

District Cooling Plants

By

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Objective

The objective of this course is to provide a general knowledge of district cooling plants. While district hot water or steam plants may share some similarities, the focus of this lesson will be on district cooling plants. Answers to the following questions will be addressed in this lesson:

- *What is a district cooling plant?*
- *What are the pros and cons of district cooling plants versus distributed cooling?*
- *What combination of cooling loads are preferable?*
- *What design considerations should be made regarding chillers, pumping arrangements, metering, and thermal storage?*
- *Who has rights to underground easements for installing piping under streets?*
- *Who should own the asset?*
- *Who should maintain the asset?*
- *What is the recommended fee structure for customers, if applicable?*
- *Who should maintain the end devices such as air handling units?*

Abbreviations

ΔT	differential temperature (supply water temperature minus return water temperature)
FL	full load
IPLV	integrated part load value
gpm	gallons per minute
hr	hour
kWh	kilowatt-hour
IPLV	integrated part load value
NPLV	non-standard part load efficiency
Ton	ton of refrigeration
vfd	variable frequency drive

What is a district cooling plant?

"District cooling provides chilled water for indoor cooling purposes to industrial, commercial and residential buildings through a closed loop pipe network" (*District Cooling*, 2013).

Often, district cooling is used for a single owner of multiple buildings. A college or university is a good example of this type of district cooling. A single chiller plant (or multiple interconnected chiller plants) serve(s) multiple buildings by distributing chilled water through large underground pipes to each building.

District cooling can also serve multiple buildings owned by different entities. Cooling is sold as a commodity like electricity. The usage can be metered at each building and billed monthly.

What are the pros and cons of district cooling plants versus distributed cooling?

Efficiency

According to the Danfoss' *District Cooling* webpage, "A district cooling system can reach an efficiency rate typically 5 or even 10 times higher than a traditional cooling system" because, "the cold water used in a district cooling system can come from free sources such as sea water, or it can be produced from sources like waste heat with the use of steam turbine-driven or absorption chillers or electric chillers" (2013).

Why can't distributed cooling (stand-alone cooling systems) take advantage of the same free sources? Free sources can also be used for stand-alone facilities, but the limited access to some of those locations limits which facilities are able to take advantage of those free resources.

For example, Niagara Falls could only provide power to the properties adjacent to the falls or the power could be harnessed for entire cities. The same is true for using the Great Lakes for cooling. The properties along the lake could use the cool temperature of the lake to cool only those buildings on the coastline, but it is not very economical in small applications. To obtain consistently cool water, a long pipe must be extended far from shore into the lake. The cost of the long pipe may not be economically justified for a small application and may be first-cost prohibitive. Providing cooling to multiple buildings, which may not have direct access to the lake, helps spread the cost of the pipe across many customers. Even then, the initial construction cost may be too high for all customers to absorb at once. The benefit of district cooling with an independent owner is that the district cooling plant can finance the cost of the construction and recoup the costs from the customers over time.

For buildings with extremely low cooling loads, distributed cooling (stand-alone cooling at the site) may be more economical. The cost of underground piping can be quite costly.

Reduced Demand Charges

Thermal storage and levelized loading can reduce electric demand charges.

"Thermal energy storage is defined as a technology that allows the transfer and storage of heat energy or energy from ice or water or cold air…. The thermal energy (either chilled or hot water) is produced in the periods of off-peak electrical demand or utilization and collected in a thermal energy storage tank, then withdrawn and distributed to the facility during peak periods" (Admin, 2017). Once again, thermal storage can be used in stand-alone, distributed cooling projects, but the economy of scale is not present.

Whether electric demand is levelized by thermal storage or more organic methods of leveling load (see the section below on the combination of cooling loads for more information on this topic), the overall electricity costs are lower while maintaining the same or slightly higher kWh usage.

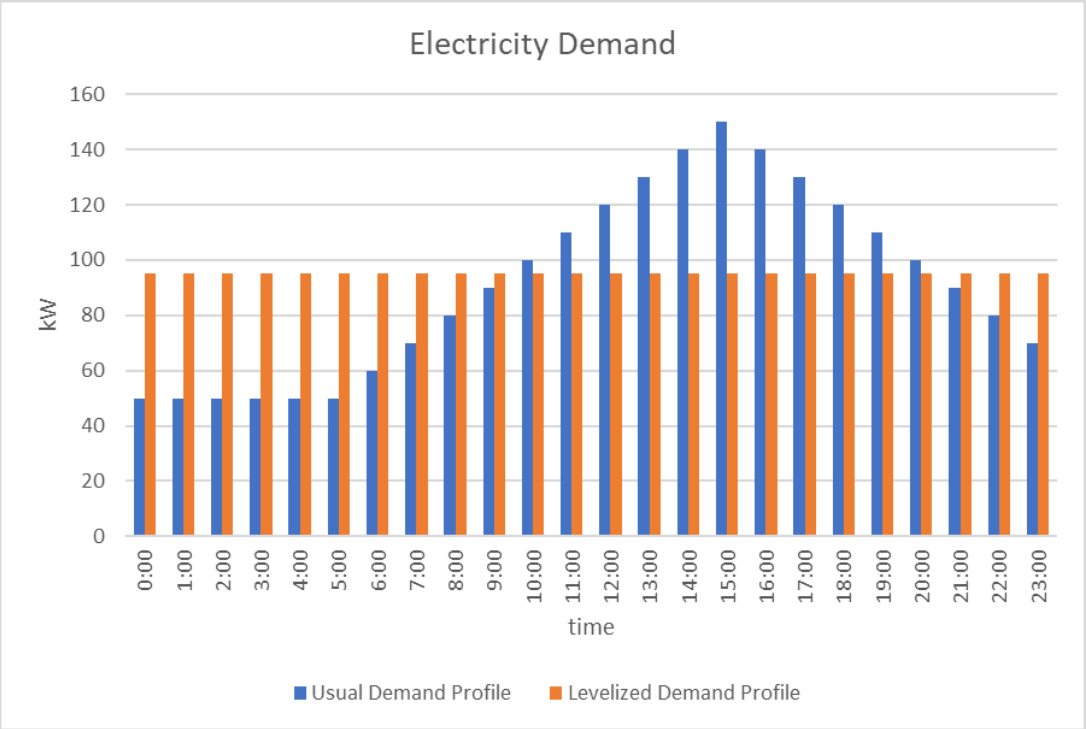


Figure 1 - Example Electricity Demand for a Typical Demand Profile compared with a Levelized Demand Profile

In Figure 1, you will see an example electrical demand curve and an ideal demand curve that has been flattened.

Assume that this customer is on a non-time of day rate and the customer rate is $25/month, the electricity energy rate is $0.11/kWh, and the demand cost is $8.50/kW for the peak usage that month. Assuming that every day's usage for a 30-day month is identical to the graph above, the monthly cost would be as follows:

Usual Demand Profile

The monthly demand in this example is 150 kW and the daily usage is 2,190 kWh.

Customer charge + energy charge + demand charge = monthly charge

$$\$25 + 2190\ \frac{kWh}{day} * \frac{\$0.11}{kWh} * 30\ \frac{days}{month} + 150kW * \frac{\$8.50}{kW} =$$

$$\$25 + \$7{,}227 + \$1{,}275 = \frac{\$8{,}527}{month}$$

Levelized Demand Profile

The monthly demand in this example is 95 kW and the daily usage is 2,280 kWh.

Customer charge + energy charge + demand charge = monthly charge

$$\$25 + 2280\,\frac{kWh}{day} * \frac{\$0.11}{kWh} * 30\,\frac{days}{month} + 95kW * \frac{\$8.50}{kW} =$$

$$\$25 + \$7{,}524 + \$808 = \frac{\$8{,}357}{month}$$

Even though the total usage in the levelized demand profile is higher than the usual demand profile (2280 kWh vs. 2190 kWh), the demand penalty in the usual demand profile highly outweighs the extra energy usage.

A time-of-day utility rate would be even more sensitive to shifting energy usage or leveling the load. As an example, assume that the summer, time-of-day tariff is as follows, where summer peak hours are from noon to 9 p.m.:

Customer charge - $50/month

Off-peak demand charge: $5/kW
On-peak demand charge: $10/kW

Off-peak energy usage charge: $0.08/kWh
On-peak energy usage charge: $0.010/kWh

Assuming that every day's usage in this fictional summer month is identical to the graph above, the monthly cost would be as follows:

Usual Demand Profile

The monthly demand and usage are as follows:
Off-peak demand: 110 kW
On-peak demand: 150 kW
Off-peak daily usage: 945 kWh
On-peak daily usage: 1,245 kWh

Customer charge + off-peak energy charge + off-peak demand charge + on-peak energy charge + on-peak demand charge = monthly charge

$$\$50 + 945\,\frac{kWh}{day} * \frac{\$0.08}{kWh} * 30\,\frac{days}{month} + 110kW * \frac{\$5}{kW} +$$

$$1245\frac{kWh}{day} * \frac{\$0.10}{kWh} * 30\frac{days}{month} + 150kW * \frac{\$10}{kW} =$$

$$\$50 + \$2{,}268 + \$550 + \$3{,}735 + \$1{,}500 =$$

$$= \frac{\$8{,}103}{\textbf{month}}$$

Levelized Demand Profile

The monthly demand and usage are as follows:
Off-peak demand: 95 kW
On-peak demand: 95 kW
Off-peak daily usage: 1,425 kWh
On-peak daily usage: 855 kWh

Customer charge + off-peak energy charge + off-peak demand charge + on-peak energy charge + on-peak demand charge = monthly charge

$$\$50 + 1425\,\frac{kWh}{day} * \frac{\$0.08}{kWh} * 30\,\frac{days}{month} + 95kW * \frac{\$5}{kW} +$$

$$855\,\frac{kWh}{day} * \frac{\$0.10}{kWh} * 30\frac{days}{month} + 95kW * \frac{\$10}{kW} =$$

$$\$50 + \$3{,}420 + \$475 + \$2{,}565 + \$950 =$$

$$= \frac{\$7{,}460}{\textbf{month}}$$

Sharing Fixed Costs

There are certain fixed costs associated with cooling equipment. For example, if one facility has two 250-ton chillers and another facility has two 500-ton chillers, both facilities will need to bring a service technician in to maintain the equipment. Some maintenance and repair costs are dependent on the size of the equipment, but some are dependent upon the number of chillers, pumps, etc.

According to *HVAC Preventative Maintenance Budget Calculator – KENRON*, the quantity of devices is the main driver in the preventative maintenance cost (2023).

If the two facilities in the example above were to share a chilled water plant, two, 750-ton chillers may be adequate. Instead of maintaining four chillers and associated equipment in two plants, only two chillers need to be maintained. Fixed costs associated with the number of pieces of equipment will be reduced. Fixed costs including trip fee, review of trends, oil sampling, etc. will be shared between the two facilities. Even though there would be costs such as oil changes that are more dependent upon the size of the chiller, there are economies of scale at work that will provide savings to each customer.

Economy of Scale

Smaller chillers are often limited to air-cooled chillers, which are less efficient than water-cooled chillers. Additionally, larger water-cooled chillers tend to be more efficient than smaller water-cooled chillers.

According to the 2020 Florida Building Code, Energy Conservation, 7th Edition, the smaller chillers are allowed to have a higher kW/ton than larger chillers. Also, the air-cooled chillers have a higher kW/ton than the water-cooled chillers since the air-cooled chillers have condenser fans that the water-cooled chillers do not. Even with the energy consumption of the cooling towers associated with the water-cooled chillers, water-cooled chillers are typically more cost effective to operate than air-cooled chillers. The major exception to this rule is where water is extremely expensive. See the table below summarizing a sampling of the requirements found in the code.

Chiller Type	Chiller Size	Maximum kW/ton allowed*
Air-cooled	Less than 150 tons	1.188 FL / 0.876 IPLV
Air-cooled	Greater than or equal to 150 tons	1.188 FL / 0.857 IPLV
Water-cooled, centrifugal	Less than 300 tons	0.610 FL / 0.550 IPLV
Water-cooled, centrifugal	300 tons to less than 400 tons	0.560 FL / 0.520 IPLV
Water-cooled, centrifugal	400 tons or more	0.560 FL / 0.500 IPLV

*Full-load path A shown for comparison; Path B shows similar trend.

In the example above with one facility having two, 250-ton water-cooled chillers and another having two, 500-ton water-cooled chillers, below is a gross comparison of the chiller electrical costs between stand-alone plants and a district cooling plant serving both facilities. If each facility has 4,000 full load hours of operation, uses a code-minimum efficiency chiller as of 2020 in Florida, and a blended electrical rate of $0.11/kWh, the cost is as follows:

Scenario 1: Two independent plants

$$Facility\ 1:\ 2\ chillers\ x\frac{250\ tons}{chiller}\ x\ 0.61\ \frac{kw}{ton}\ x\ 4{,}000\ \frac{hours}{year}\ x\frac{\$0.11}{kWh}=\$134{,}200$$

$$Facility\ 2:\ 2\ chillers\ x\frac{500\ tons}{chiller}\ x\ 0.56\ \frac{kw}{ton}\ x\ 4{,}000\frac{hours}{year}\ x\frac{\$0.11}{kWh}=\$246{,}400$$

$\$134{,}200+\$246{,}400=$ **$380,600** total for both plants

Scenario 2: District cooling plant serving both facilities

$$2\ chillers\ x\ 750\frac{tons}{chiller}\ x\ 0.56\ \frac{kw}{ton}\ x\ 4{,}000\frac{hours}{year}\ x\frac{\$0.11}{kWh}=\$369{,}600$$

This provides an overall savings of $11,000 per year. But when the chiller energy cost is distributed between the two facilities, the first facility will pay $123,200 and the second will pay $246,400.

$$Facility\ 1:\ 500\ tons\ x\ 0.56\ \frac{kw}{ton}\ x\ 4{,}000\frac{hours}{year}\ x\frac{\$0.11}{kWh}=\$123{,}200$$

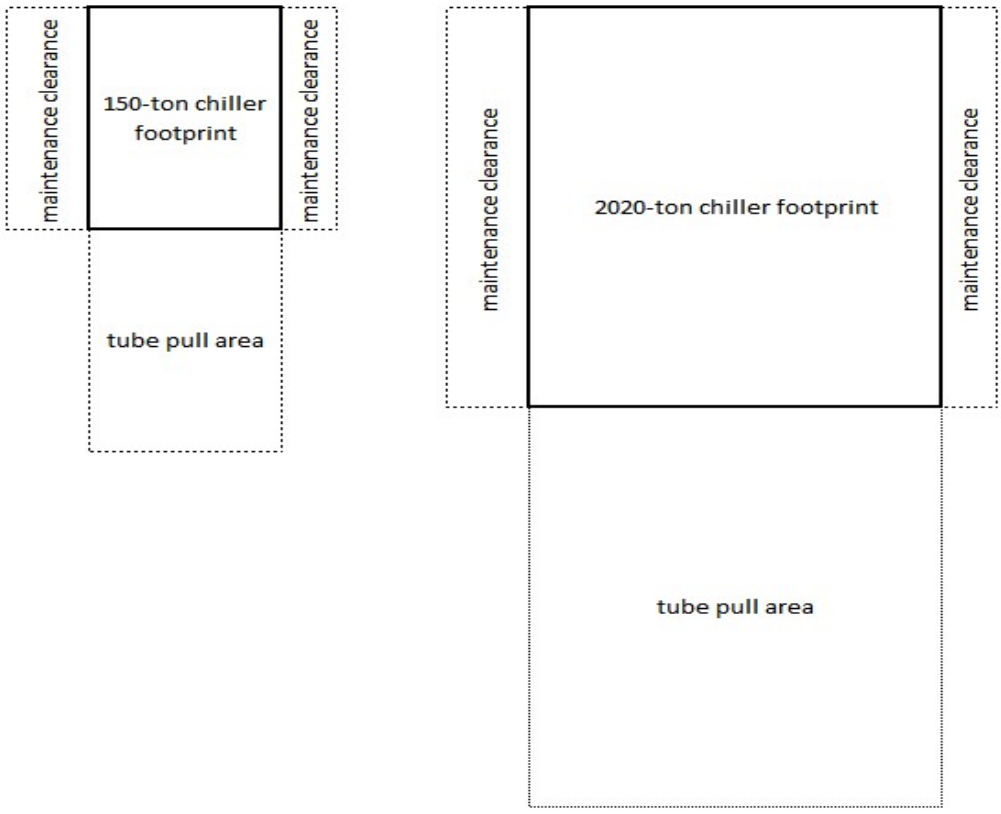
$$Facility\ 2:\ 1{,}000\ tons\ x\ 0.56\ \frac{kw}{ton}\ x\ 4{,}000\frac{hours}{year}\ x\frac{\$0.11}{kWh}=\$246{,}400$$

In this example, only the first facility will benefit from the economy of scale provided by the chiller efficiency gains in the district cooling plant. The first facility is relatively small and has lower efficiency chillers, but the second is close in size to the district cooling plant and therefore has the same efficiency chillers that the district cooling plant would have. In this case, other efficiencies are required to make a district cooling plant a win-win scenario for the larger facility.

Footprint

Land and interior real estate have a cost. Some land and some interior real estate are substantially more valuable than others. For example, land along the coast is much more valuable than land across the street or even a few blocks away from the coast. The best use of land along the coast is to provide occupied spaces with vistas of the water, not a chiller plant. So, if a water-side condominium can purchase chilled water from a district cooling plant that is located a block or two from the coast, the space that would have been required for the chiller plant on the condominium's property can be used for living space instead. Additionally, with the chiller plant farther from the coast, it may not need to be raised as much to be protected from potential storm surge. Chillers are very heavy, so the lower the chiller machine room can be built, the more economical the construction.

Another benefit of district cooling is that the footprint of the chiller plant is highly dependent upon the number of pieces of equipment. Larger tonnage chillers do require a larger footprint, but the footprint is not directly proportional. See Figure 2.



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Figure 2 – Chiller Footprint Comparison

It would take more than thirteen, 150-ton chillers to equal the capacity of one 2020-ton chiller, but the required footprint of a 2020-ton chiller would only occupy the footprint required for about three, 150-ton chillers. The sizes in the sketch are based on a York Model YZ Magnetic Bearing Centrifugal Chiller, but the trend holds true for many manufacturers. (*161.01-EG1-EN-Engineering-Guide-YZ-Centrifugal-Chiller.pdf*, n.d.)

Contract

To make a district cooling system viable, a contract is required that locks customers into purchasing chilled water for a long period of time (many years or decades). This provides stability of usage to the plant owner and the lowest rate for the customers, but it limits options for the customers if they later decide that they want to operate their own plant and become the master of their own destiny. The buy-out clause in the contract for early termination must be fair to both the customer requesting the termination and for the district plant owner (and therefore the other customers served by the district plant), since the economics change when the diversity of the customers changes.

Diversity

There are two types of diversity that can be beneficial for district cooling plants. The first is diversity of operating hours and the other is diversity of solar loads.

Diversity of operating hours is discussed in more detail in the section below, but this refers to buildings that have peak loads during different hours of the day and/or different days of the week. For example, night clubs have peak loads on weekend nights, and office buildings will peak on weekday afternoons.

The other type of diversity that can be beneficial for a district cooling plant is diversity in solar loads. One building may have many east-facing windows, where the peak may occur in the morning. Another building may have mostly west-facing windows, where the peak load will occur in the afternoon.

By combining buildings with different solar loads and operating hours, the peak demand for the entire district cooling system will be more constant (to flatten the curve).

What combination of cooling loads are preferable?

As a naïve summer intern in a manufacturing plant during college, I asked my supervisors why the plant operated 24 hours a day, seven days per week. Night/weekend work can take a toll on the human body. They explained that the amount of money invested in the manufacturing equipment gave the best return on investment if the equipment was used as much as possible. Similarly, the more that chillers can operate and be more fully loaded the more economical the system becomes.

As noted in the last section, leveling electrical usage has a cost benefit also. The most economic loading is to have all the chillers run nearly full out 24 hours a day, seven days per week, 365 days per year. This is, of course, not possible. Chillers and associated

equipment can fail and do require periodic scheduled maintenance. In addition, cooling loads are not 100% consistent throughout the day, even if thermal storage is employed. There will also be variations in weather and facility usage.

Even still, it is preferable to attempt to flatten loads as much as possible. A goal should be to obtain customers with complementary loads. For example, if one customer is a school with large weekday loads during school hours, a good choice for a second complimentary customer load is a church with large loads on Sundays and weekday evenings. A third customer with a complimentary load could be a lunch/dinner restaurant with the largest loads at night and on weekends. The church and restaurant may have small loads in comparison to the school, so the impact of adding only one restaurant and church may have negligible impact on flattening the load. In this case, it would be important to add multiple complementary loads, such as multiple churches and restaurants. See figure 3 below.

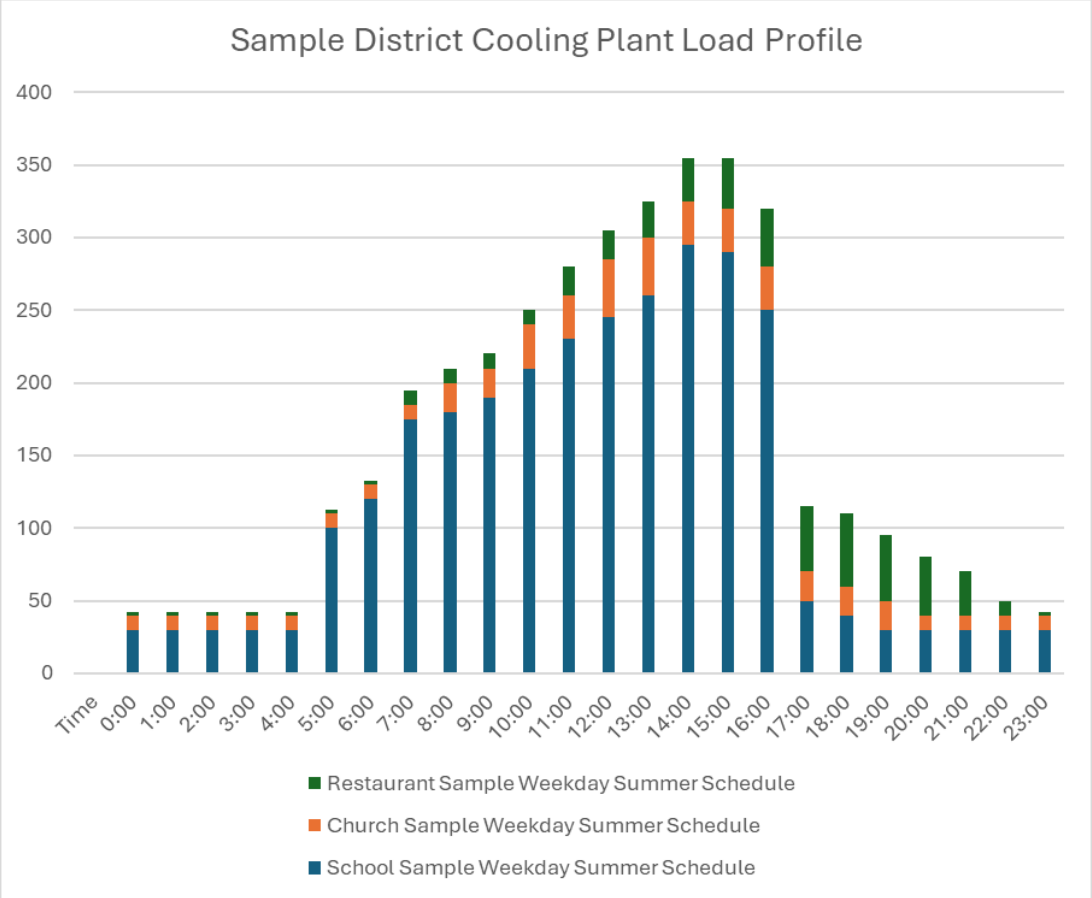


Figure 3 – Sample Weekday Summer Schedule for a District Cooling Plant

In Figure 3, this combination of customers has room for improvement. Customers with larger night loads would help improve the efficiency of the district cooling plant. Due diligence prior to construction should include an estimated load profile for all 8,760 hours per year, not just a 24-hour snapshot shown above.

What design considerations should be made regarding chillers, pumping arrangement and thermal storage?

Chillers

Regarding chiller selections, there are many factors to consider including redundancy, efficiency, loading (part-load and full-load), starter type, and chiller type.

The level of chiller redundancy required is highly dependent upon the customer base and the level of redundancy available for all components. Customers that require no interruption in cooling such as a data center may utilize chilled water from a district plant as a primary source of cooling with a secondary on-site chiller plant as a secondary source of cooling backed up by emergency generation in case of a power outage. In this case, the district cooling plant does not require a high level of availability since a sensitive customer has on-site back-up. Schools and churches, while they may appreciate a high level of cooling availability, may prefer a lower cost to higher availability. If a site does not have on-site backup, but requires a high level of cooling availability, the district cooling plant must have redundancy in all points of possible failure – chillers, pumps, cooling towers, valves, piping, electrical feeds, emergency power, controls, etc.

Popular redundancy for chillers is to have one additional chiller beyond what is required for full load (equal to the size of the largest chiller). This is also referred to as N+1 redundancy. A more expensive option is to have full redundancy. Thermal storage can also be used in lieu of providing additional chillers (Garcia, 2024). Thermal storage is discussed in more detail later in this section.

To provide pumping redundancy, pumps are headered together to allow any pumps to run through any chillers. And like chiller redundancy, more pumps are provided than are required for full load. The same thing is true for cooling towers in a water-cooled plant. Being able to use any combination of chillers and cooling towers provides added reliability.

Valving, while may seem like a minor detail, is critical in planning for redundancy. How can you reroute flow if a piece of equipment needs to be replaced or repaired? The discussion of valving is tied into the discussion of piping. If you only have one major header leaving the plant, what happens if the pipe starts to leak? Will the whole plant be down for weeks while the pipe is repaired? If the piping network is a loop and multiple valves are installed throughout the loop, most of the buildings can still operate while the repair is made. Leaking pipes are not only a concern for older systems. Pressure control systems and pressure relief systems can fail causing catastrophic failure in piping connections.

Large district cooling plants with customers needing high levels of availability should be fed from two different electrical feeds and two different transformers. In addition, emergency on-site power should be available or, if a minor delay is tolerable, an electrical quick-connect that could accommodate a rental generator may be an option. If this option is selected, an agreement should be set up ahead of time with a generator rental company to provide temporary power within a given number of hours of notification.

Control failures are common. Sensors can become uncalibrated or error prone. Controllers can have lightning damage. Fail-safe conditions are important. Which way do you want valves to fail? Fail close, fail open or fail last? What backup control strategy can you put in place in case the inputs or outputs from the primary strategy fail?

Chiller efficiency is highly dependent upon chiller type and starter type. Water-cooled chillers tend to be more efficient than air-cooled chillers from an electric standpoint, but water costs will play into the equation with water-cooled chillers. In many locations, water costs associated with a cooling tower do not exceed the additional electrical costs associated with air-cooled chillers, but there are exceptions.

Centrifugal chillers tend to have a better efficiency than screw chillers, but screw chillers traditionally handle modulation at lower temperatures better. Screw chillers have been a solid choice for ice storage applications since they modulate to the load well. Newer controls allow centrifugal chillers to generate ice without the elevated risk of freezing the chiller. Robert Garcia, who is a part owner in a district cooling plant in Florida, says that for ice storage, there is very little modulation; the chiller runs full out until the ice storage tanks are fully charged. He believes that because of its higher efficiency a centrifugal chiller is the best choice (2024).

Wye-delta starters allow chillers to have the best full-load efficiency. Variable frequency drives have a slightly worse full-load efficiency than chillers with a wye delta starter, but at part-load with condenser water relief, the efficiency is significantly improved. Please note the caveat of "with condenser water relief." In hot, humid climates, the standard IPLV does not adequately describe the performance of the chiller. An NPLV is a better way to compare chillers in each location.

"IPLV stands for integrated part load value and NPLV stands for non-standard part load efficiency. IPLV or NPLV is used to evaluate efficiency of chiller at different loading condition. The calculation formulae of IPLV and NPLV is same. The only difference between IPLV and NPLV is that IPLV is calculated as per condition specified in AHRI_Standard_550-590. While in NPLV is calculated as per site condition." (Admin, 2018)

Pumping Arrangement

Typically, high efficiency is key to a successful district cooling plant. Therefore, variable volume flow will typically be involved with the pumping arrangement. Primary/secondary/tertiary pumping systems are common, but variable primary systems with dedicated pumps at larger buildings are also prevalent.

A primary/secondary/tertiary pumping system consists of primary constant flow pumps circulating water only through the chillers, labeled "PCHWP" in the figure below. The secondary pumps send the water in a loop to each building, labeled "SCHWP" in the diagram below. Smaller buildings on smaller systems may use the water from this loop directly to feed the air handling units. Larger buildings or systems with heat exchangers at each building will utilize tertiary pumps to flow water through the building to each air handling unit. The tertiary pumps are labeled "TCHWP" in Figure 4.

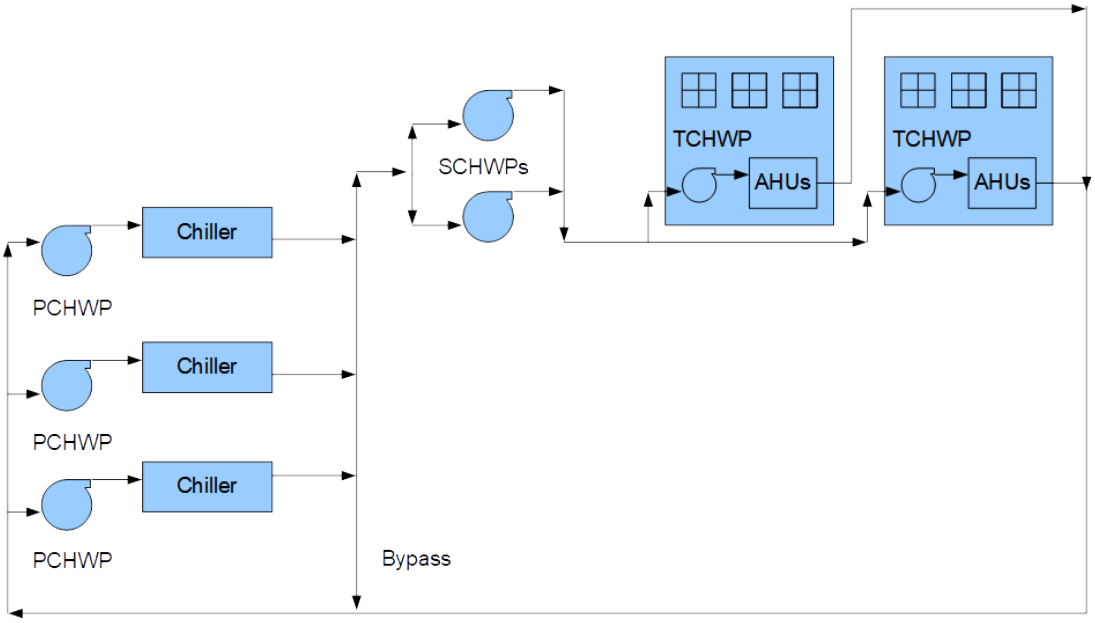


Figure 4 – Sample Primary/Secondary/Tertiary Pumping Piping Arrangement

Variable primary systems do not decouple the flow through the chillers from the water flowing to each building. The control sequence for this arrangement is more critical than the primary/secondary system. Precise control is required to prevent chiller damage due to low flow through an on-line chiller. In this scenario, the number of chillers running closely matches the load. The water flowing through the chillers meets the requirements of the load, not necessarily the design flow of the chiller. In a variable primary system, distribution pumps (referred to as tertiary pumps in the primary/secondary/tertiary system), may be used on the building side of heat exchangers to transport water throughout the building.

According to Garcia, he has found in his experience that ΔT of the plant is strongly correlated with the profit of the plant. He uses the following rule of thumb.

Chilled Water ΔT	Profit
8 degrees	Break-even
10 degrees	Fair profit
12-13 degrees	Good profit
14-15 degrees	Great profit, but is hard to obtain

The coils in the air handling units must be designed for a high ΔT up front. Additionally, customers must be trained on how to keep the ΔT as high as possible, at least during peak periods (2024).

Thermal Storage

"Thermal energy storage means heating or cooling a medium to use the energy when needed later," (*Thermal Energy Storage*, 2020).

In district cooling plants, thermal storage can be implemented in the form of either chilled water storage or ice storage to save cooling for peak periods. Chilled water storage requires very large tanks and careful flow control to minimize disturbance to the stratification in the tank. Stratification of the tank (cooler water at the bottom and warmer water at the top of the tank) is highly desired in chilled water storage. Supply water is pulled from the bottom of the tank where the water is coldest and returned to the top of the tank where the water is warmest. Once the warm water from the top of the tank descends to the bottom of the tank, the storage tank is "empty" of cooling capacity and must be recharged.

If the warmer water is sent back into the tank in a manner that stirs the water in the tank, the cooling capacity of the tank is diminished, therefore it is critical to maintain proper flows in the correct locations to maintain stratification. If stratification is not maintained and the water becomes a homogenous mixture, the capacity of the tank is essentially reduced. For example, at the end of a charging cycle, all water in a storage tank is stored at 40 degrees F. If there is proper stratification, the supply water will continue to be 40 degrees F until all cooling capacity is exhausted. If the return water mixes, the supply water temperature will continually increase until it reaches the return water temperature. The air handling units' ability to dehumidify will be impaired as the supply water temperature increases. Ice storage, on the other hand, requires much smaller tanks and stratification is not a concern, but ice is less efficient to produce than chilled water.

Thermal storage can provide multiple possible benefits to a district cooling plant. Below is a list of some of these benefits.

1) Smaller electrical demand – The electrical demand could be smaller if the electrical load is levelized across the day. On-going electricity cost savings can be substantial. Smaller wiring, breakers, transformers, etc. can reduce the first cost if the equipment is sized accordingly during the design phase.
2) Smaller chiller capacity – The total capacity of the chillers can be reduced if the load is levelized. These first-cost savings can help offset some of the construction costs required by the thermal storage system.
3) Better load matching – When thermal energy is utilized, the on-line chillers can be loaded to run at peak efficiency. The rest of the load can be satisfied using stored thermal energy. In the case of a system with constant flow primary pumps, no pumping energy is wasted since the chillers can run at full load.
4) Reliability and reduced emergency power requirements – In the case of critical loads, reliability may be more important than cost reduction. During a power outage, for example, utilization of thermal energy storage would minimize the amount of power required; smaller generators are required to circulate water through a thermal storage system than the power needed to run chillers and their associated pumps. If the stored energy is depleted before the peak energy hours end, the monthly utility cost would be higher than normal, but sometimes reliability of a system may save much more money than the extra demand charges.

Below is a list of some of the downsides of thermal storage.

1) Real estate is required to install the tanks.
2) Tanks can fail.
3) Glycol may be required.
    (a) Depending on the glycol type, there may be environmental concerns if there is ever a spill.
    (b) Glycol reduces efficiency.

Who has rights to underground easements for installing piping under streets?

On single-owner properties, such as a university, this issue is relatively simple. But when city streets are involved, which is most common for large district cooling plants, this can be tricky. In some areas, a franchise agreement is required. Chilled water is not subject to sales tax in many locations (other utilities are taxed as a monopoly); for municipalities to garner income from the sale of chilled water, they require a franchise fee to be paid for any chilled water sold (Garcia, 2024).

Who should own the asset?

There is justification for an asset to be owned by a multitude of types of entities or a combination of entities. There are pros and cons associated with each option.

Below is list of potential owners for the district cooling plant and some pros and cons to consider:

The Largest User

<u>Pros</u>

1. The largest user already must build a large plant, so the incremental upsizing benefits from the economy of scale.
2. The largest user will have control over the plant – when to replace equipment, expand, add reliability, sell, etc.
3. The largest user will likely require maintenance staff on site regardless of whether a plant is solely used by the largest user or not.

<u>Cons</u>

1. The largest user's primary business is not likely chilled water production, so it can distract the company from its core function.
2. The initial cost will be higher. Will the borrowing capacity be exceeded?
3. There are tax implications. Depreciation of an asset affects taxes differently than operating expenses. Consult an accountant to see what is best in each specific case.

The Owner of the Land Where the Plant is Located

Pros

1. While this may be the same as one of the other owner types, it does not have to be. The land could be sold from one of the users to an independent entity. The land, building, and equipment would be owned by the same entity or entities, which would provide control to the owner of the district cooling plant.

Cons

1. The initial cost will be higher. Will the borrowing capacity be exceeded?
2. There are tax implications. Depreciation of an asset affects taxes differently than operating expenses. Consult an accountant to see what is best in each specific case.

A Municipality

Pros

1. A local municipality may have fewer issues running piping under municipal streets.
2. The municipality typically does not pay property taxes. These savings can be passed on to the customers.
3. A municipality would be a stable owner. It will not go out of business.

Cons

1. The municipality typically does not pay property taxes, so this may mean lower tax revenue for the municipality, but it will increase the chilled water cost that will be shared by all customers.
2. Bonding for this type of asset may be difficult.
3. Typically, municipalities prefer to not take on more responsibility than what is required. Making chilled water is not their primary function.

An Investment Company

Pros

1. Investment companies' primary focus is to make money from investing capital.
2. Lower upfront costs are required for the users.

Cons

1. The investment company is not inherently technically savvy. While they can hire expertise, as can any of the potential owners, their focus is to make money. They may or may not make decisions that coincide with the best interests of the users.

A Design/Build Firm

Pros

1. A design/build firm is inherently technically savvy. They will design and build the plant to provide a highly efficient and maintainable system. They know how the plant was designed to be controlled, so they will know if the operator is running the plant as designed.

Cons

1. The assets can be sold to other entities, potentially to a non-technical company.

A Utility Company

Pros

1. A local utility company already has billing mechanisms in place.
2. Utilities are already in the business of providing energy, water, or sewer.

Cons

1. Many utilities are regulated. An unregulated company may need to be formed to provide this service.

An HVAC Company

Pros

1. An HVAC company can provide service and maintenance in-house.
2. Maintaining and servicing HVAC equipment is their primary business focus.

Cons

1. Does the HVAC company have the credit limit needed for the plant?

Someone Else

Things to Consider

. What is this entity's primary business?
. Is this entity technically savvy?
. What is their relationship with those who will maintain the plant?
. Are there any tax benefits associated with this entity owning the plant?
. Are they looking for a win-win scenario?
. Do they own the land?
. Do they have the necessary capital? Can they get it?

Who should maintain the asset?

This question can be broken down into multiple questions:

1) Who should check the plant daily to make sure that everything is running smoothly?
2) Who should check to see if the plant is operating efficiently?
3) Who should provide service to the equipment and controls?

Who should check the plant daily to make sure that everything is running smoothly? There are multiple good options. The on-site operator, if there is one, is the most natural answer. If there is no on-site operator, the service provider that provides equipment and/or controls service is the next best option. On-site operators are typically hired when the plant is very large and/or the customers have critical loads that do not allow for long outages. While modern control systems can text or email personnel, having an on-site presence can mitigate issues faster and reduce costs from damage.

While the same person or entity from the first question could check plant efficiency, it is not recommended. The reason is that sometimes operational stability and efficiency are opposing goals. The on-site operator or service provider wants to limit outages. Keeping a controls strategy simple (i.e. just turning everything on) will reduce outages and issues

that need to be addressed, but energy is wasted. So, a technically savvy person such as an engineer is a great option for this task. A technical owner is the best option. They are in the best position to balance efficiency and reliability.

Who should provide service to the equipment and controls? Some companies have equipment and controls service all under one roof. If the equipment and controls used in the plant were installed by a single company, this may be the best option, especially while the equipment is under warranty. If two different vendors provided the chillers and the controls, then the owner could contract with two different companies. If the owner is less technical and there is no on-site operator, hiring a mechanical service provider who will perform regular maintenance in-house and engage the equipment vendors as needed should be considered.

There is a benefit for the company that maintains the asset to be the one that owns it and sends out the bills; problems can be identified more quickly (Garcia, 2024). When there is financial incentive, problems can be addressed with more urgency. Another option is to tie the performance of the plant into the contract with the maintenance team. Providing them with an incentive to maintain an efficient plant may help the owner's bottom line. Setting up that type of incentive plan may be tricky.

What is the recommended fee structure for customers, if applicable?

The first thing to do is to categorize the various costs associated with the district cooling plant into three categories: fixed costs, costs that depend on the peak load, and costs that are affected by usage. For example, electric companies typically set up a similar tariff. There is a customer charge. Every customer on the given rate is charged the same amount per account. Then there is a demand charge. This is a cost applied to the highest usage during any 15-minute period during the billing cycle (typically billed as $/kW). Then there is a usage charge (typically billed as $/kWh). These charges fit perfectly into our table. Some charges may be difficult to organize such as an on-site operator. One could argue that his pay is a fixed cost. One could also say that his pay should be distributed amongst the customers based on their demand. So that a small customer does not pay a very large, fixed cost, the table below puts the on-site operator in the demand column. Items with an "*" could be moved into another column.

Below is a sample listing of costs. Each plant will have nuance expenses that should be included.

Fixed Costs	Demand Costs	Usage Costs
Electric Customer Charge	Electric Demand Charge	Electric Usage Charge
Water Customer Charge	On-Site Operator Salary	Water Usage Charge
Sewer Customer Charge	Property Taxes*	Sewer Usage Charge
Administrative Costs	Equipment maintenance	Franchise Fee
	Insurance*	
	Controls maintenance*	
	Equipment replacement fund	

Once the costs are distributed to the appropriate categories, a rate can be determined. The fixed cost will be billed in units of $/customer. The demand can be billed in $/maximum tonnage. The usage cost could be billed in $/ton-hr used or $/(gpm*ΔT) where ΔT is either measured or stipulated. The former option is potentially best for the customer. They are only charged for their actual usage. If the customer is using chilled water at a low temperature differential, the entire system will be less efficient, and everyone will be paying for the one customer's lack of efficient use of chilled water. If on the other hand, the chilled water rate is based on a given temperature differential, it is in the customer's best interest to maximize the chilled water temperature differential thereby increasing the efficiency of the system.

Optionally, the $/(gpm*ΔT) could be modified during off-peak times so that the ΔT could be lower at night.

Another option is to just have a $/(ton*hr) charge for large users. After a few months of data, a single charge can be identified (Garcia, 2024).

Test the rate with anticipated customer information to see if the rate structure is a win-win for each customer in comparison with each customer having their own system. If the rate for the smaller customers is not attractive, either consider not including them as a customer or shift more costs from the fixed costs column to the demand costs column. If the rate for the larger customers is not attractive, move some costs from the demand costs column to the fixed cost column.

In all cases, provide guidance to the design team of the customer's air handling units. Ensure that they are aware of the critical nature to select the chilled water coils with a high differential temperature (8 row coils tend to have a good balance between cleanability and chilled water temperature differential). The control sequence must also be designed to maximize chilled water temperature differential. Then, provide training to the customers explaining how to maintain a high chilled water temperature differential. For customers with existing air handling units and/or heat exchangers, consider replacing coils and/or modifying control sequences to ensure that the plant will operate efficiently. It is in the best interest of everyone involved.

Who should maintain the end devices such as air handling units?

Typically, the owner of the building will own the air handling units and any heat exchangers located in the building.

Another less-intuitive option is for the owner of the chilled water plant to own or at least maintain the air handling units and heat exchangers located in the customer's building. Below is a table outlining the pros and cons of each option.

Owner of End Devices	Pros	Cons
Building Owner	• No coordination is required with the plant owner for access. • The building owner can control the efficiency of the air handling units and/or heat exchangers by controlling how often they are cleaned.	• Potential finger-pointing if there is ambiguity about where cooling problems are coming from. • The building owner may not have in-house HVAC expertise and may need to subcontract maintenance anyway.
Owner of Chilled Water Plant	• Responsibility for all cooling equipment belongs to a single source.	• Coordination may be required to access the mechanical room if it is not accessible from an exterior door.

Summary

District cooling plants have the potential to be a win-win for chilled water plant owners and the customers that they serve by taking advantage of economy of scale.

A successful district cooling plant will have the following characteristics:

1) An efficient plant design
2) Efficient air handling unit selections for each customer's building
3) A chilled water rate for each customer that provides a lower cost (over the term of the contract) than if they installed the equipment themselves. Remember to include real estate costs into the comparison. There are occasions when the cost may be higher over the term of the contract, but there is some other benefit to the customer.
4) Appropriate redundancy for the needs of the customers
5) Training for the customers

They can be set up in many ways and there are pros and cons associated with each option. Depending upon the strengths of each owner and the needs of the customers, a custom configuration can be implemented that creates a win-win scenario where everyone involved can realize savings and/or profit.

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District Cooling Plants - Quiz

Updated: 11/14/2024

1. District cooling can
   a. serve multiple buildings owned by a single owner.
   b. serve multiple buildings owned by multiple owners.
   c. be billed similarly to electricity.
   d. none of the above
   e. a, b and c

2. What are some benefits of district cooling plants?
   a. improved efficiency
   b. minimized equipment footprint
   c. reduced demand charges
   d. none of the above
   e. a, b and c

3. True or False? One larger chiller typically takes up less real estate than multiple chillers with the same total tonnage.
   a. True
   b. False

4. True or False? Valving is a critical detail in planning for redundancy.
   a. True
   b. False

5. What combination of cooling loads are preferable?
   a. similar load profiles
   b. complementary load profiles
   c. only large loads
   d. only small loads

6. True or False? Uniform mixing during discharging in a chilled water storage tank provides the best results.
   a. True
   b. False

7. What is a potential con of a utility company owning a district cooling plant?
   a. utility companies don't have enough funds
   b. they will have bad publicity
   c. an unregulated company may need to be formed if the utility is regulated
   d. none of the above

8. What fee category should the electric usage ($/kwh) charge fall into?
   a. Fixed Costs
   b. Demand Costs
   c. Usage Costs

9. District cooling should benefit
   a. only the owner of the chilled water plant.
   b. only the customers.
   c. both the chilled water plant owner and the customers.
   d. none of the above

10. A successful district cooling plant will have which characteristics?
   a. an efficient plant design
   b. efficient air handling unit selections for each customer's building
   c. training for customers
   d. none of the above
   e. a, b and c