# Real Time Data Center Cooling System (RTDCCS) Comparison to Traditional Legacy Data Center Cooling Systems

## Process Cooling
## Vs
## Comfort Cooling

# R4 Ventures LLC

# Key Benefits of the Real Time Data Center Cooling System (RTDCCS)

- Eliminate chillers, compressors and EPA regulated and EU banned refrigerants
- Meet or exceed CA Title 24 code
- Use process cooling instead of comfort cooling
- Have Real Time cooling control of varying rack loads of 3 to 50kW +
- Provide ±75°F ±5°F cool air back to Data Center White Space (DC WS)
- Control temperature tolerance within the DC WS to ± 1°F of set point
- Eliminate hot aisles and cold aisles in the Data Center
- Eliminate the need for hot aisle / cold aisle containment
- Restore “Lost Capacity” or “Stranded Capacity”
- Increase leasable Floor Area by eliminating CRACs and CRAHs
- Eliminates the need for air ducts in the DC White Space
- **Realize 40 to 85% energy savings**

# Real Time Data Center Cooling System (RTDCCS)

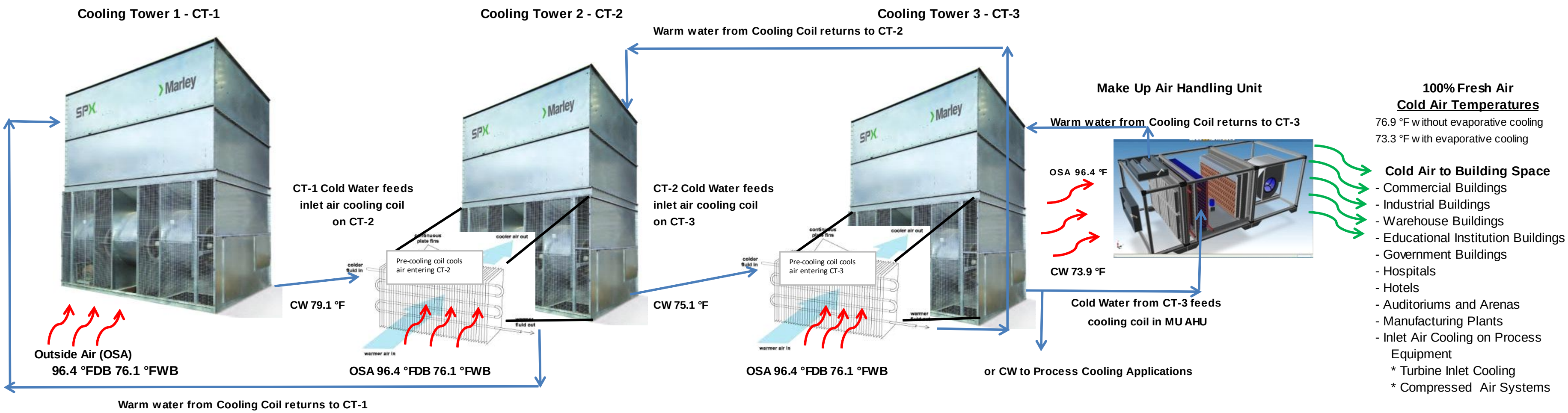
R4 Ventures LLC is applying commonly used semi-conductor clean room **process** cooling methods on semi-conductor tools to Data Center / Mission Critical racks and environments providing real time … load based **process** cooling at the rack level and eliminating hot isles and cold isles by combining its patented Multistage Evaporative Cooling System (MECS*),* patented Real Time Electronic Enclosure Cooling System (RTEECS) / Individual Server Enclosure Cooling System (ISECS) and its proprietary Real Time Monitoring and Control System (RTMCS) to create a Real Time Data Center Cooling System (RTDCCS).

## Patents

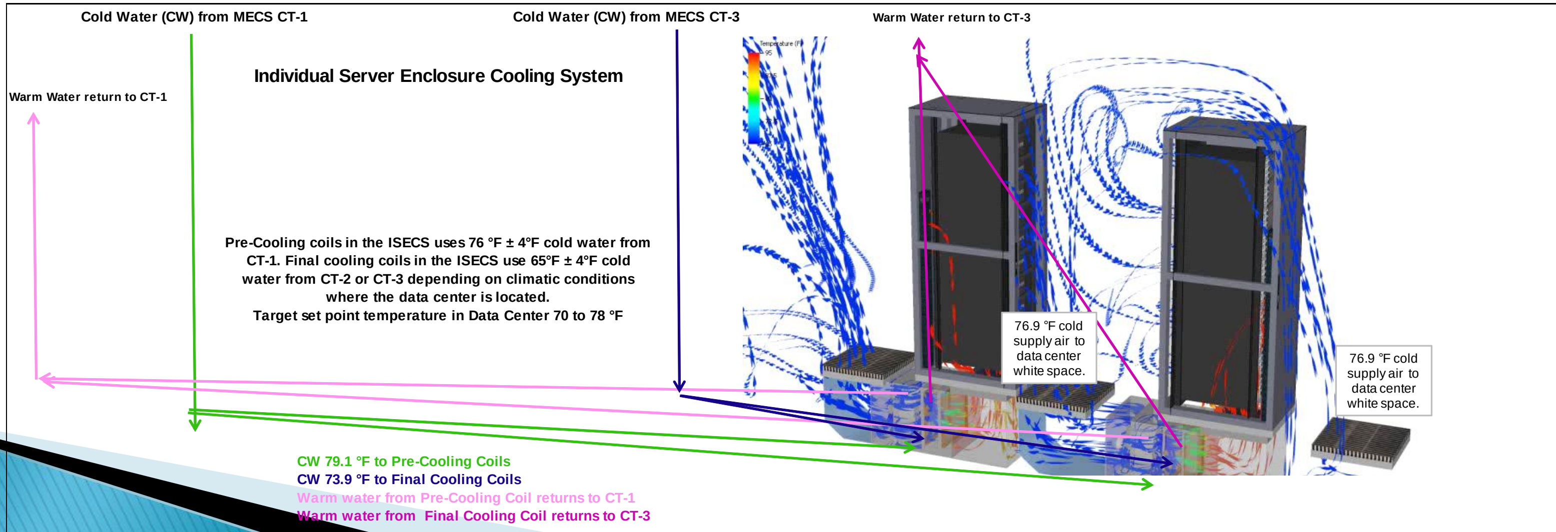
- Real Time Electronic Enclosure Cooling System (RTEECS)– US 8857204, October 14, 2014
- RTEECS – (ISECS CON1) – US 9445530, September 16, 2016
- RTEECS – (ISECS CIP1) – US 9476649, October 25, 2016
- Multistage Evaporative Cooling System (MECS) – US 8899061, December 2, 2014

# Real Time Data Center Cooling System (RTDCCS)
## Combines MECS – US 8899061, RTEECS – US 8857204, ISECS CON1 – US 9445530, and ISECS CIP1 – US 9476649

Water and air temperature of MECS based on AHRAE Phoenix AZ .4% summer design conditions for evaporative applications: 96.4°F Dry Bulb and 76.1°F Wet Bulb




* 100% Cold Fresh Air Exchange providing maximum oxygen levels to building spaces and its occupants
* No High Energy Consuming Compressors and No Harmful Refrigerants
* 60 to 80% less energy consumption than traditional commercial chillers and commercial air conditioners
* Corresponding 60 to 80% reduction in Green House Gases (GHGs) from power plants



# Diagram of Performance Analysis for Phoenix AZ of the Multistage Evaporative Cooling System (MECS - Patent #8,899,061)

Example Parameters:

1. ***Phoenix, AZ Summer Ambient Air Design Conditions (ASHRAE .4% for evaporative applications (35 hours per year) Phoenix AZ (PHX)*** are 96.4°FDB and 76.1°FWB for the Energy Recovery System (Unit) or ERU, all three CTs and the Makeup Air Handling Unit (MU AHU)
2. OSA is the inlet air at the above design parameters to all stages.
3. Air Conditions entering the Fill at each cooling tower (cooling stage):
   a. CT-1 – 96.4°FDB and 76.1°FWB **Air temperature entering Cooling Tower 1 (CT-1 designed at 3 °F approach temperature)**
   b. CT-2 – 81.1°FDB and 72.07°FWB **Pre-cooled air temp after passing thru cooling coil (c/coil) (CT-2 designed at 3 °F approach and c/coil 1.0 °F approach)**
   c. CT-3 – 77.1°FDB and 70.96°FWB **Pre-cooled air temp after passing thru cooling coil (c/coil) (CT-3 designed at 3 °F approach and c/coil 1.0 °F approach)**
4. Entered Air Conditions to the MU AHU is 96.4 °FDB and 76.1°FWB
5. Entered Air Conditions to the ERU is 96.4 °FDB and 76.1°FWB

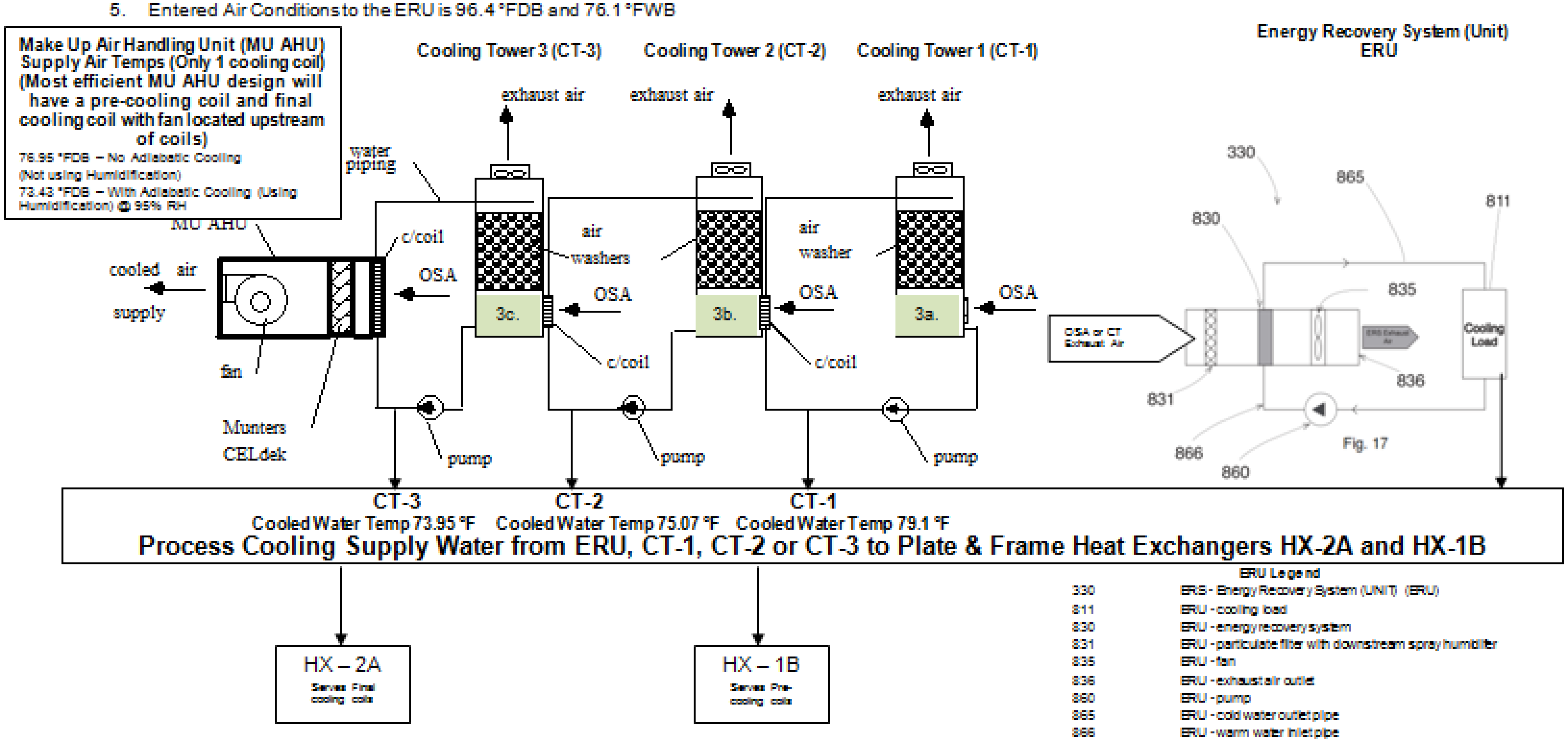



**Plate & Frame HX – HX-1B serving Pre-Cooling Coils of MU AHU and/or pre-cooling coils of ISECS. Plate & Frame HX – HX-2A serving Final Cooling Coils of MU AHU and/or final cooling coil of ISECS**

# RTDCCS Monthly Temperature Performance for Phoenix AZ

*See White Paper on our website www.natualcycleenergy.com: White Paper - Preliminary Temp Performance Evaluation MECS and RTDCCS detailing Temperature Performance in Phoenix AZ, San Jose CA and Washington DC.*

***Real Time Data Center Cooling System (RTDCCS) consisting of the Multistage Evaporative Cooling System (MECS) and Individual Server Enclosure Cooling Systems for each Rack (ISECS)***

***Cold Water & DC White Space Temp Performance in Phoenix AZ***

***ASHRAE Coincident Summer Design DB & WB Temps at .4% (Annual) for Evaporative Applications (35 hours per year)***

***Phoenix International Airport (PHX)***

**Energy Recovery Unit and / or Cooling Towers of the MECS Serving the RTDCCS**

- ERU, Cooling Towers (CT-1,CT-2, CT-3) and MU AHU commissioned to provide Cold Supply Air (green)
- ERUs and Cooling Towers that are not necessary to meet Mean Monthly Ambient Air Temps to generate cold makeup air (red)
- Selected Cold Water or Air Temps from ERU or Cooling Towers serving the application or the Supplemental Cooling Module (SCM) (yellow)

Advanced Multi-Purpose Multi-Stage Evaporative Cold Water/Cold Air Generating and Supply System (MECS) (US Patent # 8,899,061)

Real Time Individual Electronic Enclosure Cooling System (also know as Real Time Data Center Cooling System or RTDCCS) (US Patent # 8,857,204)

| | | | | | | Multistage Evaporative Cooling System (MECS) - Advanced Multi-Purpose Multi-Stage Evaporative Cold Water/Cold Air Generating and Supply System (MECS) (US Patent # 8,899,061) | | | | | Real Time Individual Electronic Enclosure Cooling System (also know as Real Time Data Center Cooling System or RTDCCS) (US Patent # 8,857,204) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Energy Recovery Unit (ERU) Cold Water Temp Leaving ERU, °F Without Outside Air (OSA) Humidification and With OSA Humidification | | Multistage Evaporative Cooling System Cold Water Temp Leaving Cooling Towers (CT), °F | | | Real Time Data Center Cooling System | | | | |
| | | | | | | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 | Column 7 | Column 8 | Column 9 | Column 10 |
| | DB °F | WB °F | Calculated Enthalpy (btu/lb) | Calculated Humidity Ratio (grains/lb) | Calculated Specific Volume (cu ft/lb) (ft3//lb) (used to determine mass flow rate in Turbine Inlet Cooling applications) | ERU without OSA Humidification | ERU with OSA Humidification to 95% RH (ERU w/H) Adiabatic Cooling(AC)) | CT-1 | CT-2 | CT-3 | Water Temp from ERU, ERU w/AC or CT-1, CT-2 or CT-3 (Source shown in RED) entering the Plate and Frame Heat Exchangers HX-1 and HX-2 (only HX-1 is needed in Phoenix AZ) | Estimated Cold Water Temp Leaving Plate & Frame HX Served by Selected Stage of MECS | Estimated Cold Air Temp Leaving Fan Coil Unit with only the PCC (FCC not necessary) serving each rack (ISECS) providing cooled air to the Data Center White Space | Lowest Achievable Data Center White Space Temperature (Temp can be set to ±78 °F in cooler months to save significant energy costs through proper configuration of the Monitoring and Control hardware and software) | ASHRAE recommeded / allowable Data Center White Space Temperature 80.6 °F DB / 89.6 °F DB (27 °C DB / 32 °C DB) (see page 11) |
| ASHRAE Coincident Summer Design DB & WB Temps at .4% (Annual) for Evaporative Applications (35 hours per year) | 96.40 | 76.10 | 40.46 | 109.72 | 15.01 | 98.40 | 79.07 | 79.10 | 74.80 | 73.59 | 74.80 / CT-2 | 75.80 | 76.80 | 76.80 | 80.6 / 89.6 |
| **ASHRAE or Local Airport Mean Monthly DB and WB Temperatures** | | | | | | | | | | | | | | | |
| January | 53.70 | 43.90 | 17.36 | 28.86 | 13.60 | 55.70 | 46.53 | 46.90 | 44.54 | 43.35 | 55.70/ ERU | 56.70 | 57.70 | 57.70 | 80.6 / 89.6 |
| February | 57.50 | 46.10 | 18.49 | 30.22 | 13.71 | 59.50 | 48.75 | 49.10 | 46.05 | 44.55 | 59.50 / ERU | 60.50 | 61.50 | 61.50 | 80.6 / 89.6 |
| March | 62.30 | 48.60 | 19.83 | 31.36 | 13.83 | 64.30 | 51.25 | 51.60 | 47.61 | 45.68 | 64.30 / ERU | 65.30 | 66.30 | 66.30 | 80.6 / 89.6 |
| April | 69.90 | 52.30 | 21.94 | 33.03 | 14.04 | 71.90 | 54.98 | 55.30 | 49.82 | 47.26 | 71.90 / ERU | 72.90 | 73.90 | 73.90 | 80.6 / 89.6 |
| May | 78.90 | 56.70 | 24.65 | 36.41 | 14.29 | 80.90 | 59.42 | 59.70 | 52.73 | 49.63 | 59.42 / ERU w/AC | 60.42 | 61.42 | 61.42 | 80.6 / 89.6 |
| June | 88.00 | 62.00 | 28.27 | 45.41 | 14.57 | 90.00 | 65.42 | 65.00 | 57.28 | 54.12 | 65.42 / ERU w/AC | 66.42 | 67.42 | 67.42 | 80.6 / 89.6 |
| July | 92.80 | 70.00 | 34.69 | 78.73 | 14.81 | 94.80 | 72.85 | 73.00 | 67.58 | 65.80 | 73.00 / CT-1 | 74.00 | 75.00 | 75.00 | 80.6 / 89.6 |
| August | 91.30 | 70.50 | 35.15 | 83.98 | 14.79 | 93.30 | 73.39 | 73.50 | 68.78 | 67.27 | 73.50 / CT-1 | 74.50 | 75.50 | 75.50 | 80.6 / 89.6 |
| September | 85.90 | 65.70 | 31.12 | 66.83 | 14.58 | 87.90 | 68.53 | 68.70 | 63.65 | 61.86 | 68.53 / ERU w/AC | 69.53 | 70.53 | 70.53 | 80.6 / 89.6 |
| October | 74.40 | 57.40 | 25.13 | 46.51 | 14.21 | 76.40 | 60.15 | 60.40 | 55.71 | 53.75 | 60.15 / ERU w/AC | 61.15 | 62.15 | 62.15 | 80.6 / 89.6 |
| November | 61.80 | [illegible] | 20.06 | 33.58 | 13.83 | 63.80 | 51.70 | 52.00 | 48.46 | 46.78 | 63.80/ ERU | 64.80 | 65.80 | 65.80 | 80.6 / 89.6 |
| December | 54.00 | 44.00 | [illegible] | 28.71 | 13.61 | 56.00 | 46.64 | 47.00 | 44.54 | 43.30 | 56.00 / ERU | 57.00 | 58.00 | 58.00 | 80.6 / 89.6 |

# Traditional Legacy Data Center Cooling Systems / Solutions

| Available Cooling System | Availability | Manufacturers | Commonality |
|---|---|---|---|
| CRAC Cooled Systems | 30+ Years | Liebert/Vertiv, APC, DataAire, Stultz | Very Common |
| CRAH Cooled Systems | 30+ Years | Liebert/Vertiv, APC, DataAire, Stultz | Very Common |
| CRAC with Hot & Cold Aisle Containment | 5 – 10 Years | Liebert/Vertiv, DataAire, Stultz plus containment from Rittal, CPI, Polargy, APC, Knurr | Gaining Acceptance |
| CRAH with Hot & Cold Aisle Containment | 5 – 10 Years | Liebert/Vertiv, DataAire, Stultz plus containment from Rittal, CPI, Polargy, APC, Knurr | Gaining Acceptance |
| Liquid Cooled Racks Unoptimized | 8 Years | Rittal, APC, Knurr, Liebert/Vertiv, HPE | Common |
| Liquid Cooled Racks Chilled Water (CW) Temp Optimized | 8 Years | APC, Liebert/Vertiv, Rittal, HPE, Knurr | Less Common |
| Liq Cooled Racks CW Temp Optimized & Evap Free Cooling | 8 Years | APC, Liebert/Vertiv, Rittal, HPE, Knurr | Less Common |
| Active Liq Cooled Doors , CW Temp Opti & Evap Free Cooling | 5 Years | APC, Liebert/Vertiv, Rittal, HPE | Less Common |
| Passive Liq Cooled Doors , CW Temp Opti & Evap Free Cooling | 8 Years | APC, Liebert/Vertiv, Rittal, IBM, Vette | Less Common |
| Pumped Refrigerant Systems | 5 Years | Liebert/Vertiv, APC | Less Common |
| Air Side Economizing | 30+ Years | Custom Engineered Solutions with components from various suppliers & manufacturers | Common |

# Comparison of RTDCCS to Legacy Cooling Systems

| Real Time Data Center Cooling System | Traditional DC Mechanical Refrigeration Systems |
|---|---|
| Uses **processing cooling** method to cool individual server rack enclosure's heat load demand at the heat source in real time whether the rack is operating at 3 KW or 50KW. | Uses traditional **comfort cooling** approach of supplying conditioned air into the data center space without regard to variable high heat load demand at specific high density server rack areas. |
| Can maintain extremely tight temperature tolerances within the data center space of + or - 1 degree F at any point in space, whether 1 foot above the raised floor or 7 feet above the raised floor. (At the individual rack level) | No extreme temperatures tolerances can be maintained in the data center due to filling the space with conditioned air and not directing it to the variable heat loads at the rack level leading to wide temperature variations at 1 foot above the raised floor and 7 feet above the raised floor.<br>Variations can range from 10 to 30 degrees F. |
| Completely eliminates hot aisles and cold aisles and thereby eliminating the need for any containment systems, additional duct work, or additional fans. This capital cost is eliminated. | Data center white space is set up in a traditional hot aisle and cold aisle configuration and requires special hot aisle or cold aisle containment systems, additional duct work, and various additional fan configurations at substantial additional capital cost. |
| Data Center white space set point temperature can be set at the current ASHRAE recommended temperature of 80.6 °F or allowed temperature of 89.6°F saving data centers significant cooling energy costs without fear the hot air reaching the individual server rack enclosure air inlets and thereby putting server warranties in jeopardy. | Data Center white space temperature must be set at a significantly lower temperature to insure the top server in each individual rack is receiving conditioned air at a temperature that will not violate warranties, requires the traditional system to be oversized by 50 to 100% adding substantial capital costs, and will use significantly more cooling energy and energy costs. |

# Competitive Edge - Continued

| Real Time Data Center Cooling System | Trad'l DC Mechanical Refrigeration Systems |
|---|---|
| The Real Time Data Center Cooling System can be "Right Sized" to meet the longer term design criteria of the data center white space without over sizing the system and can be easily expanded to meet higher densities and cooling loads of individual server rack enclosures. | Due to the fact that traditional mechanical refrigeration systems are inherently unable to deliver the required amounts of the cooling air to all individual server rack enclosures and meet real time cooling demand as rack densities increase, this cooling system must be oversized by 50 to 100% to insure the amount of supply air will be available to meet the cooling requirements of the space. |
| Retro-commissioning an existing legacy data center with a RTDCCS can bring back "Lost Capacity" or "Stranded Capacity" due to inadequate cooling. | "Lost Capacity" or "Stranded Capacity" cannot be recaptured without a significant expansion of the traditional mechanical refrigeration system at a significant capital cost. |
| **Retro-commissioning an existing legacy data center with a RTDCCS will allow the removable of CRAC and CRAH units from the data center white space (if applicable) thereby freeing up space for additional server rack enclosures. Legacy data centers can increase rack capacity by 10 to 20% and leasable power thereby significantly increasing revenue without a large CAPEX cost. Uptime Institute has estimated the capital cost of "Lost Capacity" to be $8,308 per KW or $8,308,000 per MW.** | Not available with traditional mechanical refrigeration systems. |

# RTDCCS Energy and GHG (Carbon Footprint) Savings

***Comparing Various Data Center Cooling System Energy Usage in KW per Ton***

White Paper - KW / Ton data from Rittal White Paper 507: Understanding Data Center Cooling Energy Usage & Reduction Methods by Daniel Kennedy (See pages 7-30)

- **Note 1: Rittal Corporation White Paper Data -The impact of these energy savings is dependent on the installation location because of the variances in ambient outdoor temperatures in different parts of the world. The average annual hourly energy usage analysis figures for six major cities (New York, Chicago, San Francisco, Phoenix, Miami and Atlanta) were used in developing this analysis and KW / Ton calculations.**

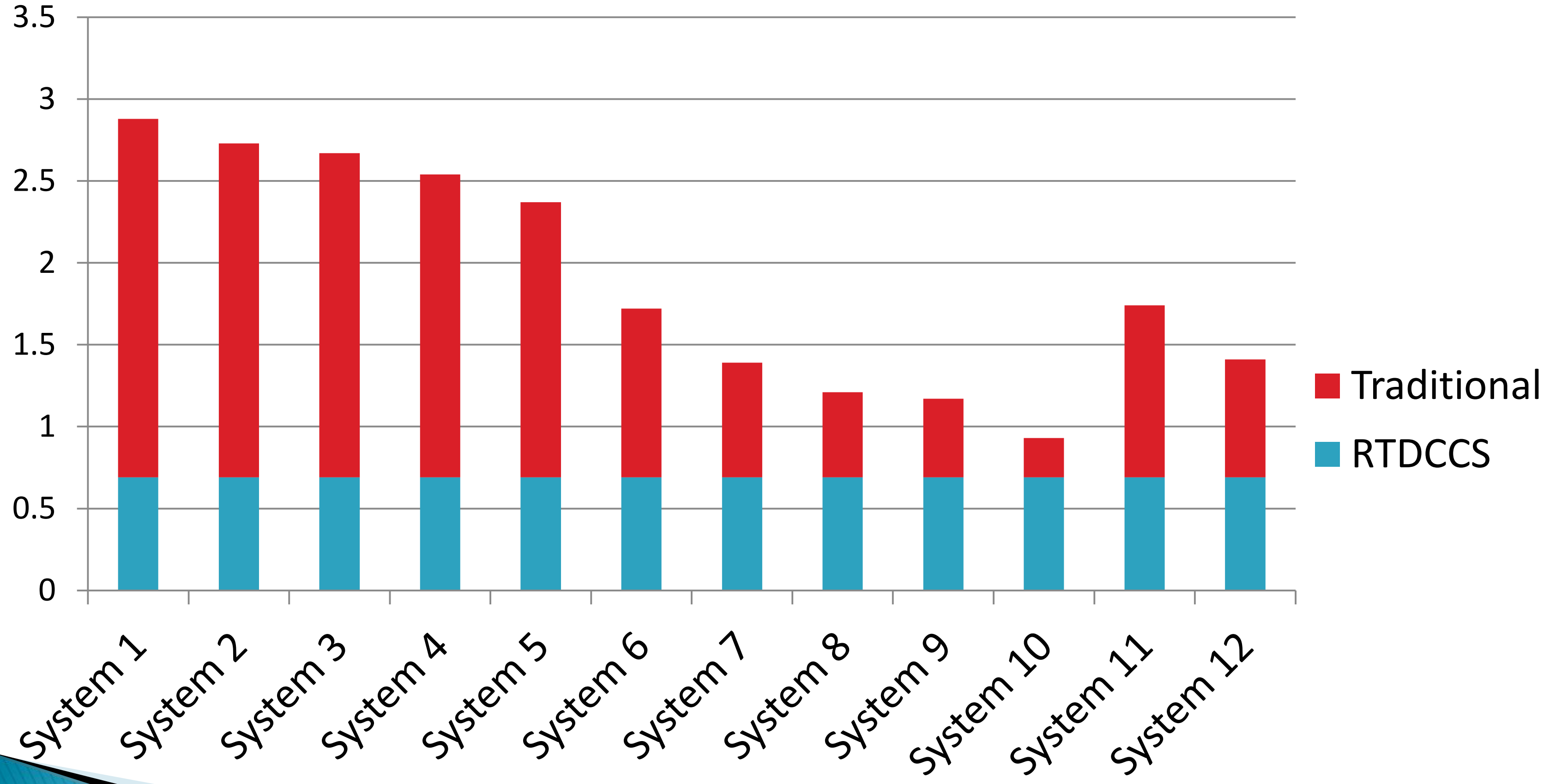
- **Note 2: R4 Ventures LLC data and analysis for determining energy usage of the Real Time Data Center Cooling System (RTDCCS), which incorporates the Multistage Evaporative Cooling System (MECS) and the Individual Server Enclosure Cooling System (ISECS), is based similar conditions to those stated in Note 1 above.**

# Energy Usage Comparison of Traditional Data Center Cooling Systems to RTDCCS

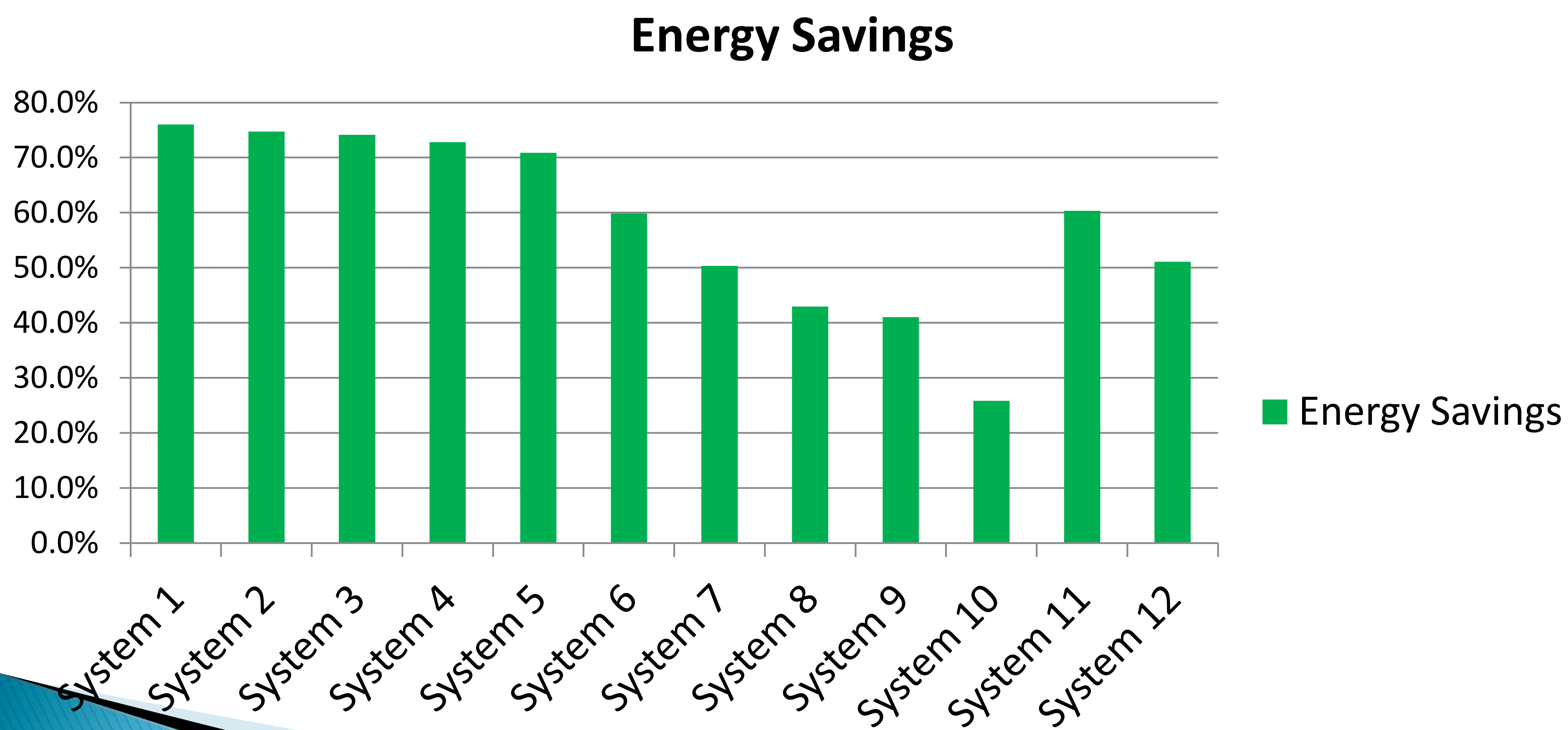
| | | Trad'l Mechanical Cooling KW / Ton | RTDCCS KW / Ton | KW / Ton Savings | % Energy Savings |
|---|---|---|---|---|---|
| System 1 | CRAC Cooled System | 2.88 | 0.69 | 2.19 | **76.0%** |
| System 2 | CRAH Cooled Systems – Chilled Water Based | 2.73 | 0.69 | 2.04 | **74.7%** |
| System 3 | CRAC Cooled System w Containment | 2.67 | 0.69 | 1.98 | **74.2%** |
| System 4 | CRAH Cooled System w Containment | 2.54 | 0.69 | 1.85 | **72.8%** |
| System 5 | Liquid Cooled Racks Unoptimized | 2.37 | 0.69 | 1.68 | **70.9%** |
| System 6 | Liquid Cooled Racks Chilled Water Temperatures Optimized | 1.72 | 0.69 | 1.03 | **59.9%** |
| System 7 | Liquid Cooled Racks Chilled Water Temperatures Optimized and Free Cooling Systems | 1.39 | 0.69 | 0.70 | **50.4%** |
| System 8 | Liquid Cooled Racks Chilled Water Temperatures Optimized and **Evaporative** Free Cooling Systems | 1.21 | 0.69 | 0.52 | **43.0%** |
| System 9 | Active Liquid Cooled Doors, Chilled Water Temp Optimized, & Evaporative Free Cooling Systems | 1.17 | 0.69 | 0.48 | **41.0%** |
| System 10 | Passive Liquid Cooled Doors Chilled Water Temp Optimized & Evaporative Free Cooling Systems | 0.93 | 0.69 | 0.24 | **25.8%** |
| System 11 | Pumped Refrigerant Systems | 1.74 | 0.69 | 1.05 | **60.3%** |
| System 12 | Air Side Economizing | 1.41 | 0.69 | 0.72 | **51.1%** |

Source Data: White Paper - RTDCCS Benefits and Energy Savings Comparison to Traditional Cooling Systems January 2014

# Comparison Energy Usage in KW / Ton

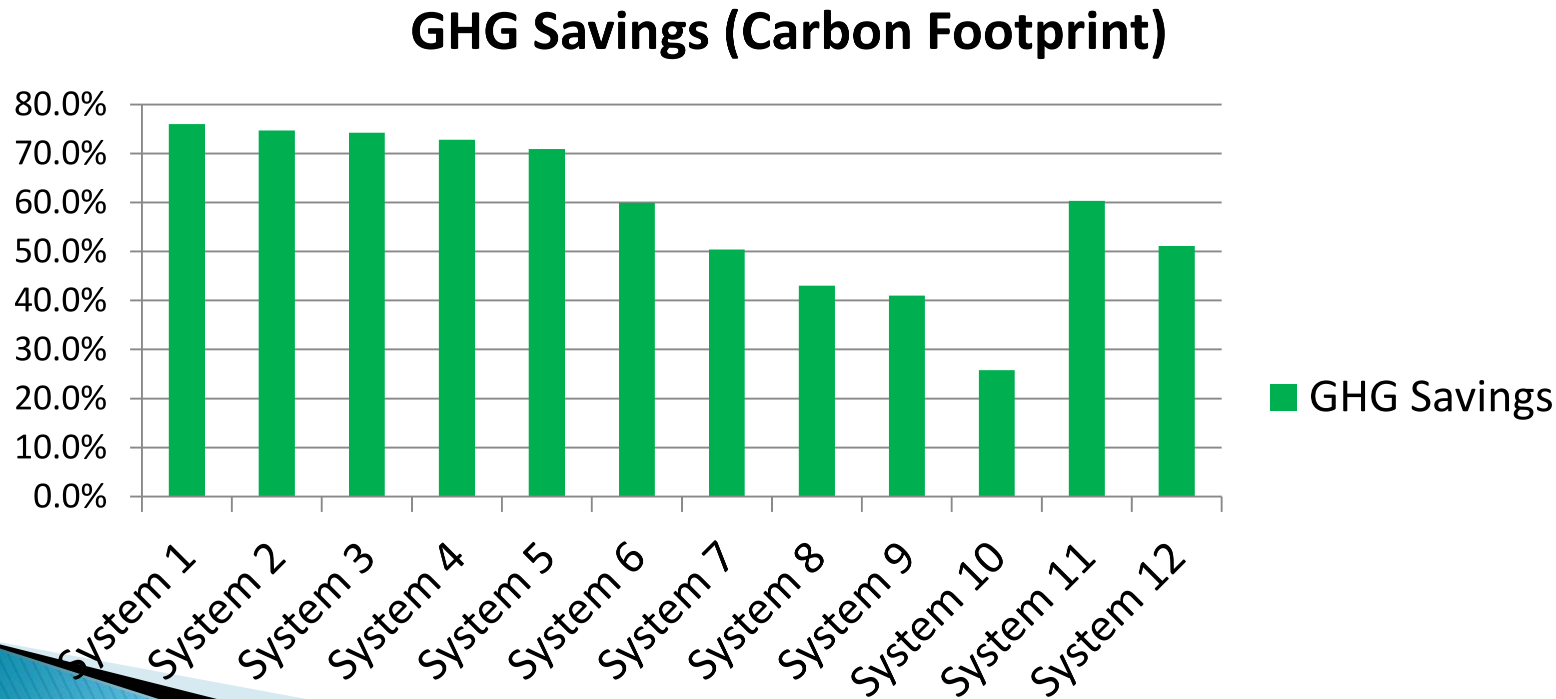


# RTDCCS Energy Savings vs. Traditional Mechanical Systems



# RTDCCS GHG Savings vs. Traditional Mechanical Systems

The carbon output per kWHr assumed is 0.524 pounds per kWHr based on Pacific Gas and Electrics published numbers for the generation of electricity in traditional power plants



# Technology Risk Comparison

| | Real Time Data Center Cooling System | Traditional Data Center Mechanical Refrigeration System | Commercial / Industrial Central Plant / Chillers |
|---|---|---|---|
| **System Design** | Custom | Custom | Custom |
| **Designed by:** | MP&E Firm | MP&E Firm | MP&E Firm |
| **Large System Components (Chillers, Cooling Towers, Air Handling Units, etc.)** | Specified by Mechanical Engineering Firm & Commissioned by Mechanical Contracting Firm | Specified by Mechanical Engineering Firm & Commissioned by Mechanical Contracting Firm | Specified by Mechanical Engineering Firm & Commissioned by Mechanical Contracting Firm |
| **Small System Components (Fans, pumps, motors, piping, ductwork, flow control valves, sensors, etc.)** | "Off the Shelf" | "Off the Shelf" | "Off the Shelf" |
| **Monitoring & Control Software** | Modified "Off the Shelf" integrated with Energy Management System | Modified "Off the Shelf" integrated with Energy Management System | Modified "Off the Shelf" integrated with Energy Management System |
| **Engineering Expertise** | Thermodynamics, HVAC, Process & Comfort Cooling | Thermodynamics, HVAC and Comfort Cooling | Thermodynamics, HVAC, Comfort & Process Cooling |
| **Installation & Commissioning** | Mechanical Contractor | Mechanical Contractor | Mechanical Contractor |
| **Bank Financing Risk** | None w/ Experienced MP&E & Mechanical Contractor | None w/ Experienced MP&E & Mechanical Contractor | None w/ Experienced MP&E & Mechanical Contractor |

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