Sustainable Cooling : District Cooling

11.07.2023

experts of ingenious built environments

COMPANY PROFILE

grfn

ABOUT US

We are a progressive independent multi-disciplinary consultancy that delivers energy-efficient and sustainable engineering, design solutions, and advisory services that best serve our clients and the well-being of their local communities.

Our expert team of designers, engineers and technical consultants are committed to providing you with solutions and services that remit tangible and quantifiable value throughout the lifecycle of your project.

Our proven track record and portfolio of projects ranges from new construction, intervention and policy and advisory services. No matter the sector, size or type of the built environment, we embrace your needs and complexity with our unique skillset, and promise to provide efficient, functional, future-proof solutions and sound technical advice that drives transformative outcomes.

OUR MISSION

To provide energy-efficient, progressive and functional engineering & design solutions for sustainable built environments and professional consultancy and expertise for wide range of Industrial & Healthcare projects.

Established in **2013**

55+ team members in 2024

Certified
ISO 9001:2015
ISO 14001:2015
ISO 45001:2018

Active on the local and regional boards of Governors/ Directors of **ASHRAE** and **CIBSE**

Technical Committee members of **Efficiency Valuation Organization (EVO)**

Active members and ex-board members of **Emirates Green Building Council**

Our values reflect our true **work ethic, philosophy**, and **delivery** methods.

OUR SERVICES

Buildings

Project Development Consultancy
Architecture and Urban Design
Interior Design
Buildings Engineering
FM & Operational Consultancy
Commissioning Management

Infrastructure

District Cooling
Smart Cities
Data Centres
Sustainable Infrastructure

Strategy & Advisory

Trainings and Capacity Building
Transactional due diligence
Technical Expertise and Arbitration
Technical Studies for government and private sector

Energy & Resilience Planning

Energy Retrofit Management
Energy Audits
Energy Modelling
Resource Efficiency
Building Performance
Net Zero
Regenerative Designs

Sustainability & Environmental Consultancy

Green Building Rating Systems
Human-centric Design
Sustainable Design
Carbon Management
Environmental and Social Impact Assessments
Sustainability Strategy and Reporting

Industry and Healthcare

Project Development Consultancy
Project Management Strategy
Design development
Construction realization
Value Engineering
Time, Cost and Change management
Commissioning Management

Sectors | Buildings High-rise & Low-rise, Hospitality, Retail, Food & Beverage, Corporate, Industry & Healthcare, Infrastructure & District Cooling

COMPANY PERFORMANCE

5 office bases

Dubai (HQ) - 2013
Abu Dhabi - 2019
Egypt - 2020
Lebanon – 2020
Riyadh - 2024

14 markets

UAE
KSA
Qatar
Bahrain
Oman
Kuwait
Egypt
Pakistan
UK
Turkey
Tanzania
Iraq
Poland
Romania

AWARDS

2024

AEE ME Energy Project of the Year – Al Dar Retrofits
Dubai DSM Recognition Programme- Private Sector Energy Efficiency Leader- Hassan Younes
Dubai DSM Recognition Programme- Private Sector Energy Retrofit Project- TECOM Properties

2023

CIBSE Building Performance Awards- *shortlisted*

2022

CIBSE Building Performance Awards- *shortlisted*

2021

CIBSE BPA Retrofit Project of the Year- AD DoE Pilot Retrofit Project

2020

AEE ME Energy Project of the Year- AD DoE Pilot Retrofit Project

CIBSE Building Performance Awards- *shortlisted*

2019

CIBSE Build2Perform- *shortlisted*

GITEX Energy Sustainability Champion

2018

Retrofit Tech Energy Consultant of the Year

2017

Retrofit Tech Energy Consultant of the year

2014

ITP Middle East Boutique Consultancy of the Year

2016 to 2024

ITP Top 20 Middle East MEP Consultants

PROJECT HIGHLIGHTS

Design and construction supervision for new construction and existing buildings renovations & retrofits.

Critical Buildings- Burj Khalifa
Design & construction supervision of critical MEP systems retrofit in the top floors of Burj Khalifa.

BURJ KHALIFA
EMAAR

Mixed-Use Buildings- value of USD110M
Design & construction supervision of Al Ferdous Complex on Al Wasl Street, Dubai.

DUBAI REAL ESTATE CENTRE
BY A.R.M. HOLDING

High-rise buildings- more than 40 floors
MEPF design of a five-star hotel in Sobha Hartland for Alsheraifi Group.

الشريفي
ALSHERAIFI

More than 600 villas in Arabella I
Design review and construction supervision of HVAC rectification works in Mudon Arabella I.

NORTH25

BURJ KHALIFA MEP RETROFIT

Highest water-cooled chillers installation in the world to segregate the chilled water supply in the top 15 floors. Innovative design of condenser cooling by return water from the return chilled water of the rest of the tower.

PROJECT HIGHLIGHTS

Peer reviews & value engineering for major projects.

نخيل
NAKHEEL

DEIRA MALL	CAPEX SAVINGS- $1.98M
NAD AL SHEBA MALL	CAPEX SAVINGS- $820,000
AL KHAIL AVENUE	CAPEX SAVINGS- $1.8M

GEMS
EDUCATION

GEMS PRIMARY SCHOOL- ALREEM	30.6% ANNUAL ENERGY REDUCTION
GEMS SECONDARY SCHOOL- ALREEM	32.9% ANNUAL ENERGY REDUCTION
GEMS NATIONAL SCHOOL- BOYS	22% ANNUAL ENERGY REDUCTION

DUBAI REAL ESTATE CENTRE

28% less electrical connected load
18% less MEP construction cost
60% less cooling load demand

SAABRIN

PROJECT HIGHLIGHTS

Technical & Project Management Consultants for Energy Retrofits of some of the largest projects worldwide

> 58,000 MWh of **Achieved** Energy Savings

> 1,030,000 MWh of **Identified** Energy Savings

~ $18,000,000 of **Achieved** Saved Utility Costs

~ $41,000,000 of **Potential** Savings in Utility Costs

~500 buildings for ADNOC
of various uses owned by ADNOC in Abu Dhabi

~200 Aldar buildings in Abu Dhabi
Residential, Commercial, Retail, Hospitality and Schools

TECOM buildings in Dubai
106 buildings, **41** boutique offices, **9** warehouses, **5** souks and **various other** types of buildings

>22M SQM of Area
9 Malls + 1 Hotel

SUSTAINABILITY & ENERGY EFFICIENCY SERVICES FOR ALDAR PROPERTIES

grfn manages the LEED certification, energy retrofit, and renewable energy installations for 200 of Aldar Properties buildings.

PROJECT HIGHLIGHTS

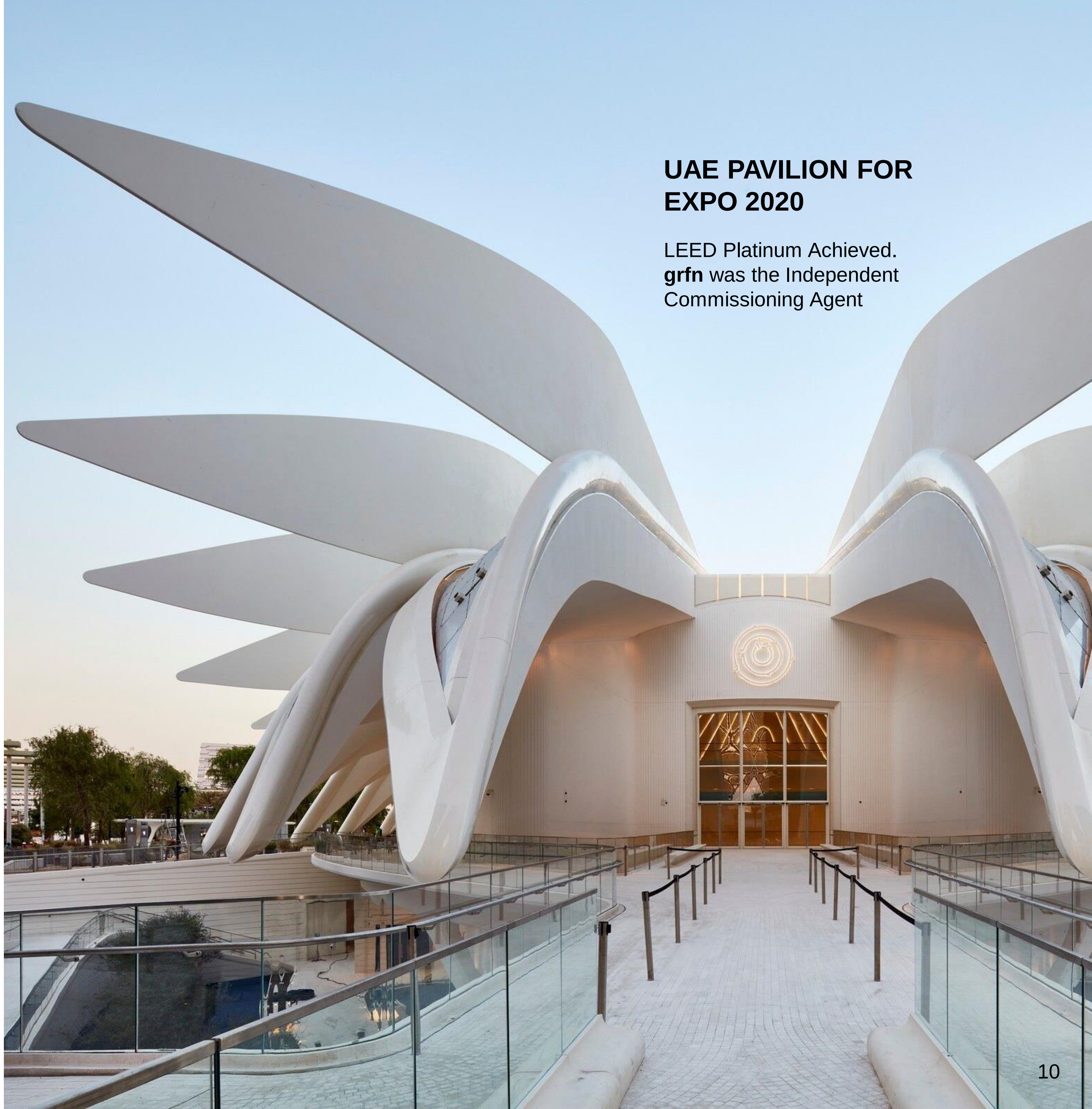
Sustainability consultancy and advisory services for small- to large- scale projects & developments.

LEED Consultancy for over 80 buildings in Abu Dhabi
Residential, Commercial, Retail, Hospitality and Schools

Green Coast- LEED Gold
Commercial buildings in Dubai

Al Khobar Waterfront
Sustainability strategy and LEED compliance for the initial phases of the development providing 1 million square feet of mixed-use space

Project Solis
1,000MWh on-grid Solar Photovoltaic installation at Dutco labor camps in Jebel Ali, Dubai.



UAE PAVILION FOR EXPO 2020

LEED Platinum Achieved.
grfn was the Independent Commissioning Agent

PROJECT HIGHLIGHTS

Technical and Project Management Consultants for key District Cooling schemes

>430,000 TR of District Cooling Designed

>380,000 TR, >35 plants of District Cooling Assessed & Optimized

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DISTRICT ENERGY GUIDELINES
Development of technical design, commissioning, and O&M guidelines for District Energy for adoption across NEOM projects.

OXAGON ZONE A DCP
Feasibility study, full fledge design and tendering for a 32,000TR Plant for Oxagon Zone A in NEOM.

PAHW District Cooling
Technical, Commercial & Regulatory guidelines and feasibility for DC adoption in Kuwait + 300,000TR scheme implementation concept for Al Mutlaa City

Saadiyat DCP 1
Detailed design and tender for the 22,500TR plant in Al Saadiyat Island Abu Dhabi

Emicool DCP Energy Retrofits
Energy Retrofit Management for plants 4, 6, 7 and 11 for improved efficiency and reduced utility costs.

DIRIYAH GATE DEVELOPMENT

A key giga-project in KSA's Vision 2030 plan.
grfn provides technical consultancy services for the District Cooling Plant serving the development.

PROJECT HIGHLIGHTS

Technical advisory services for multiple stakeholders serving multiple cities.

DUBAI DSM STRATEGY MEASUREMENT & EVALUATION
Rectification of measurement & evaluation for Dubai DSM Strategy savings reporting mechanisms.

TAQATI

PUBLIC AUTHORITY FOR HOUSING WELFARE DC GUIDELINES
Technical, business, and regulatory guidelines for adoption of District Cooling in new Kuwaiti cities.

Public Authority for Housing Welfare

DUBAI COOLING MARKET STUDY
Advisory services to determine market size and efficiencies of systems

RSB for Electricity & Water

BUILDINGS ENERGY RATING SYSTEM
Consultancy for establishing a buildings rating system

Ras Al Khaimah Municipality

DUBAI'S BUILDINGS ENERGY & WATER RATING SYSTEM

Benchmarking for an energy & water rating system for buildings in Dubai.

For- Dubai RSB

Cooling Systems Comparison

Cooling Systems Comparison in Buildings

S.N.	Parameter	Direct Expansion	VRF	Air Cooled Chilled Water	Water Cooled Chilled Water Systems	District Cooling
1	System Complexity	Simple	Medium	Medium	High	Simple
2	Operating Efficiency	1.25 to 1.9 kWh/Tonh	1.0 to 1.3 kWh/Tonh	0.96 to 1.93 kWh/Tonh	0.86 to 1.32 kWh/Tonh	DCP Plants have efficiencies of 0.8 to 1.05 kWh/Tonh
3	Capital Investment	Low-Medium	Medium-High	High	High	Low
4	Energy Consumption	High	Moderate	Moderate	Moderate	Low
5	Maintenance	High failure rates Moderate maintenance cost	Moderate failure rates High maintenance cost	Moderate failure rates High maintenance cost	Moderate failure rates Moderate maintenance cost	Low failure rates Low maintenance cost
6	Reliability	Low/Moderate	Low/Moderate	Moderate	Moderate	Very High (99.94% IDEA 2008)
7	Space Utilization	Large outdoor space needed due to high number of dedicated units around 2.9 m2 /Ton	Space requirements are moderate compared to DX 0.5 to 0.9 m2 /Ton	Space requirement is moderate 0.4 to 0.7 m2 /Ton	Space requirement is low but part of it indoors around 0.3 m2 /Ton	Space requirement is very low ETS rooms only. Around 0.1 m2 /Ton
8	Noise and Vibrations	Moderate	Moderate	High	High	Almost None
9	Aesthetic Impact on the building's architecture	High	Moderate	High	High	No Impact

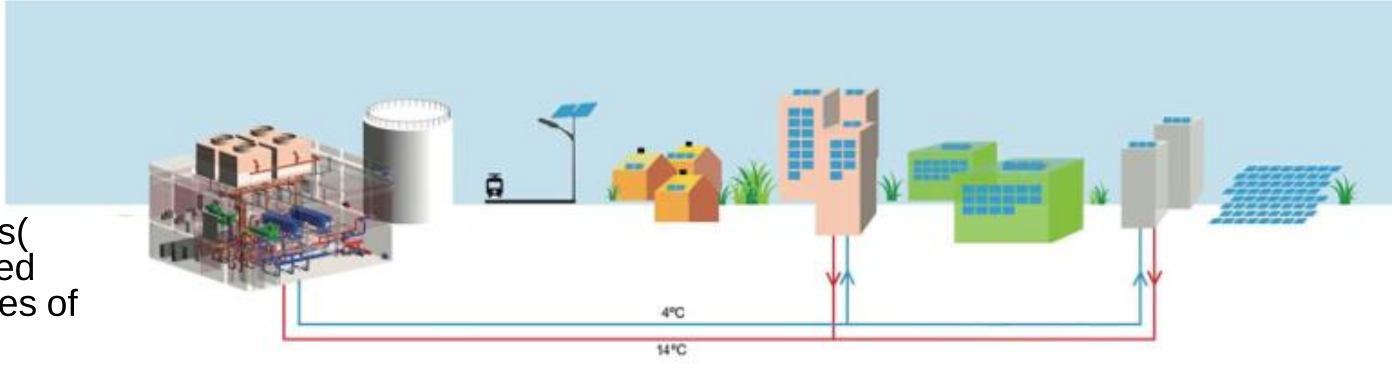
Cooling Systems Comparison

S.N.	Parameter	Direct Expansion	VRF	Air Cooled Chiller	Water Cooled Chiller	District Cooling
10	Refrigerant use	High rate of refrigerant recharges due to increased leaks	Random failures (leaks) causes more frequent refrigerant recharges	Low refrigerant re charges since the failures are mostly to the accessories	Very Low refrigerant re charges since the failures are mostly to the accessories	None
11	Legionella Impact	None	None	Chemical treatment has to be done for the chilled water network	Chemical treatment has to be done for CHW and condenser water network	Chemical treatment has to be done for the chilled water network
12	Median Equipment lifespan	12	15	20	25-30	25-30+
13	Cooling Technology Suitability per cooling density	Low load density to medium Load density	Low to medium Load density	Medium Load density	High Load density	High Load density
14	Recommended Development size (X)	X < 15,000 m2	300 < X < 40,000 m2	5,000 < X < 50,000 m2	X > 30,000 m2	Varies

District Cooling Systems

Definition and Overview

District cooling is a **centralized air conditioning system** that distributes chilled water through a network of underground pipes(could be above ground) to cool multiple buildings within a defined area, like a city district or a large campus. It leverages economies of scale and efficient, large-scale chillers to provide cooling while reducing environmental impact.



District Cooling Components

- Central Cooling Plant
- Distribution System
- Cooling Consumers

Environmental and Economic Benefits for Buildings

- Reduced Carbon Emissions
- Reduce O&M Staff
- Lower Insurance Cost
- Increased Usable Space and Reduced Noise
- Higher Reliability
- Higher Efficiency
- Reduce Demand

Benefits of District Cooling

SOCIAL

- **Job** creation
- improved urban planning → improved **living** status of citizens

ECONOMIC

National Level

- Efficient use of **resources** → wealth retention
- Additional **income** opportunities
- Improvements in air quality → **reduction** in healthcare **costs**
- Compact urban planning → **less** energy and utilities **costs**
- Centralized systems → **reduced maintenance costs**

End User

- Possible reduction of cooling **bills**
- **Space** savings
- Building **Sustainability** Ratings
- More Aesthetically pleasing developments

ENVIRONMENTAL

- Less **Greenhouse emissions**
- Less **air** pollution
- **Resilience**

Challenges and Lessons Learnt

End User

- Cooling Tariff rates
- Quality of service
- General acceptance of added value

Economic and Financial

- Required high cooling demand density
- Fees acceptance
- Differences in electricity tariff and subsidy rates
- Land prices

Planning and Execution

- Integration with infrastructure and planning
- Design criteria for developers
- Overestimated cooling demand and plant sizing
- Cooling load buildup and phasing
- User behavior and occupancy rate
- Business models
- Realistic feasibility studies
- Energy-efficient and feasible district cooling concepts
- Professional implementation along the project value chain, including planning, design, procurement, construction, installation, commissioning, and operation and maintenance.

District Cooling Applicability

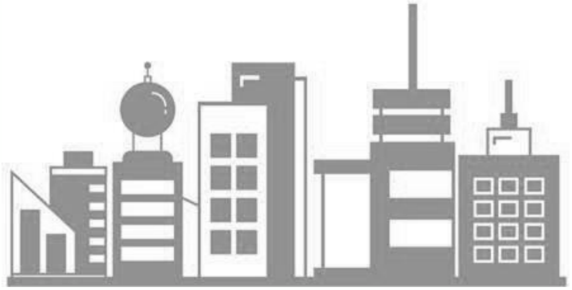
District Cooling in Different Sectors

LOW DENSITY RESIDENTIAL

- Low EFLH
- low diversity
- Non stable occupancy levels
- Low Plant Capacity Utilization (**30-60%**)
- High Network Costs

HIGH DENSITY RESIDENTIAL

- High EFLH
- Medium diversity (based on occupants behaviors)
- Accepted occupancy levels
- Medium Plant Capacity Utilization (**60-80%**)
- Low Network Costs



HIGH DENSITY MIXED USE

- High EFLH
- High diversity (different buildings uses)
- Accepted occupancy levels
- High Plant Capacity Utilization (**80-95%**)
- Low Network Costs

POLICIES & Strategies

The Role of Governments

PLANNERS	REGULATORS	CONSUMERS
• District Cooling a **utility**	• Direct Policies and Regulations	• Anchor Loads
• High density zones • Bulk and anchor loads	• Enabling Strategies	• Guaranteed Customers- low risk

Policies and Strategies

- Direct Policies

Designation Zones

Mandate district cooling in high density mixed use developments by:
- Making it an element of urban planning
- Early feasibility studies (for example mandatory in Abu Dhabi)

Tariff Regulation

Regulated and transparent tariffs that are competitive with next available technologies
- protect the property owners and the end user
- ensure commercial success

Service standards and technical codes

- Municipal codes (Thermal Energy Storage – TSE Water Use)
- Design and installation guides
- Operational guides

Policies and Strategies

- Enabling Strategies

Energy Strategy

Use DC as a pillar to achieve targets

Energy Mapping

Existing and projected developments to expand existing schemes or plan new ones

Franchise Zones

Exclusive operation of DC Provider and mandatory developer connections

Connection Policies

Government providing anchor loads, guaranteed customers, and efficient urban planning

Financial Strategies

Tailored Electrical Tariff for DC

Capital Grants

Low interest loans

Business Model

HYBRID BUSINESS MODEL

MODEL

Build Own/Operate and Transfer (BOOT)

- Used when the **private sector** finds the project's ROI is attractive, and the **local authority** requires the expertise and capital of investors
- Service Provider will **design, build, own (or partially own), and then transfer** the project for a specific number of years (example: 20 years) in the concession period
- During this period, the government/developer can detail **targets and rates** to match the social, economic, and environmental targets of the government and to the benefit of the citizens.
  - A cap on tariff rates
  - A minimum percentage of local hiring to build capacity
  - A minimum number of seats on the board of directors or management to influence decisions and goals of the project on the short and long term.

PROS

- Tap into external funding, implementation and operational capabilities and securing a faster time to market
- Mitigate financial and operational risks through partner expertise and capabilities
- Gradually build and scale in-house capabilities to takeover operation and maintenance
- Preserve the possibility to recover full control
- Preserve the power to influence rates to match national targets

CONS

- Depend extensively on partner's implementation and operation capabilities
- Require close monitoring of Service Level Agreements and of contractual commitments
- Requires technical, financial and legal consultants involved with the developer

Typical Billing for District Cooling

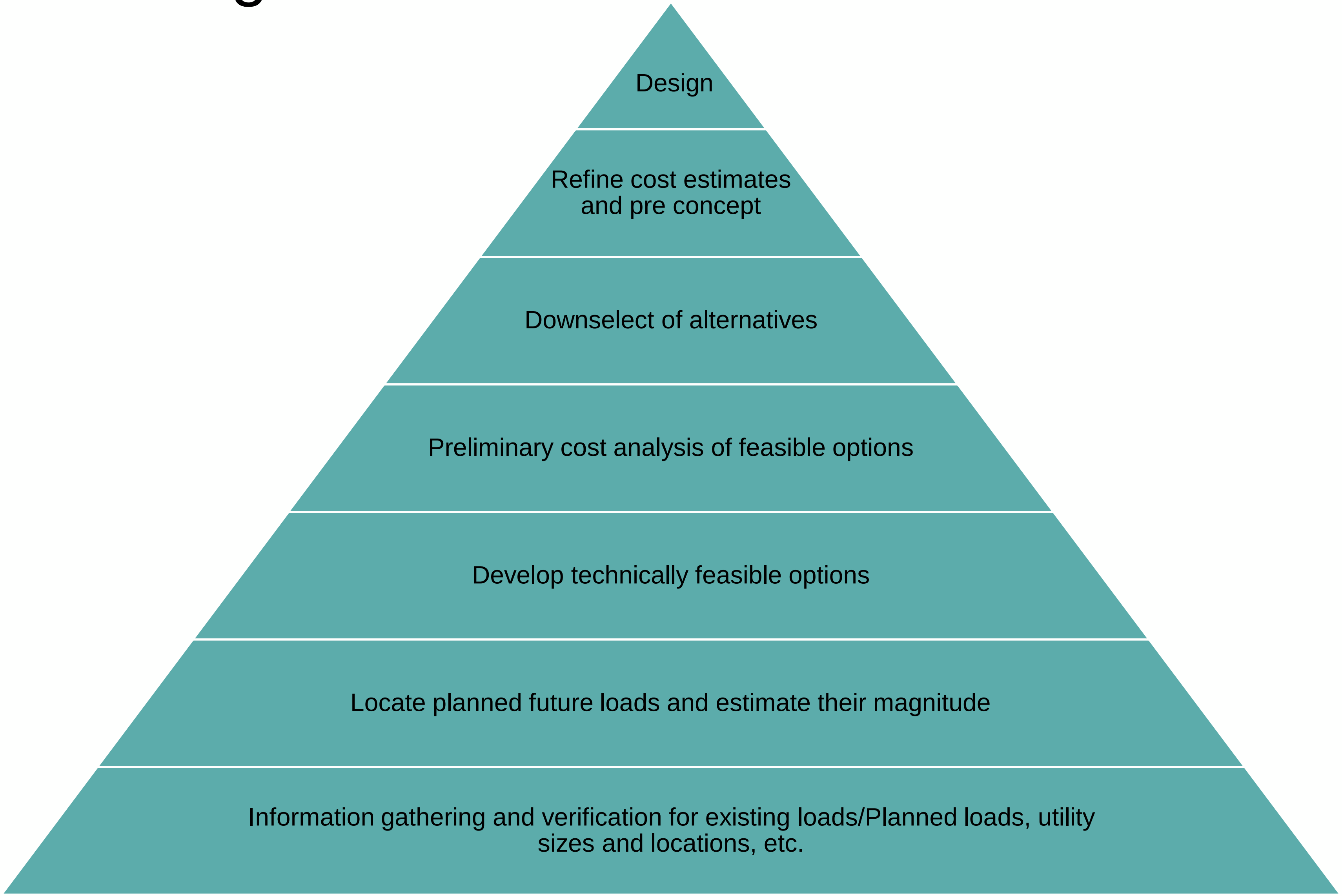
Capacity Charge ***(AED/TR/yr)***	The district cooling capacity charges are the yearly charges imposed by the DC provider over the customer and are calculated based on the contracted capacity, to recuperate the cost of constructing the plant, as well as infrastructure costs
Consumption Charge ***(AED/TRh)***	The district cooling consumption charges are the charges associated with the cooling energy consumption for the systems connected to the plant, in order to maintain utility and other running costs for the production of chilled water
Connection Charge ***(AED/TR)***	One Time Payment at the beginning of the project to partially compensate for the plant infrastructure works

Planning

Planning Considerations

- Load Densities and distributions
- Load growth projections
- Available plant sites and distribution piping routes
- Electricity and Water Tariffs
- Location of Subatations
- Energy cost escalation
- Capital budgets

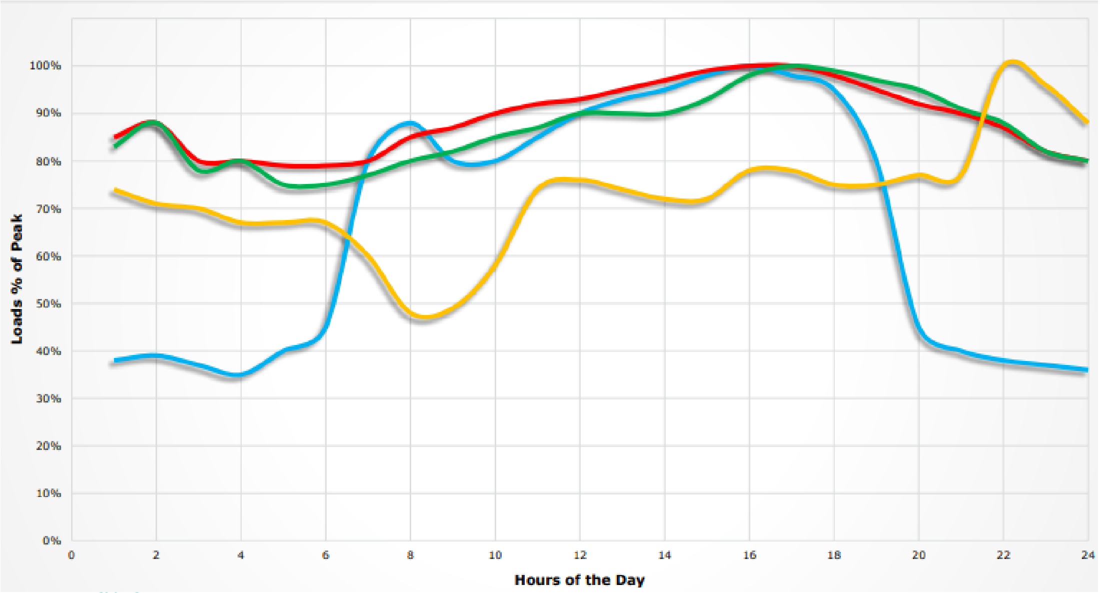
System Planning Process

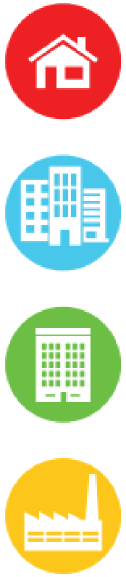


DCP simulation & Design Criteria

Load Data

- Existing load and future growth are critical data
- Load diversity (peak/connected) is critical
- When measured data exists, prefer it to modeling, or use it to validate models
- In some cases, modeling must substitute for data

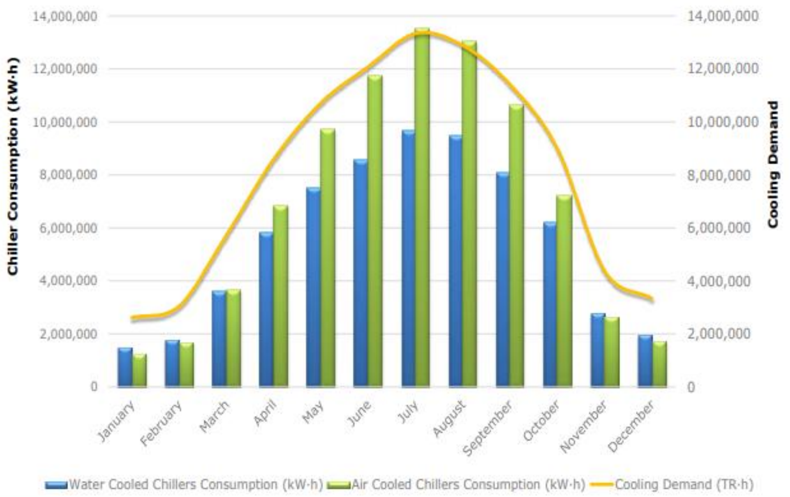




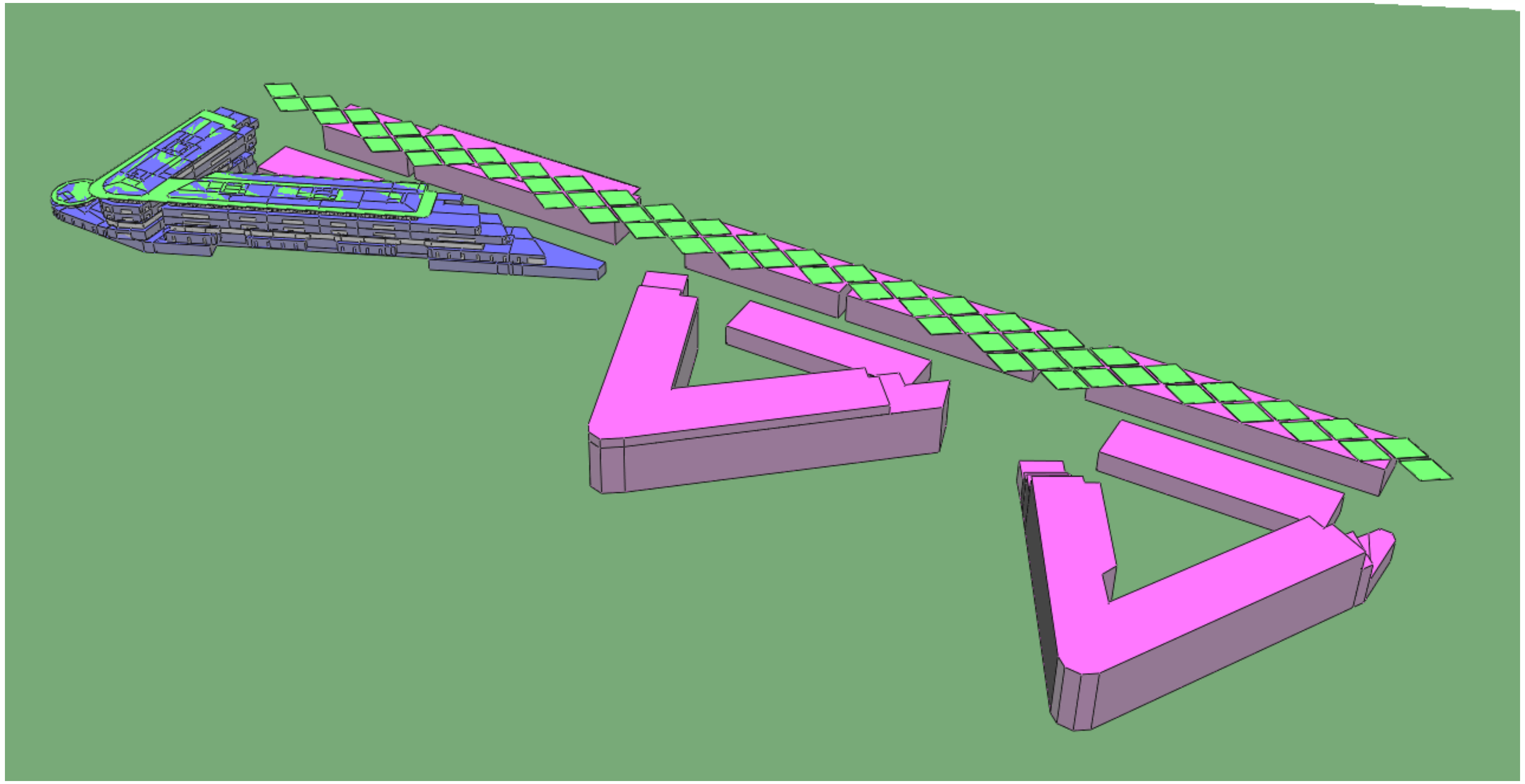
DCP simulation & Design Criteria

Load Analysis

- Load and energy modeling
- Compare diurnal, annual variation of different load profiles
- Relationships suggest strategies for thermal storage and CHP
- Peak cooling load should be determined



Planning, City Wide Cooling/Energy Modeling



Aesthetics

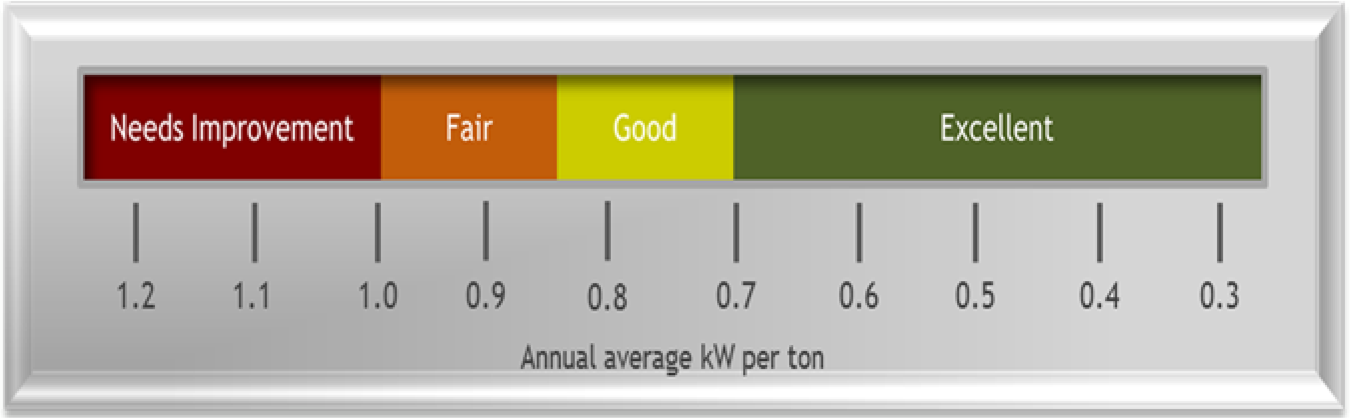
DC plants are normally hated by Master Planners

Aesthetics: DC plants and Thermal Storage tanks can be Aesthetically pleasing

DCP - Sustainable Design

- Maximum Design Zero Tolerance Point KW/Ton (Total Plant)
  - Cond. 94 / 106^{O}F + CHW 56 / 40 ^{O}F (Middle east) 0.80 kWh/Tonh
- Cost effective
  - Less Than US $ 1,750 / Ton for total plant for a plant size of > 10,000 Ton, network between 500 and 1000 US $/ton
- Smallest foot print:
  - 10 Ton / m2 inclusive of thermal storage for plant size of less than 10,000 Ton capacity
  - 12-15 Ton / m2 inclusive of thermal storage for plant size of more than 20,000 Ton capacity
- 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

Chiller Plant Efficiency Scale

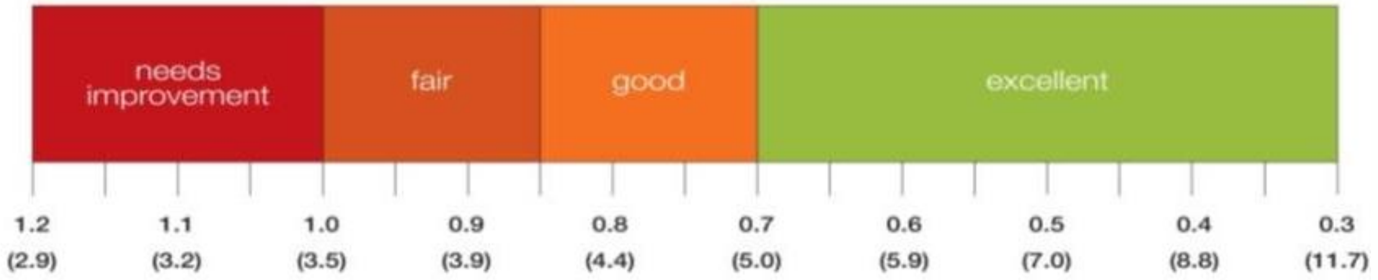


Average Annual Chilled Water Plant Efficiency in kW/TR
(Input kW includes Chillers, Cooling Tower Fans, Condenser Pumps and Chilled Water Pumps with design of 44°F CHW outlet temp & 85°F COW inlet temp)

For DCPs in UAE, annual average kW/TR is seen in the range 0.75 to 1.05 kWh/TRh

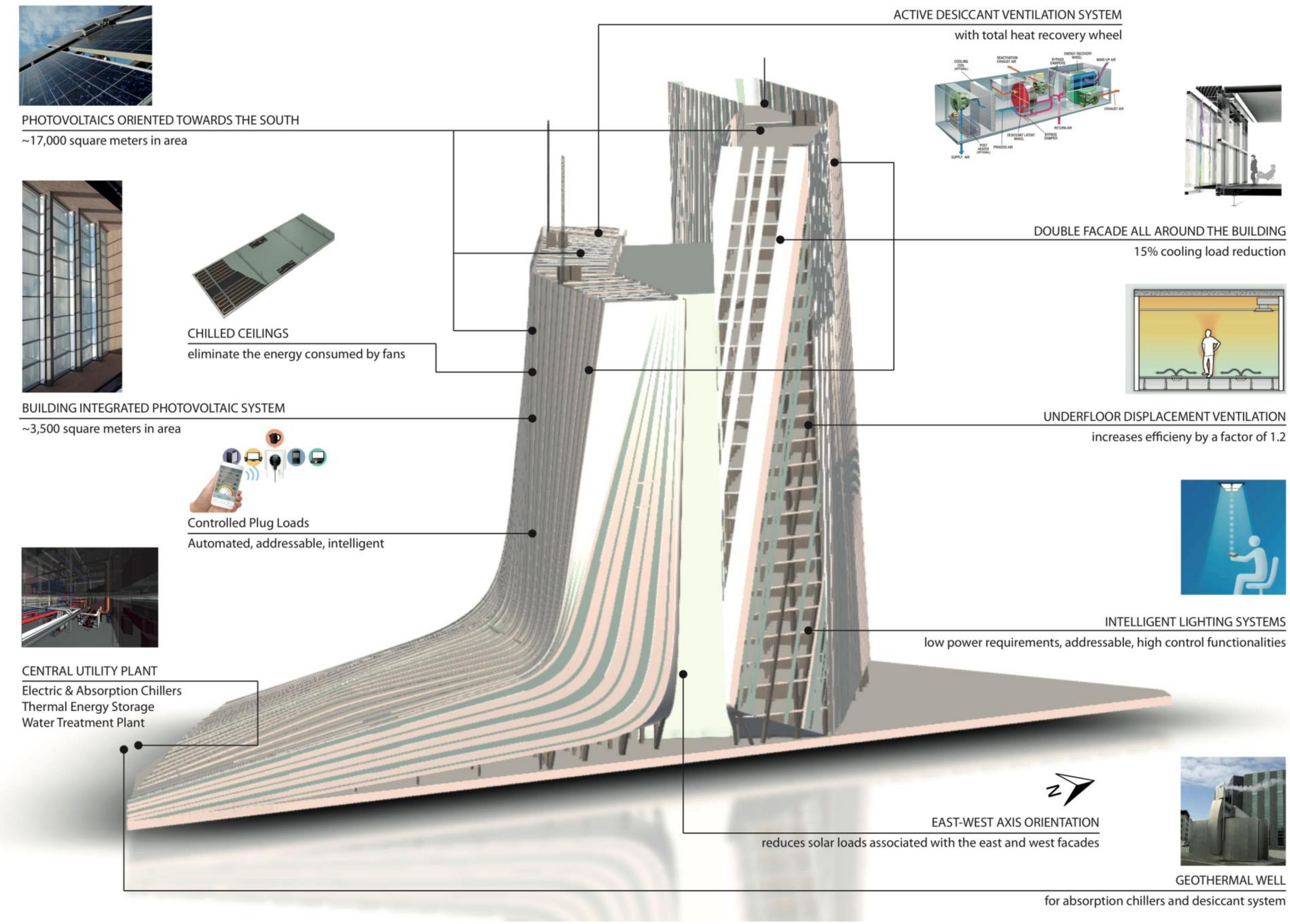
Chiller Plant Efficiency Scale

Efficiency Scale (kW/TR)

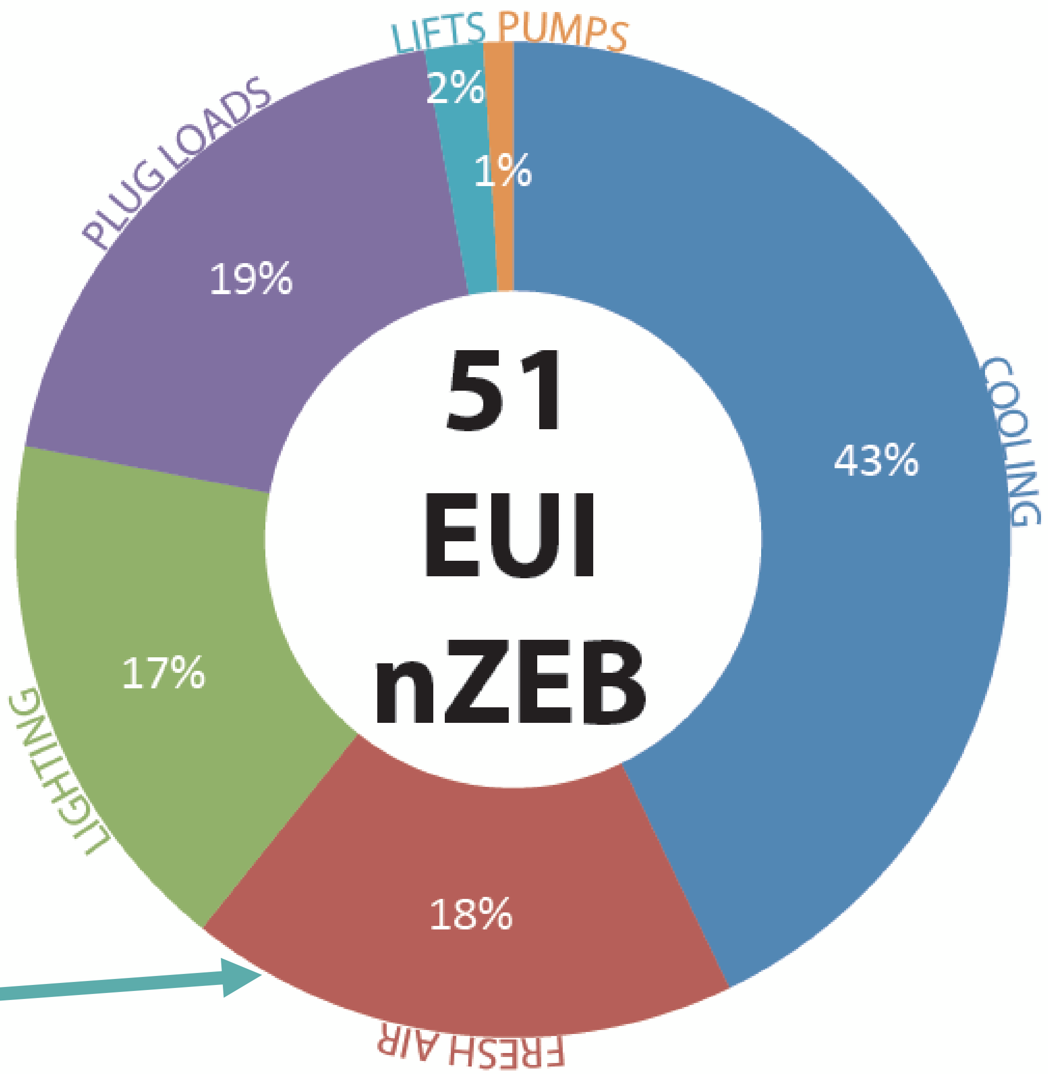


Poorly performing DCP	Average DCP	Best-in-class DCP
No tracking of data or reporting	Measurement with manual, periodic reporting	Real-time measurement & dashboard reporting; fault analysis
No optimization	Some optimization loops	Perpetual Optimization
Reactive maintenance	Planned maintenance	Predictive maintenance
Manual control of plant	Classic feedback automation	Data Recording & Analytics
Improperly applied equipment	Acceptable equipment application	Best-in-class equipment application
Minimum efficiency equipment	Moderate efficiency equipment	High efficiency equipment

Net Zero Energy Buildings

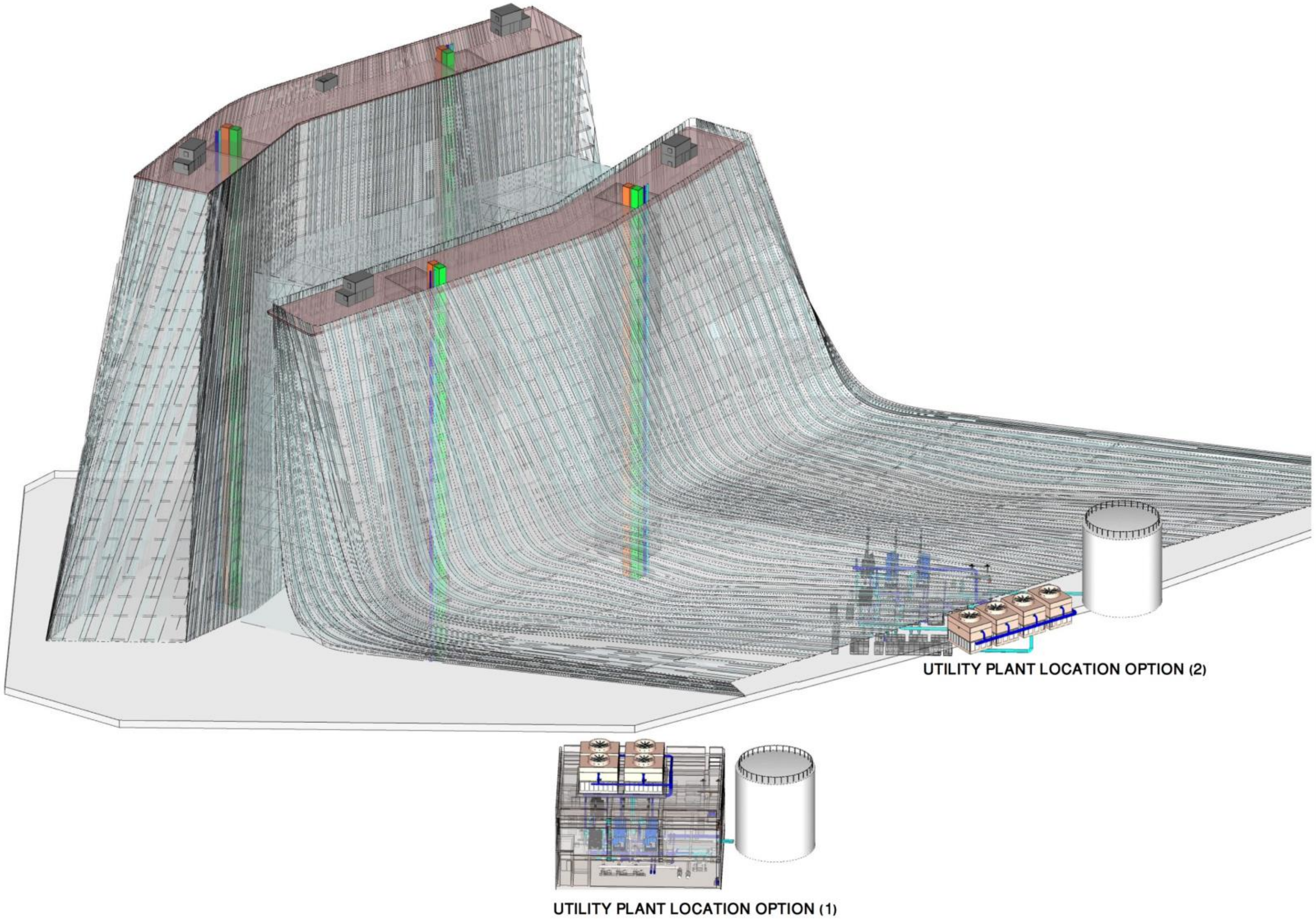

PHOTOVOLTAICS ORIENTED TOWARDS THE SOUTH
~17,000 square meters in area
CHILLED CEILINGS
eliminate the energy consumed by fans
BUILDING INTEGRATED PHOTOVOLTAIC SYSTEM
~3,500 square meters in area
Controlled Plug Loads
Automated, addressable, intelligent
CENTRAL UTILITY PLANT
Electric & Absorption Chillers
Thermal Energy Storage
Water Treatment Plant
ACTIVE DESICCANT VENTILATION SYSTEM
with total heat recovery wheel
DOUBLE FACADE ALL AROUND THE BUILDING
15% cooling load reduction
UNDERFLOOR DISPLACEMENT VENTILATION
increases efficieny by a factor of 1.2
INTELLIGENT LIGHTING SYSTEMS
low power requirements, addressable, high control functionalities
EAST-WEST AXIS ORIENTATION
reduces solar loads associated with the east and west facades
GEOTHERMAL WELL
for absorption chillers and desiccant system

Annual Energy Use Intensities



Can be reduced by half using the IAQP and advanced filtration systems

Utility Plant

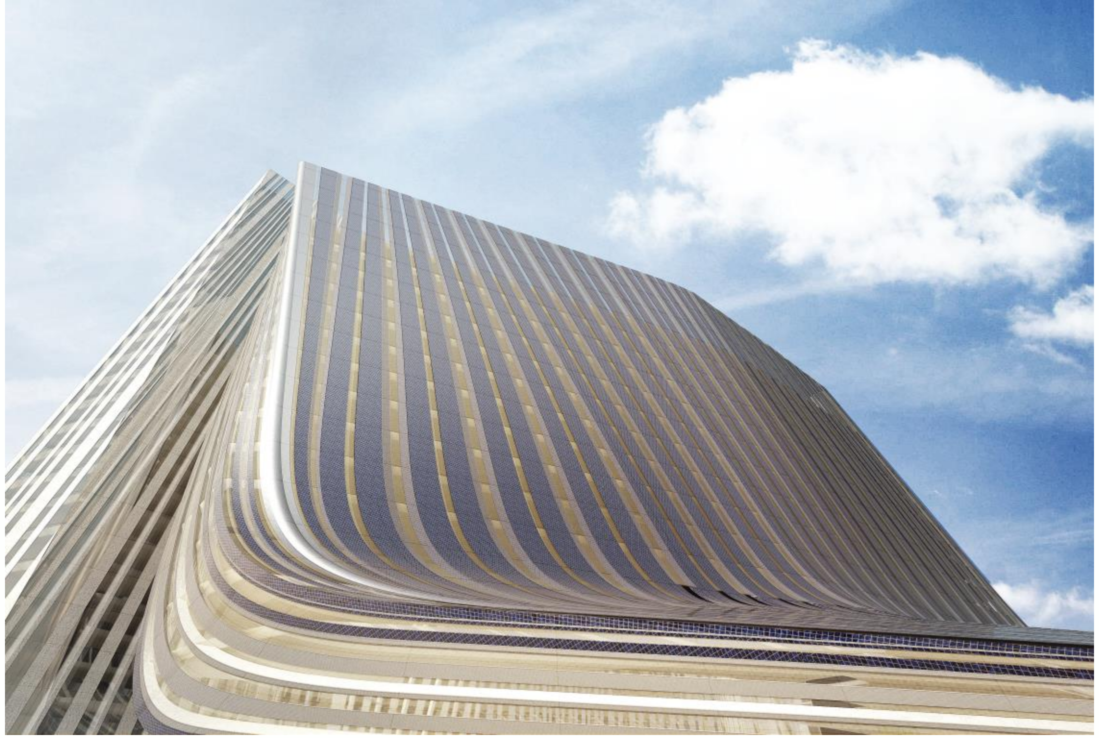


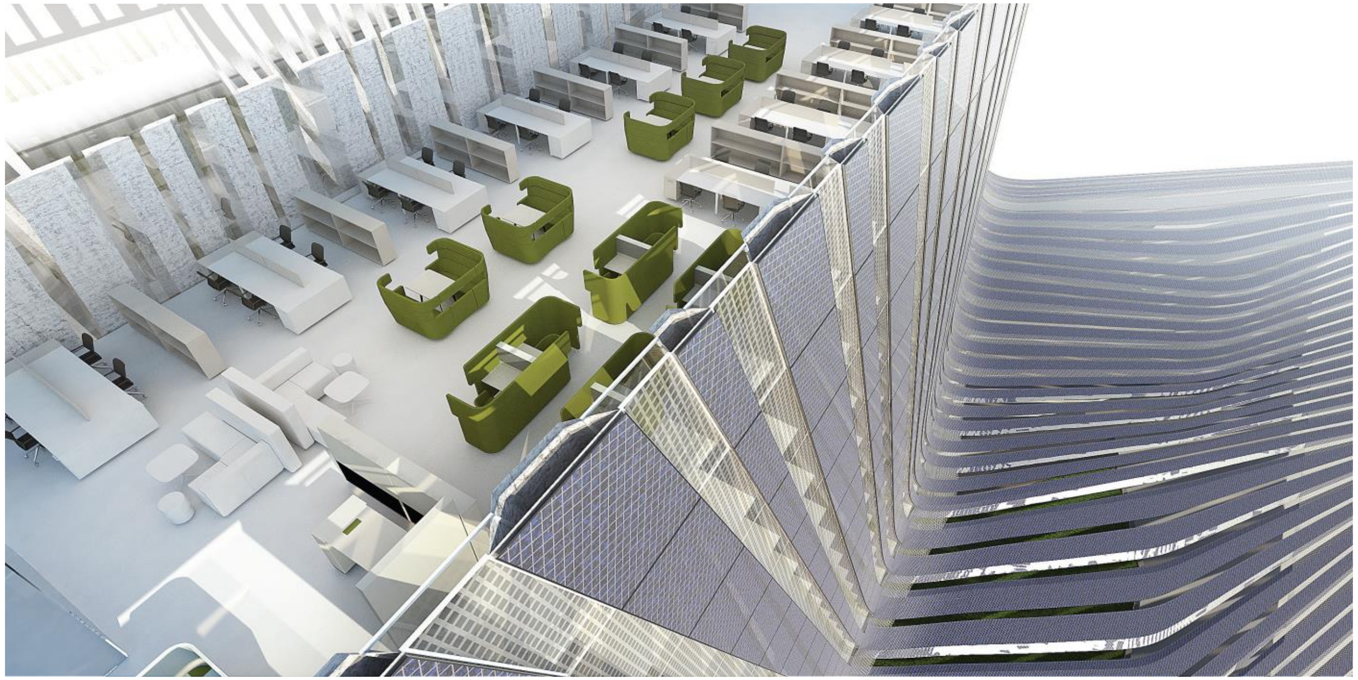
Utility Plant

Outside Air System

Underfloor Displacement Ventilation

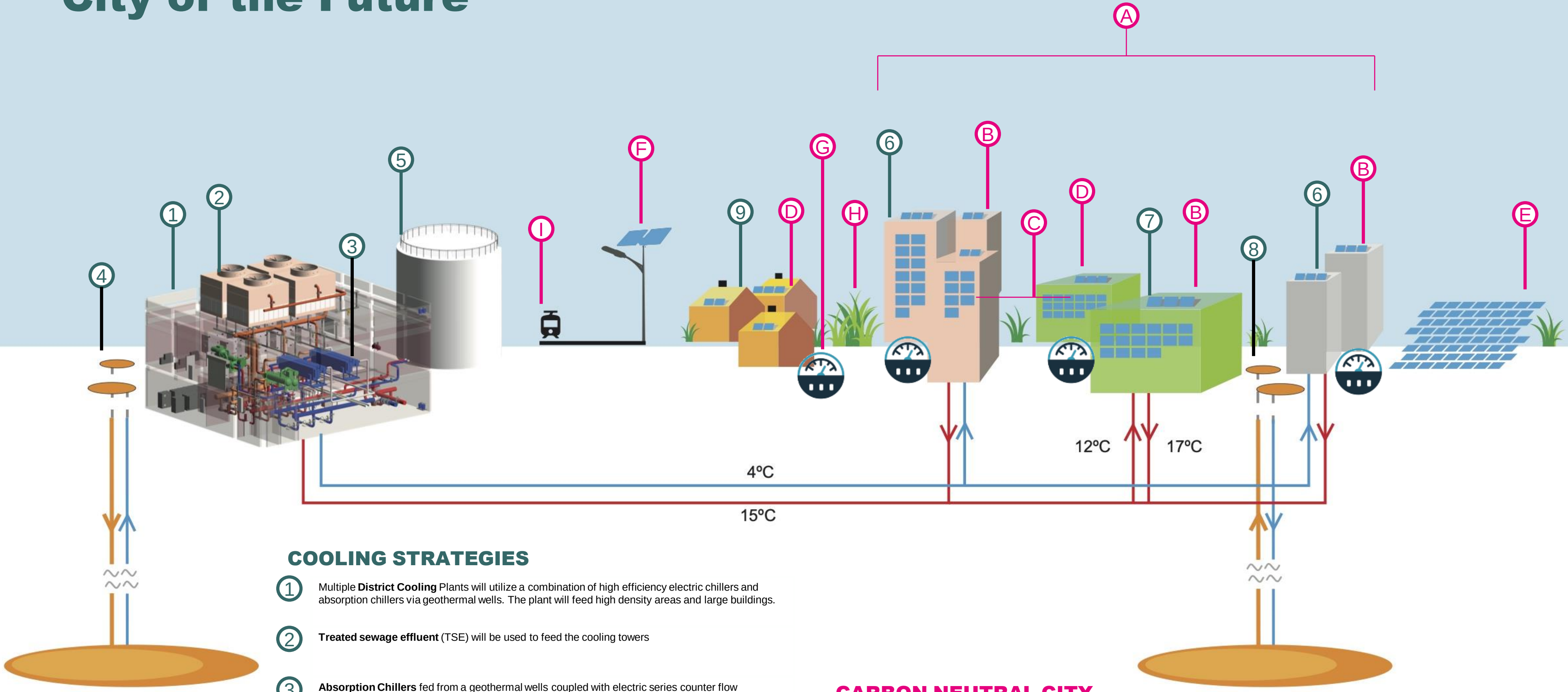
Façade Integrated PV





Net Zero Development/City

City of the Future



COOLING STRATEGIES

1. Multiple **District Cooling** Plants will utilize a combination of high efficiency electric chillers and absorption chillers via geothermal wells. The plant will feed high density areas and large buildings.
2. **Treated sewage effluent** (TSE) will be used to feed the cooling towers
3. **Absorption Chillers** fed from a geothermal wells coupled with electric series counter flow centrifugal chillers and thermal storage tanks provide optimum efficiency
4. **Geothermal wells** are proposed for every central utility plant. Geothermal energy is available 24/7 and will render the absorption chiller operational during the peak days for 24 hours.
5. **Thermal Energy Storage** store cooling energy in the low cooling demand period of the day and utilized during the high demand periods.
6. Most buildings will house conventional cooling systems with high efficiencies.
7. Selected buildings will use chilled beams technology fed by chiller water return along with desiccant systems
8. Geothermal wells will be used to supply the showcase buildings with domestic hot water and to feed the desiccant systems
9. Ultra efficient VRF systems will be used for villas and town houses

CARBON NEUTRAL CITY

A. The city houses efficient buildings with passive design elements like optimum orientation and high insulation levels facilitating low energy usage via innovative cooling methods and other strategies.

B. **Rooftop Solar Photovoltaic panels** are facilitated by reducing the VAC equipment space requirement on the roofs by the use of district cooling

C. **Façade Integrated Solar Panels** will be placed on south facing building facades for more renewable energy generation.

D. **Solar Hot Water** will be utilized wherever feasible.

E. **Solar Parks** will be placed at the non-urbanized sections of the masterplan to complement the renewable energy generation to achieve a neutral carbon city.

F. **Solar-powered Street lighting** will be used throughout the city.

G. **Smart Metering** enable intelligent measurement, monitoring, and control of the entire grid including monitoring users' power consumption and production from distributed energy sources.

H. **Treated Water** will be used for irrigation of landscaped areas.

I. **Sustainable Public Transport** will facilitate a low carbon city.

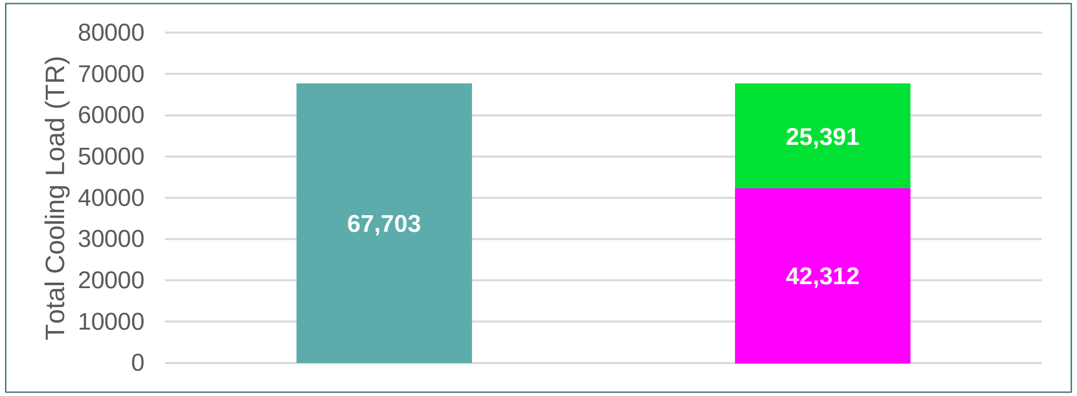
District Cooling

Case Study

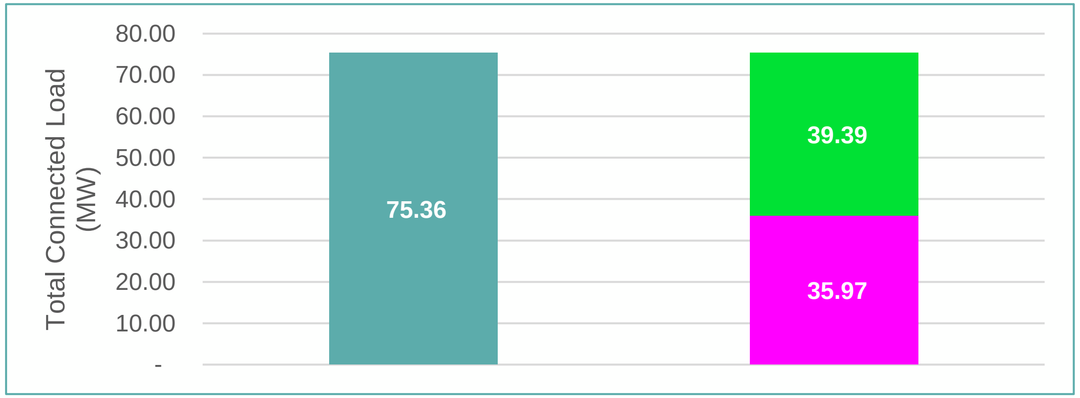
Case Study: Large Development Dubai

Study Results

Total Cooling Load (TR) Standalone Vs. DC



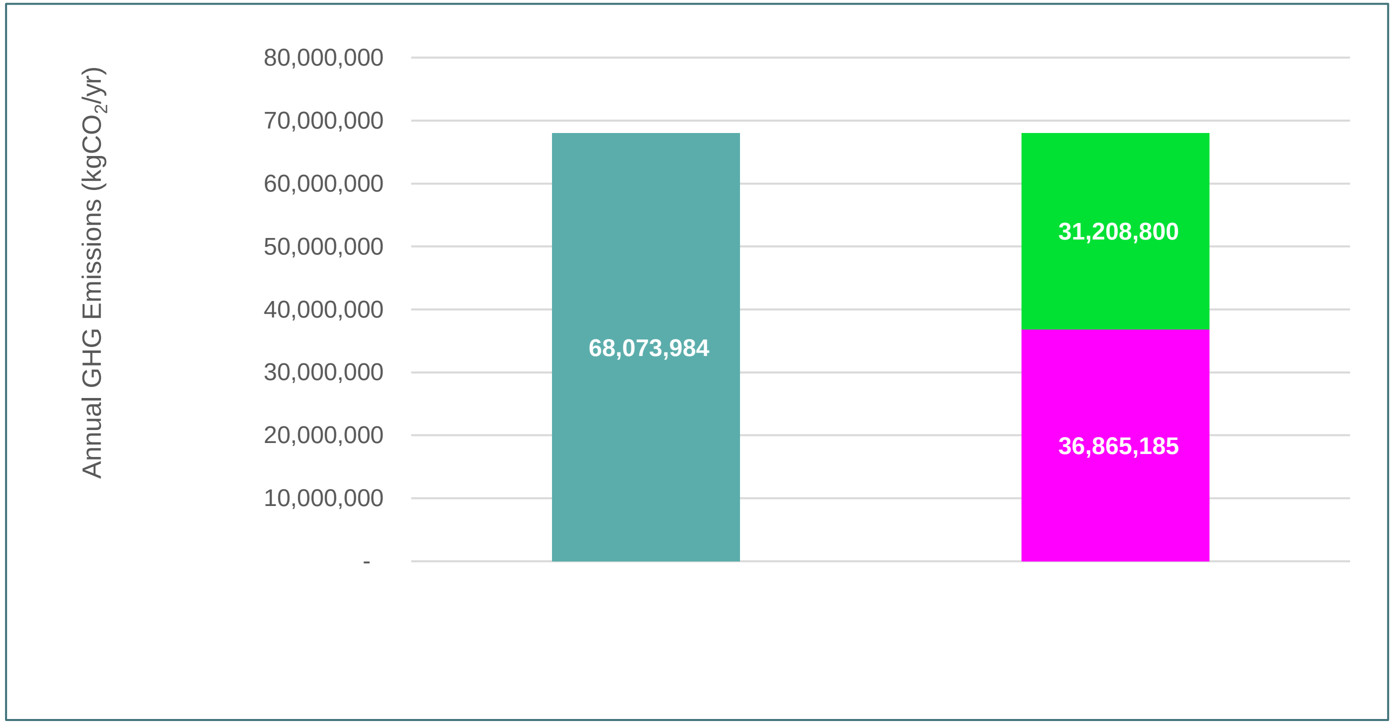
Power Required (MW) Standalone Vs. DC



Case Study

Study Results

GHG Emissions due to Power Consumption ($KgCO_2/yr$)
combined with GHG Emissions from Refrigerant Leak ($KgCO_{2eq}/yr$)



Case Study

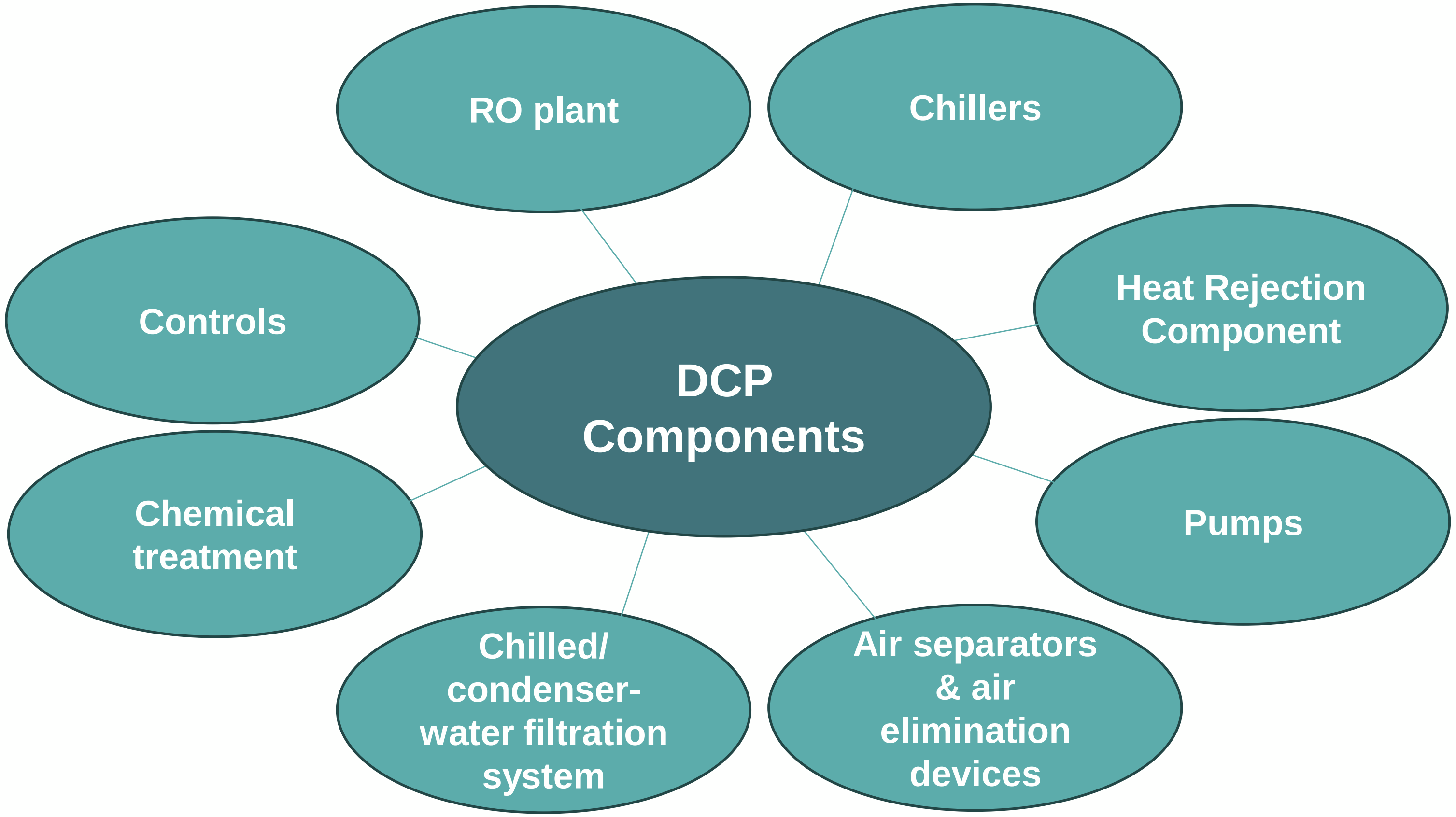
Study Results

Additional Capital and Operating Cost required for Standalone systems vs. District Cooling

Cooling Approach	CAPEX RATE	OPEX RATE*
	AED/TR	*AED/yr/TRh*
Additional Required for Water-Cooled Chillers	**+ 7,500 to 8,500**	**+0.41**
Additional Required for Air-Cooled Chillers	**+6,000 to 7,000**	**+0.59**
Additional Required for VRF	**+6,500 to 7,500**	**+0.51**

**OPEX rate includes Equipment O&M, electrical utility (DEWA), and consumables*

District Cooling Plant - Main Equipment



Chillers

Chiller Basics & Types

Air-cooled Chiller

- Air-cooled chillers are typically pre-assembled packages with the controls, compressors, evaporator, and air-cooled condenser all included.
- The capacity of such chillers may go up as high as 550 tons

Water-cooled Chiller

- Water-cooled chillers utilize water as a method to remove the heat from the chiller condenser. through natural heat sinks or through dry or wet cooling towers .
- Water-cooled chillers may be as large as 10,000 tons per unit,
- The most cost-effective capacity is around 2,500 tons to 3500 as the larger units are of the industrial type and have higher costs per unit of capacity. The expected life span of the units is around 25 years or longer.
- Water-cooled plants are typically used in most large DC systems even though the water consumption can be an additional cost factor.

Chiller Selection

Chiller Selection Criteria and Considerations

- Load profile and Duration
- Range of capacity and availability
- Reliability
- Energy Efficiency
- Environmental Impact
- Construction Phasing
- Plant Configuration and Pumping Scheme
- Available Space
- Redundancy requirements
- Lifecycle cost analysis

Load Profile and Duration + Range of Capacity and Availability

Load Profile and Duration

- Estimating and calculating system loads and load durations annually is crucial for choosing the appropriate plant size and chiller sizes.
- Chillers must fulfill both peak and minimum cooling requirements and all partial loads in between while operating efficiently under various conditions.

Range of Capacity, and Availability

- SCREW up to 500 TR , 1000 TR with SCF
- CENTERFUGAL can reach up to 3500 TR, 7000 TR with SCF

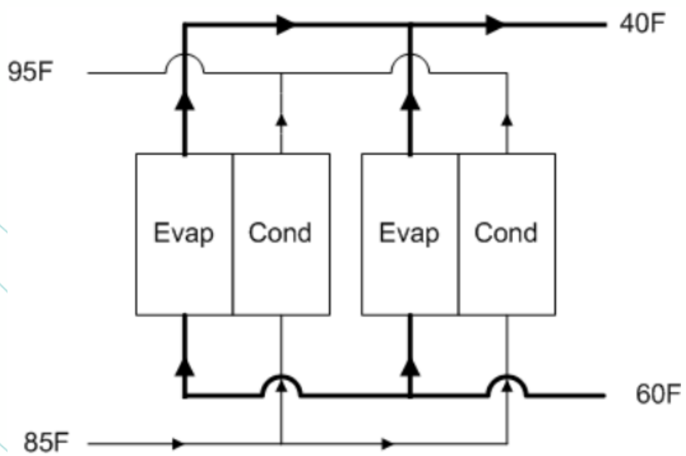
Chiller Selection

Long-term performance and reliability of any equipment come from engineered design and analysis:

- The chiller operation should be evaluated at various loads and under different condenser water temperatures.
- Zero tolerance performance which refers to the chiller's ability to maintain consistent efficiency, regardless of changes in load and condenser water temperatures. Manufacturers should provide detailed performance tables 100% to 15% load, with condenser water temperature variations of 2 °F intervals.
- Chiller should be designed to operate surge-free even at +3 °F of design condenser water temperature and be able to unload at 15%, and this should be demonstrated in documentation and testing.
- Hot-gas bypass shouldn't be used.
- Variable frequency drives (VFDs) play a crucial role in optimizing chiller performance, especially when assessing their efficiency in lift operation and cooling load management. When analyzing chiller systems, it is essential to consider the prevailing weather conditions. In situations where the load profile indicates a significant number of hours with partial cooling requirements, integration of VFDs can be considered.
- Variable Flow Systems: Selection should be suitable for flow variations ranging from 40-135% of the design flow
- The maximum allowable pressure drop should not exceed the specified value of 30 ft.
- Chillers should be suitable for variable flow also on the condenser.

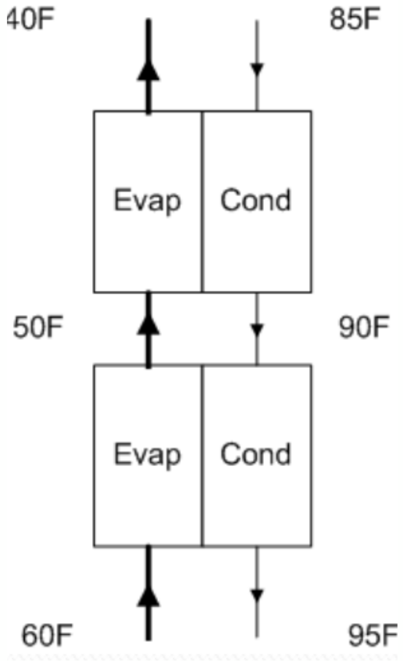
Multiple Chiller Arrangement

Parallel flow



Each chiller operates at maximum system lift

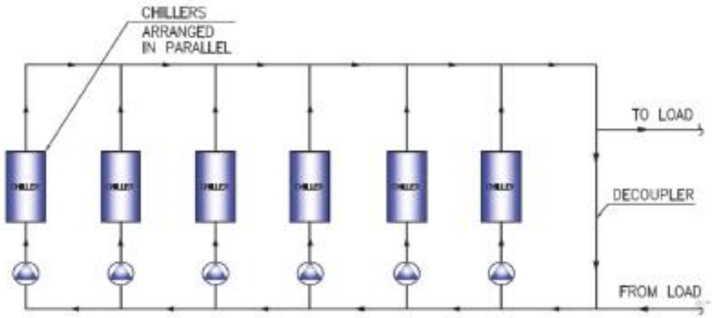
Series Counterflow



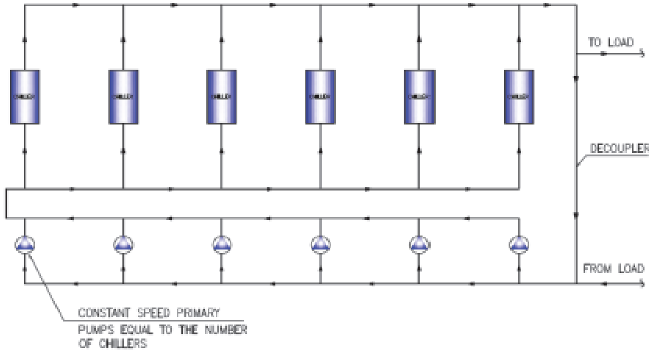
Each chiller has lower lift than in parallel flow

Plant Configurations

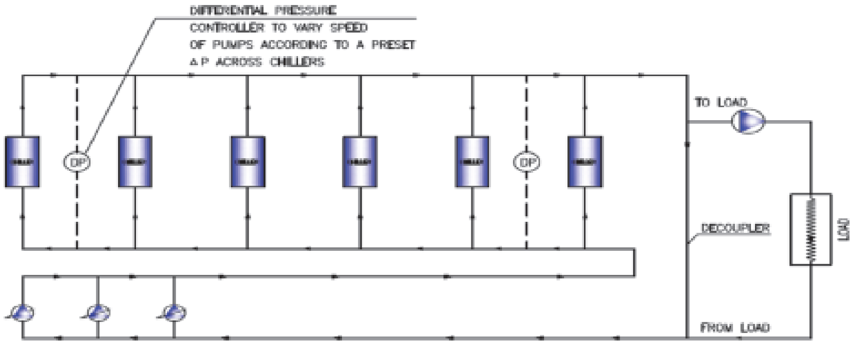
Parallel chillers with individual pumping for each chiller



Parallel chiller arrangement with headered constant-speed pumping

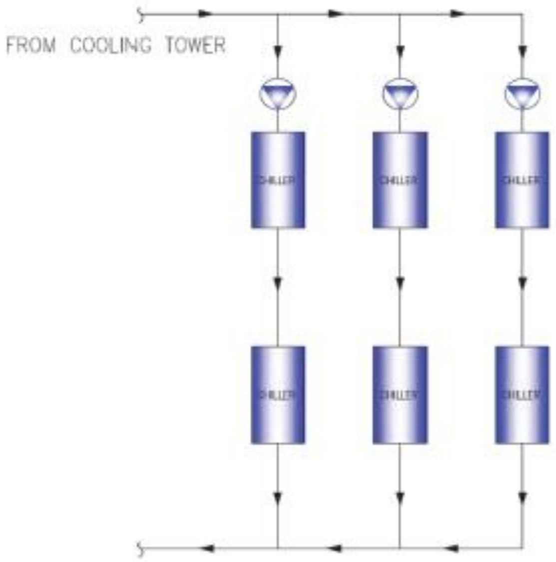


Parallel chiller arrangement with headered variable-speed primary pumping

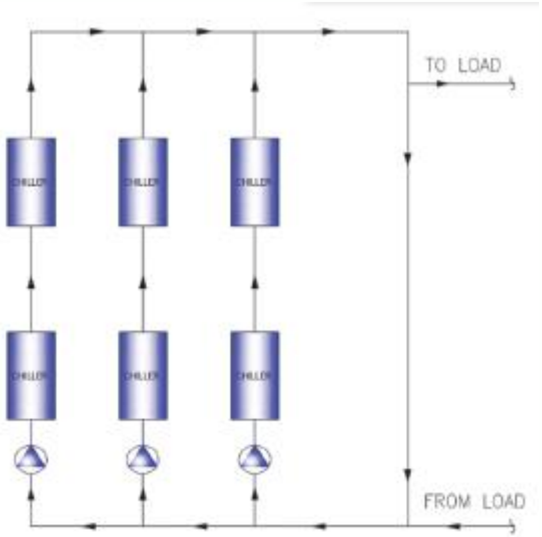


Plant Configurations

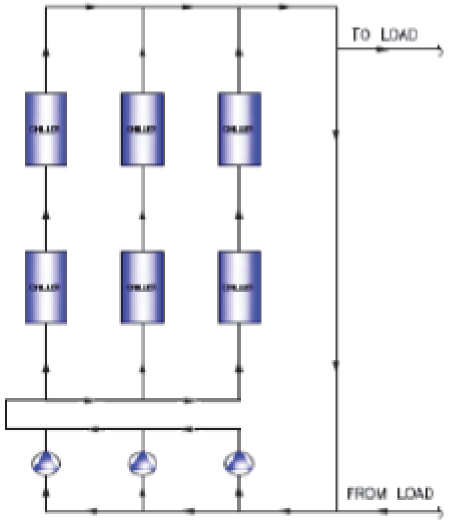
Condenser-water flow for in-series chillers with individual pumping per module



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



Series chillers with headered variable-speed pumping



Cooling Tower

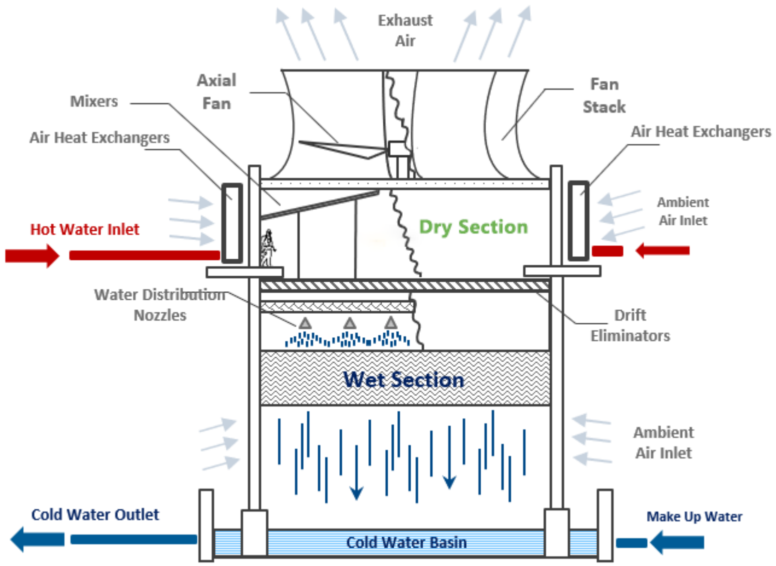
Cooling Tower

Overview

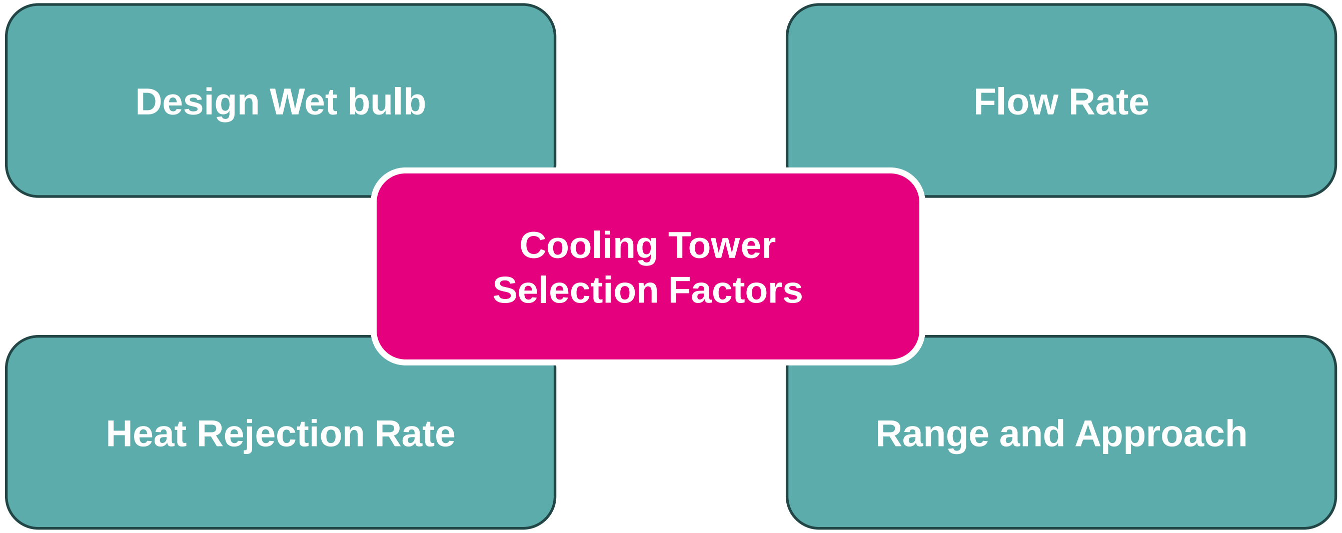
- Reject heat mostly via evaporation
- Selection based on wet bulb temperature peak conditions
- Leaving water approaches ambient wet bulb—more efficient than air-cooled
- Water consumption an issue in some locations not in Bkk
- CFD might be required to study airflow and assure no recirculation

Characteristics

- Fan type (low noise recommended)
- Fan motor control
  - Two-speed
  - Variable speed (Recommended)
- Air flow pattern
  - Crossflow
  - Counterflow



Cooling Tower Selection



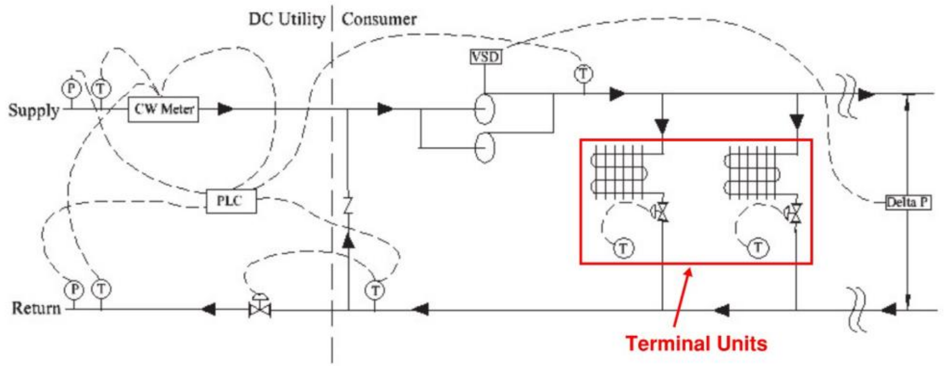
End User Interface

End User Interface

CHW from district cooling plants from district heating plants can either be used directly by the building terminal units or process loads, or indirectly via a heat exchanger located in an ETS room

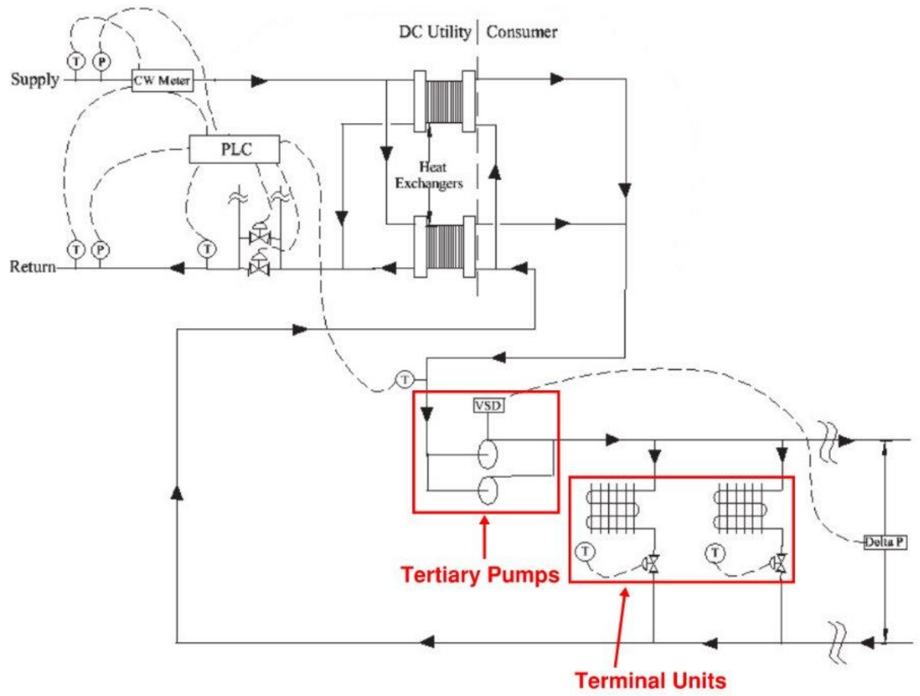
Direct Connection

In direct connection, there is no barrier between the district fluid (CHW water or hot water) and the building's HVAC system.



Indirect Connection

In indirect connection, the buildings are connected to the plant and distribution network through an ETS room



End User Interface

Direct vs Indirect Connection

Item	Direct Connection	Indirect Connection
Cost	Lower cost	Higher cost due to the installation of heat exchangers and additional controls.
Reliability	Failures within the building may cause problems or potentially even outages for the whole district system.	DES is isolated of any problems that might occur in the buildings beyond the interconnection.
Delta T	Potential for higher delta T due to the absence of heat exchangers.	The delta T is highly dependent on the approach temperature in the heat exchangers.
Pressure	Additional means of protection might be needed in terms of pressure control devices. Buildings closer to the plant might need to be protected from higher pressures. DES may be subjected to higher pressures when tall buildings are directly connected to it.	Heat exchangers isolate DES pressure from building systems pressure. Each may operate at their preferred pressures without influence from the other.
In-building Space Requirements	Lower space requirements	Additional space required for the ETS room where the HEXs are located.
Water Consumption	CHW leakage within the building will affect the DES and might be difficult to control and correct.	Water leakage is within the control of the DES.

End User Interface

ETS Room

Heat Exchangers

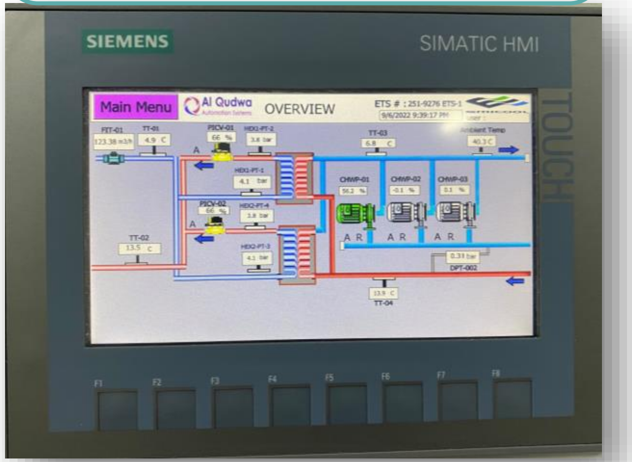
Transfer thermal energy between the CHW/HW supplied by the DEP and the water within the building.

Tertiary CHW Pumps

Circulate the CHW/HW within the building (to the terminal units)

Control System (PLC)

Controls the operation of the equipment in the ETS.



BTU Meter

BTU meter is mainly used for billing. It calculates the amount of energy consumed by the building.

Field Devices

Field devices are mainly temperature sensors, pressure transmitters, flow control devices, etc.

End User Interface

Temperature Differential Controls

Maintaining a high delta T is important in district energy systems

- Cost effective as it allows for the use of smaller piping
- Reduces energy consumption of the pumps

Low delta T refers to a situation where the temperature difference (delta T) between the supply and return water in a hydronic heating or cooling system is less than the specified design value

Actual Delta T < Design Delta T

End User Interface

Low Delta T – Root Causes

Root cause of low delta T is mainly due to inefficiencies in the buildings and not in the DEPs. Below are some common causes that result in low delta T:

- Improper equipment sizing
- Balancing issues
- System leakages
- Presence of multiple open bypasses
- Control valves are faulty or of a bad quality and are not capable of proper shut-off especially under high pressures
- Improper cleaning practices of air filters which clogs airflow
- Dirty cooling coils that clog the airflow in AHUs or FAHUs
- Improper operational practices of the terminal units

End User Interface

Low Delta T – Consequences

While the root cause of the low delta T is always due to inefficiencies in the buildings connected to the plant, the consequences mainly affect the plants.

- Extra pumping energy
- Increased energy consumption by the condenser water pump and the cooling tower fans
- Increased usage of makeup water
- DCP efficiency degradation

End User Interface

Low Delta T – Considerations

Below are some design considerations that aid in achieving a high delta T:

- Usage of variable water flow on the customer side
- Sizing coils to operate at 2°F to 3°F (1.1°C to 1.7°C) above the main CHW supply temperature for district cooling and 2 °F higher DT
- Eliminating the use of three-way valves from terminal units and employing PICVs preferably EPICVs

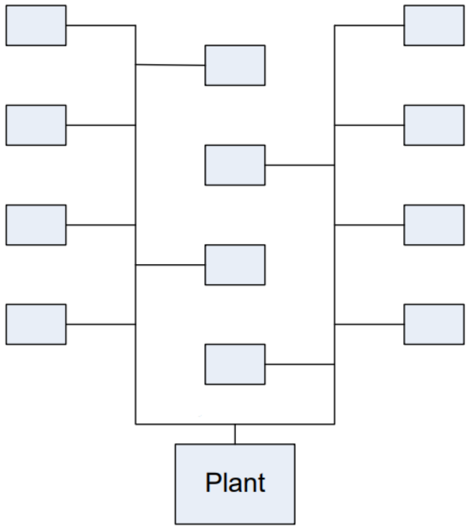
Impact of supply temperature and flow rate on cooling coil selection

	"Conventional" system design	"Low flow" system design
Coil face area, ft^2 [m^2]	29.01 [2.69]	29.01 [2.69]
Face velocity, fpm [m/s]	448 [2.3]	448 [2.3]
Coil rows	6 rows	6 rows
Fin spacing, fins/ft [fins/m]	85 [279]	85 [279]
Total cooling capacity, MBh [kW]	525 [154]	525 [154]
Entering fluid temperature, °F [°C]	**44 [6.7]**	**40 [4.4]**
Leaving fluid temperature, °F [°C]	54 [12.2]	55.6 [13.1]
Fluid ΔT, °F [°C]	**10 [5.6]**	**15.6 [8.7]**
Fluid flow rate, gpm [L/s]	105 [6.6]	67.2 [4.2]
Fluid pressure drop, ft H_2O [kPa]	14.0 [41.8]	6.3 [18.8]

Distribution Systems

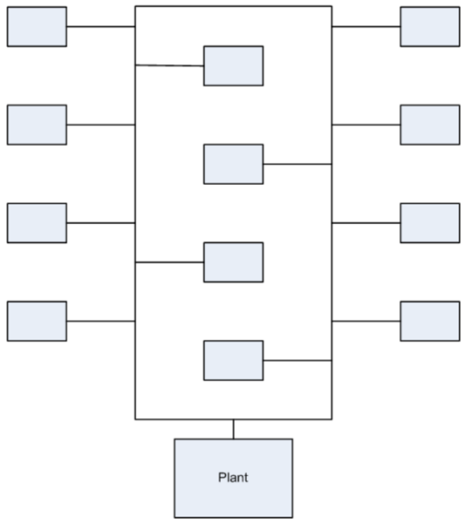
Distribution Alternatives

Radial Systems



- Extend outward from plant with ever-decreasing pipe size
- Susceptible to capacity shortfall; new loads often added at perimeter of system
- Large pressure difference near plant

Loop Systems



- Multiple paths to most load redundancy
- Less size reduction more uniform pressure drop, easier to expand
- Typically more expensive than radial distribution

Piping

- Steel and HDPE most popular
- Laid in the ground and forgotten
- Proper supervision and testing to be done to make sure no future failures
- Polyurethane foam is normally used for insulation. Pre-insulated pipes are used
- Important to check the heat gains to the piping (follow ASHRAE district cooling guide second edition equations)
- Valve chambers should be added for large piping
- For smaller diameter piping pre-insulated valves suitable for direct burial are available and recommended.
- Hydraulic modeling to be done
- Stress analysis
- Surge Analysis
- Digital twins can be created with advanced modeling software

Thermal Energy Storage

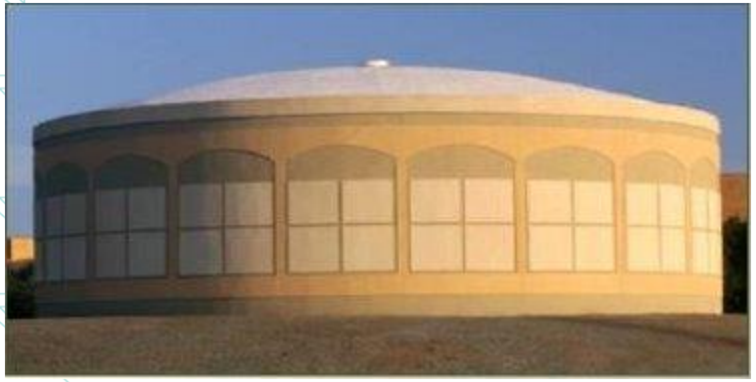
Thermal Energy Storage

Thermal Storage is a principle where cooling energy is produced and stored in the low cooling demand period of the day (typically at night) and utilized during the high demand period of the day (typically in the afternoon time). Thermal storage allows a great reduction of peak power. Where the electric grid is heavily dependent on PVs, thermal storage is used at night instead and storage happens during the day where surplus of PV electricity is available

The two basic strategies of thermal storage are load levelling and load shifting:

- Load Leveling, load shedding, or peak shaving is when the chillers capacity is sized to meet the average daily load.
- Load Shifting is when the chillers are shut off during peak hours and only thermal storage is utilized. Load Shifting would require large thermal storage system and large chillers capacity.

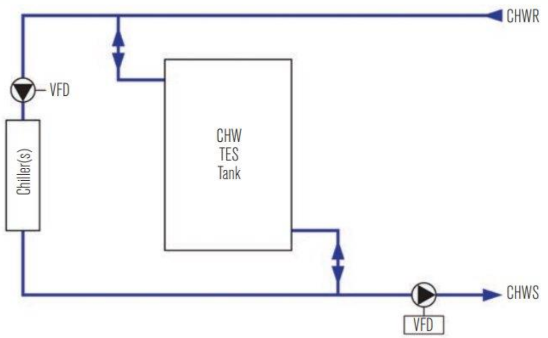
Ice Storage



Chilled Water Storage

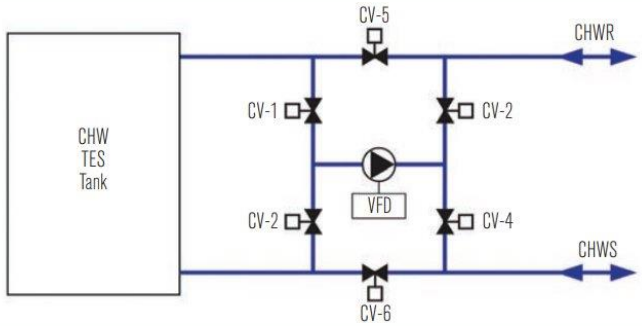
TES Tank Integration to District Cooling Plant

Local TES



- TES tank is located adjacent to the chiller plant. it can be seamlessly connected between the plant's primary and secondary chilled water loops without the need for additional TES pumps.
- Warm water from the upper part of the tank connects to the CHWR header, and cold water from the lower part connects to the CHWS header.
- Charging occurs when the primary CHW flow exceeds the secondary flow, while discharging happens when the secondary flow exceeds the primary flow.
- This method is cost-effective and straightforward, eliminating the need for complex control valves.

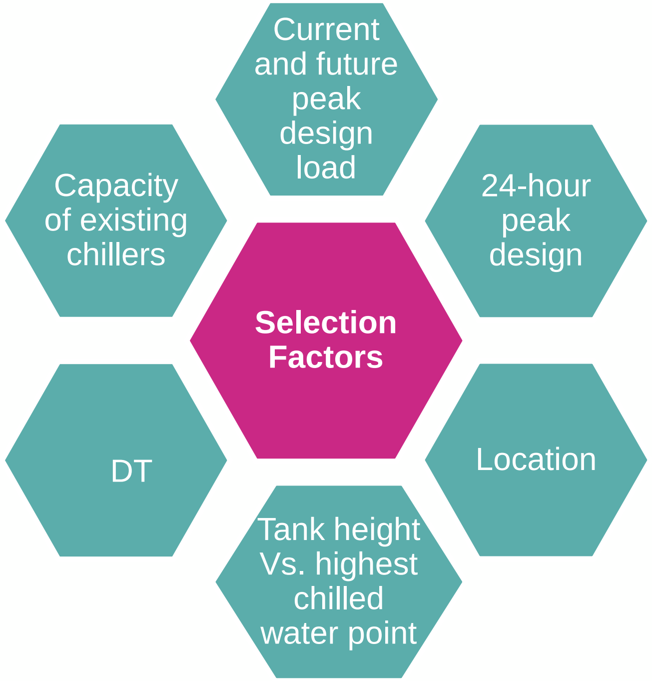
Remote TES or VPF



- TES tank located away from the chiller plant(s), a dedicated TES pumping station must pump water in and out of the tank.
- Warm water from the upper section is pumped into the CHWR header during charging, and cold water from the lower section is pumped into the CHWS header during discharge.
- The same set of TES pumps is typically used for both processes.
- Control valves (CV-1 to CV-4) are used to manage the system, with CV-5 and CV-6 modulating if the TES tank is lower than the chilled water system piping, ensuring proper back pressure control.

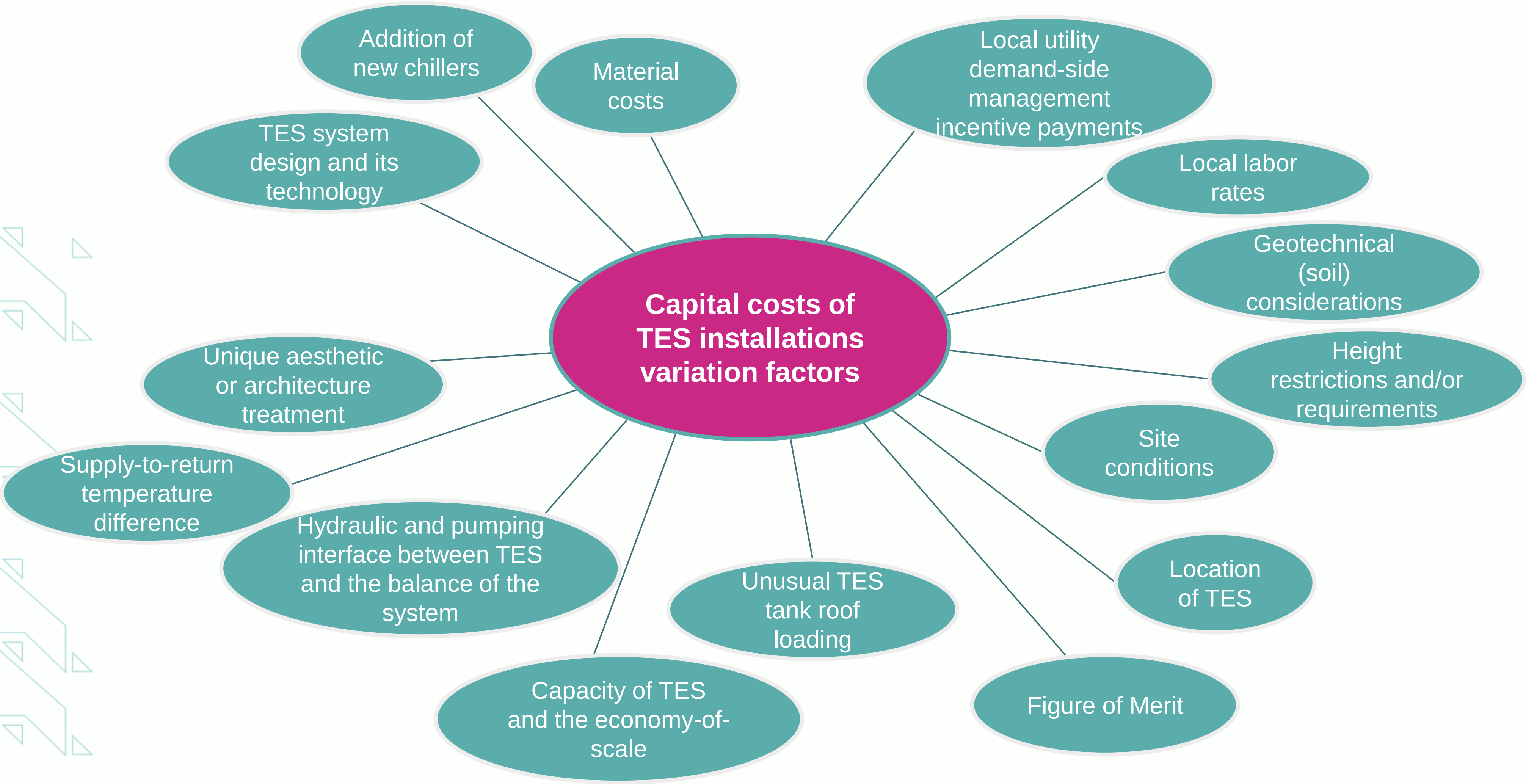
TES Selection

- Selecting the optimal capacity for a Thermal Energy Storage (TES) system involves considering several application-specific parameters.



- Future electricity tariffs or alternative electricity purchase scenarios should also be factored in.
- If the TES system has secondary uses, such as serving as an emergency cooling reserve or providing fire protection, these purposes must be considered when determining the appropriate capacity for the system.

TES Costs


Capital costs of TES installations variation factors
Addition of new chillers
Material costs
Local utility demand-side management incentive payments
TES system design and its technology
Local labor rates
Geotechnical (soil) considerations
Unique aesthetic or architecture treatment
Height restrictions and/or requirements
Site conditions
Supply-to-return temperature difference
Hydraulic and pumping interface between TES and the balance of the system
Unusual TES tank roof loading
Location of TES
Capacity of TES and the economy-of-scale
Figure of Merit

Refrigerants

Refrigerants - Past and Future

- The effort to reduce the environmental footprint of HVAC/R systems spans several decades. In 1987, ozone depletion was addressed by the Montreal Protocol, which set the requirements for the complete elimination of refrigerants having a substantial ODP (Ozone Depleting Potential), especially CFCs and HCFCs. These efforts are widely viewed as being successful with recent reports indicating the ozone hole is shrinking.

- Global warming is a heating effect caused by greenhouse gases being trapped in the earth's atmosphere. These gases act like a blanket by preventing heat from escaping, thereby warming the planet (boiling?).

- Carbon dioxide (CO2) emissions are the greatest contributor to the greenhouse effect. CO2 is introduced to the atmosphere through the burning of fossil fuels (oil, coal, natural gas). Refrigerants are also a contributor to the GHGs emissions due to their high GWP
- As a result, the refrigerant industry is successfully transitioning away from Ozone Depleting Substances (ODS) and is now focusing on Greenhouse Gas (GHG) emissions and total carbon footprint.

Lifecycle Emissions and Energy Efficiency

Energy consumption is the most dominant contributor to the total cost of ownership of HVAC/R systems, making energy efficiency a key driver when comparing technologies.

$$Lifetime\ GHG\ emissions\ (in\ CO2\ equivalence) = Indirect\ emissions + Direct\ emissions$$

Indirect Emissions

- Indirect emissions are the result of CO2 emissions from the energy used to operate HVAC/R systems.
- According to the European Partnership for Energy and the Environment (EPEE), indirect emissions typically account for 80 percent or more of the total lifetime GHG emissions.
- GHG emissions will vary according to equipment efficiency, operating schedule, and the carbon footprint of the electricity used.

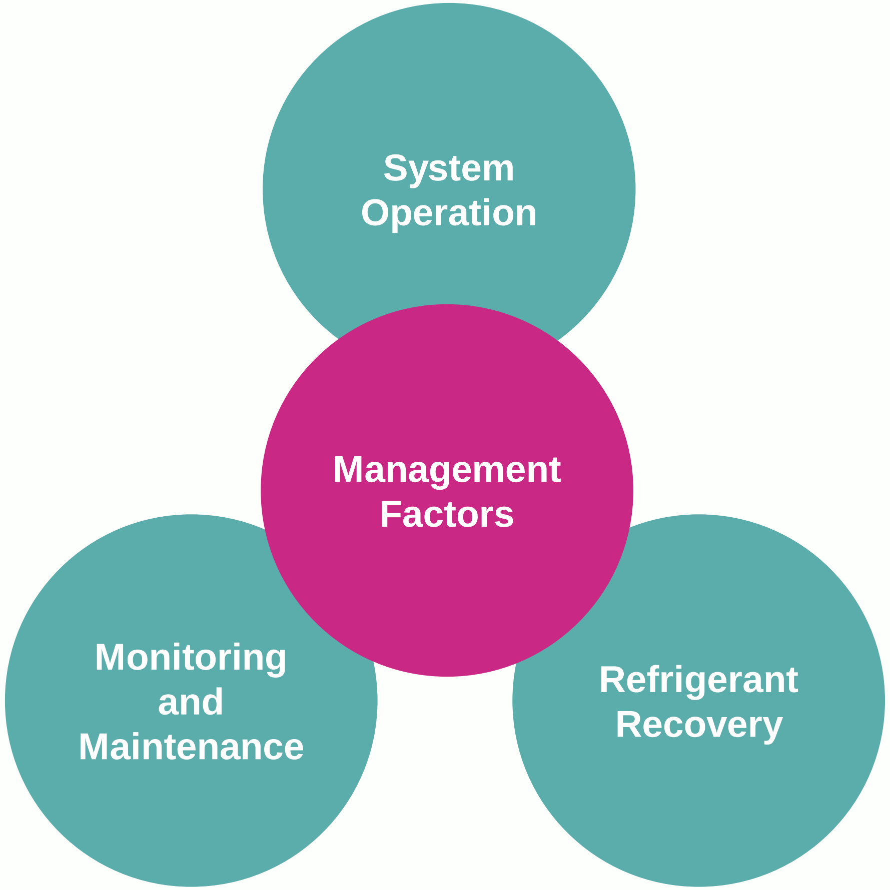
Direct Emissions

- Direct emissions are derived from a combination of refrigerant GWP, leakage, and end-of-life recovery.
- The quantities of refrigerant released to atmosphere are highly dependent on HVAC/R equipment design, maintenance requirements and refrigerant management practices.

Evaluating and Selecting Refrigerants

Refrigerant Management

Refrigerant gas will not directly impact the environment unless it is released into the atmosphere. Therefore, comprehensive refrigerant management practices provide one of the greatest opportunities to reduce GHG emissions during HVAC/R system operation, maintenance, and end-of-life recovery.



Refrigerants

	Medium Pressure Refrigerants				Low Pressure Refrigerants		
Refrigerant	R-134a	R-513A	R-1234yf	R-1234ze(E)	R-123	R-1233zd(E)	R-514A
Type	HFC	HFO Blend*	HFO	HFO	HCFC	HCFO	HFO Blend*
Flammability	1	1	2L	2L	1	1	1
Toxicity	A	A	A	A	B	A	B
Theoretical Fluid Efficiency	8.5 COP	8.3 COP	8.2 COP	8.5 COP	9.4 COP	8.85 COP	8.91 COP
Capacity Change Compared to Base	Base	Similar	5% Loss	25% Loss	Base	35% Gain	~5% Loss
GWP	1300	573	<1	<1	76	<1	2
ODP	0	0	0	0	0.012	~0	0
Atmospheric Life	4900 days	2200 days	16 days	11 days	475 days	26 days	22 days

***Red Text denotes "Drop-in" Refrigerant**

Instrumentation and Control

Instrumentation and Controls

SCADA system architecture: the 4 layers were defined along with their components, functions, and requirements:

Management Level	SCADA software, Human Machine Interface, Operator Workstations and Uninterruptable Power Supply
Communication Level	Switches, routers, and fiber optic communication media
Automation Level	Microprocessor Programmable Logic Control (PLC) unit with control chassis along with communication ports, I/O modules, terminal blocks, mounting kits, enclosures, and power supply, and any required accessories
Field Level	Sensing, measuring, and switching devices, meters, valves, and actuators.

Questions?

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