Advanced Cooling Strategies for Hot Dry Climates

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Electricity: Cooling is the Culprit

- Cooling causes electricity peaks
  - Á**7%** Load Factor for Residential
  - Á**22%** Load Factor for Non-Residential
- Cooling peak reducers - best new peaking plants

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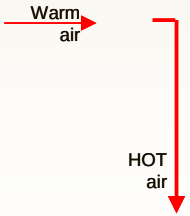
Western Climates: Issues = Opportunities

- Large Diurnal Temperature Swings
  - Issue – Poor Load Factor
  - Opportunity – Thermal Storage

- Low Outdoor Humidity
  - Issue – Non-Optimized Equipment
  - Opportunity – Evaporation for Cooling, Radiant Cooling



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WCEC: Who We Are

- Founded with UC Davis Energy Efficiency Center (2007)
- Industry Affiliation Structure
  - Utilities
    - PG&E, SCE, SMUD, SEMPRA
  - Manufacturers
    - Ice Energy, ICI, Lennox, Munters, NovaTorque, Seeley Intl., Speakman, Thermal Flow, Trane, Uponor, Viega, VRTX
  - Contracting/Design Firms
    - Beutler, Davis Energy Group, Timmons Design Engineers
  - State Agencies
    - CEC, DGS
  - Retailers
    - Wal-Mart, Target

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What We Do

- Cooling technologies optimized for hot, dry west
  - Á Support affiliate alliances and partnerships
  - Á Address market impediments (e.g. codes and standards)
  - Á Help bridge commercialization “valle
  - Á Emerging technology demonstrations
- Research and development
  - Á Identify, conduct and support key R&D
- Outreach activities
  - Á Catalog of energy-efficient cooling systems
  - Á Website, newsletters, presentations, publications
  - Á Education – university and professional

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Advanced Cooling Technology Portfolio

- **Technologies appropriate for new and retrofit**
  - Á Roof-top packaged units (including night-time ice)
    - Evaporative accessories
  - Á Evaporative cooling technologies
    - Stand-alone evaporative equipment
    - Hybrid evaporative/vapor-compression equipment
    - Water-cooled condensers
  - Á Swimming-pool-based air conditioning
  - Á Improved thermal-distribution/ventilation performance
- **Technologies for new construction**
  - Á Radiant floors
  - Á Low-cost chilled water storage
  - Á Night-sky radiative cooling

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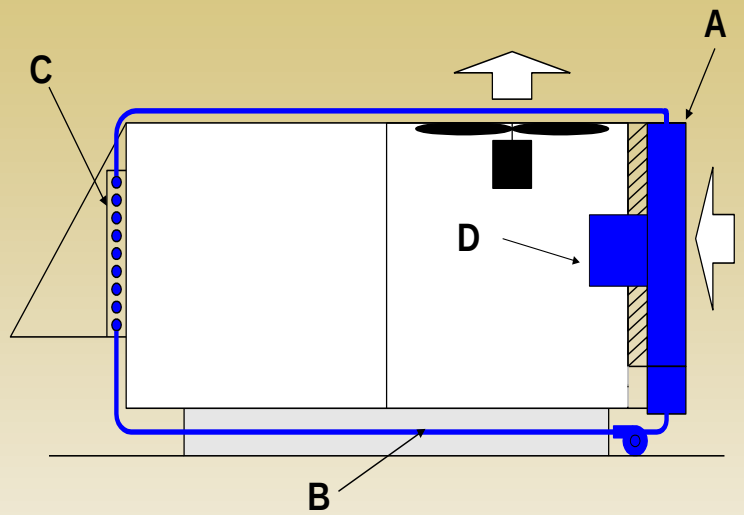
Evaporative Technology: DualCool

- Accessory system for RTUs
- Pre-cools condenser and ventilation air
- DOES NOT add moisture to indoors
- 25-30% energy and demand savings



SYSTEM SCHEMATIC

A - High quality condenser air pre-cooler

B - Pump & copper supply/return piping

C - Ventilation air precooling coil

D - Controls

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Radiative Technology: Roll-Out Radiant Floor

- Prior cost $6-7/ft^2
- Rollout cost ~$2/ft^2
- Full-scale installation at Wal-Mart store

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Radiant Floor Benefits

- Reduces latent cooling and blower energy
- Facilitates non-compressor cooling
- Projected savings 60-65%
- Projected demand reduction 45%+

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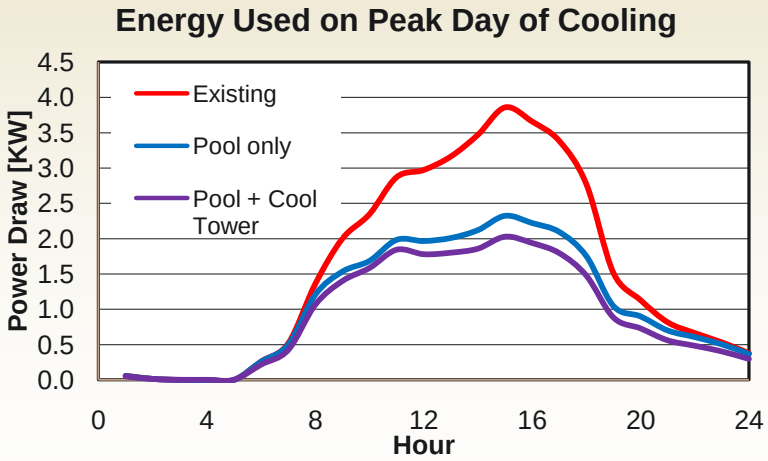
Combined Pool-Heating/Building-Cooling

- **Residential/Commercial Swimming Pools**
  - Night-time cooling (non-refrigerative) makes pool water available for day-time low-temperature heat rejection
    - 20-40ºF reduction in refrigerant condensing temperature
    - 20-50% improvement in EER – higher at peak conditions
  - Rejected heat serves useful function
    - Eliminates/reduces gas consumption for pool heating



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WCEC Market Activities

- **Policy and Market Drivers**
  - **Demonstrations**
  - **Western Cooling Challenge**
  - **Hot, Dry Air Conditioners**
  - **Water Initiative**
    - Water management for evaporative air conditioning
  - **DOE Standards**
    - SEER regional standards
    - Lab tests for annual savings predictions
  - **ASHRAE Standards**

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Western Cooling Challenge

- **Target Market:** Roof-Top Units (RTUs) with 3 – 30 ton capacity (>500-unit production capacity)

  RTUs cool 70% of non-residential floor space in the Western US
- **Target Performance:** 40% reduction in energy use and peak electricity demand
- **Reward Structure:** MOUs w CA IOUs and SMUD for incentive programs – Retailer program sponsorship

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Western Cooling Challenge: Performance

- Sensible **EER** (w/all parasitics):
  - Á at 105db/73wb: **14.0**
  - Á at 90db/64wb: **17.0**
- Max **gal/ton-hr** at 90/64: **4**
  (with 200 ppm hardness mineral content)
- Testing/data-analysis under WCEC observation
  (at manufacturer-party facility)cation or th
  - External static at 350 cfm/ton **0.7 in. H_2O**
  - MERV 7 Filtration
  - Outdoor Air **120** cfm/ton
  - Max Supply Humidity Ratio: **0.0092**
  - No use of R-22
  - Integral FDD, Voltage droop response

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Western Cooling Challenge: Key Issues

- **Performance Targets:**
  - Ground-up re-design eliminates major manufacturers
  - Bolt-on components for existing high-efficiency equipment
- **Technology Options:**
  - High-performance indirect evaporative systems (100% OA)
  - Hybrid ground-up designs
  - Accessorized existing equipment

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Western Cooling Challenge: Entry Status

Company	Original Equipment Manufacturer	Component Supplier
AMAX	Air handling equipment with evaporation and refrigeration	
Coolerado	Hybrid cooling units with indirect evaporative cooling	Advanced indirect evaporative module
Desert Aire	Dehumidification and dedicated outdoor air equipment	
Ice-Energy	Modular ice storage equipment and controls technologies	
Integrated Comfort Inc		Evaporative condenser pre-cooler, indirect outdoor air cooling
Munters	Full line of roof top humidity control equipment combining evaporative and refrigeration components	
Munters-Des Champs, DEG	Roof top humidity control equipment (partnership with Davis Energy Group)	
NovaTorque		Super-efficient, variable speed motors
Seeley International	Direct and indirect evaporative cooling equipment	Advanced indirect evaporative module
Thermal-Flow		Fluid coolers for RTUs
Trane	Full line of roof top unitary equipment (RTUs)	

Western Cooling Challenge: Schedule

January 2009	Laboratory testing of WCC entries can begin
June 2009	Field testing of WCC entries can begin
January 2010	Shipments of WCC-compliant products can begin

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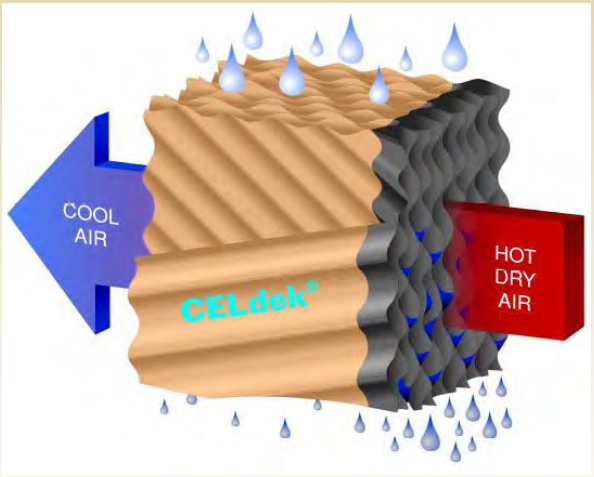
Advanced Technology Issue: Water Use

- Impediments to water-based cooling
  - Á On-site water use
  - Á Equipment maintenance
- Successful water-based systems for buildings
  - Á Cooling towers
  - Á Pressurized domestic water
  - Á Pools
  - Á Irrigation
- Water conservation
  - Á Techniques exist
  - Á Not optimized for small-scale evaporative cooling



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Evaporative Cooling: Water Use Metrics

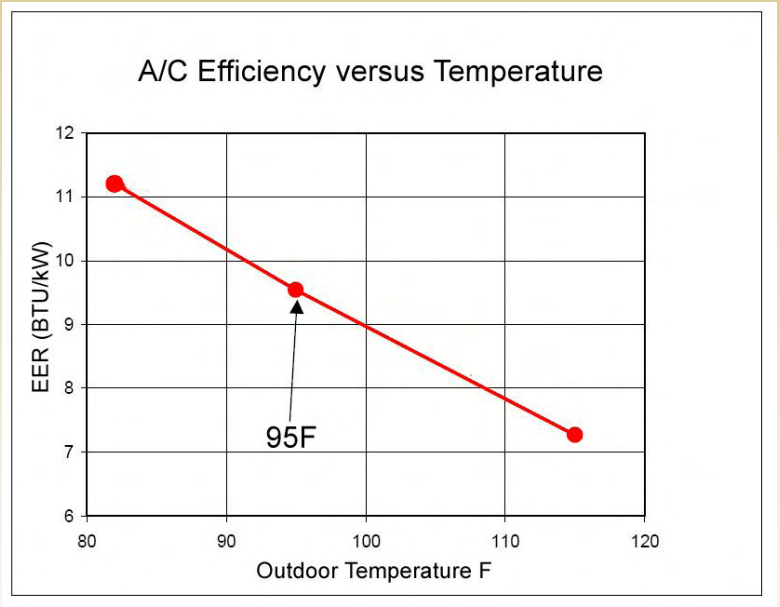
- Evaporative-Cooling Water Use
  - Á Treat water evaporation as the cooling source
  - Á Cooling potential = mass of water * heat of vaporization

$$Q_{cool-\max} = \frac{1050\left[\frac{Btu}{lbm}\right] * 8.3\left[\frac{lbm}{gal}\right]}{12{,}000\left[\frac{Btu}{ton \cdot h}\right]} = 0.73\left[\frac{ton \cdot h}{gal}\right] \qquad \eta_{cc} = \frac{Q_{delivered}}{Q_{cool-\max}}$$

- Maintenance Water Use
  - Á Rule of Thumb: 2/3 evaporation, 1/3 maintenance
  - Á Large Impact of Water Quality
- Indirect Water Consumption for Electricity Generation
  - Á Enormous range of values - 0.1-72 gal/KWh

Water Use for Condenser-Air Pre-Cooling

- Analysis Technique
  - Á Calculate change in EER with respect to condenser air temperature
    - Relatively linear
    - 1-2% change per ^{o}F
  - Á Calculate condenser temperature change per unit of water evaporated
  - Á Use EER change to calculate extra cooling delivered for the same electricity consumed



$$\eta_{cc} = 15 - 30\%$$

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Combined On-Site and Off-Site Water Use

- Evaporative Cooling[1]

$$W^{\#}_{combined} = W^{\#}_{on-site} + W^{\#}_{indirect}$$ = (1.4 to 6) + (0.2 to 8.8)

= **1.6 to15 gal/ton h**

- Compressor Cooling[1]

$$W^{\#}_{indirect}$$ = 0.6 to 22 gal/ton h

= **2.4 gal/ton h** (weighted average)

- Condenser Pre-Cooler[1]

$$W^{\#}_{combined} = W^{\#}_{on-site} + W^{\#}_{indirect}$$ = (0.1 gal/ton h ^{o}F)*ΔT + (2.4 gal/ton h)*(1-ΔT*1.5%)

= **3.1 gal/ton h** (average)

[1] EERs: 10 for compressor, 25 for evaporative, Average pre-cooler temperature depression 10^{o}F

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Advanced Technology Issue: Water Use

- WCEC Activities
  - Áprovide “institutional memory” on water issues
    - water-use yardsticks
  - Áaccess large cadre of water scientists at UCD
  - Ápursue water conservation solutions
    - save rain runoff for cooling
    - irrigate w/flushed water
    - night-sky water cooling

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WCEC Mission Summary

"Partner with stakeholders to develop energy efficient technologies, conduct research and demonstrations, disseminate information, and implement programs that reduce cooling-system electrical demand and energy consumption in the West"

http://wcec.ucdavis.edu/

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