DC PRO ENGINEERING

districtCOOLING2016
A CLIMATE SOLUTION
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District Cooling

Sustainable Design

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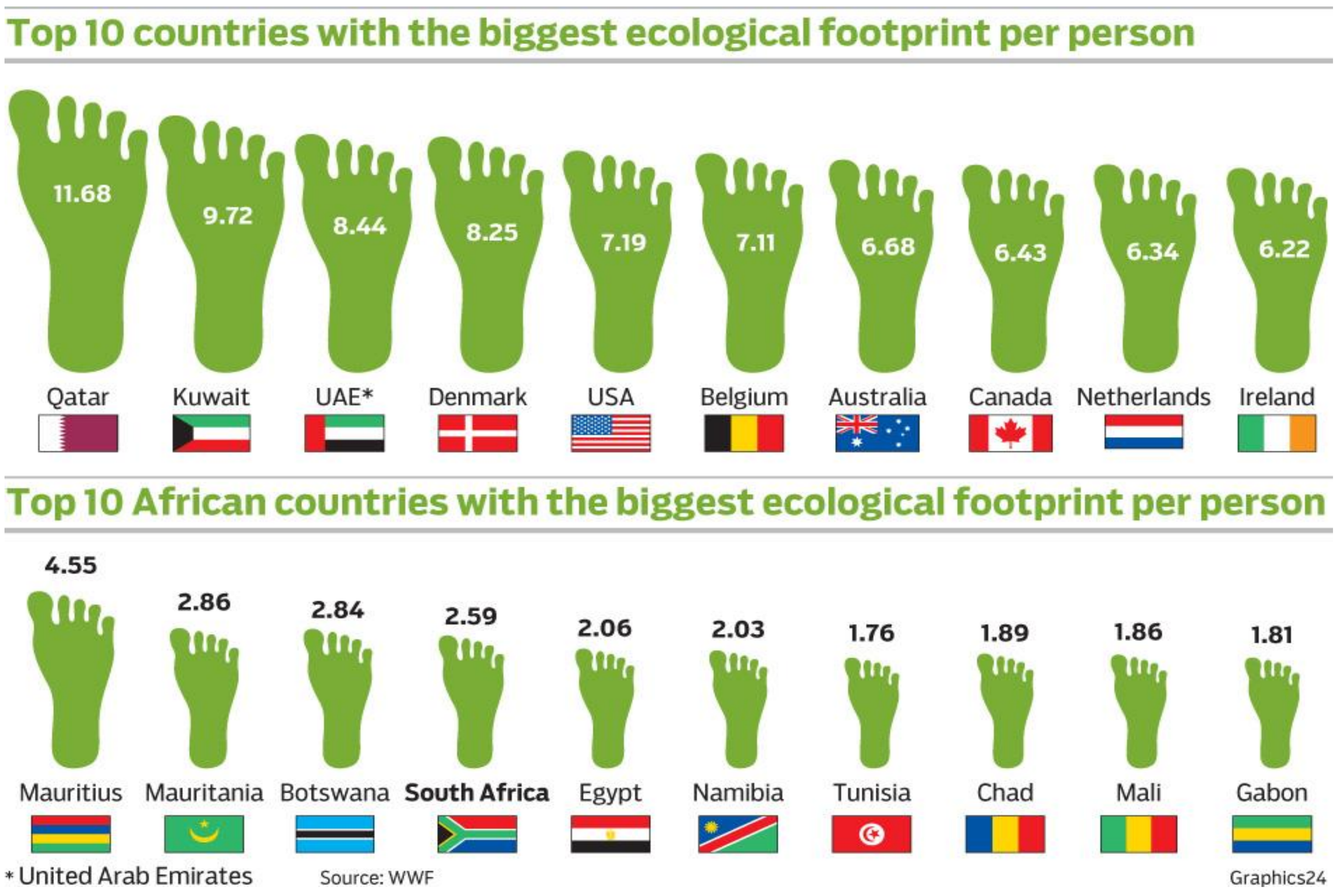
District Cooling
Brief History & Future

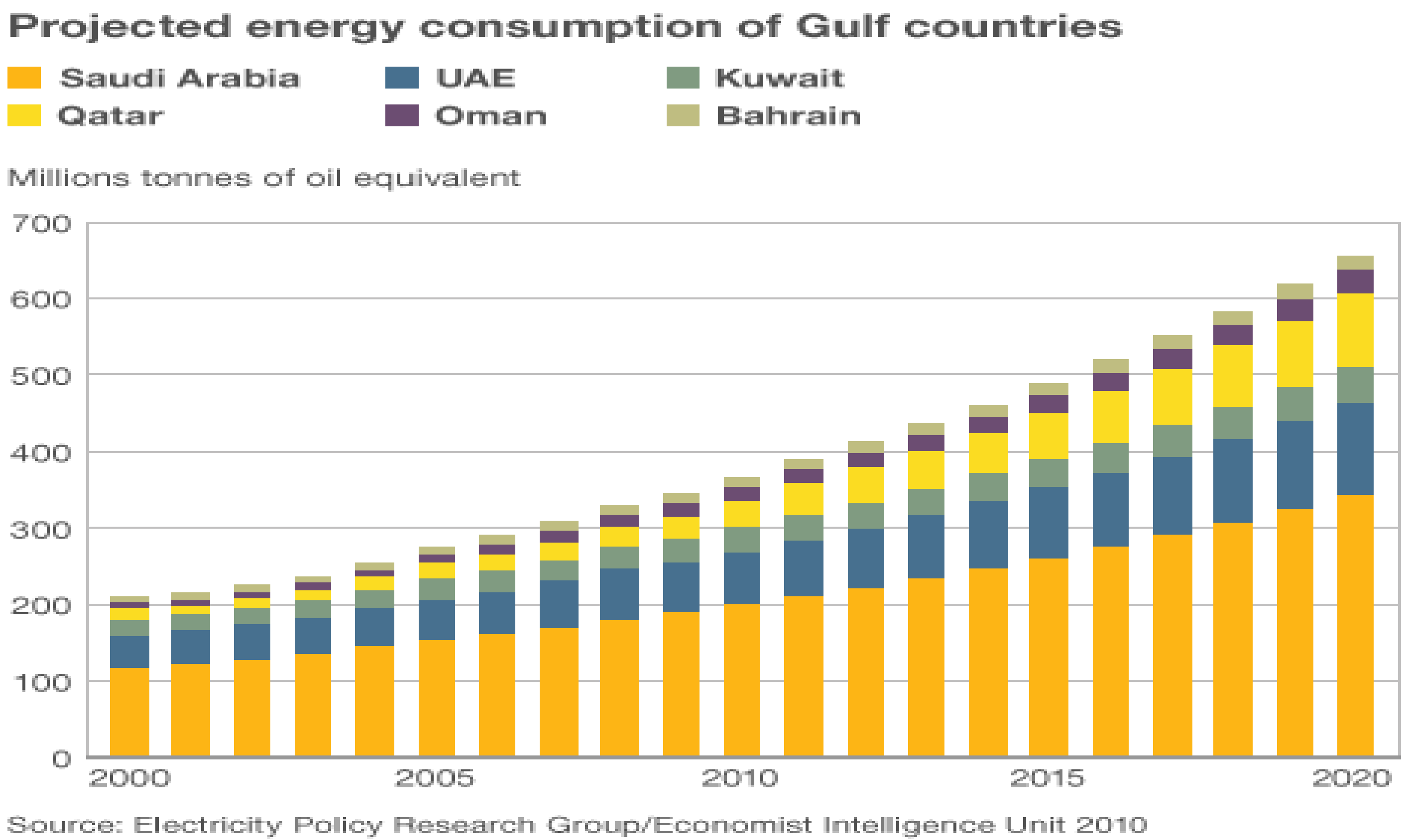
- Central Chilled Water plants existed in the Middle East as early as the 1960's. Few examples are old Beirut Airport and American University of Beirut.
- First District Cooling utility company started in Abu Dhabi in 1998 by building a 4,000 Ton Gas Engine Driven Centrifugal Chillers plant serving the 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



Regional
Electricity Consumption



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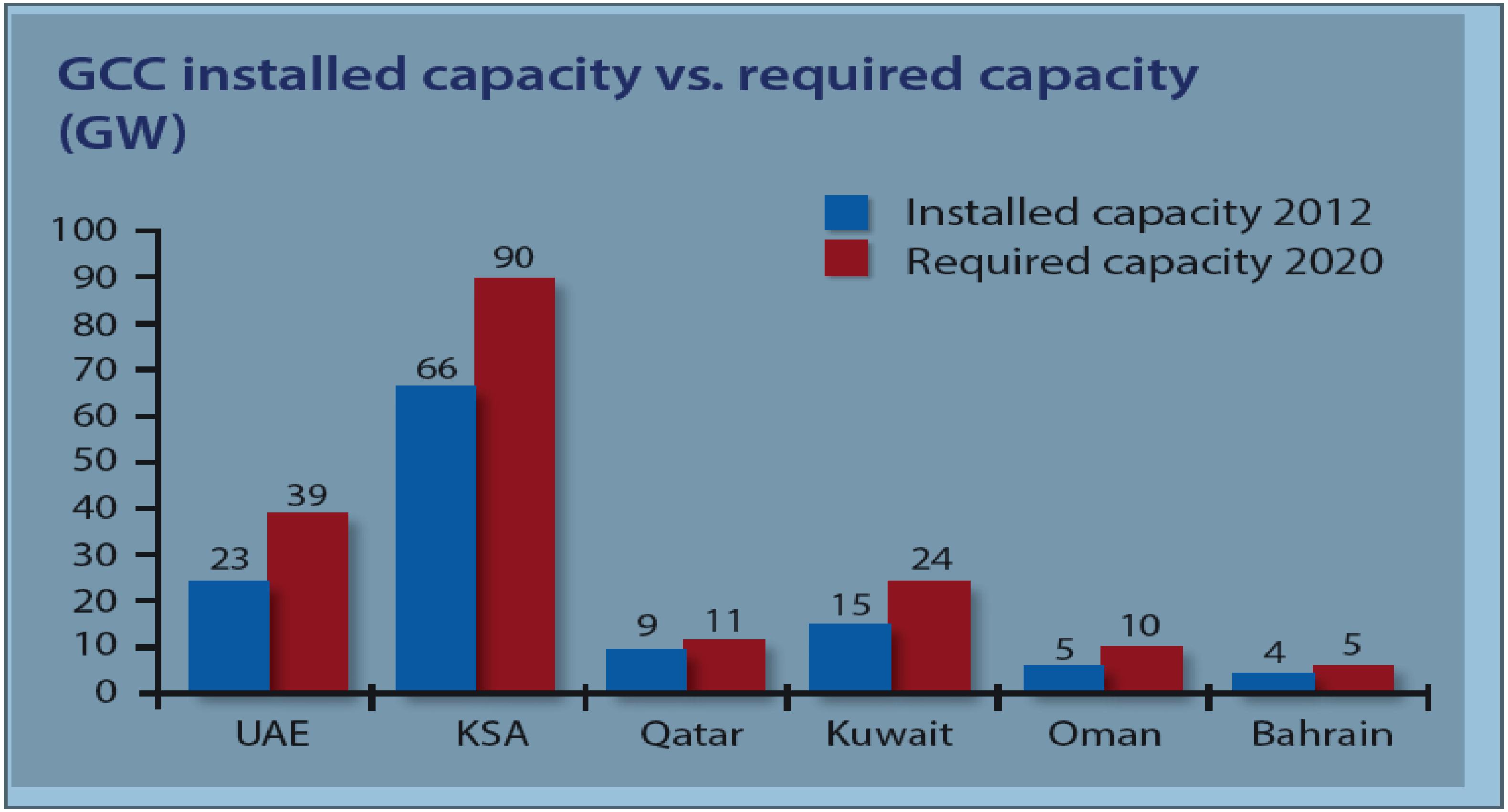

District Cooling

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 CO_2 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 ^{O}F + CHW 56 / 40 ^{O}F (Middle east) **0.90 KW/Ton**
  - Cond. 85 / 107 ^{O}F + CHW 56 / 40 ^{O}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 / m^2** inclusive of thermal storage for plant size of less than 10,000 Ton capacity.
  - **15 Ton / m^2** 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.

District Cooling Plants Sustainable Design

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Typical Chillers Selection (Parallel & series / Parallel counter Flow)

	Qty	Chiller Capacity Ton	Compressor or pump Input Power KW	Compressor or pump Input Power KW/Ton	Condenser Flow GPM	Condenser Pressure drop ft	Condenser Pumping Power KW	Evaporator Flow GPM	Evaporator Pressure drop ft	Evaporator Pumping Power KW	CT Fan absorbed Power KW	Total Electric Power Demand KW	Total Electric Power Demand KW / Ton
Parrallel flow													
94 / 104 ^{O}F Cod. Water Temp. , 2.91 GPM/Ton													
Parallel Chillers	10	1,255	910	0.73	3,654	22	21	1,880	11	6	35	971	0.774
Cooling Tower lift	10				3,654	15	14						
Total Plant		12,550	9,100	0.73			353			55	350	9,858	0.785
Total Plant (Mech. + TES)		15,688	9,100	0.58			353			55	350	9,858	0.628
Parrallel flow													
94 / 106 ^{O}F Cod. Water Temp. , 2.44 GPM/Ton													
Parallel Chillers	10	1,184	883	0.75	2,887	14	11	1,773	10	5	24	922	0.779
Cooling Tower lift	10				2,887	15	11						
Total Plant		11,840	8,830	0.75			221			47	240	9,338	0.789
Total Plant (Mech. + TES)		14,800	8,830	0.60			221			47	240	9,338	0.631
Series - Parrallel Counter flow													
94 / 106 ^{O}F Cod. Water Temp. , 2.43 GPM/Ton													
Upstream Chiller	5	1,215	858	0.71	6,072	12	19	3,680	8	8	25	910	0.749
Downstream Chiller	5	1,285	903	0.70	6,072	12	19	3,680	8	8	25	955	0.743
Cooling Tower lift	5				6,072	15	24						
Total Plant		12,500	8,805	0.70			308			77	250	9,440	0.755
Total Plant (Mech. + TES)		15,625	8,805	0.56			308			77	250	9,440	0.604
Series - Parrallel Counter flow													
94 / 107 ^{O}F Cod. Water Temp. , 2.2 GPM/Ton													
Upstream Chiller	5	1,215	874	0.72	5,478	12	17	3,680	8	8	22	921	0.758
Downstream Chiller	5	1,285	906	0.71	5,478	12	17	3,680	8	8	22	953	0.741
Cooling Tower lift	5				5,478	15	21						
Total Plant		12,500	8,900	0.71			278			77	220	9,475	0.758
Total Plant (Mech. + TES)		15,625	8,900	0.57			278			77	220	9,475	0.606
Series - Parrallel Counter flow													
94 / 108 ^{O}F Cod. Water Temp. , 2.05 GPM/Ton													
Upstream Chiller	5	1,222	875	0.72	5,070	9	11	3,701	8	8	20	914	0.748
Downstream Chiller	5	1,250	900	0.72	5,070	8	11	3,701	8	8	20	939	0.751
Cooling Tower lift	5				5,070	15	20						
Total Plant		12,360	8,875	0.72			212			77	200	9,364	0.758

District Cooling Plants
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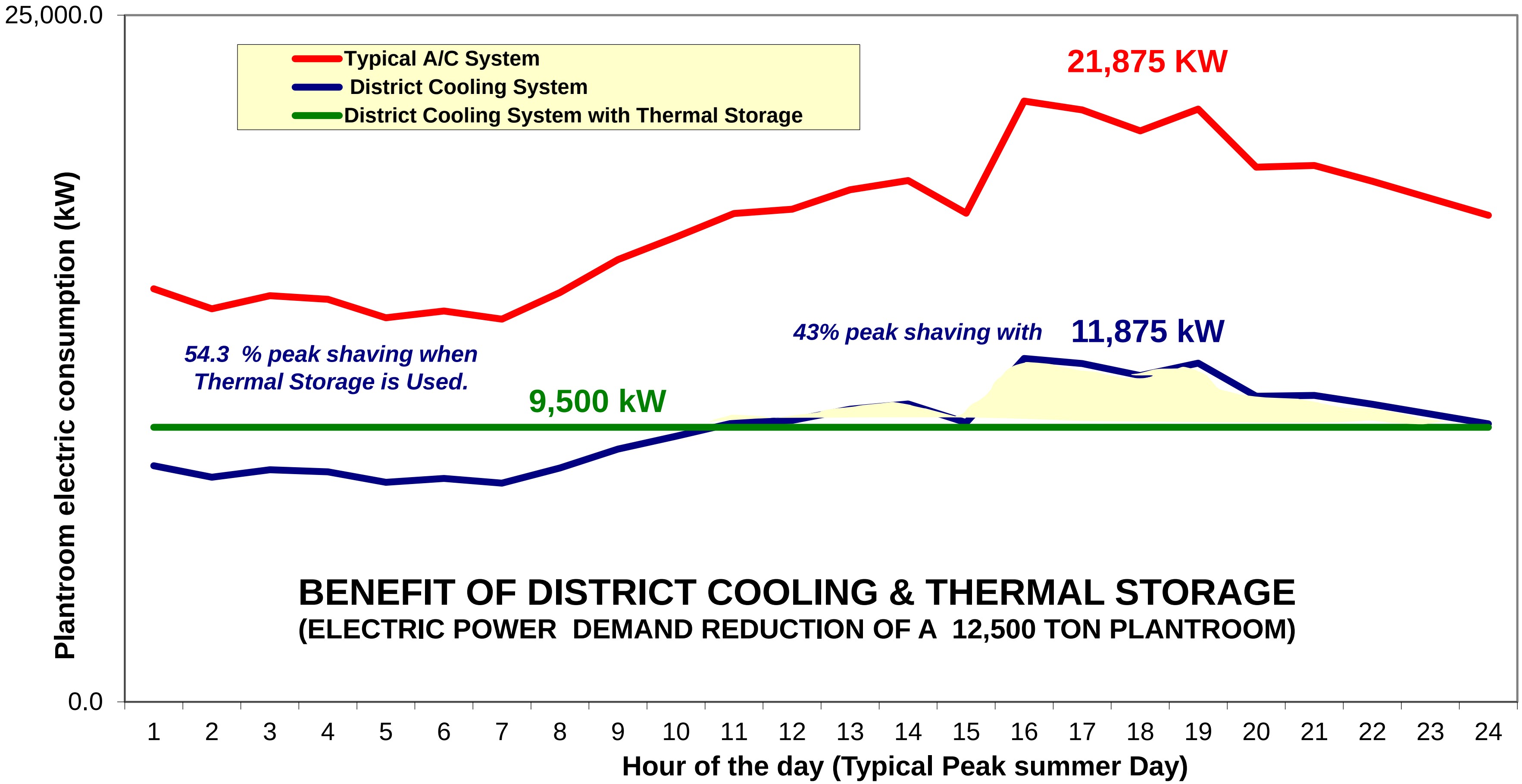
Benefits of Thermal Storage

- According to field Data the load profile indicate 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



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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).

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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(down stream with automatically adjustable set point from the plant PLC by simply linking it to ambient temperature.

District Cooling Plants
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Chiller Plant Part Load Performance @ 85^{O}F Ent. Cond. Temp.
Impact of Low Chilled Water Δ T

Description												
Demand Cooling Load - Ton		5,000		5,000		5,000		5,000		5,000		5,000
Chiller Capacity - Ton		2,500		2,500		2,500		2,500		2,500		2,500
Chiller CHW Flow - GPM		3,750		3,750		3,750		3,750		3,750		3,750
Number of Operating Chillers		2		3		4		4		6		8
Chiller % Loading		100.0%		75.0%		62.5%		50.0%		37.5%		25.0%
Chilled water supply Temp. - ^{O}F		40		40		40		40		40		40
Chilled water return Temp. - ^{O}F		56		52		50		48		44		44
Chilled Water Delta T - ^{O}F		16		12		10		8		6		4
Chilled Water Flow - GPM		7,500		10,000		12,000		15,000		20,000		30,000

	KW / Unit	KW	KW/Ton	KW	KW/Ton	KW	KW/Ton	KW	KW/Ton	KW	KW/Ton	KW	KW/Ton
PCWP Pump	63	125	0.025	188	0.038	250	0.050	250	0.050	375	0.075	500	0.100
SCWP Pump		25	0.005	59	0.012	102	0.020	200	0.040	474	0.095	1,600	0.320
CCP Pump	175	350	0.070	525	0.105	700	0.140	700	0.140	1,050	0.210	1,400	0.280
CT Fan	75	150	0.030	225	0.045	300	0.060	300	0.060	450	0.090	600	0.120
Chiller Compressor		3,347	0.669	3,367	0.673	3,490	0.698	3,694	0.739	4,112	0.822	4,928	0.986
Plant Auxilliaries		250	0.050	250	0.050	250	0.050	250	0.050	250	0.050	250	0.050
Total Plant		4,247	0.849	4,614	0.923	5,093	1.019	5,394	1.079	6,711	1.342	9,278	1.856
% Increase			Base		8.6%		19.9%		27.0%		58.0%		118.5%

O & M Cost Optimization through ΔT Control

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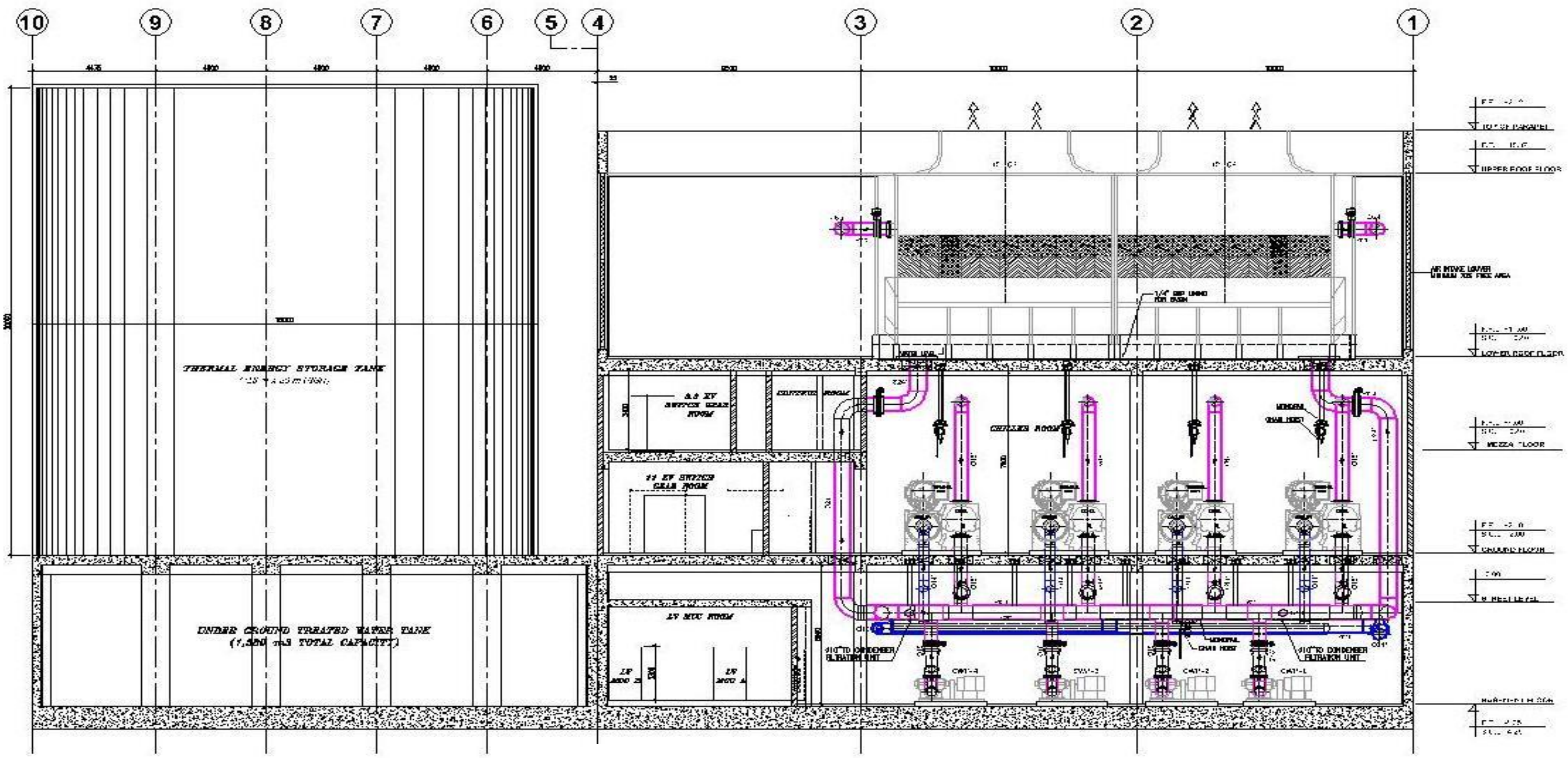

Plant Foot Print Optimization

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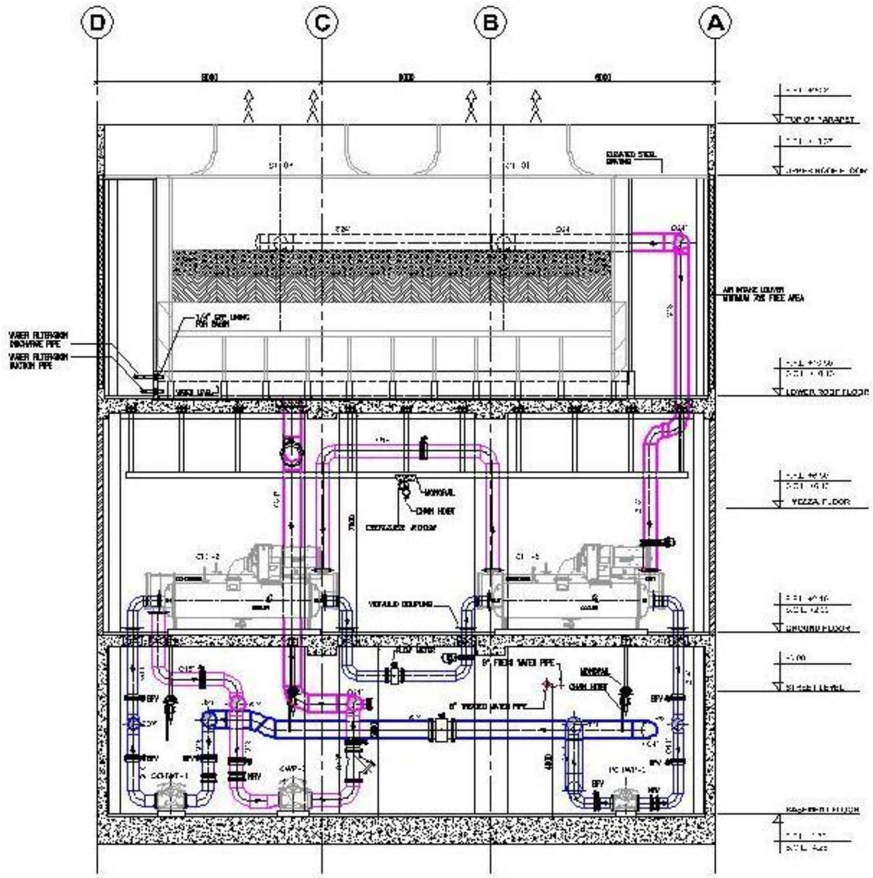

Plant Foot Print Optimization

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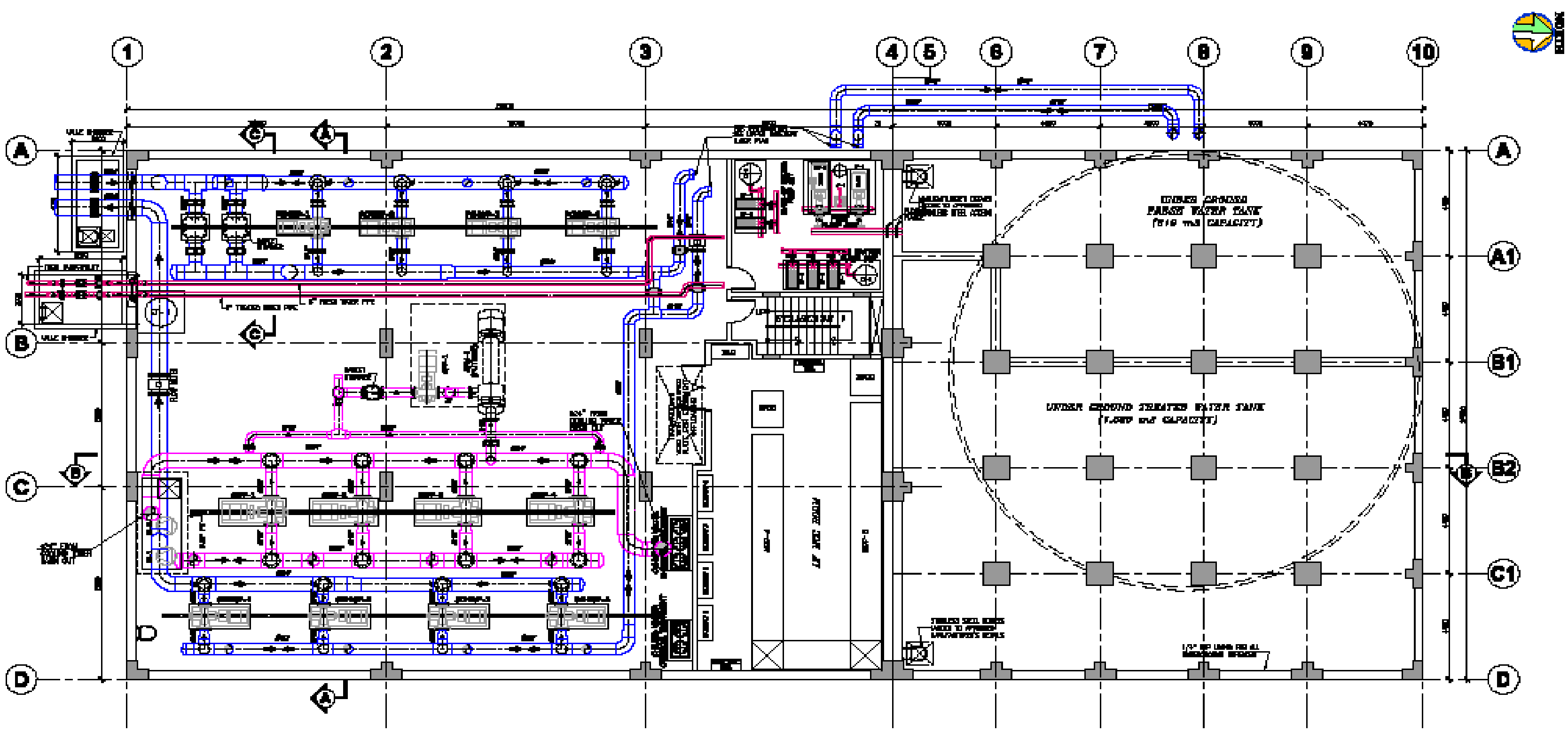

LOWER BASEMENT FLOOR PLAN

Plant Foot Print Optimization

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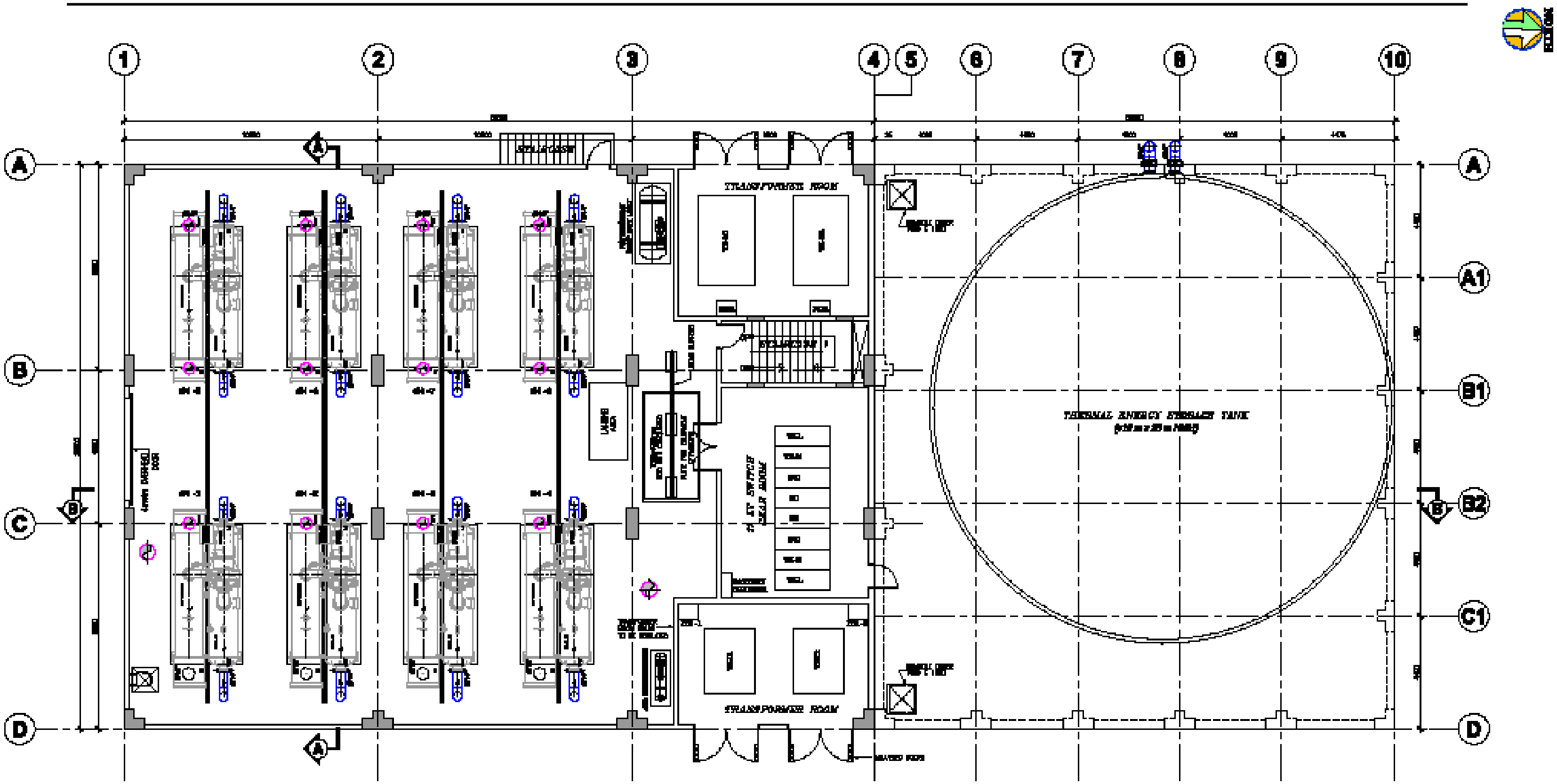

GROUND FLOOR PLAN

Plant Foot Print Optimization

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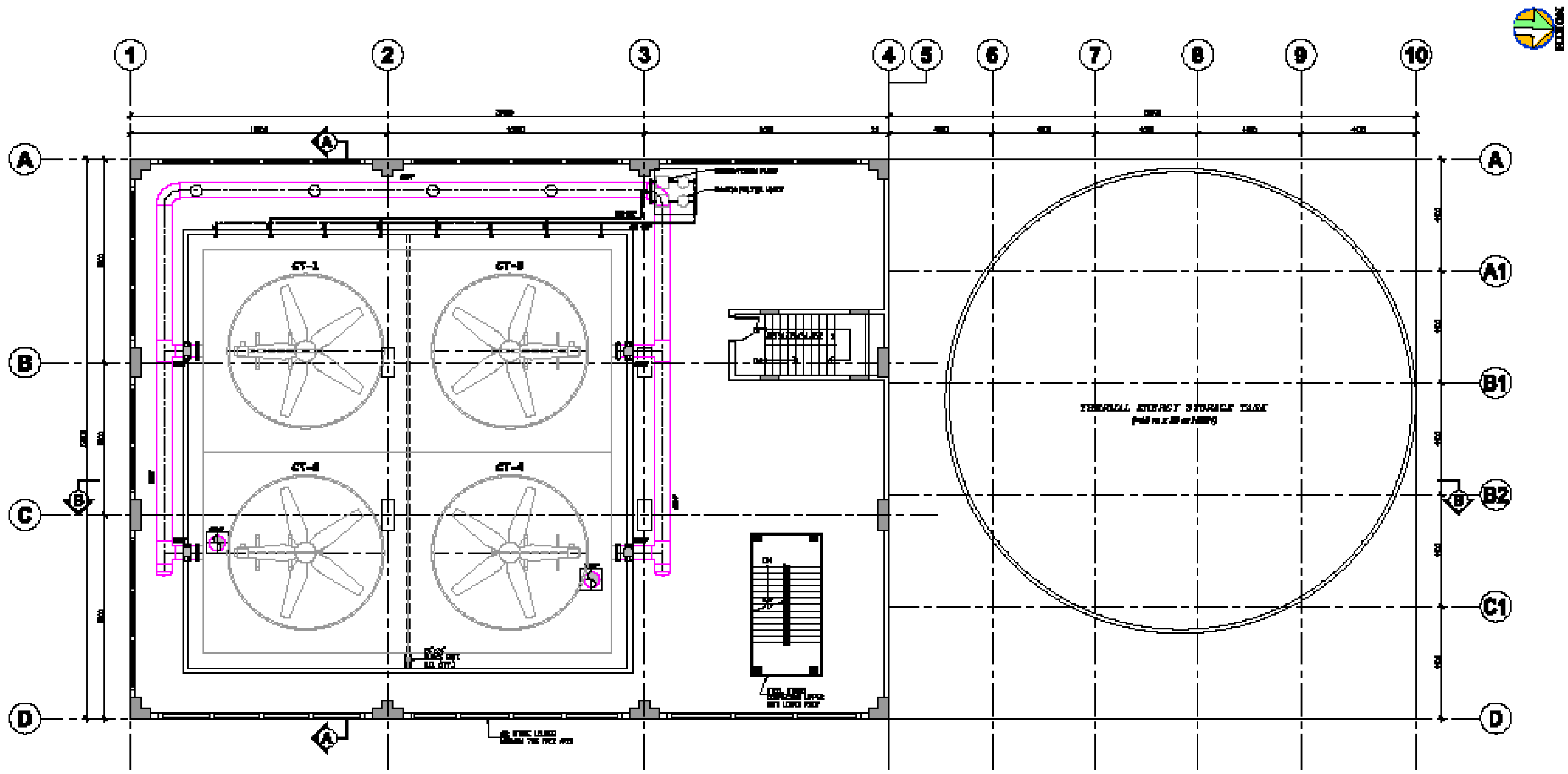

LOWER ROOF FLOOR PLAN

Plant Foot Print Optimization

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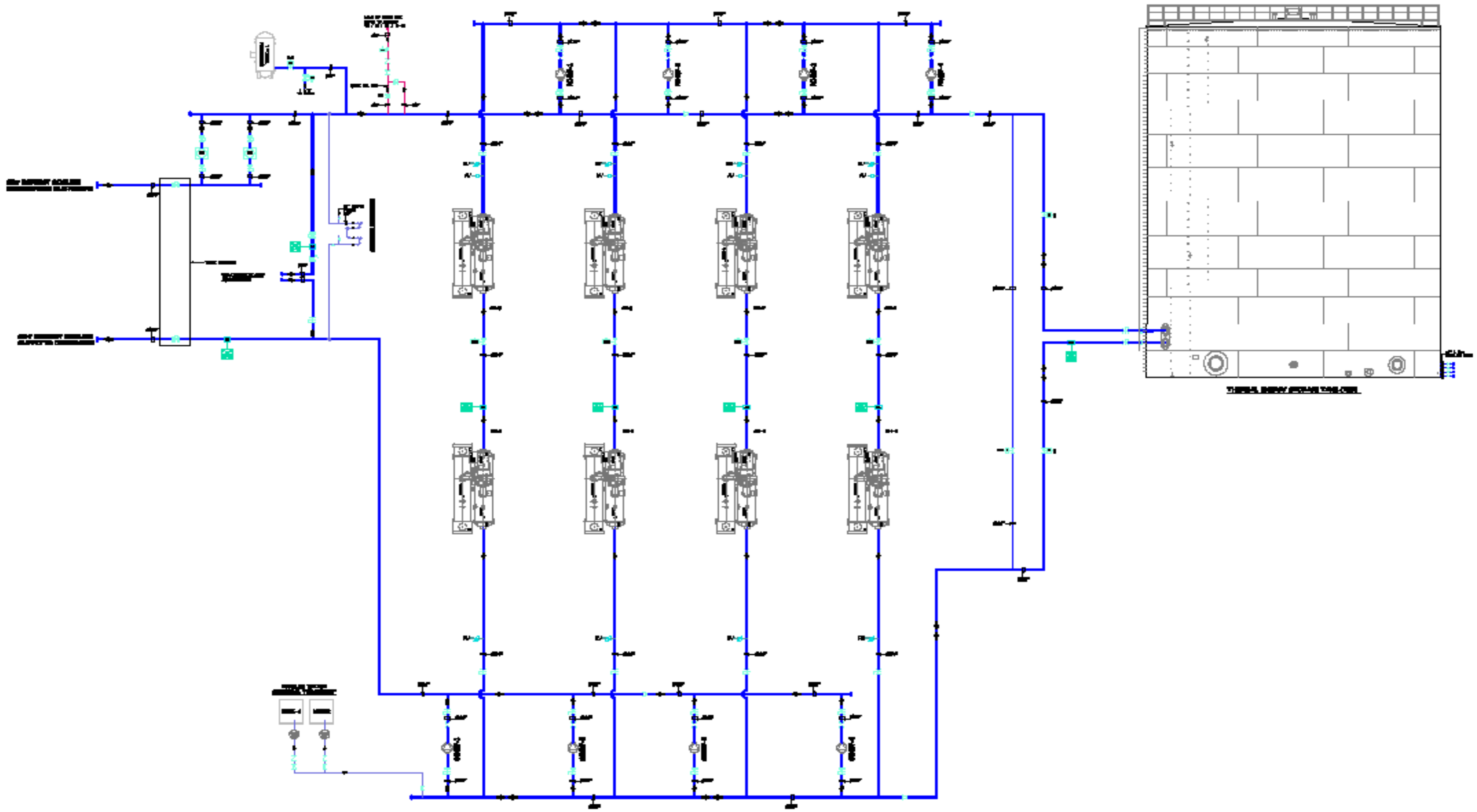

Chilled Water Schematic Diagram

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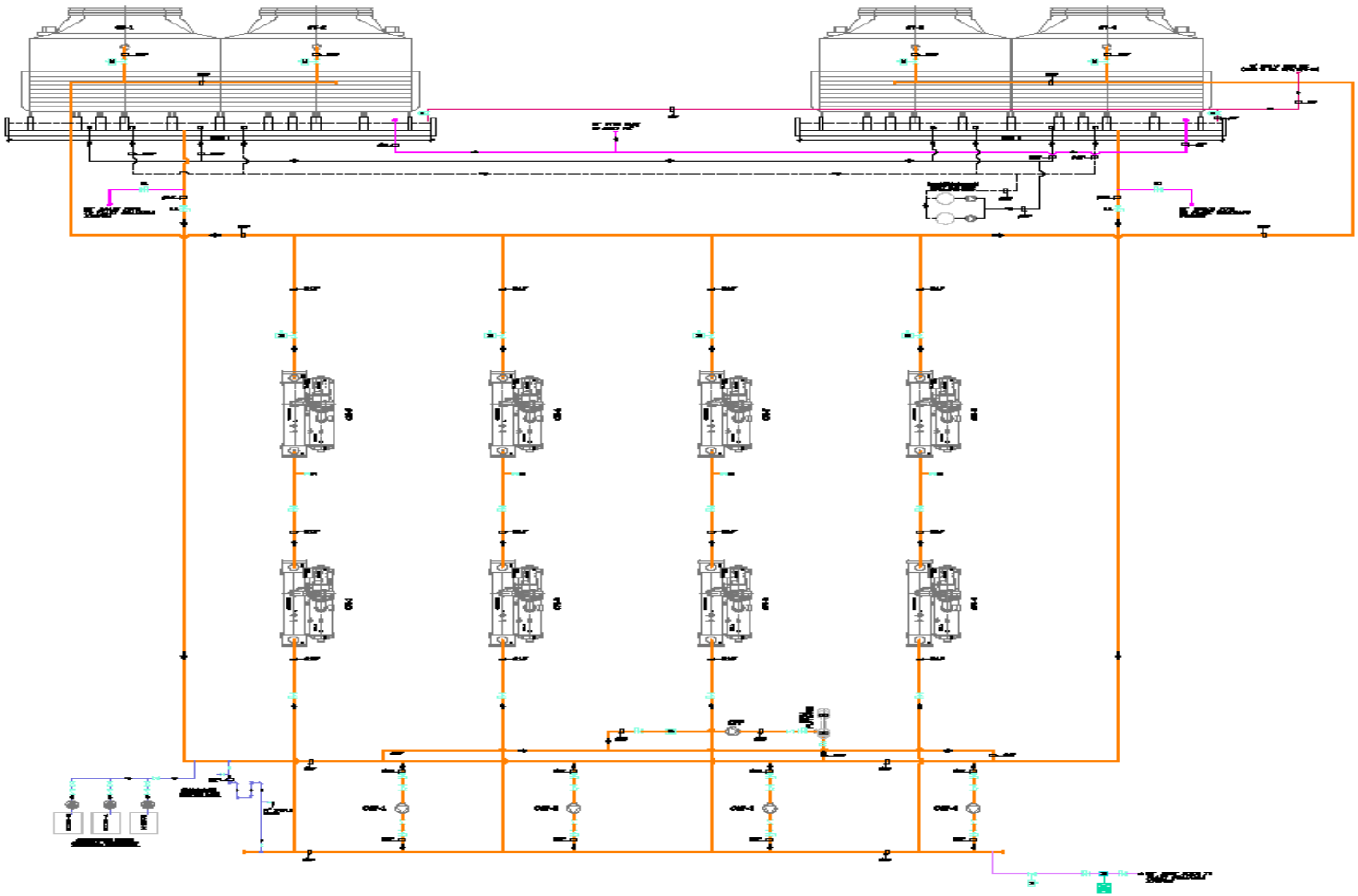


Condenser Water Schematic Diagram

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 / m^2 / Yr) and Demand Cooling per square meter (m^2 / 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.

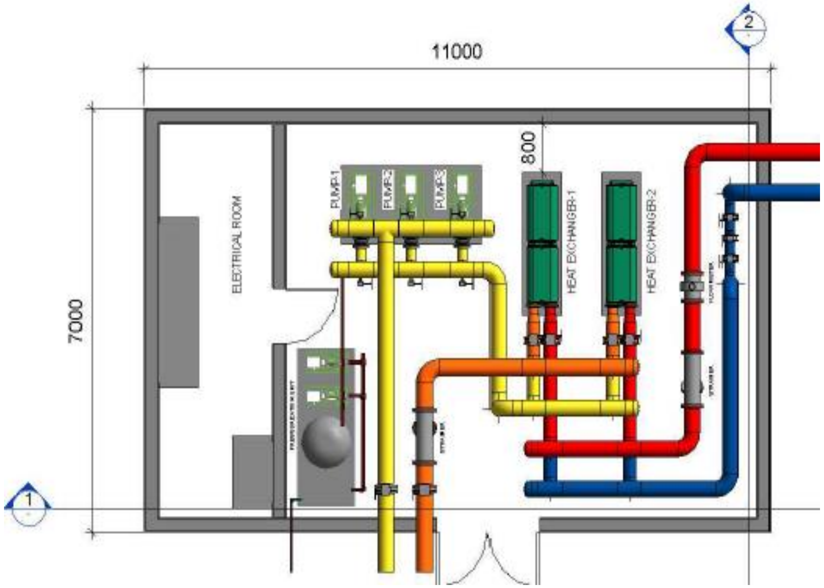
Indirect connection with plate heat exchanger

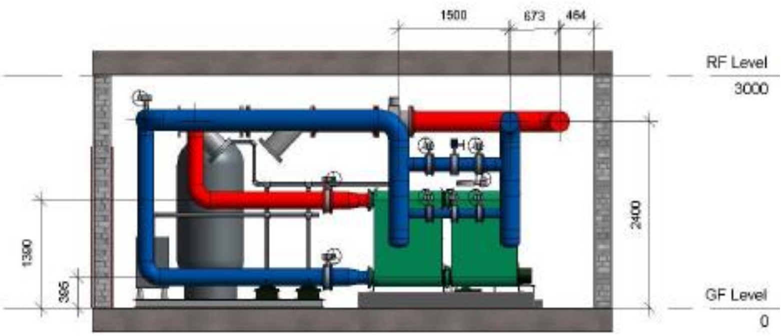
- Recommended for high rise with large customer buildings.
- Decouple secondary and tertiary that increase reliability.
- Consider parallel plate or Brazed exchangers.

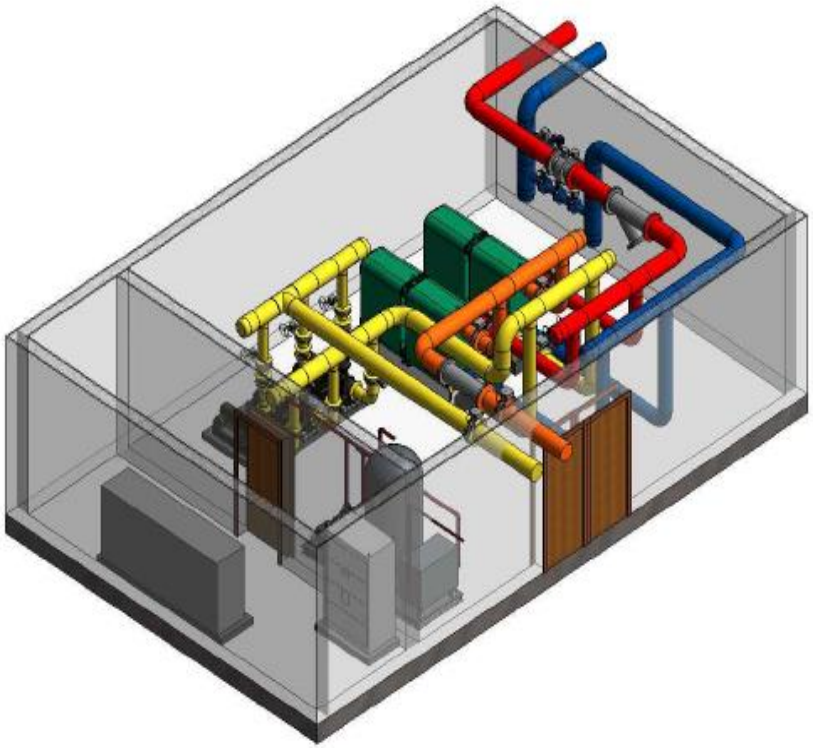
Customers’ interphase
Low ΔT control

- 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^{O}C set DP = 1.0 Bar (15 psig)**
  - **At ambient temperature of 25^{O}C set DP = 0.2 Bar (3.0 psig)**
  - **At ambient temperature of 35^{O}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

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