WHAT IS DISTRICT COOLING?

- Centralized production and distribution of energy (Cooling/Heating)
- In Conventional applications, Chilled water is the medium of distribution through a network of supply & Return Pipes (Underground/Tunnels)
- Individual user normally interface with chilled water network at Energy Transfer Stations.
- DCS can be used only where high cooling load demand densities is available this is why they are used in downtown.
- A typical District cooling system comprises of:
  1. Central Chiller Plant
  2. Distribution Network
  3. User Energy Transfer stations
DISTRICT COOLING BENEFITS

CUSTOMER

INFRASTRUCTURE

ENVIRONMENTAL
CUSTOMER BENEFITS

- Comfort
- Convenience
- Flexibility
- Reliability
- Cost-effectiveness
• Industrial Grade-equipment used to provide a consistent and high-quality source of cooling.
• Healthier indoor environment due to providing better temperature and humidity control through specialist attention on optimal operation and maintenance of cooling systems.
• Quieter buildings as there is no heavy equipment generating vibration and noise.
• During Part load seasons, plant with storage may be switched off by night thus offering quieter surrounding.
CONVENIENCE

- Cooling is always available in the pipeline
- Avoid the need to start and stop building cooling units
- Building manager not to worry about managing the equipment, refrigerant, labor and materials required for operating and maintaining chiller and cooling tower systems
- Refrigerant is kept away from building
Building part cooling loads can be met easily and cost-effectively whenever occurs.

No need to worry about chiller size and capacity.

Increased capacity can be covered easily.
RELIABILITY

- Industrial equipment can last 50 years
- Operation through properly trained staff
- Standby capability
- Several plant location to maintain network reliability
- Routine, preventive, proactive maintenance
- Thermal storage to cover several hrs of interrupted power supply
COST EFFECTIVENESS

- Diversified Load
- Optimized operations
- Advanced Technologies
- Better Staff economies
- Customer Risk management
- Cost Comparison
- Not all buildings have their peak demand at the same time.
- When cooling loads are combined in the district cooling system, more buildings can be reliably served at lower cost.

![Graph showing diversified load](image)
- Equipment can be operated at the most efficient levels
Thermal Energy Storage (TES)

- Reduce peak power demand
- Save Energy
- Enhance Reliability
- Reduce Capital Expenses
Absorption & Natural gas-driven chillers

- Optimize cost effectiveness
- Increase energy efficiency
- Promote operational flexibility
- Reduce greenhouse gas emissions
- No Threat to Ozone Depletion
- Utilize Recovered Heat
Treated Sewage effluent (TSE) for condenser cooling

- Saving Fresh Water
- Lower Make-up water Costs

Challenges:
- Availability and Timing
- Priority to be utilized in Irrigation
- Quality is not Predictable
Seawater for condenser cooling

Challenges:
- Warm seawater in the Middle East
- Environmental studies
- Piping & Condenser-tube materials to resist seawater aggressive nature
BETTER STAFF ECONOMIES

- Specialized expertise to operate and maintain the equipment
- Reduced staff to operate building plants
CUSTOMER RISK MANAGEMENT

- No Capital cost in the building for Cooling equipment
- Eliminated Operating Risks
- Building Higher Market Value
## District Cooling System Costs

<table>
<thead>
<tr>
<th></th>
<th>Customer Defray</th>
<th>Chiller system within the Building</th>
<th>Building connected to DC system</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital Costs</strong></td>
<td></td>
<td>• Construction cost of space for equipment</td>
<td>• ETS room Space</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Chiller &amp; Condenser cooling equipment</td>
<td>• DC connection Charges (400-600 USD/TR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Pumps and controls</td>
<td>(In case of DC producing low chilled water temperature, savings in building HVAC system shall be noticed due to reduction in the size of fans and ducts)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Power Utility connection fees</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Transformers and Cables</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Engineering Services</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chiller system (1000-1300 USD/TR)</td>
<td></td>
</tr>
<tr>
<td><strong>Annual Costs</strong></td>
<td></td>
<td>• Opportunity cost of chiller system space rental</td>
<td>• Capacity Rate charge (300-400 USD/TR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Electricity</td>
<td>• Consumption Rate charge (0.1-0.2 USD/TR/hr)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Scheduled annual maintenance</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Periodic major maintenance</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Unscheduled repairs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Refrigerant management</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Labour &amp; Spare parts</td>
<td></td>
</tr>
</tbody>
</table>
INFRASTRUCTURE BENEFITS

- Efficient power consumption
- Peak power demand reduction
- Reduction in governmental power sector costs
EFFICIENT POWER CONSUMPTION

- Optimum System
- Long lasting Equipment
- Highest equipment efficiency
- Proper Maintenance
- Equipment operate at their maximum efficiency point
- Higher system COP Cooling & Heating
Refrigeration Machines Power Demand

<table>
<thead>
<tr>
<th>Split System</th>
<th>Chilled Water (Air Cooled)</th>
<th>Chilled Water (Water Cooled)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 KW/TR</td>
<td>1.9 KW/TR</td>
<td>0.95 KW/TR</td>
</tr>
</tbody>
</table>

Buildings Electric Power Requirements (Design)

<table>
<thead>
<tr>
<th>Building</th>
<th>HVAC (W/m²)</th>
<th>Electric (W/m²)</th>
<th>HVAC Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>70</td>
<td>40</td>
<td>64%</td>
</tr>
<tr>
<td>Residential</td>
<td>44</td>
<td>30</td>
<td>60%</td>
</tr>
<tr>
<td>Retail</td>
<td>70</td>
<td>43</td>
<td>62%</td>
</tr>
</tbody>
</table>

Actual HVAC percentage in operating buildings reaches 70%
District Cooling reduces the capital investment required for additional:
- Power generation
- Transmission infrastructure
- Distribution infrastructure

District Cooling reduces power sector operating costs
Capital costs of power generation

- More than 275 GW new power generation is required for the Middle East and Africa over the next 15 years.
- Capital costs are increasing rapidly due to increase in material costs and the limited number of qualified contractors.
- Capital cost for power generation \(\sim 1200 \text{ USD/KW}\)
- The average cost for T&D infrastructure \(\sim 300 \text{ USD/KW}\)
- The total Capital cost for power plant to building panel is about 1500 USD/KW
Power sector operating costs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Plant heat rate</td>
<td>7050 Btu/KWh</td>
</tr>
<tr>
<td>Generation efficiency</td>
<td>49 %</td>
</tr>
<tr>
<td>T&amp;D Losses</td>
<td>25-30 %</td>
</tr>
<tr>
<td>Net efficiency</td>
<td>30 %</td>
</tr>
<tr>
<td>Variable O&amp;M</td>
<td>2.2 USD/MWh</td>
</tr>
<tr>
<td>Fixed O&amp;M</td>
<td>13 USD/KW</td>
</tr>
<tr>
<td>Capacity factor</td>
<td>0.6</td>
</tr>
<tr>
<td>Average non-fuel O&amp;M Cost</td>
<td>4.7 USD/MWh</td>
</tr>
</tbody>
</table>

- New combined-cycle power plants maximum efficiency drops from **55%** to **49%** in the Middle East due to increased ambient air temperatures.
- Although a state-owned power utility may buy fuel very cheaply, but **Opportunity Cost** must be considered.
Power utility recognition of district cooling benefits

- While district Cooling is viewed as beneficial in reducing power demands, accordingly, governments to incorporate incentives to reduce peak power demand, such as:
  - A portion of the cost of the service to be paid in a demand or capacity charge
  - Rates during the high-load summer season are often set above the rates for the other parts of the year
  - Rates during high-load times of day are higher than low-load periods
  - Capital incentive to install thermal energy storage
ENVIRONMENTAL BENEFITS

- Energy efficiency
- Climate change
- Ozone depletion
ENERGY EFFICIENCY

- Reduction in annual electricity consumption by 45% to 85%
- Reduction in required municipal water by utilizing Seawater or TSE
CLIMATE CHANGE

- Reduction in greenhouse gas emissions
- Economic incentives for energy-efficient technologies such as District Cooling
District Cooling can be a key strategy for accomplishing an economical and environmentally wise phase-out of harmful refrigerants.

District Cooling systems are better able to control emissions of whatever refrigerant is used.
SUMMARY WHY DISTRICT COOLING

- Improved Energy Efficiency
- Enhanced Environmental Protection
  (CO₂ & harmful gas)
- Fuel Flexibility
- Ease of operation and maintenance
- Reliability
- Comfort and convenience for customers
- Improved life cycle costs
- Decreased building capital costs
- Improved architectural design flexibility
SUMMARY WHY DISTRICT COOLING

- Developers 8% Capital Cost Saving
- Developers Valuable Area Saving
- Providers 15% IRR (Internal Rate of Return)
- Government 50% Power Consumption Reduction
- Government 40% Peak Power Demand Reduction
- Environment 40% CO₂ Emission Reduction
Global District Cooling Market Size – US $ Billions

CAGR : Compounded Annual Growth Rate
DC SYSTEM MARKET SIZE & EXPECTATIONS

Middle East & Africa Cooling Market Size 2017-2028 US Billions

- 2017: 8.43
- 2018: 9.28
- 2019: 19.5
DC SYSTEM MARKET SIZE & EXPECTATIONS

Market Size

- UAE aims to meet 40% of its cooling demand through DCS by 2030.
- Largest share will be middle east due to climate and increasing infrastructure projects investment.
REASONS OF DC RAPID GROWING-SUMMARY

- Utilization of resources that cannot be applied with conventional systems as waste heat, garbage, sea water, treated sewage effluent.
- Improved Architectural design.
- Increasing demand for comfort cooling, due to construction of many new buildings that are tighter than older buildings and contain more heat-generating equipment.
- A growing trend toward outsourcing certain operations to specialist companies that can provide these services more efficiently.
- Reductions in peak electricity demand provided by district cooling.
- Reduction in water consumption.
- Environmental policies to reduce emissions of air pollution, greenhouse gases and ozone-depleting refrigerants.
- The customer value provided by district cooling service in comparison with conventional approaches to building cooling.
- Noise containment of buildings HVAC equipment.
- Buildings safety as refrigeration/heating equipment are out of building served.
- Possible implementation of energy efficient design to save on customer side and national side.
DISTRICT COOLING SYSTEM DESIGN
Conditions Affecting DC Concepts

- Seasonal and daily load characteristics
- Type of cooling load and special reliability requirements (e.g., hospitals, computer servers, etc.)
- Plant plot size and any conditions or constraints relating to the site (Height restriction, air emissions, noise sensitivities to neighbors, etc.)
- Location with respect to sea, lakes/rivers
- Plant plot remoteness from load
- Availability and prices of electricity, water and natural gas
- Availability and prices of TSE water
- Local codes and regulations
- Organizational resources
- Financial criteria and strategic goals of district cooling company
- Chilled water supply temperature
## Cooling Load Figures

- Normally plants are designed prior plots loads are determined.
- Load figures differ from those estimated figures by buildings designers.

<table>
<thead>
<tr>
<th>Application</th>
<th>Load Figures (m²/TR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ASHRAE</td>
</tr>
<tr>
<td>Residential</td>
<td>35</td>
</tr>
<tr>
<td>Retail</td>
<td>21.5</td>
</tr>
<tr>
<td>Offices</td>
<td>26</td>
</tr>
<tr>
<td>Hotel</td>
<td>28</td>
</tr>
<tr>
<td>Mixed Use</td>
<td>26</td>
</tr>
</tbody>
</table>
Cooling Load Diversity Factor

- Plant diversity factor 70% and may be less
- Network diversified flow varies according to served plots
Load parameters Impacting Design

- Plant peak day load
- Plant minimum load
- Plant load profile
- Yearly profile and base load
- Load profile shape and Storage Possibility
  - Load leveling
Temp Difference Selection

- Higher $\Delta T$ reduces flow & pumping energy.
- Lower flow rate correspond to deeper cooling coil rows & higher fan power.
- Higher $\Delta T$ achieved by lowering supply temp (evaporator temp) and increasing return temp.
- Supply temp should not go below 36°F to avoid evaporator freezing particularly in variable flow system.
- When stratified CHW storage is feasible, temp lower than 39.2°F (4°C) should be avoided for proper water stratification (cold water density reduces below 35.2°F).
- Majority of CHW DCPs supply temp are designed on 40°F (4.4°C) supply and 56°F (13.3°C) return.
- Each 1°F (0.6°C) reduction in supply temp will increase energy consumption (kw/TR) by approx. 2%.
- Return temp higher than 56°F (13.3°C) up to 60°F (15.5°C) may be considered to reduce pumping but building HVAC systems should be checked.
Temp Difference Selection

![Diagram showing the relationship between percent total heat transfer and percent design flow, with lines indicating total heat, sensible heat, and latent heat.](image)
Major Plant Components

- Chillers
- Heat rejection equipment
  - Cooling tower (water cooled)
  - Radiator (air cooled)
- Condenser water pumps
- Chilled water pumps
  - Primary
  - Variable primary
  - Primary-secondary
  - Primary-distributed secondary
- Expansion tank
- Energy storage
  - Chilled storage
    - Stratified
    - Empty tank
**Major Plant Components**

- Ice storage
  - External melt
  - Internal melt
  - Eutectic
  - Harvested ice

- Filtration system
  - Side stream/full stream
  - Sand filters
  - Bag filters
  - Cyclone filters

- Air separators
- Brush cleaning system
- Refrigerant recovery unit
Major Plant Components - Chillers

- Vapour Compression
  - Centrifugal
  - Screw
  - Reciprocating
- Absorption
  + Lithium bromide (Carrier) – water (Ref)
    - Single stage
    - Double stage
  + Water – ammonia
- Absorption VS Electrical
  - Electrical occupy space 50% lesser than absorption.
  - COP of electrical is higher than absorption (6 versus 1.37)
  - Absorption produce more CO₂ emission but refrigerator freindly.
  - Waste heat / garbage absorption reduces CO₂ emission and their use is expected to grow.
# DISTRICT COOLING SYSTEM DESIGN

## Major Plant Components - Chillers

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Compression Chillers</th>
<th>Absorption Chillers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Energy</td>
<td>Reciprocating</td>
<td>Electric Motor</td>
</tr>
<tr>
<td>Fluids</td>
<td>Electric Motor</td>
<td>Electric Motor</td>
</tr>
<tr>
<td>COP</td>
<td>4-6</td>
<td>&gt; 7.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Absorption Chillers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Energy</td>
<td>Hot water, 65°C &lt;temp, &lt; 80°C</td>
</tr>
<tr>
<td>Fluids</td>
<td>H₂O with LiBr, NH₃ with H₂O</td>
</tr>
<tr>
<td>COP</td>
<td>0.6 to 0.75</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Absorption Chillers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Energy</td>
<td>Steam or fire, temperature &gt; 170°C</td>
</tr>
<tr>
<td>Fluids</td>
<td>H₂O with LiBr, NH₃ with H₂O</td>
</tr>
<tr>
<td>COP</td>
<td>1.2-1.5</td>
</tr>
</tbody>
</table>
Major Plant Components - Chillers

Coefficient of Performance (COP)

\[ \text{COP} = \frac{\text{Heat input in Evap}}{\text{Work input to the Cycle}} \]

\[ = \frac{\text{Cooling load Btu/hr(w)}}{\text{Work Input Btu/hr(w)}} \]
DISTRICT COOLING SYSTEM DESIGN

Major Plant Components - Chillers

P-H Diagram of the Vapor Compression Cycle
Absorption Refrigeration Cycle

Major Plant Components - Chillers
Major Plant Components - Chillers

PTX Chart, Single-Effect
Major Plant Components - Chillers

Carnot Coefficient of Performance

\[
COP_{\text{Carnot}} = \frac{T_{\text{evap}}}{T_{\text{cond}} - T_{\text{evap}}}
\]

\(COP_{\text{Carnot}}\) = Max COP that may be achieved by an idealized refrigeration cycle operating between isothermal heat load and isothermal heat sink.

\(T \, ^oR \, (K)\)
Carnot COP as a Function of Condensing and Evaporation Temp
Impact of Evaporation/Condenser Temp – VC Chillers

VC Chiller
- Each 1.8°F on Evap. Temp will have 2% impact on energy

\[ \text{Power (kw)} = \frac{12000}{\text{COP} \times 3400} \]
**Major Plant Components - Chillers**

**Impact of Condenser Temp – VC Chillers**

- Increasing condenser temp and reducing evap temp will reduce flow rate and net power supply.
Not recommended to work below 40%
Major Plant Components - Chillers

Impact of Evaporator/Condenser Temp

- Absorption Chillers
  - Limitation on chilled water as the stable lowest CHW supply temp is 42°F (5.6°C) [very few manufacturers generate 40°F (4.5°C)].
  - Rated at 89.6°F (32°C) Cond Temp. Performance is reduced by 10% for every 1.8°F (1°C) temp above this.
  - Chillers are not rated above 95°F (35°C).
  - Gulf wet bulb 86°F (30°C) ie CT approach will be 3.6°F (2°C). This is not practical and so expensive.
Absorption Chiller Part-Load Capacity Chart, Single-Effect

May operate down to 10-15%
Major Plant Components - Chillers

Chillers Part Load Operation

Absorption

Chiller Part-Load Energy Usage
**Major Plant Components - Chillers**

- Large chillers variable speed drive (VSD) cost ~ 100$/TR.
- Constant speed apply leaving temp reset to ensure chillers are fully loaded before starting the 2\textsuperscript{nd}
  - Reduces chiller efficiency
  - Total plant energy remains less than starting another chiller
- Stage chillers off to avoid staging back on too quickly as this cause tear and wear on chillers and starters.
- Manufacturers adds anti-recycle timer to limit the number of start/stop in a certain time frame.
- With VS chiller, operation to be analyzed based on chiller make and model. It might be more efficient to operate (2/3) chillers at part load (50%/33%) than one chiller at 100%.
- VS chiller operates more efficiently at part load above 30%.
- For different sizes, advantage of starting smaller chiller first to be taken into consideration.
- With thermal storage concept, it is recommended to operate chillers at their max efficiency point.
- For hybrid plants (Abs+VC), absorption to start first and in advance of demand due to lengthy delay before they reach capacity.
- Absorption chiller COP is highest at 50% loading.
Absorption Cooling Versus VC Cooling

- Efficient solution wherever waste heat recovery or low cost thermal driving heat source are available.

- Three myths about absorption cooling.

**Myth 1: Inefficient**
- Electric chiller: COP typically 6 - 6.5
- Absorption: COP 1.35
- Electric chillers COP does not account for 60-70% losses in electricity generation and transmission.
- Higher COP of electric does not mean it is the lowest operational cost.
Absorption Cooling Versus VC Cooling

- Three myths about absorption cooling.

**Myth 2: Rigid Operating Requirements**
- Technology changes.
- Water Flow Rate can be changed at 5% per minute up to 50% over 10 minutes.
- Turn down from 100 to 10% cooling load.
- True they have slower response time due to the inertia of lithium bromide solution on highly fluctuating loads.
- Cond temp must be 68°F (20°C) or higher while electric chillers can handle temp as low as 55°F.
- Entering Condenser water temp can be as low as 68°F (20°C)
- Can achieve low leaving evaporator temp 34°F (1°C) down to 23°F (-5°C).
Three myths about absorption cooling.

**Myth 3: Not reliable due to crystallization**

- Over heating or overcooling the salt cause crystallization. Control system can prevent this.
- Commonly caused by low entering condenser water temperature.
- Salt solution concentration values directly impact crystallization temperature.

<table>
<thead>
<tr>
<th>Salt % in Solution</th>
<th>54%</th>
<th>57%</th>
<th>58%</th>
<th>60%</th>
<th>61.5%</th>
<th>63.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystallization Temperature</td>
<td>-16.1°C (3.02°F)</td>
<td>-3°C (26.6°F)</td>
<td>0.9°C (33.6°F)</td>
<td>10.5°C (50.9°F)</td>
<td>18°C (64.4°F)</td>
<td>26°C (78.8°F)</td>
</tr>
</tbody>
</table>
DECREASING CONDENSER TEMP EFFECT
Emission Factor
- By using waste heat-driven cooling, the electricity need for compression cooling will be reduced.
- Reducing the electricity consumption could lower the global CO$_2$ emission if the electricity produced by fossil based fuels.
- Price fluctuations on the electricity market are another argument for the use of heat-driven cooling.
- Gas fired heat-driven chillers produce more CO$_2$ than electric-driven chillers.
Chillers - Absorption Cooling Versus VC Cooling

- Estimating CO₂ Emissions
  - One liter of diesel weight 835 grams
    - Diesel consists of 86.2% carbon
    - ie 720 grams of carbon/liter diesel
    - To combust this carbon, 1920 O₂ is needed
    - The sum is then 720 + 1920 = 2640 grams CO₂/liter diesel
  - One kg of Low CV of CNG consist of 61.4% carbon
    - i.e 614 grams of carbon
    - To combust this carbon to CO₂, 1638 grams, of oxygen is needed
    - The sum is then 614 + 1638 = 2252 grams CO₂/kg of L-gas
  - One kg of high CV of CNG consists of 72.7% carbon
    - ie 727 grams of carbon
    - To combust this carbon to CO₂, 1939 O₂ is needed.
    - The sum is 727 + 1939 = 2666 grams CO₂/KG of H-gas.
Chillers - Absorption Cooling Versus VC Cooling

- **CO₂ Emission**
  
  Consider 1TR for 200 days 5 hrs/day

  - Centrifugal ~ 270 kg CO₂/Y
  - Absorption ~ 550 kg CO₂/Y
  - Split Units ~ 880 kg CO₂/Y

**Note:** Power generation & transmission loss considered
### Chillers - Absorption Cooling Versus Centrifugal Cooling

- **Current values of consumption cost-Egypt**

#### Government Rates

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical consumption</td>
<td>1.3 LE/KW</td>
</tr>
<tr>
<td>Water Consumption</td>
<td>9 LE/m³</td>
</tr>
<tr>
<td>NG consumption</td>
<td>3.6 LE/m³</td>
</tr>
</tbody>
</table>

#### Cent. Chiller

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>KW/TR</td>
<td>0.65 KW/TR</td>
</tr>
<tr>
<td>Water consumption for one chiller</td>
<td>0.008 m³/TR</td>
</tr>
<tr>
<td>Electrical consumption</td>
<td>0.845 LE/TR</td>
</tr>
<tr>
<td>Water consumption</td>
<td>0.072 LE/TR</td>
</tr>
<tr>
<td>Total</td>
<td>0.917 LE/TR</td>
</tr>
</tbody>
</table>

#### ABS. Chiller

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>COP</td>
<td>1.52</td>
</tr>
<tr>
<td>Water consumption for one chiller</td>
<td>0.01 m³/TR</td>
</tr>
<tr>
<td>NG Consumption for one chiller</td>
<td>0.25 m³/TR</td>
</tr>
<tr>
<td>Electrical consumption</td>
<td>0.0351 LE/TR</td>
</tr>
<tr>
<td>Water consumption</td>
<td>0.09 LE/TR</td>
</tr>
<tr>
<td>NG consumption</td>
<td>0.9 LE/TR</td>
</tr>
<tr>
<td>Total</td>
<td>1.0251 LE/TR</td>
</tr>
</tbody>
</table>

#### Air Cooled Screw Chiller

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>KW/TR</td>
<td>1.5 KW/TR</td>
</tr>
<tr>
<td>Electrical consumption</td>
<td>1.95 LE/TR</td>
</tr>
<tr>
<td>Total</td>
<td>1.95 LE/TR</td>
</tr>
</tbody>
</table>

#### Water Cooled Screw Chiller

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>KW/TR</td>
<td>0.63 KW/TR</td>
</tr>
<tr>
<td>Water consumption for one chiller</td>
<td>0.008 m³/TR</td>
</tr>
<tr>
<td>Electrical consumption</td>
<td>0.819 LE/TR</td>
</tr>
<tr>
<td>Water consumption</td>
<td>0.072 LE/TR</td>
</tr>
<tr>
<td>Total</td>
<td>0.891 LE/TR</td>
</tr>
</tbody>
</table>
Consumption Cost Between Different Chiller Types

- Cent. Chiller
- ABS. Chiller
- Air Cooled Screw Chiller
- Water Cooled Screw Chiller

Consumption Cost (£GP)

Bar chart showing the consumption cost comparison between different chiller types.
CHILLER ARRANGEMENT

- Arrange to reduce pumping energy
- Arrange to have chillers receiving same return temp.

Improper Decoupler Location that will Impact Chiller Loading
Hydraulic decoupler arrangement to avoid adverse impacts from loop flow momentum.
Chiller Arrangement

- Ensure min flow through evaporator achieved

Primary Pumping System
Chiller Arrangement – Parallel

Parallel chillers with individual pumping for each chiller
**Chiller arrangement parallel**

- Chiller piping and accessories are smaller
- With primary secondary piping, circulated water through the decoupler is smaller thus better chillers efficiency achieved
Chiller Arrangement - Series

Chilled water flow with in-series chillers with individual pumping per chiller module

Series chillers with headered variable-speed pumping
Chiller Arrangement Impact on COP

Series Arrangement

For Parallel flow each chiller operates at max system lift

With series-counter-flow arrangement each chiller has lower lift than when in a parallel arrangement
Chiller ARRANGEMENT Impact on COP

Series Arrangement

- Refrigeration Temp. (lift) = 95 – 40 = 55°F

\[
COP_{\text{Carnot}} = \frac{40 + 460}{55} = 9°F
\]

- Refrigeration Temp. (lift)
  
  Upstream 95°F – 50°F = 45°F
  
  \[\text{COP}_{\text{carnot}} = 11.3\]

  Downstream 90°F – 40°F = 50°F
  
  \[\text{COP}_{\text{carnot}} = 10\]

- Manufacturers claims series arrangement grant 5% energy reduction

- Parallel arrangement for chillers up to 7 chillers / 15000 TR
COOLING TOWERS
Heat Rejection

- Sink to reject heat (Evap + Comp) could be
  - Ambient air linked to:
    - Dry: Air Cooled
    - Wet: Water Cooled
  - Sea
  - River
  - Lake
  - Ground: Geothermal
**Ambient Air Heat Sink**

- Direct connection between hot gas tubes and ambient dry bulb
  - Air cooled condenser
  - Radiator gas/water
- Direct connection between hot gas tubes and water linked to ambient wet bulb
  - Evaporative cooling tower
  - Cooling tower
- Wet bulb temp is lower than dry bulb temp thus comp lift and energy are lower.
COOLING TOWERS

- Cross Flow

Induced Draft Cross-flow Tower
Courtesy of SPX Cooling Technologies
COOLING TOWERS

- Counter Flow

Induced draft Counter Flow Tower
Courtesy of SPX Cooling Technologies
COOLING TOWERS

- Counter Flow Advantages:
  - Smaller footprint.
  - Easy to maintain as CT basin open on all sides.
  - Wet deck is supported from structure support under this prevents sagging.
  - Upper casing under negative pressure reducing the risk of water leak.
  - Working system guarded from sun ray.
  - Basin is subject so sun rays so less algae.
  - Prevailing winds do not directly affect the fill.
  - Inlet louvres serve as screens to prevent debris from entering.
  - Cleaned fill.
COOLING TOWERS

- Counter Flow Disadvantages:
  - Higher discharge plenum
  - Higher intake
  - Higher air pressure drop
  - Require more pump head due to height
  - Require more pump head due to spray nozzle
  - Smaller fill foot print results in deeper fill and ore resistance.
Packaged CT Compared to Field Erected

- Most sized are FM rated and do not require fire sprinkler.
- Shorter manufacturing.
- Shorter life due to limited material.
- Difficult to clean and maintain.
- Shorter height and more prone to recirculation.
- Limited configuration to fit layout.
- Care must be taken not to lay out more than (2) towers side by side for accessibility reason.
- Higher installed power and operating cost.
- Higher initial cost
- Limited capacities lead to large number of towers.
Cooling Tower Selection

- Selection affected by:
  - Thermal load to be rejected
  - Inlet and outlet hot water temp
  - Design wet-bulb temp

- Design wet-bulb temp
  - ASHRAE (2009) WB 1%
  - Add 2°F as safety for fouling of the fill and aging effects.
  - Add recirculation temp effect (CFD modeling) or calculation.

Diagram showing definition of “Cooling Range” and “Approach”

Note: All temperatures used are illustrative only and subject to wide variation
Cooling Tower Selection

Effect of chosen approach on tower size at fixed heat load, gpm and wet-bulb temperature

Effect of varying range on tower size when heat load, wet-bulb temp and cold water temp are constant
Effect of wind velocity and discharge velocity on plume behavior

Recirculation potential in a forced draft cooling tower

Note that the higher the discharge velocity, the better the plume velocity

% Recirculation = \( \frac{\text{Intake Temp} - \text{Ambient Temp}}{\text{Discharge Temp} - \text{Ambient Temp}} \)
Comparative recirculation potential of round and rectangular towers
Cooling Tower Makeup Water

- Air borne close to towers gets drawn into the tower basin.
- As water evaporated, TDS concentration increased resulting in coating chiller tubes and scale that affects chiller efficiency.
- TDS should be maintained below 2000 ppm.
- To limit TDS, part of the re-circulated water should be drained off.
- Make up water depends on:
  - Drained water (blow down) impacted by TDS
  - Evaporated water affected by CT performance & Temp range
  - Drift loss (water carry over) impacted by drift eliminated loss.
Cooling Tower Basin Cleaning
Cooling Tower Makeup Water

- **Blow Down**

\[ B = \frac{E - [(C-1)*D]}{C - 1} \]

- \( B \) = rate of blow down
- \( E \) = Rate of evap \( \simeq 0.0008 \times \) circ. flow rate GPM * Tower Temp range
- \( C \) = Final TDS/initial TDS
- \( D \) = Drift loss \( \simeq 0.0002 \times \) circ rated GPM

- **Total Makeup**

\[ E + D + B \]
Cooling Tower Makeup Water

- Example

For 10,000 TR, 85 – 95°F

Cooling fresh water TDS = 500

Heat Rejection = 10,000 * 15000 = 150,000,000 Btu/hr

C = 2000 / 500 = 4

D = 0.0002 * 30000 = 6 GPM

E = 0.0008 * 30000 * 10 = 240 GPM

\[ \beta = \frac{240 - [(4 - 1) * 6]}{4 - 1} = 74 \text{ GPM} \]

Make up water = 240 + 6 + 74

= 320 GPM

= 19200 GPM (~ 2 GPM/TR)

Assume 16 HR peak operation

One day storage = 307200 GAL

= 1160 m³
CT Orientation

Recommended Tower Cells Orientation
Proper orientation of towers in a prevailing longitudinal wind (requires relative minimal tower size adjustment to compensate for recirculation and interference effects)
Proper orientation of towers in a prevailing broadside wind

Note this requires significantly greater tower size adjustment to compensate for recirculation and interference effects
PUMP BASICS REVIEW

- Net positive suction head impact on CT height

Pump Curve Showing NPSHR

NPSHA in Proposed Installation

NPSHA = h_p + h_z - h_{vpa} - h_f
PUMP BASICS REVIEW

- Net positive suction head

NPSH Required

\[ \text{NPSH} = \text{Pa} + \text{Ps} - \text{Pvp} = \text{Pf} \]

\[ = 32.3 + 5 - 1.4 - 6 = 29.9 \text{ ft.} \]
Net positive suction head

- Vapor Pressure & Specific Weight for Water, 32 to 212°F

Vapor pressure is the absolute pressure, psia, at which water will change from liquid to steam at a specific temperature. For each temperature of water, there is an absolute pressure at which water will change from a liquid to a gas.
PUMP BASICS REVIEW

- Gas impact on pump flow
PUMP BASICS REVIEW

- Equations from Pump Affinity Laws

### Speed Change

<table>
<thead>
<tr>
<th>Flow:</th>
<th>Head:</th>
<th>Horsepower:</th>
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<tbody>
<tr>
<td>$Q_2 = Q_1\left(\frac{N_2}{N_1}\right)$</td>
<td>$H_2 = H_1\left(\frac{N_2}{N_1}\right)^2$</td>
<td>$BHP_2 = BHP_1\left(\frac{N_2}{N_1}\right)^3$</td>
</tr>
</tbody>
</table>

### Impeller Diameter

<table>
<thead>
<tr>
<th>Flow:</th>
<th>Head:</th>
<th>Horsepower:</th>
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</thead>
<tbody>
<tr>
<td>$Q_2 = Q_1\left(\frac{D_2}{D_1}\right)$</td>
<td>$H_2 = H_1\left(\frac{D_2}{D_1}\right)^2$</td>
<td>$BHP_2 = BHP_1\left(\frac{D_2}{D_1}\right)^3$</td>
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---

Equations From Pump Affinity Laws

System Curve Plot
PUMP BASICS REVIEW

- Variable Speed Drive

Variable Frequency Drive Control Efficiency

<table>
<thead>
<tr>
<th>POINT</th>
<th>% S</th>
<th>PUMP E</th>
<th>PUMP FLOW</th>
<th>PUMP HEAD</th>
<th>PUMP HP</th>
<th>MOTOR</th>
<th>CONTROL</th>
<th>KW</th>
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<tbody>
<tr>
<td>A</td>
<td>100</td>
<td>83</td>
<td>1200</td>
<td>70</td>
<td>25.6</td>
<td>89</td>
<td>92</td>
<td>23.3</td>
</tr>
<tr>
<td>B</td>
<td>90</td>
<td>83</td>
<td>1000</td>
<td>59</td>
<td>17.9</td>
<td>89</td>
<td>92</td>
<td>16.3</td>
</tr>
<tr>
<td>C</td>
<td>75</td>
<td>80</td>
<td>700</td>
<td>44</td>
<td>9.7</td>
<td>89</td>
<td>92</td>
<td>8.8</td>
</tr>
<tr>
<td>D</td>
<td>67</td>
<td>70</td>
<td>440</td>
<td>36</td>
<td>5.7</td>
<td>89</td>
<td>92</td>
<td>5.2</td>
</tr>
<tr>
<td>E</td>
<td>63</td>
<td>50</td>
<td>230</td>
<td>32</td>
<td>3.7</td>
<td>89</td>
<td>92</td>
<td>3.4</td>
</tr>
</tbody>
</table>
- Variable Speed Drive
Control Curve

Illustration of Control Curve & Change-over Point for Parallel C/S Pump
Control Curve

Operation of Paralleled V/S pump at Low Flow, Up to Change-over Point
Control Curve – Pump sizes to be watched

Small Lower HD Pump-”Humps” is Flow-Head Curve onto Larger Pump
Control Curve – operating two VS pumps

High Flow Need; V/S Pump “Humps” onto C/S Pump Curve
PUMP BASICS REVIEW

- Control Curve – End of Curve

Over Headed Pump Runs out of flow Capacity
Exceeds Curve End at Over 60% Speed
PUMP BASICS REVIEW

- Control Curve – End of Curve

Energy Wasting Solution to Parallel Pump
“End of Curve” Problem

Increase Maintained Constant Head Difference
PUMP BASICS REVIEW

- Control Curve

Best Solution to Parallel pump “End of Curve”
- Control Curve

Parallel Pump Application of Variable Volume Example
Control Curve

Model Building for System Head Area Evaluation

Uniform System Head Curve for Model Building

Model Building for System Head Area Evaluation
Control Curve

a. Uniformly loaded building 40% load on each AHU
b. Non-uniformly loaded building, AHUs close to pumping source fully loaded

Model Building Loading
Control Curve

c. Non-uniformly loaded building, AHUs far from pumping source fully loaded

Model Building Loading
Control Curve

Configuring an HVAC Water System

System Head Area
Control Curve

a. Load loss variation in central plant

b. System head area caused by non-uniform flow in building “B” & other buildings

Campus Type Chilled or Hot Water System
**Control Curve**

**Points of Pump Selection & Operation**

b. Pump operating point.

c. Point of pump selection.
Type and arrangement impact positively or negatively the chiller performance.

Flow variation impact on energy:
- Reduction in water flow through chiller evaporator will lead to capacity loss.
- Flow increase through evaporator will lead to higher supply temp.
- Reduction in water flow through chiller condenser will lead to chiller efficiency reduction (COP) and capacity reduction.
- Flow increase through condenser will reduce chiller specific energy consumption.
PUMPING & RESSURE GRADIENT

Distribution system diagram

Pressure Gradient diagram for a distribution system at full load
- Part load pressure gradient (variable)

Direct return pressure gradient at part-load operating
(Note: pump is not riding the curve)
Part load pressure gradient (Constant)

New pressure gradient with pump riding the curve-constant-flow system

Pump riding the curve at part load

Figure 3.27  Pump riding the curve at part load.
PART LOAD

- **Constant flow constant speed pumps**
  - For constant speed pump, operating point will ride the curve.
  - Advisable to provide pressure control valve to maintain constant differential pressure across the control valve.

- **Variable flow will be controlled via VSD and network ΔP.**

- **For VS & CS, it will take time to ramp down pump speed at part load and the pressure across consumer interconnection will be increased till pump ramp down speed.**
Pressure Gradient at full load in a reverse-return system

Pressure Gradient at part load in a reverse-return system
(Note: pump is not riding the curve)
Reverse return implemented in a loop-distribution system
DISTRIBUTION NETWORK PUMPING SYSTEM

- Constant Primary

Constant Primary
DISTRIBUTION NETWORK PUMPING SYSTEM

- Variable Primary

Primary Pumping System
DISTRIBUTION NETWORK PUMPING SYSTEM

- Primary-Secondary

Primary-Secondary Pumping System
Primary-Secondary-Tertiary Pumping System
DISTRIBUTION NETWORK PUMPING SYSTEM

- Primary-Distributed-Secondary

Primary with Distributed Secondary Pumping
- Dedicated Pumping
  - Pump failure will affect a module.
  - Standby is costly and require a header, standby pump and valves.
  - Pumps need to have a space close to chillers to avoid extensive runs of pipes from pumps to chillers
Headered Pumping

Individual module CS Pumping and a common Header
- Headered
  - Almost constant flow through chillers thus maintaining constant supply temp.
  - Less number of pumps and associated accessories.
  - Any pump can work with any module
  - No need for extra header with associated valves.

**Individual module CS Pumping, Pump is directly connected to the chiller**
PLANT ROOM DESIGNING
CASE STUDY
PLANT ROOM DESIGN

1. Dictated by the cost of land
2. Dictated by the maximum permitted building height
3. Dictated by the required heat rejection equipment area
4. Dictated by:
   a) The chilled water interface
   b) The power supply interface
5. Dictated by local regulations for storage requirement
6. Dictated by the phasing requirement
7. Layout should consider:
   a) CT location
      • Roof
      • On grade
      • Below grade
      • Inside building
   b) Chiller location
      • Ground floor
      • Basement
      • Above ground floor
   c) Pumps location
      • Ground
      • Basement
      • Above chiller hall
8. Layout should consider:
   a) Chiller access and removal
   b) Cooling tower component removal (gear box, motor, fan blades)
   c) Chemical storage room + lab
   d) Control room
   e) Plant manager room
   f) Staff lockers CT location

9. Indoor Design
   a) Below 90°F
DISTRICT COOLING PLANT – CASE STUDY
DISTRICT COOLING PLANT – CASE STUDY

CHILLERS
## Cooling Demand (TR)

<table>
<thead>
<tr>
<th></th>
<th>End of 2021</th>
<th>End of 2022</th>
<th>End of 2023</th>
<th>Unknown</th>
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<tbody>
<tr>
<td>Financial District + HUB</td>
<td>38,000</td>
<td>14,000</td>
<td>8,000</td>
<td>48,300</td>
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<tr>
<td>GOV. 1</td>
<td>49,500</td>
<td></td>
<td></td>
<td>12,000</td>
</tr>
<tr>
<td>GOV. 2</td>
<td>10,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>97,500</td>
<td>111,500</td>
<td>119,500</td>
<td>179,800</td>
</tr>
<tr>
<td>Total (Div. 70%)</td>
<td>68,250</td>
<td>78,050</td>
<td>83,650</td>
<td>125,860</td>
</tr>
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</table>
### Ultimate Phase Energy Demand

<table>
<thead>
<tr>
<th>Plant Power Demand</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Energy Peak reduction with thermal storage</td>
<td>25%</td>
</tr>
<tr>
<td>Centrifugal chiller power demand</td>
<td>0.65 KW/TR</td>
</tr>
<tr>
<td>Absorption chiller power demand</td>
<td>0.02 KW/TR</td>
</tr>
<tr>
<td>CTs + Pumps, etc ..</td>
<td>0.25 KW/TR</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.73 KW/TR</strong></td>
</tr>
<tr>
<td>Resultant power demand/TR considering storage</td>
<td>0.56 KW/TR</td>
</tr>
<tr>
<td><strong>Total Plant Power Demand</strong></td>
<td><strong>70 MW (35 MW * 2)</strong></td>
</tr>
<tr>
<td>Energy demand if Individual Plant/Building</td>
<td>180,000 TR* 1 KW/TR  = 180 MW</td>
</tr>
</tbody>
</table>
# Plant Economics

## Why Thermal Storage??

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Thermal storage cost / TR</td>
<td></td>
<td>7500 L.E/TR</td>
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<tr>
<td>Refrigeration Plant cost / TR</td>
<td>~</td>
<td>30,000 L.E /TR</td>
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</tbody>
</table>
Energy Demand

- DCP Plant: 70 kW
- Individual Plant/Building: 180 kW
- Individual Plant Considering standby: 225 kW
## DISTRICT COOLING PLANT – CASE STUDY

<table>
<thead>
<tr>
<th>Plant Economics</th>
<th>PHASE (1)</th>
<th>PHASE (2)</th>
<th>TOTAL</th>
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<tbody>
<tr>
<td>Two Plants</td>
<td>63,000 TR</td>
<td>63,000 TR</td>
<td>126,000 TR</td>
</tr>
<tr>
<td></td>
<td>(222,350 KW)</td>
<td>(222,350 KW)</td>
<td>(444,700 KW)</td>
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<tr>
<td>Building Connected Load</td>
<td>180,000 TR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diversity Factor</td>
<td>70%</td>
<td></td>
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<tr>
<td>Network Preinsulated Pipes Length</td>
<td>47 KM</td>
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<td></td>
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<tr>
<td>Construction Cost/LE</td>
<td>2,100,000,000 L.E</td>
<td>1,500,000,000 L.E</td>
<td>3,600,000,000 L.E</td>
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<tr>
<td></td>
<td>135,000,000 $</td>
<td>95,000,000 $</td>
<td>230,000,000 $</td>
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<td>~ 28,500 L.E</td>
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<td>(1825 $/TR)</td>
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<tr>
<td>Construction Cost/TR Connected</td>
<td>20,000 L.E/TR</td>
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<td></td>
<td>(1280 $/TR)</td>
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<td>Building Conventional Plant Construction Cost</td>
<td>26,400 L.E/TR</td>
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<td>4,752,000,000</td>
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<td>Building Conventional Plant Const Cost</td>
<td>33,000 L.E/TR</td>
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<td>5,940,000,000</td>
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<td>Considering 25% Standby</td>
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<td>Net Saving/TR *</td>
<td>13,500 L.E/TR</td>
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<tr>
<td>Saving / Project *</td>
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<td>~ 2,340,000,000 L.E</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>~ 150,000,000 $</td>
</tr>
</tbody>
</table>

(*) Excludes power supply savings
End user charges

- **Connection Charge**
  - To Cover ETS Investment

- **Capacity Charge**
  - To Cover Plant & Network Investment

- **Consumption Charge**
  - To Cover Actual Utilities & Mark Up

- **Operation & Maintenance Charge**
  - To Cover Chemicals, Spare Parts, Staff & Overhauling of Equipment.

- **Emirates district cooling charges**
  - **Consumption Charge**: It is calculated according to the meter reading as per the usage. It will be charged at Dhs 0.568 fils per RT (refrigeration ton) per hour.
  - **Demand Charge**: It is a recurring yearly charge. It is around AED 750 per RT/annually. It is billed quarterly in advance.
  - **Fuel Surcharge**: This charge is levied on the bill due to a rise in fuel prices. It is 6.5 fils / kWh.
- Water Costs
- Low ΔT Syndrome
- Billing and Collection
- Infrastructure Planning
- Master Planning
• Fresh Water Cost reaches 9 EGP/mt³ including waste disposal for private facilities and 6.7 EGP/mt³ including waste disposal for government supported industrial facilities & reaches 19.5 EGP/mt³ for remote governorates including waste disposal.

• District Cooling fresh water consumption for make-up ≈ 0.11 mt³/Peak day/TR

• For 60,000 TR DCP, 6,600 mt³ of fresh water is required for make-up in a peak day

• Seawater and TSE are the available replacement for fresh water
**Causes:**
- Three-way Valves
- AHU set points lowered below design
- System Components Not Designed For the Same Temperature Range
- Coils and Control Valves Not Properly Selected
- Dirty Coils
- Airside Economizers and Make-Up Air Units

**Solutions:**
- VFD or Dual Compressor Chillers
- Oversize Primary Pumps
- Reduce Temperature Range on Primary Side
- Add Flow Control Valves at Each ETS room
- Variable Primary Flow
- Proper ETS room and Control elements design
- Penalties to be applied on low temperature return

**LOW ΔT SYNDROME**

Reduced Plant efficiency as chillers operates at part loads
BILLING AND COLLECTION RISK

- Inadequate chilled-water delivery results in unsatisfied customer
- Delays in connecting buildings which may reduce revenue, risks can be reduced by:
  1. Ongoing customer communication and technical assistance
  2. Contract initiation of payments at a certain date
  3. Plant phasing
- Accurate metering for appropriate billing of DC customers, risks can be reduced by:
  1. Procurement of high quality meters
  2. Certified Billing Software
  3. Regular meters calibration
- Issue of necessary decree for safe collection and penalties on delay.
INFRASTRUCTURE PLANNING

- Unforeseen congestion in underground services already in the street
- Safety margins should be incorporated into the construction budget
- Soil samples in advance of the installation help mitigate surprises for underground soil conditions (excessive sand or rocks)
- Utilize available space in existing services culverts
- Any new development to consider a corridor for future network installations
MASTER PLANNING

- Strategic plant locations for reasonable piping distribution installations considering pipe sizes and pumping energy.
- Connecting near by district cooling systems through the distribution networks for redundancy purpose in case of failure of one distribution network or DC plant.

DC plant location to consider:
1. Adequate supply of power
2. Pipeline access to Make-up water (Fresh, TSE or seawater)
3. Site area for waste water treatment facility
HOW TO REDUCE CHARGES

- Reduce Bank Loans/Interest

- Reduce Energy Cost
  - 60,000 TR Plant
    \[ 60,000 \times 200 \text{ day} \times 5 \text{ hr} = \]
    \[ \approx 60,000,000 \text{ TR.hr/Y} \]
    Power Tariff = 1.35 LE/KW
    Power consumption = 81,000,000 L.E/Year
    each 0.1 KW/T reduction in power corresponds to 8,100,000 L.E/Y

- Reduce Plant and Network Costs
  - District cooling network is very expensive due to small \( \Delta T \) between supply & return (\( \approx 16^\circ F \)).
## HOW TO REDUCE CHARGES

- Reduce Plant and Network Costs

<table>
<thead>
<tr>
<th></th>
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<th>600 mm</th>
<th>500 mm</th>
<th>200 mm</th>
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<td>11,000</td>
<td>9,000</td>
<td>2,500</td>
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<tr>
<td>Tee</td>
<td>125,000</td>
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<td>Gate Valve</td>
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<td>160,000</td>
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<tr>
<td>Check valve</td>
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<td>1 mt Pipe Length</td>
<td>9,000</td>
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THANK YOU