District Cooling
Sustainable Design

Presented by George Berbari
CEO of DC PRO Engineering
**Central Chilled Water plants existed in the Middle East as early as the 1960’s. Few examples are old Beirut Airport and American University of Beirut.**

**First District Cooling utility company started in Abu Dhabi in 1998 by building a 4,000 Ton Gas Engine Driven Centrifugal Chillers plant serving the military maintenance facilities.**

**By the end of 2006 more than 500,000 Tons of District Cooling Plants were operational with investments exceeding US $1.1 Billion.**

**In 2015 the District Cooling industry jumped to over 5 Million Tons in the GCC countries equivalent to the total United States for the past 100 years.**

**According to new market research study, the District Cooling market is expected to reach US$ 29 Billion by 2020 at a CGAR of 11.4%.**
Why District Cooling
Top Countries
Ecological Foot Print

Top 10 countries with the biggest ecological footprint per person

1. Qatar
2. Kuwait
3. UAE*
4. Denmark
5. USA
6. Belgium
7. Australia
8. Canada
9. Netherlands
10. Ireland

Top 10 African countries with the biggest ecological footprint per person

1. Mauritius
2. Mauritania
3. Botswana
4. South Africa
5. Egypt
6. Namibia
7. Tunisia
8. Chad
9. Mali
10. Gabon

*United Arab Emirates

Source: WWF

Graphics24
Regional Electricity Consumption

Projected energy consumption of Gulf countries

- Saudi Arabia
- UAE
- Kuwait
- Qatar
- Oman
- Bahrain

Millions tonnes of oil equivalent

Source: Electricity Policy Research Group/Economist Intelligence Unit 2010
Regional Electricity Consumption

GCC installed capacity vs. required capacity (GW)

- UAE: Installed capacity 2012 = 23 GW, Required capacity 2020 = 39 GW
- KSA: Installed capacity 2012 = 66 GW, Required capacity 2020 = 90 GW
- Qatar: Installed capacity 2012 = 9 GW, Required capacity 2020 = 11 GW
- Kuwait: Installed capacity 2012 = 15 GW, Required capacity 2020 = 24 GW
- Oman: Installed capacity 2012 = 5 GW, Required capacity 2020 = 10 GW
- Bahrain: Installed capacity 2012 = 4 GW, Required capacity 2020 = 5 GW
District Cooling

Main Drivers

Developers
- Up to 8% Capital Cost Savings

District Cooling Provider
- 12 to 15% Internal Rate of Return (IRR)

Government or Utility Company
- Over 50% Reduction of Electric Power Consumption

Environment
- Reduction of CO2 and Refrigerant Emissions by 40 to 70%
District Cooling
Sustainable Designs
District Cooling Plants
Sustainable Design

Design Broad Objectives

- Most Design Point Energy Efficient.
- Cost effective.
- Smallest foot print.
- Most Energy Efficient based on Year Round Operational.
- High reliability.
- Maintainability.
- Good Aesthetics.
District Cooling Plants
Sustainable Design

Design Specific Objectives

◦ Maximum Design Zero Tolerance Point KW/Ton (Total Plant)
  ◦ Cond. 94 / 106°F + CHW 56 / 40 °F (Middle east) 0.90 KW/Ton
  ◦ Cond. 85 / 107 °F + CHW 56 / 40 °F (USA) 0.82 KW/Ton

◦ Cost effective
  ◦ Less Than US $ 1,200 / Ton for total plant for a plant size of around 10,000 Ton.

◦ Smallest foot print
  ◦ 10 Ton / m² inclusive of thermal storage for plant size of less than 10,000 Ton capacity.
  ◦ 15 Ton / m² inclusive of thermal storage for plant size of more than 20,000 Ton capacity.

◦ Most Energy Efficient based on Year Round Operation
  ◦ Annual operating Efficiency of 0 to 10% lower than design
District Cooling Plants
Sustainable Design

Design Specific Objectives

- High reliability.
  - **99.96%** Availability (Less than 3.5 Hours Total Outage per Year)
- Maintainability.
  - Ability to clean condenser tubes once a year in less than 4 working Hours per condenser.
  - Ability to remove any component in the plant within 8 working hours.
- Good Aesthetics.
  - As Judged by general public
Series Counter flow vs. Parallel Chillers’ arrangement

- Simplifies piping arrangement and reduce # of primary chilled water pumps, condenser pumps, valves, control valves and possibly cooling towers cells.

- Hence reduce foot print and construction cost.

- Reduce power consumption by 0.03 KW/Ton or around 3.9%.

- Reduction in # of chillers may have an adverse effect on part load performance as well as overall plant reliability which will resolved by using thermal storage.
## Typical Chillers Selection (Parallel & series / Parallel counter Flow)

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<tr>
<th></th>
<th>Qty</th>
<th>Chiller Capacity Ton</th>
<th>Compressor or pump Input Power KW</th>
<th>Compressor or pump Input Power KW/Ton</th>
<th>Condenser Flow GPM</th>
<th>Pressure drop ft</th>
<th>Pumping Power KW</th>
<th>Evaporator Flow GPM</th>
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</table>
Benefits of Thermal Storage

- According to field data, the load profile indicates that 20% peak shaving is the analyzed average field data vs. less than 10% in computer modeling due to non-accuracy of weather and solar data.

- Stratified water thermal storage tank reduce total construction cost by almost US $2,000,000 in a 12,500 Ton plant or by 12% of the total chilled water plant cost of around US $15,500,000.
District Cooling Plants
Sustainable Design

BENEFIT OF DISTRICT COOLING & THERMAL STORAGE
(ELECTRIC POWER DEMAND REDUCTION OF A 12,500 TON PLANTROOM)

- Typical A/C System
- District Cooling System
- District Cooling System with Thermal Storage

- 54.3% peak shaving when Thermal Storage is Used.
- 43% peak shaving with District Cooling Plants

- 21,875 kW
- 11,875 kW
- 9,500 kW
District Cooling Plants
Sustainable Design

Cooling Tower make Up Water

- Evaporation Losses is estimated at 7.2 Lit/ton-Hr (1.9 US Gal / Ton-Hr) or 1.3% of the 2.43 US GPM / Ton of condenser Flow Rate.

- Desalinated Fresh Water in UAE is very soft and has salt content of 150 ppm. Hence # of cycle of concentration is 5 and the blow-down from the cooling tower is 1.8 Lit/ton-Hr (0.475 US Gal / Ton-Hr) making the total water usage of (9.0 Lit/ton-Hr (2.375 US Gal / Ton-Hr).

- Treated Sewage Effluent (TSE) is rich in nitrate and other dissolved solid. The # of cycle of concentration is 2.5 and the blow-down from the cooling tower is 4.8 Lit/ton-Hr (1.27 US Gal / Ton-Hr) making the total TSE water usage of (12.0 Lit/ton-Hr (3.17 US Gal / Ton-Hr).
District Cooling Plants
Sustainable Design

Cooling Tower make Up Water (cont’d)

- The best application for Cooling Tower water optimization is to utilize TSE water when available and fresh water when TSE water is short. Hence the plant is designed to operate with both water sources with separate tank and pumping arrangement for each.

- The best Application to reutilize blow-down water is its direct usage in irrigation for non edible plantation.

- One application in UAE has recycled blow-down via dechlorinification process (As Chlorine deteriorate the R.O membrane) and the via an R.O plant for re-use in cooling tower make up.
District Cooling Plants
Sustainable Design

Cost & Plant Foot Print Optimization Key Strategies

◦ Install Thermal Storage Tank above water storage.

◦ Have a proper equipment layout where piping is flowing in smooth logical sense and along with proper layout and under ceiling cross over would minimize piping length and maintain adequate and open maintenance space.

◦ Proper Electrical Equipment Layout where Medium Voltage Switchgear and transformer room are segregated in separate G.F rooms with proper cooling or ventilation and adequate fire protection is maintained.

◦ Install low voltage MCC under transformers directly and close to the pumps in the basement level to minimize cable runs.
District Cooling Plants
Sustainable Design

Cost & Plant Foot Print Optimization Key Strategies

◦ Industrial Control: **If you cannot measure it you cannot manage it.**

◦ Industrial control based on PLC and SCADA that communicate directly with electric equipment switchgear and can communicate Industrial communication protocol’s that generate automated online, hourly, daily, weekly and monthly reports on plant power and water consumption.

◦ Utilize high precision field bus communicated industrial grade instrumentation, High accuracy magnetic or ultrasonic flow Meters and high accuracy class 0.5 amp meters.
District Cooling Plants
Sustainable Design

O & M Cost Optimization Key O&M strategies

- Manpower Planning: Minimize the number of staff for maximum two per day shift to carry out routine maintenance and water testing and one per afternoon or night shift.

- Resolve the low delta T syndrome by design and by proper operation:
  - I pioneered the concept of customers’ or tertiary pump control from the plant PLC via the Energy Transfer Station (Heat Exchanger) PLC when indirect building connection is utilized.
  - Direct Pumping to the building with industrial grade differential pressure transmitter installed in ¾ of the chilled water loop (downstream with automatically adjustable set point from the plant PLC by simply linking it to ambient temperature.)
# District Cooling Plants
## Sustainable Design

## Chiller Plant Part Load Performance @ 85°F Ent. Cond. Temp.

### Impact of Low Chilled Water ΔT

<table>
<thead>
<tr>
<th>Description</th>
<th>Demand Cooling Load - Ton</th>
<th>Chiller Capacity - Ton</th>
<th>Chiller CHW Flow - GPM</th>
<th>Number of Operating Chillers</th>
<th>Chiller % Loading</th>
<th>Chilled water supply Temp. - °F</th>
<th>Chilled water return Temp. - °F</th>
<th>Chilled Water Delta T - °F</th>
<th>Chilled Water Flow - GPM</th>
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<th>KW / Unit</th>
<th>KW</th>
<th>KW/Ton</th>
<th>KW</th>
<th>KW/Ton</th>
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<th>KW</th>
<th>KW/Ton</th>
<th>KW</th>
<th>KW/Ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCWP Pump</td>
<td>63</td>
<td>125</td>
<td>0.025</td>
<td>188</td>
<td>0.038</td>
<td>250</td>
<td>0.050</td>
<td>250</td>
<td>0.050</td>
<td>375</td>
<td>0.075</td>
<td>500</td>
</tr>
<tr>
<td>SCWP Pump</td>
<td>25</td>
<td>350</td>
<td>0.005</td>
<td>59</td>
<td>0.012</td>
<td>102</td>
<td>0.020</td>
<td>200</td>
<td>0.040</td>
<td>474</td>
<td>0.095</td>
<td>1,600</td>
</tr>
<tr>
<td>CCP Pump</td>
<td>175</td>
<td>350</td>
<td>0.070</td>
<td>525</td>
<td>0.105</td>
<td>700</td>
<td>0.140</td>
<td>700</td>
<td>0.140</td>
<td>1,050</td>
<td>0.210</td>
<td>1,400</td>
</tr>
<tr>
<td>CT Fan</td>
<td>75</td>
<td>150</td>
<td>0.030</td>
<td>225</td>
<td>0.045</td>
<td>300</td>
<td>0.060</td>
<td>300</td>
<td>0.060</td>
<td>450</td>
<td>0.090</td>
<td>600</td>
</tr>
<tr>
<td>Chiller Compressor</td>
<td>3,347</td>
<td>0.669</td>
<td>3,367</td>
<td>0.673</td>
<td>3,490</td>
<td>0.698</td>
<td>3,694</td>
<td>0.739</td>
<td>4,112</td>
<td>0.822</td>
<td>4,928</td>
<td>0.986</td>
</tr>
<tr>
<td>Plant Auxilliaries</td>
<td>250</td>
<td>0.050</td>
<td>250</td>
<td>0.050</td>
<td>250</td>
<td>0.050</td>
<td>250</td>
<td>0.050</td>
<td>250</td>
<td>0.050</td>
<td>250</td>
<td>0.050</td>
</tr>
<tr>
<td>Total Plant</td>
<td>4,247</td>
<td>0.849</td>
<td>4,614</td>
<td>0.923</td>
<td>5,093</td>
<td>1.019</td>
<td>5,394</td>
<td>1.079</td>
<td>6,711</td>
<td>1.342</td>
<td>9,278</td>
<td>1.856</td>
</tr>
<tr>
<td>% Increase</td>
<td>Base</td>
<td>8.6%</td>
<td>19.9%</td>
<td>27.0%</td>
<td>58.0%</td>
<td>118.5%</td>
<td>58.0%</td>
<td>118.5%</td>
<td>58.0%</td>
<td>118.5%</td>
<td>58.0%</td>
<td>118.5%</td>
</tr>
</tbody>
</table>

O & M Cost Optimization through ΔT Control
District Cooling Plants
Sustainable Design

Plant Foot Print Optimization
District Cooling Plants
Sustainable Design

LOWER BASEMENT FLOOR PLAN

Plant Foot Print Optimization
District Cooling Plants
Sustainable Design

GROUND FLOOR PLAN

Plant Foot Print Optimization
District Cooling Plants
Sustainable Design

LOWER ROOF FLOOR PLAN

Plant Foot Print Optimization
District Cooling Plants
Sustainable Design

Chilled Water Schematic Diagram
District Cooling Plants
Sustainable Design

Condenser Water Schematic Diagram
Customers’ Interphase
Recognition of Green Buildings Regulations

District Cooling Utilities sell cooling energy and meter that energy on hourly basis, it can recognize efficient building from non efficient building from the perspective of cooling Energy Usage per square meter of building per year (Ton-Hr / m² / Yr) and Demand Cooling per square meter (m² / Ton) which is a key requirement of measurement and verifications of many Green Buildings codes.

District Energy Can issue an Energy Efficiency awards for different type of buildings categories (Malls, hotels, Residential, Offices, etc..)
Customers’ interphase
Connections type

Direct Connection
- Recommended for low rise with total capacity below 15,000 Ton.
- Precautions should be given for monitoring buildings highest point pressure with motorized valve to isolate buildings with potential leakage.
- Is the most energy efficient method and simplest to control Low ΔT Syndrome.

Direct connection with tertiary customer pumps
- Recommended for low rise with large customer buildings of at 1,000 Ton per building.
- De-coupler between secondary and tertiary circuit and control the secondary pumping to achieve minimal pressure of 5 psi (0.3 Bar) at the suction of the tertiary pump.
- Difficult to control and manage, require careful design details.

Indirect connection with plate heat exchanger
- Recommended for high rise with large customer buildings.
- Decouple secondary and tertiary that increase reliability.
- Consider parallel plate or Brazed exchangers.
Customers’ interphase
Low $\Delta T$ control

• Utilize Industrial grade Differential Pressure Indicator.

• Control **The secondary pumps and tertiary pumps from the Plant Room SCADA** utilizing a polynomial proportional to the ambient temperature to set automatically the Differential Pressure set point to control the signals that set the VFD drives speed. For example:
  • At ambient temperature of 45°C set DP = 1.0 Bar (15 psig)
  • At ambient temperature of 25°C set DP = 0.2 Bar (3.0 psig)
  • At ambient temperature of 35°C set DP = (1+0.2)/2 =0.6 Bar (9 psig)

• This will resolve low Delta syndrome and save pumping energy at all level.

• Improve plant room efficiency.

• Improve Thermal storage tank capacity.
Typical ETS BIM with Brazed HX
Thank you

www.dcproeng.com

gberbari@dcproeng.com