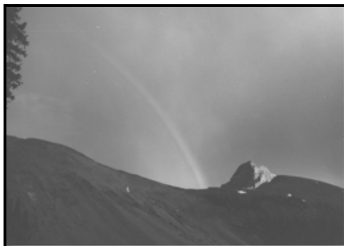

Presentation to Rocky Mountain ASHRAE Tech Conference

Sustainable HVAC Futures

Low Energy Mechanical Systems

May 18, 2007

by:

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Building Energy

- Heating
  - Infiltration
  - Windows
  - Skin
- Cooling
  - Infiltration
  - Solar
  - Skin
  - Lighting
  - Equipment
  - Process

Mechanical Systems in Context

The Future of HVAC

- Conservation
- Efficiency
- Integration
- Living Buildings

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Calculating the Goal for Efficiency

- IPCC:
- 13 or so of the world's most powerful supercomputers ….
- Simplified version: envelope and a calculator

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Handout for detail

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 CO_2, :
  - **The 15% need to reduce by 97%!**
  - For buildings, the goal should be:
    - Zero, or perhaps Net Zero

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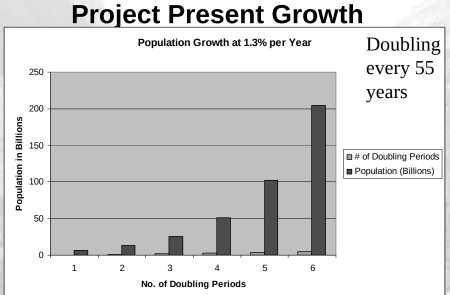
What Do We Need to Save?

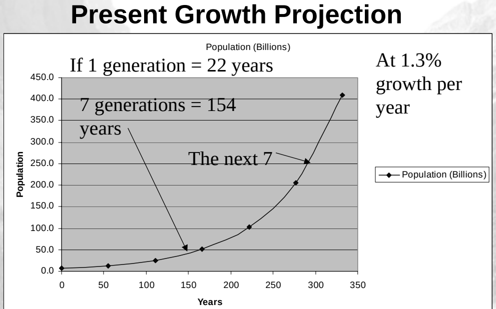
- To maintain, but for all peoples, 90% to 100%
- Even LEED Platinum doesn't promise 90% savings
- Assumes world population stabilizes at present level!
- LEED projects average 30% energy savings above ASHRAE standards

Validating the Stabilized Population Assumption – Project Present Growth



Handout only

Stabilized Population Assumption – Present Growth Projection



Stabilized Population Assumption – Ponder the Implications

- 1.3% Growth can't continue
- SOMETHING will stop Population Growth!

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Population Growth vs. Energy Goals

- If No population growth = 90% Energy reduction
- Any population growth must mean net zero, net producers
- All buildings must on average be self-sufficient

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Back to Buildings & the Crystal Ball (Basic Engineering "Logic")

- One way or another
  - WILL use less energy
  - Building efficiency
  - Systems efficiency
- Building Uses
  - Industry, processes, data centers, etc – WILL ALSO use less energy
- **It is inevitable**

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The Future of HVAC

- The future of buildings
- The future of climate

Which leads?
How to predict HVAC?
The impact on design, energy modeling, life-cycle analysis, TAB, Cx & M & V

Emerging Opportunities

What Can't Happen?

- Water Use
  - Water Table Drop:
    - Beijing, China: 1 meter/yr
    - Tianjin, China: 4.4 m/yr
    - U.S.: 25% > replacement
  - Standard U.S. diet: 4,200 gallons per day
  - Vegan diet: 300 gallons per day
  - ¼ lb hamburger: 600 gallons
  - Large cheeseburger: 1,000 gal
- Short-term Business Strategy: conservation
- Long-term: dietary changes

Handout only

Emerging Opportunities

What Can't Happen?

- Exponential Population Growth
  - Now: 6.6 Billion
  - 2050 (UN): 9 Billion
  - 2050 (World Watch): 12 Billion (1.3% growth, 2 child/couple)
  - China 1-Child Policy since 1970's
    - Still growing 0.6% net per year
  - 15 to 40 Yr Olds – max fertility
    - Time Lag: 70 years
  - Agriculture Capacity: <4 Billion ?
- Short-term: Instability & conflict
- Long-Term: Stable Population

Key Strategies

Emerging Opportunities

What Can't Happen?

Handout for detail

- Agriculture Yield Growth (per acre)
  - 1950 to 1980: 3% growth
  - Now: 1% Growth
- Nutritional Value of Fruits & Veg :
  - From 1940 to 1991 Veg lost 76% of copper, 46% of calcium, 27% of iron, 24% of magnesium, 16% of potassium
  - From 1978 to 1991 Veg lost 57% of zinc
  - Direct result of overuse of fertilizers
- Future: organic farming practices

Emerging Opportunities

What Can't Happen?

Handout for detail

- Diet & Land Use
  - 1960 - world population 3 Billion, cropland: 0.5 hectare per person
  - 2004 - world population 6.5 Billion, cropland: 0.23 hectare per person
  - US (2004): 0.23 hectare per person; 1,481 kg/person/year
  - China (1979): 0.11 hectare per person
  - China (2004): 0.08 hectare per person – primarily vegetarian; 785 kg/person/year
  - *1 hectare = 2.47 acres
- Future: organic farming practices

Sustainable Materials & Practices

- Many not here yet, but ARE in Future – Emerging Opportunities
- Research & Education
  - De-mountable
  - Recyclable
  - Sustainably produced materials
  - Gray water systems
  - Bio-water treatment systems
    - "Living Machines"

Design Process

- Defined Owner Goals – sustainability expectations
- Life-Cycle Mechanical (& other) Systems Analysis
- Integrated Design
- Commissioning

Integrated Design

- Building heating, cooling needs minimized, then efficient systems
- Systems integrated during design
  - Lighting - photocells, motion det
  - Lighting - HVAC coordination
  - Natural ventilation - window bugs
- Occupant feedback
  - Mode lights, message boards
  - Open/close window recommendations
- Weather information
- Predictive information

Buildings Impact

- Sustainable materials & processes
- Perhaps healthier building expectations
- Dual purpose materials – building becomes part of mechanical system

HVAC Impact
How much Efficiency?

- How low “can” energy use go?
- How low does energy use need to go?
- Which systems, existing or future imagined, meet the criteria?
- If we don’t know where we are going ….. ?

Handout for detail

Global Economics of Climate Change

- Sir Nicholas Stern
  - Past Chief Economist, World Bank; current chief economic advisor to UK Treasury
  - Asked, July 2005, by Chancellor of the Exchequer to provide economic analysis
  - 2 degrees C MAX
- CO2 equivalent PPM (CO2e)
  - Historic CO2: 280
  - CO2 now: 380
  - Add methane & others, CO2e: 430
- Meltdown probability
  - CO2e 450: 26-78%
  - CO2e 550: 63-99%

Handout for detail

Global Economics of Climate Change

- Sir Nicholas Stern
  - “Meltdown” defined as climate spiraling out of control = environmental catastrophe
  - Balance against economic collapse
  - Exceeding 2C temp rise above pre-industrial = “meltdown”
- Results (% of global GNP (GGNP))
  - Bus. as usual, 650-1200 PPM by yr 2100; coping cost equiv. of combined WWI, WWII, 1930 stock market collapse
  - 550: 1% GGNP
  - 450: 3% GGNP + economic collapse

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

- Separate outside air systems
- Individual comfort control – integrated
- Desiccant cooling – solar thermal regeneration

Handout for detail

What's Next?

- Lower energy use systems
- Integration of systems & buildings
- New, as yet imagined, mechanical/building systems
- New methods of control, TAB – Cx – M & V
- New analysis tools

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Resistance to Integrated Design

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- The LAST Time…….
  - Scope and Budget developed independently – non-integrated
  - Tight budget, fixed TEAM fee
  - Low-e windows, low energy lighting, reduced mechanical system
  - Over budget – delete sustainable and energy features
  - Re-design larger system into smaller space
  - Result
    - **Poor access, difficult maintenance**
    - **Architectural compromises**
    - **Lost client - Never again!**

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Integrated Design
Load Reduction

- Integration – window shading, reduced loads & mechanical cost, view
- Optimize use of natural light
- Daylighting
- Lighting minimizes contrast

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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

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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)

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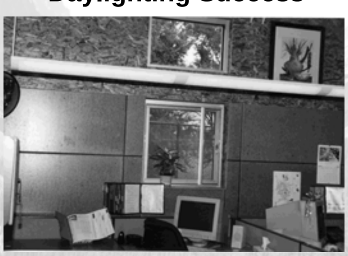
Systems & Equipment
Daylighting Success



- Upper vs. Lower windows

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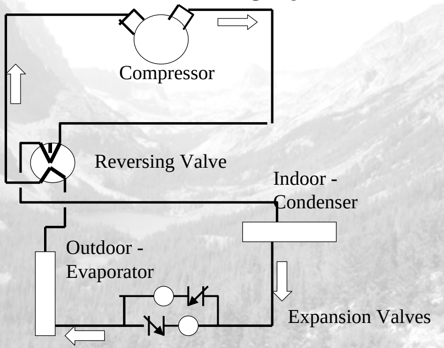
GSHP Basic Heating Cycle



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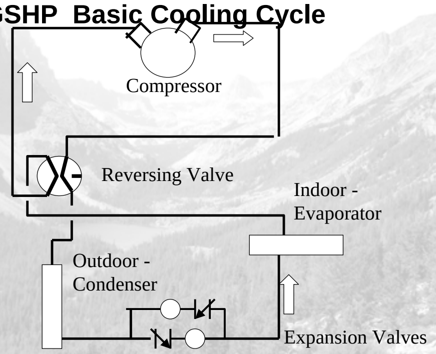
GSHP Basic Cooling Cycle



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Ground Source Heat Pumps

- 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

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GSHP Conductivity Test

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

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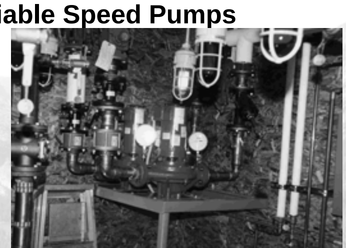
Energy Recovery Ventilator

- Min OSA only for HPs?
- No Air-side Economizer

Variable Speed Pumps



- Variable Speed Drives
  - Controlled from supply to return DP
  - HP varies about $(S1/S2)^{2.3}$
  - Reduce parasitic energy use

Systems & Equipment
Natural Ventilation
Integration with Mechanical

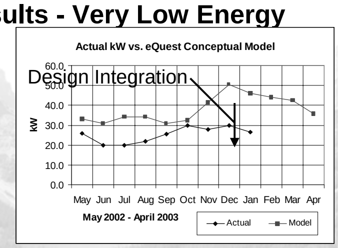
- Manual window operation vs. mechanical energy consumption
- Window sensors (“bugs”)
- Feedback to Occupants
- Mechanical lock-outs
- Commissioning
- Automatic or Manual?

Educational Tool - Mechanical Room

- Mode Lights
- Visual Flow Meters

Results - Very Low Energy

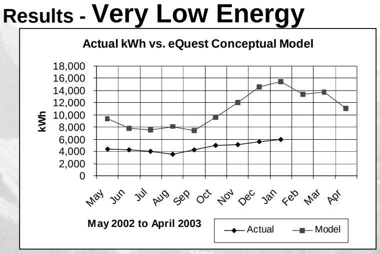
kW



- Demand (kW) is 68.2% of model for 1st 9 months
- Original: 0.8 + 0.31 W/SF lighting
- Final: 0.25 perim, 0.5 interior

Results - Very Low Energy

kwh



- Energy (kwh) is 45.8% of model for 1st 9 months
- Lighting reduction plus aggressive natural ventilation

Handout for detail

Basic Concepts & Systems

- Air - side economizers
  - Outside air (OSA) for cooling
  - OSA cooler than return air
  - Building pressurization
  - Adequate return / exhaust air path
  - Coil freezing potential
  - Air stratification potential

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Handout for detail

Basic Concepts & Systems

- Hydronic (water - side) economizers
  - Evaporative cooling (cooling tower, …) source
  - OSA wet bulb low enough to provide chilled water or chilled water pre-cooling
  - Tower freeze-up precautions
    - Bypass control - two position
    - Valve icing / drainage
  - Chiller condenser water limits
    - Low limit
    - Change-over warm-up

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Control & Operation - Air Economizers

- Outside air temperature (OSA) limit (vs. return air temp.)
- OSA Temperature switch - over control (e.g.: DX system)
- Pre-cool control (more energy savings)
- Modulate return, exhaust, & OSA dampers together
- Close OSA damper when off (coil freezing)
- Heater in OSA plenum (coil freezing when off)

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Control & Operation - Hydronic Economizers

- OSA wet bulb / equipment performance limit
- Temperature or wet bulb switch - over control
- Calculation / prediction switch - over control
- Performance / results control
- Tower bypass
- Variable chiller condenser flow

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When to Use Which

- Rule #1: If air side economizer is available, it is generally more cost effective.
- Rule #2: Rule #1 does not always apply.
- Look at the situation, for example:
  - Existing system, 100% OSA available
    - Air economizer: add dampers & controls, check return air path
    - Hydronic economizer: add controls, cooling tower (or revise piping & valving), heat exchanger, pumps, possibly coils
  - Computer room, humidification requirements
    - Colorado OSA dry - add humidification load

Handout only

(When to Use Which) - Pg. 2

- Existing system - 100% OSA NOT available
  - Air economizer: add controls, OSA ductwork & louvers, relief ductwork & louvers, variable volume relief or exhaust fan system, check return air path
  - Hydronic economizer: add controls, cooling tower (or revise piping & valving), heat exchanger, pumps

Control System Issues

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Des & CA – Energy vs Reality

- Green buildings that don’t perform
- Last 10% of controls most crucial to energy
  - Example: kW monitoring – control of ice
  - Importance of commissioning – esp energy
- Advanced control system capabilities =
  - Opportunity

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Des & CA – KISS

- Need to raise the lowest common denominator
  - Education, training, intuitiveness
- Beyond just “works & simple”
  - Increasing need to save energy
  - Added capability
- Often simplest is complex behind the scenes
  - Extensively de-bugged, many scenarios anticipated & “tested” (commissioned)

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Des & CA – Owner Expectations

- Changes from design
  - Low cost
  - Don't need Cx
- To Operation
  - More zone control
  - Lower energy costs
  - Everything work as intended
- Advocate for adequate budget & schedule

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Des & CA – Commissioning

- Essential in today's market
- Commissioning tools
  - Extensive trending
    - Multiple variable plots
    - Flexibility – sample rate, scale, etc
    - Export to excel
    - Data storage
  - Ability of Cx to "drive" the system

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Operations/Service

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Ops/Service – Intuitive O & M's

- If not clear – won't operate as intended
- O & M Manual, User interface screens
  - Screen shots – all functions
    - Clearly marked explanations
  - Clear master screens – "contents"
  - Individual screens – clear navigation
- More emphasis on design intent explanation
  - Contract documents
  - Owner training

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Ops/Service – Back-ups (controls programming)

- Reliable & simple to implement back-ups
- Truly latest version
- Clear procedure for re-install
- Clear process for updating changes
  - And updating back-up

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Handout for detail

Ops/Service – Close the Loop

- Operations feedback to Design
  - Data
  - What works, doesn't work
- Systems reports to engineer
  - Data on system performance
    - Energy, maintenance
  - Simple, concise, automatic

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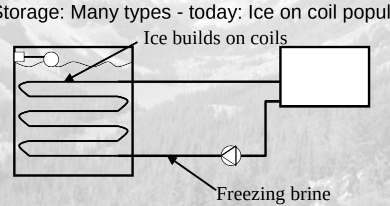
Ice Storage Basics
Freeze Cycle

- Cooling source - chiller, DX, …
- Brine, refrigerant, …
  - Storage: Many types - today: Ice on coil popular



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Basics –
Storage Calculation

- 1 ton for 1 hour = 1 ton-hour (T-H)
- 100 tons for 8 hours = 800 ton-hours
- Avail. Freeze Time, full capacity (Mode 1): M - F, 9:30 PM to 6:30 AM = 9 hours
- Avail. Freeze Time with simultaneous cooling (Mode 3): 6:30 PM to 6:30 AM = 12 hours
- Faster freeze (shorter time) requires higher freeze rate, both chiller & storage

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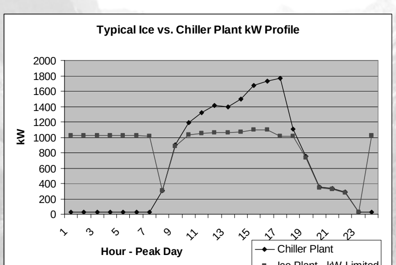
kW Shifting



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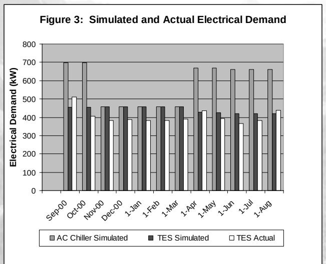
kW Reduction



Maintenance - Issues

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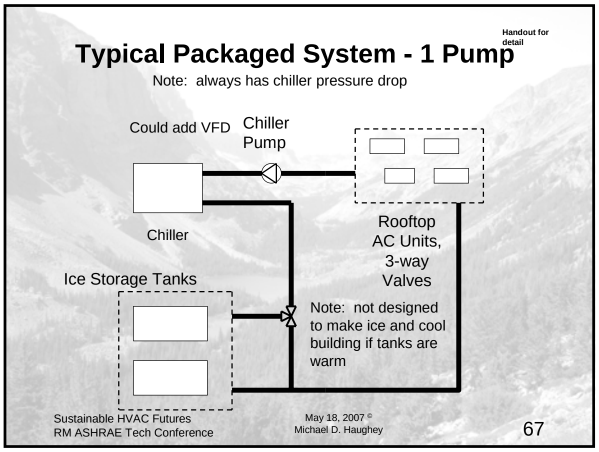
- Number of compressors
  - RTU / DX: 11 refrigeration systems
  - Chilled water: three-compressor chiller, possibly two chillers
  - Ice storage: two-compressor unit
- Efficiency/environmental impact
  - Chillers mostly at night
    - < period of low utility line losses
    - < more efficient base-load power plants
- Equipment life
  - Central chiller more robust than RTU / DX: 20 - 25 years+ vs. 12 - 15 years typical amortization life
- Complaint calls
  - Chilled water more flexible = higher comfort

Saving Energy Cost
Typical Utility Rates

Handout only

- Utility company requirements
  - Utility plant size, peak capacity, distribution costs
  - Fuel and operating costs
  - High customer demand, infrequent use – utility company still needs to provide equipment capacity
- Typical rate structures
  - Demand charge pays for peak capacity ($ / kW)
  - “Ratchet” clause: pay 75% of peak next 11 months
  - Energy charge for fuel and operating costs ($ / kWh)
  - Time-of-day rates/real-time pricing coming**?**


Handout for detail
Typical Packaged System - 1 Pump
Note: always has chiller pressure drop
Could add VFD
Chiller Pump
Chiller
Rooftop AC Units, 3-way Valves
Ice Storage Tanks
Note: not designed to make ice and cool building if tanks are warm
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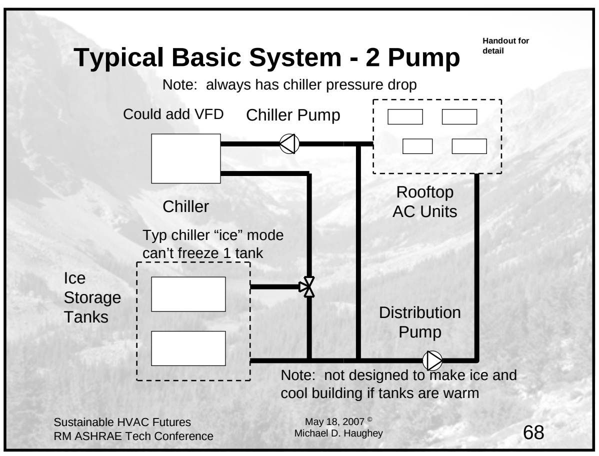
Handout for detail
Typical Basic System - 2 Pump
Note: always has chiller pressure drop
Could add VFD
Chiller Pump
Chiller
Rooftop AC Units
Typ chiller "ice" mode can't freeze 1 tank
Ice Storage Tanks
Distribution Pump
Note: not designed to make ice and cool building if tanks are warm
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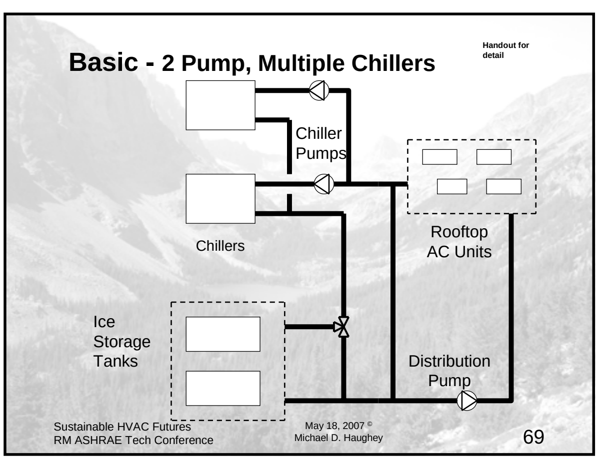
Handout for detail
Basic - 2 Pump, Multiple Chillers
Chiller Pumps
Chillers
Rooftop AC Units
Ice Storage Tanks
Distribution Pump
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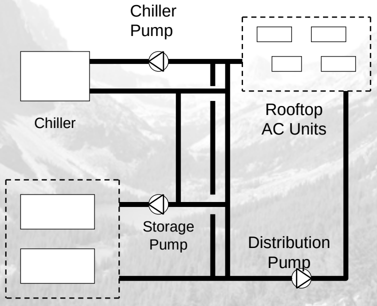
Flexible Pumping



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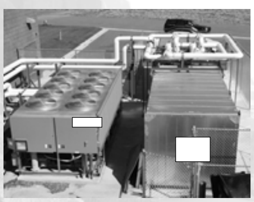
Ice Storage Equipment
Chiller - Ice - Valves/Pumps/Controls



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Ice Storage - Benefits

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- Utility company goals
  - Minimize utility system demand
    - Level the utility demand profile
    - Maximize utilization of generation capacity investment
    - Avoid new plant construction costs
  - Technology demonstration
- 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

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Ice Storage System Goals/Operation

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- Avoid / reduce building electrical demand peak
  - Monitor building kW to control chiller
  - Modulate and start-stop chiller
  - Automatic ice use for continuous cooling
  - Ice storage sized for one peak load day
  - Adjust kW limit seasonally or monthly

Ice Storage System Goals/Operation

Handout for detail

- Shift electrical chiller loads to off-peak
- Minimize pumping energy via dedicated pumps
- Demand-limit day and night (HVAC and ice modes)
- Ready for real-time pricing / time-of-day rates
- Chiller LWT control in HVAC and ice modes
- RTU load shedding

Handout only

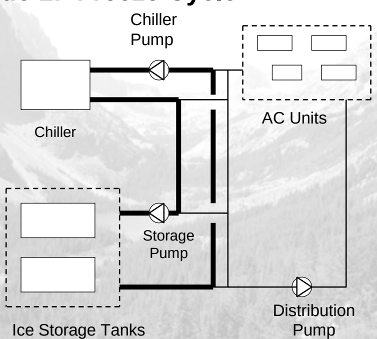
Design Intent & System Operation

- Chiller Priority:
  - Chiller runs as much as possible to satisfy load
  - Storage is used when chiller cannot handle load
  - Chiller is limited by controls in response to building kW limit
  - The lower the building kW limit, the less the chiller can do, the more storage is used
  - Ideally, run out of storage just at the end of a peak load day - Practically, save just a little extra (10 - 20%)
  - Also can adjust the kW limit manually either seasonally or monthly to obtain more savings
  - Future - add programming to track real time pricing

Design Features

- Factory-packaged valves, pumps, and controls
  - Factory commissioned: intent vs. reality
  - Single-source control responsibility (except chiller - interface required)
  - User-friendly touch-screen interface for monitoring and control
  - Remote interface via modem – commissioning
- Five modes of operation
  1. Just make ice
  2. Cool with ice
  3. Make ice while cooling building
  4. Cool with ice and chiller
  5. Cool with chiller

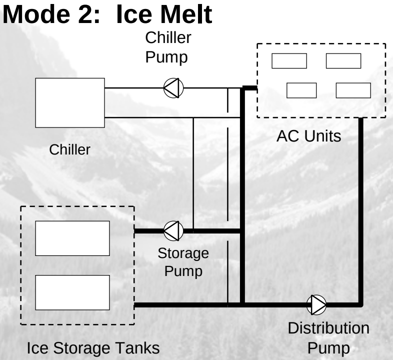
Mode 1: Freeze Cycle



Modes of Operation

- Freeze Cycle (Mode 1)
  - Most systems: modulate storage pump VFD to match chiller GPM (or be slightly less). This system: pumps in series, increase to 250 GPM to lower DT
  - Chiller LWT is set at 24F
  - Stop cycle at full charge:
    - Tank LWT drops to about 31F
    - Calculation indicates full charge
    - Check with tank ice sensor
  - System Balance
    - Temperature Setpoints Design vs. Actual

Mode 2: Ice Melt

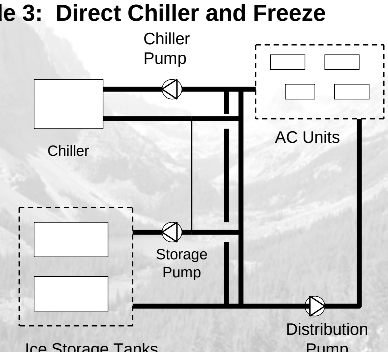


Modes of Operation

Handout only

- Ice Melt Cycle (Mode 2)
  - Modulate storage pump VFD to maintain 45F supply temp (approx 31F ice glycol mixed with approx. 57F system return)
  - Distribution pumps modulate to follow system GPM requirement
  - Actual Operation Temperatures
    - <Ice Storage LWT: _______

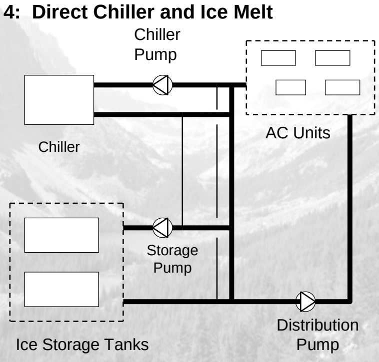
Mode 3: Direct Chiller and Freeze



Modes of Operation

- Simultaneous Direct Chiller Cooling and Freeze Cycle (Mode 3)
  - Chiller LWT is set at 24F (for freezing ice)
  - Modulate chiller diverting valves to maintain 45 supply to system (mixing 24F from chiller and approx 57F return
  - Excess chiller GPM is used to freeze ice
    - Modulate storage pump to flow slightly less than chiller GPM minus distribution GPM

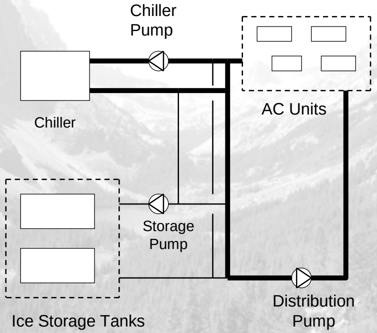
Mode 4: Direct Chiller and Ice Melt



Modes of Operation

- Simultaneous Direct Chiller Cooling and Melt Cycle (Mode 4)
  - Chiller LWT is set at 45F
  - Chiller kW is limited to keep building kW below preset value (adjustable, as is everything)
  - Modulate storage pump to maintain 45F system supply
    - Approx 57F system return and 45F+ chiller LWT (kW limited) are mixed
    - Above mixed supply mixed with approx 31F ice LWT to make 45F system supply

Mode 5: Chiller-only Cooling



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Modes of Operation

- Chiller Only Cooling Cycle (Mode 5)
  - Chiller GPM constant
  - Chiller modulated to maintain 45F LWT
  - Distribution pumps modulate
  - Excess chiller GPM flows in the bridge piping

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Ice Storage/Control Status

- How “full” are the ice tanks
  - M1: Ice Tank LWT (Freeze/Melt end points only)
  - M2: Btu calculation
  - M3: Tank “Inventory” meters
    - <Float type - in tank
    - <“Radar”
    - <Float - external in heated housing (this project)

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Ice Storage Control/Status Actual

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- M1: Tank LWT
  - Use for end-point determination: Freeze complete; Melt complete
  - Some use chiller LWT (indirect, a little less accurate)
- "Knee" of freeze curve

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Ice Storage Control/Status Actual

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- M2: BTU calculation
  - Most vulnerable to flow meter accuracy, secondarily to temperature sensor accuracy
- Tank EWT, LWT, Flow
- Cumulative – compounding errors
- Daily reset (on full freeze or melt)

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Ice Storage Control/Status Actual

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- M3: Tank inventory meters
  - In-tank floats and sensors prone to mechanical difficulties: hang up, get caught in ice, etc.
  - External pressure sensor in heated enclosure works reasonably well
  - All susceptible to proper water level
- Heat trace

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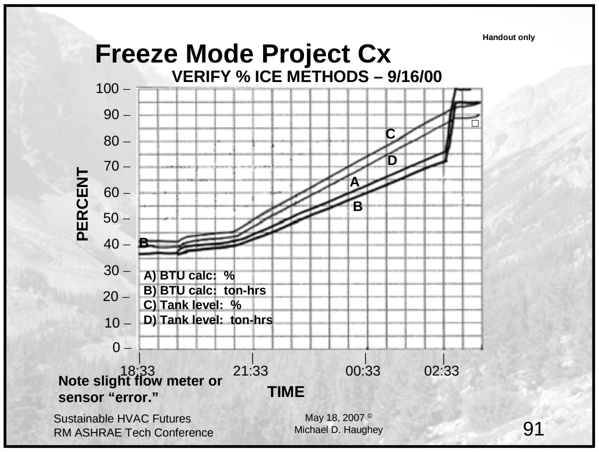
Handout only
Freeze Mode Project Cx
VERIFY % ICE METHODS – 9/16/00
PERCENT
100
90
80
70
60
50
40
30
20
10
0
C
D
A
B
B
A) BTU calc: %
B) BTU calc: ton-hrs
C) Tank level: %
D) Tank level: ton-hrs
18:33
21:33
00:33
02:33
TIME
Note slight flow meter or sensor "error."
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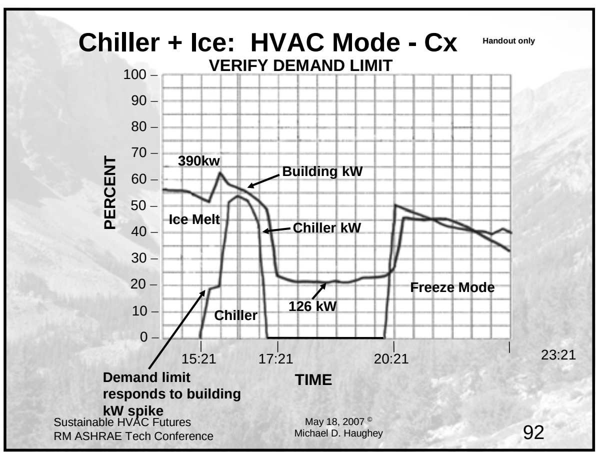
Chiller + Ice: HVAC Mode - Cx
Handout only
VERIFY DEMAND LIMIT
PERCENT
100
90
80
70
60
50
40
30
20
10
0
390kw
Building kW
Ice Melt
Chiller kW
126 kW
Freeze Mode
Chiller
15:21
17:21
20:21
23:21
TIME
Demand limit responds to building kW spike
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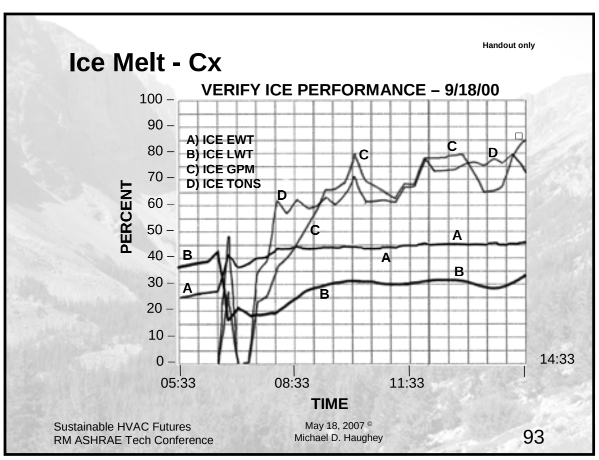
Handout only
Ice Melt - Cx
VERIFY ICE PERFORMANCE – 9/18/00
PERCENT
100
90
80
70
60
50
40
30
20
10
0
A) ICE EWT
B) ICE LWT
C) ICE GPM
D) ICE TONS
D
C
C
D
C
A
A
B
B
A
B
05:33
08:33
11:33
14:33
TIME
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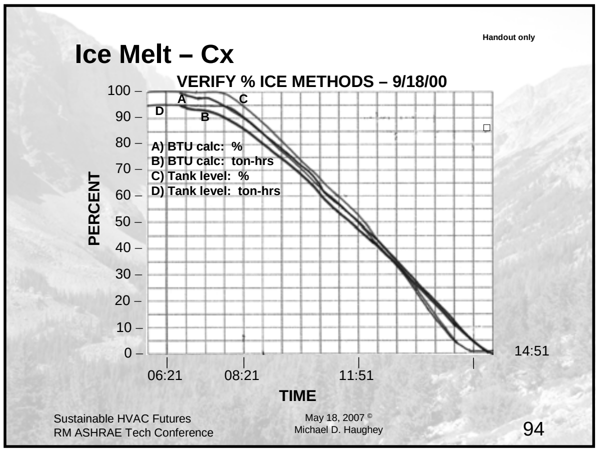
Handout only
Ice Melt – Cx
VERIFY % ICE METHODS – 9/18/00
A) BTU calc: %
B) BTU calc: ton-hrs
C) Tank level: %
D) Tank level: ton-hrs
PERCENT
TIME
06:21
08:21
11:51
14:51
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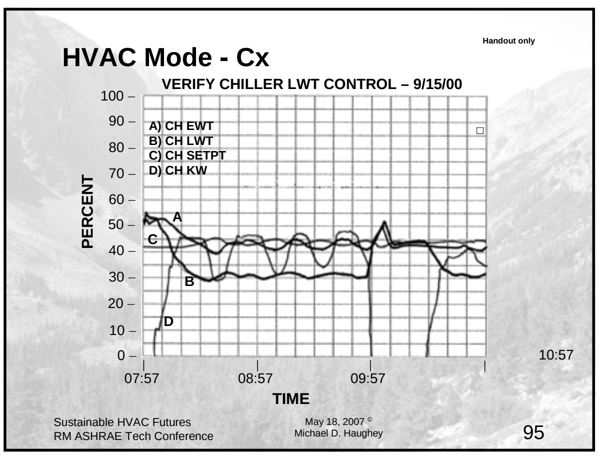
Handout only
HVAC Mode - Cx
VERIFY CHILLER LWT CONTROL – 9/15/00
A) CH EWT
B) CH LWT
C) CH SETPT
D) CH KW
PERCENT
TIME
07:57
08:57
09:57
10:57
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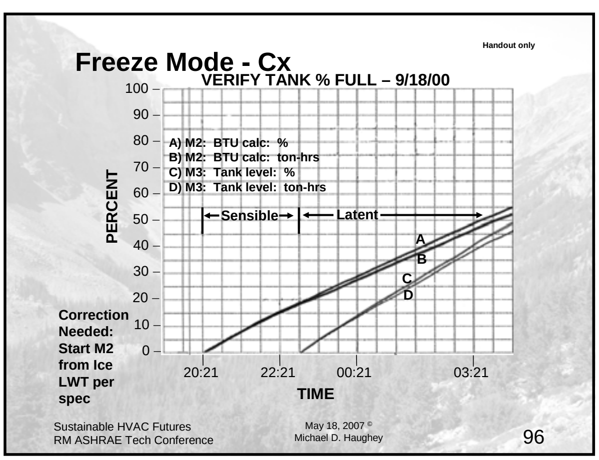
Handout only
Freeze Mode - Cx
VERIFY TANK % FULL – 9/18/00
A) M2: BTU calc: %
B) M2: BTU calc: ton-hrs
C) M3: Tank level: %
D) M3: Tank level: ton-hrs
Sensible
Latent
PERCENT
Correction Needed: Start M2 from Ice LWT per spec
TIME
20:21
22:21
00:21
03:21
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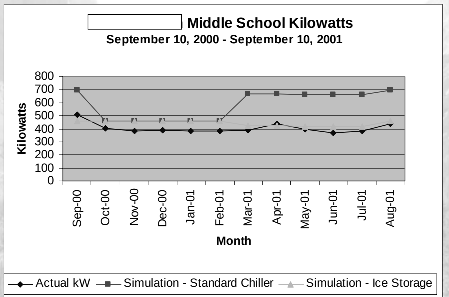
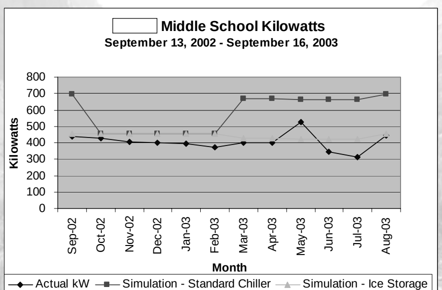
Actual kW
Energy Bills – 1st Year



Actual kW
Energy Bills - 2003



Outside Air
System Examples

- Outside air, heat recovery
- Accurate OSA measurement & control
  - Truth? – needed now, but not done
  - OSA Measurement
    - RTU's
    - Louvers
    - Delivery

Outside Air System Examples

- OSA distribution
- OSA tempering
- TAB – Cx - M & V Challenges
- Separate OSA systems
  - CO2 control
  - TAB – Cx - M & V
- Building-integrated OSA
  - “Cool tubes”
  - Hollow-core floor slabs

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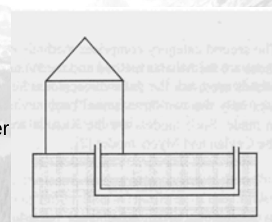
Ground Tempered OSA “Cool tubes” similar

- OSA ducts or “pipes”
- Issues
  - Control
  - Moisture, mold, other growths
  - Filtration
  - Optimization



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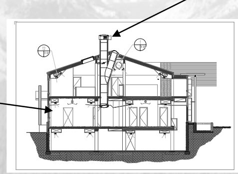
Building Mass & Natural Ventilation
Wind Tower

Windows let air in

Wind tower draws air out



Building & Mechanical System Integrated & Inseparable

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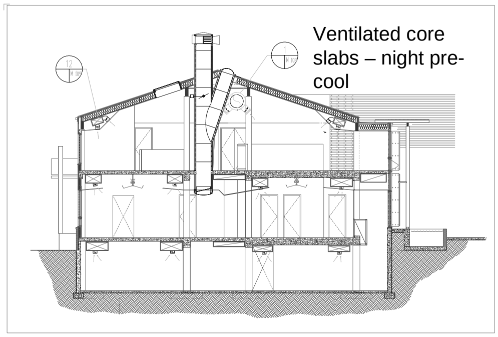

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Ventilated Core Slabs
TAB – Cx - M & V Challenges

- Predicting need for cooling
- Estimating how much
- 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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Zero or Net Zero
What, Why, How?

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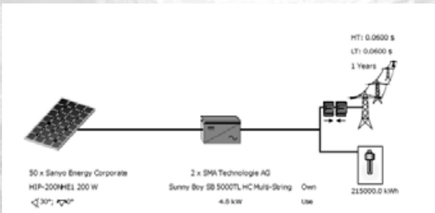
Zero What?

- Energy from THE GRID



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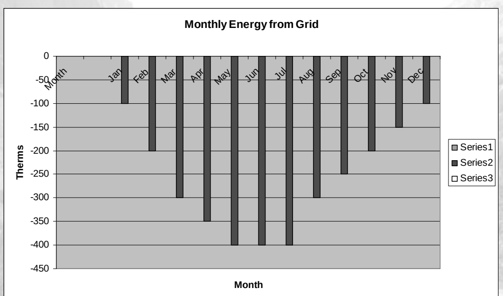
Zero



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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

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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 – cost effective
- 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

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

Handout only

Is 90% Savings In Commercial – Industrial Possible?

- Remember where we started – it has to happen!
- Buildings and systems
  - Lighting
  - Heating
  - Cooling
- Building uses (Processes)
  - Example – data center
    - Servers vs.
    - Multiple "blades"

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Net Zero Energy Homes - Local

- Local Project #2
  - Since Oct 2005:
    - Produced 600 kWh more than used
    - 35% more than used on energy source basis
    - 30 Therms of gas
- Local Project #1
  - Operational last Fall
  - Produced 200 kwh more than used
  - No backup heat system

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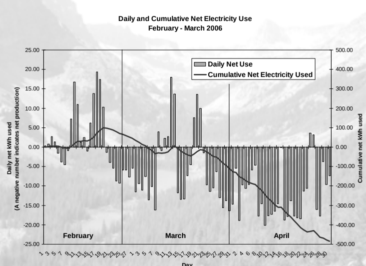
Local Project #2 – Daily net Elec



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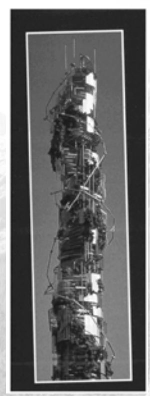
Toward Living Buildings – What is it?

- 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

The Living Building As A Mechanical System

- Traditional mechanical system does less heating, cooling, ventilating
- The building itself becomes the mechanical system – engineers assist with "engineering" the building as an active, "living" system



Ken Yang
Editt Tower - Singapore

- Bioclimatic skyscraper
- Vertical landscape
- Ground ecosystem integration & continuity
- Plant transpiration cooling

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

Natural Ventilation

- Operable Clerestory windows
  - Induce natural stack effect

Systems & Equipment
Natural Ventilation
Integration with Mechanical

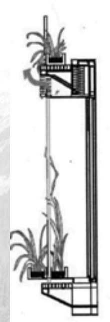
- Goals - low energy, occupant outside connection
- Manual window operation vs. mechanical energy consumption
- Window bugs ("mag contacts")
- Feedback to Occupants
- Mechanical lock-outs
- Commissioning

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

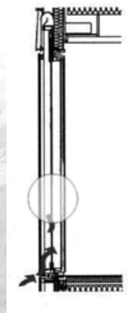
Double Skin Wall Systems (High Performance Facades)

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



Interactive Wall

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



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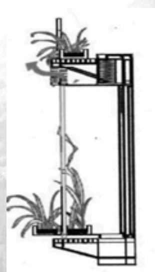
Vegetation Conditioning

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



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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, …

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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

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)

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

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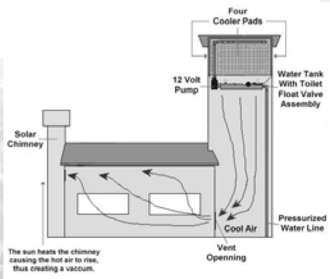
Cool Towers & Solar Chimneys

- Cool air falls
- Operable Windows
- Warm air induces draft



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Green Roofs

- Passive mechanical component
- R-Value calc?
- Cost – benefit: mech alternate
- Chicago City Hall – can be 60F cooler than adjacent roofs

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Adaptive Windows

- Human eye adjusts to light
- Future Adaptive Windows:
  - Adjust to light - transmittance
  - R-Value
  - SC
- Controllable surface coatings
- TAB – Cx – M & V Challenges?
  - Adjust adaptations to sunlight to proper light and heat transmission levels
  - This won't be easy!

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Continuous Education & Research Needs

- New design challenges
  - Transpiration cooling – ivy vs. cedar?
  - Mass timing – 2 PM vs 10 AM peak?
  - Radiant floor cooling
  - Simulation tools and data?

Handout for detail

Future

- Goal
  - Adapt as society adapts
  - Population increase, then stabilization
  - Incredible energy efficiency needed
- Method
  - Buildings will become net energy producers
  - Design & energy modeling of new innovations
  - TAB – Cx – M & V to optimize energy use