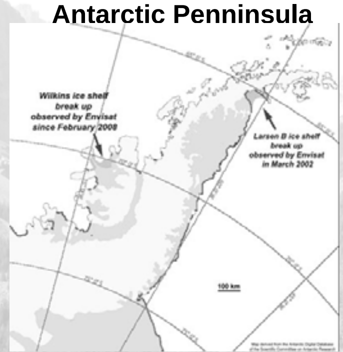


- *Envisat's Advanced Synthetic Aperture Radar (ASAR) captured the early stage of the disruption of the ice bridge that connects the Wilkins Ice Shelf to Charcot and Latady Islands on 2 April 2009 at 05:18 UTC. The new rifts that developed along the length axis of the ice bridge are visible. The first detachment along these new rifts occurred about seven hours later. (Credit: ESA (Annotations by A. Humbert, Münster University))*

Wilkins Ice Shelf bridge collapsed April 6, 2009



Antarctic Penninsula

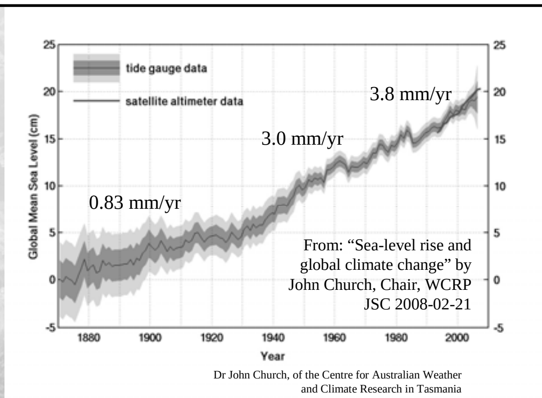


An Island Made by Global Warming
By Michael McCarthy
The Independent UK

- "Warming Island" satellite photos – several miles long
  - ❖ 1985 – part of Greenland Coast
  - ❖ 2002 – small ice bridge
  - ❖ 2005 – completely separate
- 2003
  - ❖ Sea levels rising about 3.1mm per year - average 1993-2003.
  - ❖ average of 1.8mm per year 1961-2003.
  - ❖ Greenland ice now accounts for about 0.5 millimeter

Predictions – Sea Level Rise

- 2007 IPCC Report
  - ❖ **Consensus** document from 130 countries
  - ❖ 450 lead authors
  - ❖ >800 contributing authors
  - ❖ 2,500 experts reviewed the documents
- Sea level rise: 20 to 60 cm by 2100
- Caveat: little input from melting ice sheets: Greenland and Antarctica
  - ❖ That data is now emerging



Sea Level Implications

- Nearly half of the 6.7 billion people live near the coast and are vulnerable to storms and sea level rise
- 8 of 10 largest cities in world, and 15 of 20 largest urban areas in U.S. are within 100 km of the coast and 10m above sea level

Sea Level Rise potential

- Thermal expansion: a few meters
- Glaciers: about 10 ft.
- Greenland ice sheets: about 20 ft.
- West Antarctica: about 20 ft.
- East Antarctica: 170 ft.
- Grand total potential: about 220 ft.
- Where would you not:
  - ❖ Build?
  - ❖ Install desalination plants
  - ❖ Obtain cooling water
  - ❖ Install wind turbines

Global Warming gasses and chemicals

- CO_2
- Methane (30XCO_2)
- Refrigerants
  - CFC-114 (10,000 to 20,000XCO_2) – leaks from uranium enrichment (leaky pipes at Paducah, KY plant)
- Combustion
- Animals
- Plant decomposition
- Sequestered methane
- Other Sources
  - 1 ton CO_2 per ton cement manufactured
  - 1 ton CO_2 per ton steel manufactured

CO2 Increase Rate Accelerating

- Atmos. Conc.
  - 1970 to 2000
    - 1.5 ppm/year
  - 2000 to 2008
    - 2.1 ppm/year
- CO_2 emissions growth
  - 1990's: 0.9%/yr
  - 2000+: 3.5%/yr
- Oceans and Forests saturating – less able to absorb CO_2
  - More staying in the atmosphere

Methane

- Atmosphere: 1.8 PPM
  - Overall about 50% of GW impact
- 2007: 1st increase since 1998
- More methane beneath Arctic than all global coal reserves
- Arctic: 4C temp rise last few decades
- Increase Sources:
  - Asia industrialization
  - Arctic & tropics wetlands
  - Possible permafrost thawing
  - Arctic seabed (sub-sea permafrost thaw)
    - N. Russia coast rapid warming

Global Economics of Climate Change

- Sir Nicholas Stern – "The Stern Report"
  - ❖Past Chief Economist, World Bank; chief economic advisor to UK Treasury
  - ❖2 degrees C MAX above pre-industrial = "meltdown"
- CO2 equivalent PPM (CO2e)
  - ❖Historic CO2: 280
  - ❖CO2 2006: 380
  - ❖Add methane & others, CO2e: 430
- Meltdown probability
  - ❖CO2e 450: 26-78%
  - ❖CO2e 550: 63-99%

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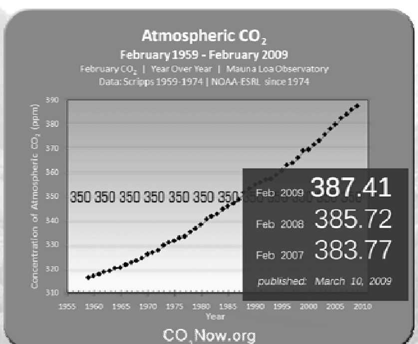

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Emissions Calculators www.cleanerandgreener.org

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Climate Change - Mechanical Systems Impacts

- New weather data
  - ❖ Changing, higher design conditions, more variable, changing cloud and sunlight patterns
- Populations migrate to poles and away from rising seas
- Higher occupancy densities
- Air chemistry changing?
- More system capacity?
- Need for zero net carbon (renewable energy)
- Solar less effective?
- Solar-driven cooling
- Wind more effective?
- Vegetarians proliferate?
- Methane for heating
- Biofuel diesel backup

Low Energy Systems – How Low?

- Moving targets
  - ❖ 20% below ASHRAE 90.1-2001
  - ❖ 20% below **ASHRAE 90.1-2004**
  - ❖ 30% below ASHRAE 90.1-2004
  - ❖ 30% below IECC 2006
  - ❖ 50% by 2020
  - ❖ 90% by 2030
  - ❖ Net zero by 2030
  - ❖ Net Energy producers
  - ❖ Restorative buildings
  - ❖ Living buildings
  - ❖ And lots more!
  - ❖ Geez!

How Are We Doing?

- E-mail from ASHRAE 2009-04-02:
  - ❖ World energy consumption is projected to ***increase*** from 2005 to 2030
  - ❖ Projecting failure?
- USGBC
  - ❖ Average LEED building saves 30% (presumably compared to ASHRAE 90.1-2001)

International Protocols

- International baseline: 1990
- Kyoto: reduce to 5% below 1990 levels
- Reduce various nations' energy use / carbon output compared to 1990 levels

Simple Mechanical Goal: Solve the Problem

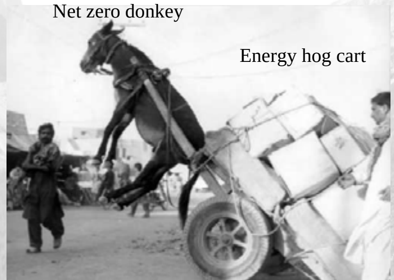
- Buildings
  - ❖Net Energy Producers (renewable)
- Mechanical Systems
  - ❖Very High-efficiency
  - ❖Building-Integrated

Zero Energy Mechanical Systems?

- Is there such a thing?
- Any clients tell you to make their building "net zero"?

Net Zero Rule

- Can't put a net-zero mechanical system on an energy hog
- "Here are the plans – now make it net zero energy"

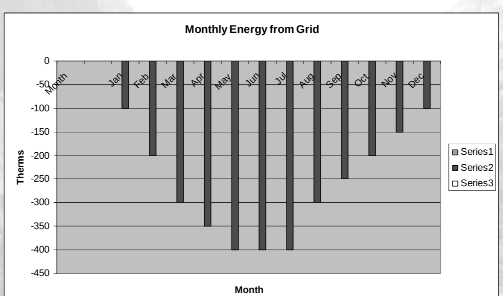


First Things First

- High Performance Building
- Low Energy Mechanical System

- Integrated Mechanical and Building Design

Zero

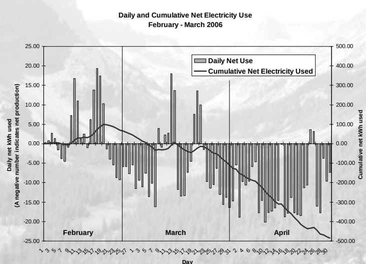


Handout for detail

Net Zero

- Annualized: produce more than use
- Winter – might use more gas for heat, put PV into Grid
- Summer – might use more electricity for cooling, put solar thermal into Grid
- Daytime – put PV into Grid
- Nighttime – take electricity from Grid

Net Zero – Daily net Elec



Handout for detail

Which is Which?

- Zero
  - ❖ Needs NO energy from THE GRID
  - ❖ NO utility infrastructure for heating, cooling, electricity to these buildings
- Net Zero
  - ❖ Grid-connected
  - ❖ A natural form of carbon trading
  - ❖ More economical in terms of first cost
  - ❖ Utility infrastructure exists
  - ❖ Does use fuel input to utility grid

How

- Super insulation, great windows
- Mass integration
- Daylighting, natural ventilation
- Energy Conservation – can be very low cost
- Wind energy – competitive (high ROI)
- PV – relatively expensive first cost
- Solar Thermal - relatively expensive first cost

Handout for detail

Priorities

- Very efficient building design
- Reduce building demands first
  - ❖Heating, cooling, lighting, appliance, process, etc. loads
- Use efficient, integrated systems
  - ❖Daylighting, Compact fluorescents
  - ❖Efficient heating & cooling, energy recovery
- Last – use renewable sources to make up difference: wind, PV, solar thermal, biomass, etc., and become **Net Producer**

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

Handout for detail

Load Reduction - Daylighting

- Healthy, Comfortable Lighting
  - ❖ Diffuse, even, low glare
- Reduced Mechanical Loads
  - ❖ Occupancy sensors: open offices
  - ❖ Daylight control system - photocells

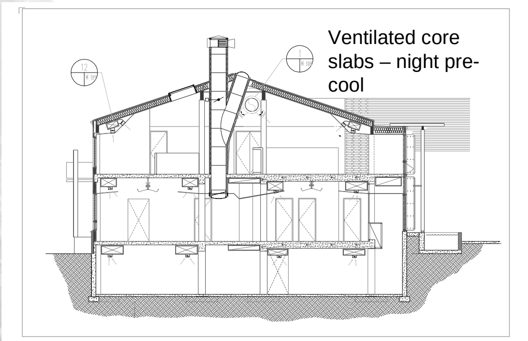
❖ Low energy: Reduced Mechanical & Electrical Costs

Mechanical Systems Economics of Net Zero

- No longer “energy payback” or “ROI”
- Now compare:
  - ❖ Incremental Mechanical cost
  - ❖ To (avoided cost of)
  - ❖ Solar PV, Wind
  - ❖ or
  - ❖ Solar thermal – heating or cooling

Building – Mechanical – Passive Integration

- Diurnal variations
  - ❖ Store night cool or day heat
- Use of Mass
  - ❖ Integrate with mechanical
  - ❖ Natural – surface exposed to space
- Techniques
  - ❖ Mass floors, walls
  - ❖ Multiple 5/8 drywall layers
  - ❖ Rock storage
  - ❖ Water storage
  - ❖ Concrete “core slabs”
  - ❖ Insulated concrete



MDH – 1999 Design

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Ventilated Core Slabs
Design - TAB – Cx - M & V Challenges

- Predicting need for cooling or heating
- Estimating how much
  - ❖ Peak vs. daily
  - ❖ $ savings from peak reductions
- May or may not get capacity reductions
- Controlling rate of "release" (or no control?)
- Setting & adjusting response rates
- Verifying prediction algorithms
- What needs to be controllable or adjustable?

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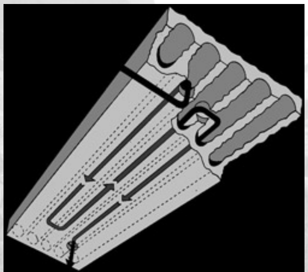
Pre-manufactured core-slabs



- Commercially available
- Proprietary controls and energy models

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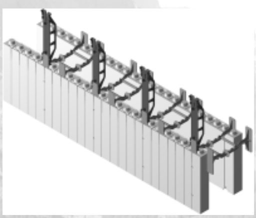
Model-based Design

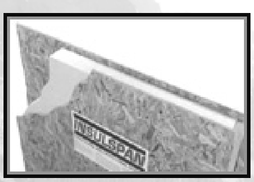
- Current & developing tools for:
  - ❖ VAV, fan-coils, RTUs, some radiant
  - ❖ Sorta displacement
  - ❖ Sorta ground-coupled heat pump
  - ❖ Other “standard” systems
- Need more tools for:
  - ❖ Ground HX
  - ❖ Mass and passive
  - ❖ Hollow-core slabs
  - ❖ Insulated mass panels
  - ❖ Double skin walls
  - ❖ Everything we try to approach net zero

Insulated Concrete Forms (ICF)



- Insulated foundations, walls, roofs
- Double as forms

Structural Insulated Panels (SIPS)

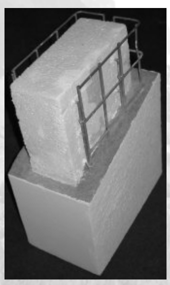


- Pre-manufactured
- Walls, roofs, …
- Site-cut for wiring, plumbing, etc
- Or – pre-installed raceways
- Limits thermal short-circuits (no studs or rafters)

Insulated Concrete Panels R36

- EPS foam – 7-1/4”
- Reinforcing steel
- Wall ties
- Each side: 2-3/8” Fiber-reinforced shotcrete – 4,000 psi
- Mass on inside of insulation
- Fire rating
- Remember – the wall is now part of the mechanical system!

Insulated Concrete Panels



- Another product
- Site built system
- Use any insulation material, so higher R-values?

Passiv Haus

Systems in Europe
Passiv Haus

- 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

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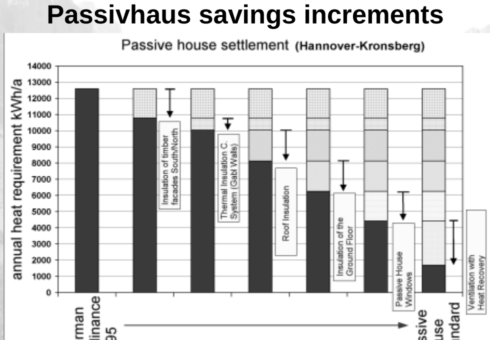
Passivhaus savings increments



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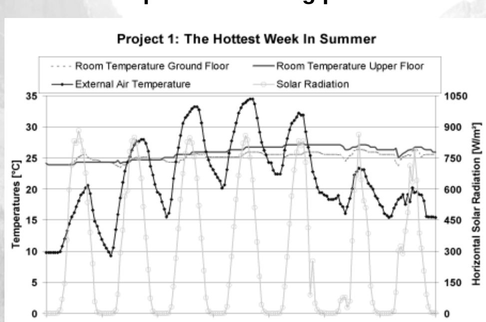
Passivhaus passive cooling performance



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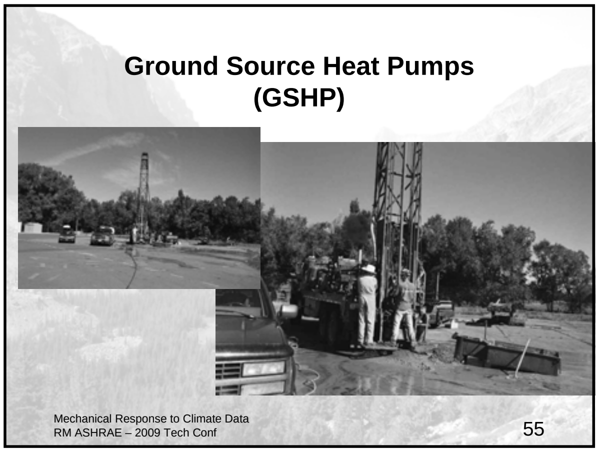
Ground Source Heat Pumps
(GSHP)
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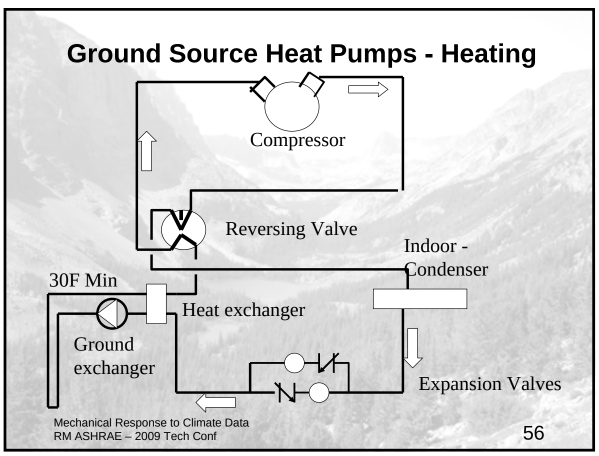
Ground Source Heat Pumps - Heating
Compressor
Reversing Valve
Indoor -
Condenser
30F Min
Heat exchanger
Ground
exchanger
Expansion Valves
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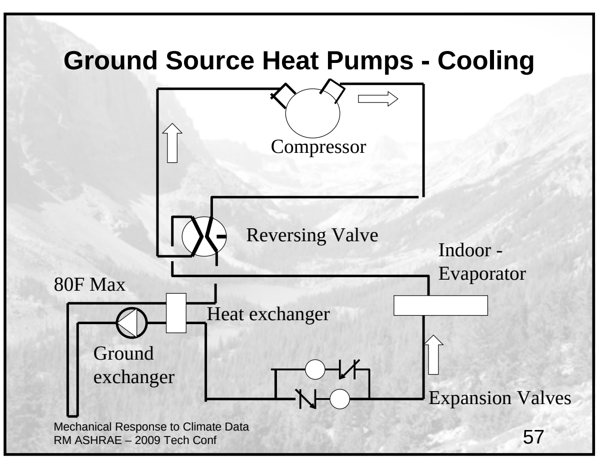
Ground Source Heat Pumps - Cooling
Compressor
Reversing Valve
Indoor -
Evaporator
80F Max
Heat exchanger
Ground
exchanger
Expansion Valves
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GSHP Efficiency Factors

- Just being GSHP not enough
  - ❖Large(er) HX surface area = high(er) efficiency
- Minimal GSHP to get bid = low efficiency
  - ❖Low HX surface area
  - ❖If contractor sizes the loop field, provide and enforce criteria

Ground Loop Efficiency – Project example

- “Standard” condition (example)
  - ❖80F EWT and 19.2 EER
  - ❖Less cost
- Efficient (example)
  - ❖70F EWT and 22.2 EER
  - ❖15.6% more efficient
  - ❖More ground piping

Displacement Ventilation & Underfloor Air

Floor Distribution

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Displacement Ventilation - Sidewall

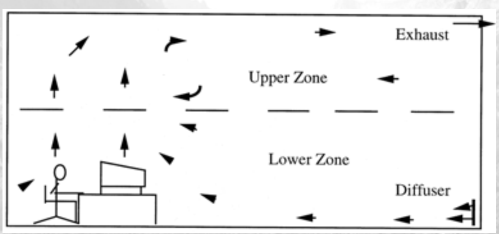

Figure 1 *Sketch of displacement ventilation.*

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Underfloor air mixing within stratification zone

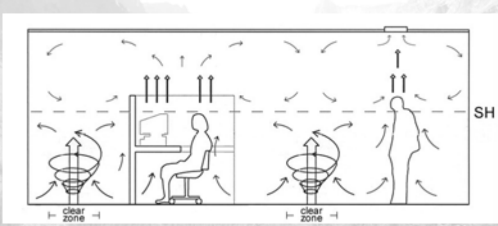

Image: CBE

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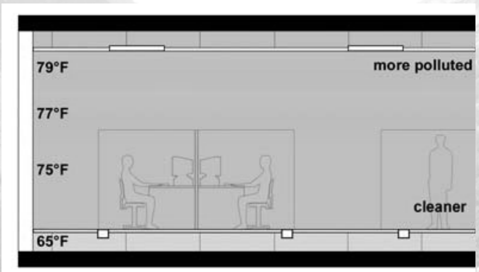
Room Air Stratification (cooling operation)



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Underfloor HVAC Concept

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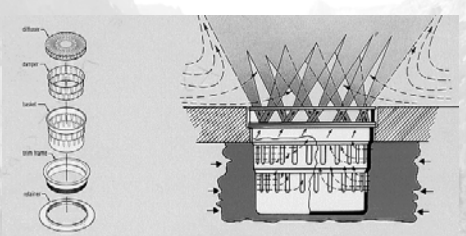
Swirl Diffusers Individually adjustable



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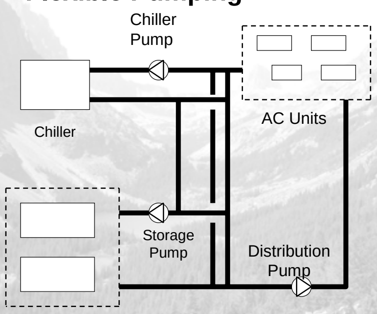
Ice Storage - Benefits

Handout only

- Utility company goals
  - Minimize utility system demand
    - Level the utility demand profile
    - Maximize utilization of generation capacity investment
    - Avoid new plant construction costs
- Savings
  - Reduce on-peak demand
  - Reduce cooling energy (at power plant)
    - Greater chiller efficiency at night
    - Lower utility line losses at night
    - Higher-efficiency utility generators at night
  - Reduce size of cooling equipment

Flexible Pumping



Campus Systems

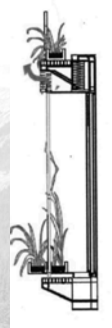
- Variable pumping
- Dedicated loop or level pumps
- Reasonable pumping distances
- Building pumps
- System pumps
- AHU pumps
- Multi-level pumping
  - ❖Each loop separately pumped
  - ❖Each pump sized for the loop
- Many system concepts
  - ❖All: advantages & disadvantages

Campus Systems

- Beware 3-way valves and return main over-pressurization
- Higher DT's, but not too high
- Pump only what is needed
- Variable chiller flow (except some older chillers)

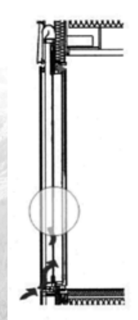
Double Skin Wall Systems (High Performance Facades)

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



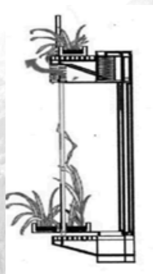
Interactive Wall

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



Vegetation Conditioning

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



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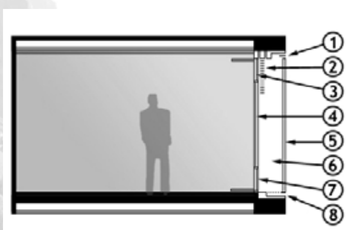
Double Skin Facades



1. **Exterior upper air outlet**
2. **Controllable solar control device**
3. **Interior upper operable window (air inlet)**
4. **Interior operable or fixed view window**

- **5. Exterior glazing layer**
  6. Air cavity
  7. Interior lower operable window (air inlet)
  8. Exterior lower air inlet

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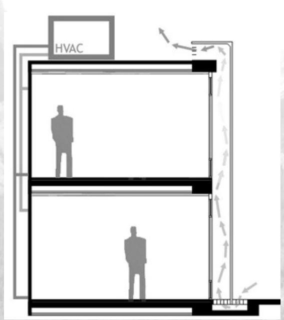
Double Skin Facades



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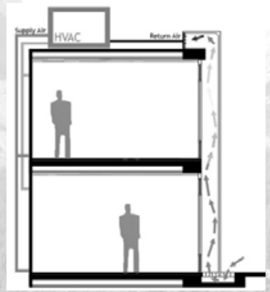
Double Skin Facades



Double Skin Facades

- Be Careful
  - ❖DSF is low energy compared to traditional single skin curtain wall.
- The Question
  - ❖Is curtain wall the right answer?
  - ❖Will PV-integrated systems make the difference?

Handout only

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, …

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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

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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)

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Pearl River Tower, Guangzhou, China

- 71 stories, 2.2 million square feet, "net" zero-energy
- Wind turbines: - building's facade accelerates the wind
  - ❖ 1.5 to 2.5 times ambient wind speeds
  - ❖ Up to 15X freestanding wind turbine power
- Solar PV
- Rainwater collection, part heated by the sun to provide hot water
- The building is cooled, in part, through heat sinks and vertical vents
- Turbine openings through which the wind flows help reduce the overall wind load on the skyscraper

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Ocean One Tower
Thailand

- The building (set to be completed in 2010) will be the first eco-friendly high-rise and tallest building to be built in Thailand.

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Destiny Hotel Complex
Syracuse, NY

- roofed with solar and photovoltaic panels
- biomass gasification power plant will utilize agricultural and solid waste from the hotel
- will be the largest facility of its kind powered by renewable energy

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Remember the 1973 oil embargo?
"Energy Code Buildings"?

- 1975:
  - ❖VAV Systems
  - ❖Energy Code buildings
- 1980's
  - ❖Energy code building = building that doesn't work.
  - ❖Low airflow
  - ❖IAQ issues
- This time – cautions
  - ❖Keep productivity foremost!
  - ❖Productivity = comfort
  - ❖Beware lifestyle requirements
    - ➢May be the lemon building of the future!

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Lifestyle requirements caution

- Lifestyle requirements = a building that is only comfortable if lifestyle requirements are imposed, such as :
  - ❖ very light clothing, warmer temperatures, necessity of breezes, pretending you are comfortable when really you are too hot - just to be P.C.
- Productivity will suffer. Building may become the lemon of the future.

Controllability to accommodate Lifestyle Operation

- Provide necessary peak capacity
- Provide controllability
  - ❖ Operators can adjust to current lifestyle requirements
  - ❖ Operators can adjust to improve productivity (comfort)

Mechanical Design Comfort Criteria

- Lower criteria to pay for sustainability features?
- Is productivity and comfort adequately considered?

The Future of HVAC

- Conservation
- Efficiency
- Integration
- Living Buildings

- Warmer climate
- Higher global humidity
- Higher populations
- Expectations: healthier buildings

Summary
Instead of Targets – Solve the Problem

- Buildings
  - ❖ Net Energy Producers (renewable)
- Mechanical Systems
  - ❖ Very High-efficiency
  - ❖ Building-Integrated
- 2030 challenge
  - ❖ Net Zero by 2030

- Economics
  - ❖ Beyond "paybacks"
- Now compare:
  - ❖ Incremental Mechanical cost to
  - ❖ Solar PV, Wind, or Solar thermal – heating or cooling to achieve Net Zero

Questions & Discussion

***Michael D. Haughey, PE, HBDP, LEED™ AP** 2009 ©*

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