Guidelines

How to approach District Cooling

January 2014

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CONTENT

1 Introduction

District cooling has been a commercial alternative to traditional A/C and refrigeration technologies since the mid-90s. It started on a small scale in Sweden and France but spread after just a few years to all Western Europe, and must now be considered as a very strong competitor in most European countries.

A District Cooling system can be based on one, or most often several of the following technologies:

- Electricity-driven mechanical chillers
- Absorption or adsorption chillers driven by District Heating or waste heat
- Free cooling from air, water or geothermal energy

District cooling operators are very often backed up by strong financiers such as energy companies, municipalities or large industry conglomerates. Local AC&R contractors therefore experience difficulties in getting their voice and arguments heard when debating the pros and cons of local vs. centralised AC&R systems.

This guideline is produced in order to support local AC&R contractors in their work by presenting how DC planners and operators think, act and argue for their technology.

"District cooling is considered to be all forms of cooling in which the cooling production is centralised, and the product is offered to a broader market."
"The main idea of district cooling is to use local sources for cooling that would otherwise be wasted or not used, in order to offer the local market a competitive and highly efficient alternative to the traditional solutions."
Quotes from one major district cooling actor.

2 The history of District Cooling

District cooling has its roots in the early 1800s when plans were made to distribute clean, cold air to buildings through underground pipes. It is not known if these plans were actually carried out, and district cooling was not introduced on a practical level until the Colorado Automatic Refrigerator Company was established in Denver in 1889. Many of the earlier systems used ammonia and salt water to freeze meat and cool buildings used by the public such as restaurants, theatres etc. In the 1930s large cooling systems were built in the Rockefeller Centre in New York City and the United States Capitol buildings.

1960s. First commercial district cooling systems were installed in the USA in commercial areas near cities.

1967. Europe obtained its first district cooling system. Climadef began supplying district heating and cooling to the La Défense office complex in Paris.

1989. Scandinavia obtained its first district cooling system in Baerum outside Oslo.

1992. Västerås Energi & Production initiated the production of district cooling in Sweden.

1995. District cooling was successfully established in Stockholm. Only 5 years later this system was one of the largest, most environmentally compatible and energy-effective in the world. Sweden's district cooling potential, estimated in the 1990s on a national scale, had already been surpassed. The amount of energy per year doubled at the outset, and it currently appears that growth will continue at a rate of about 20% per year. Not many business fields can currently match this rate of growth. District cooling has been of the highest quality since it was introduced. This is due to it being able to draw upon more than 50 years of technical development related to the production of district heating and distribution in Sweden. In 2002, district cooling was supplied to about 500 customers, with an energy output of almost 500 GWh in Sweden alone.

2.1 District Cooling development in Europe

During last 15 years district cooling has developed in densely populated areas in Europe in service industries, public buildings and, in some cases, in the residential sector. District cooling networks are operated in several countries as illustrated below, and many new systems are under development or in the feasibility study phase. On-site block cooling is operated in all EU countries in order to meet the energy needs of large buildings, airports or industries.

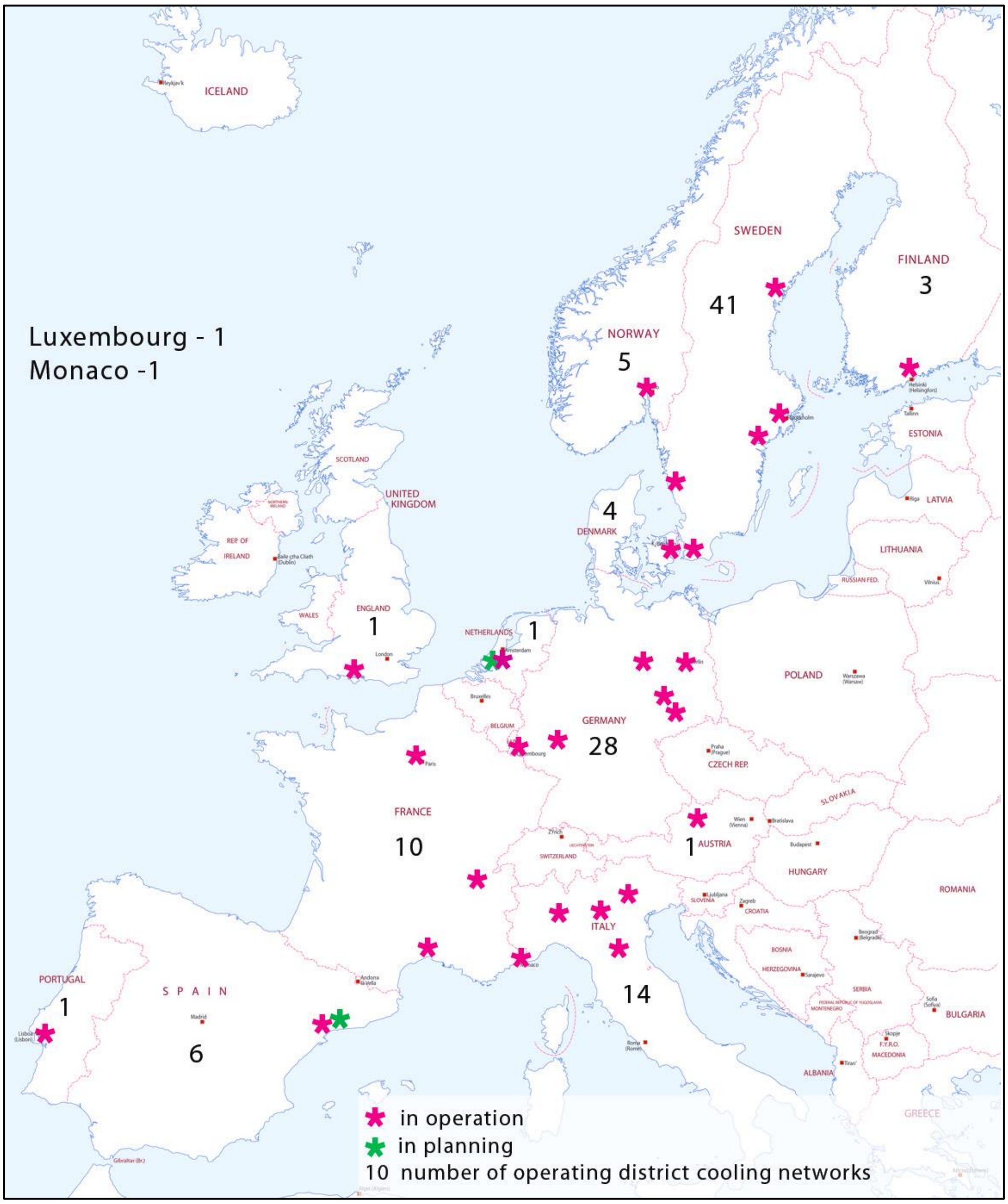

Figure: Indicative mapping of cooling networks and on-site cooling installations (5 biggest indicated per country). 2006 figures

The market share of district cooling is currently about 1-2%, or between 2 and 3 TWh cooling. The district cooling industry itself estimates that it could take a 25% share of the rapidly expanding cooling market, corresponding to between 500 and 700 TWh in 2012 according to the preliminary findings of the on-going Ecoheatcool study (www.euroheat.org/ecoheatcool/).

3 How does District Cooling work?

3.1 General

District cooling refers to cooling that is commercially supplied through a cold/heat carrier medium against payment on the basis of a contract. District cooling can be a network serving several customers; it can also refer to the local production and distribution of cooling to supply the needs of an institution - business centres, airports, hospitals, universities and public buildings. Experience demonstrates that this type of block cooling can be the starting point for a district-cooling network when new users are added.
Centrally-produced district cooling can reach an efficiency rate often 5 or even 10 times higher than that of traditional local electricity-driven equipment. This is achieved by a combination of free cooling and traditional cooling. It also offers great flexibility, tailored to users' needs, to combine cooling production with different possibilities such as:

- Deep sea or deep lake water "free cooling"
- Absorption chillers (in combination with surplus heat production from industrial sources, waste burning plants or cogeneration production plants)
- Heat pumps in combination with heat demand (i.e. district heating systems)

To increase efficiency and reliability, these cooling sources and production techniques are often combined with different kinds of storage solutions, such as:

- Seasonal storage where free cooling in winter is stored for use during the summer period
- Night-to-day storage facilities where overcapacity during the night is stored for use during daytime.

3.2 District Cooling systems

The centralisation of cooling production is a prerequisite for high efficiency insofar as it makes possible the use of "free cooling" or surplus heat sources, and thereby offers the benefits of large-scale energy production. A distribution network is therefore necessary to provide the cooling supply to customers.
There are two main schematics that are used in district cooling systems:

- "**Real**" district cooling systems, in which "cold" pipework is used to distribute the cold fluid from a central cooling station to the final user.

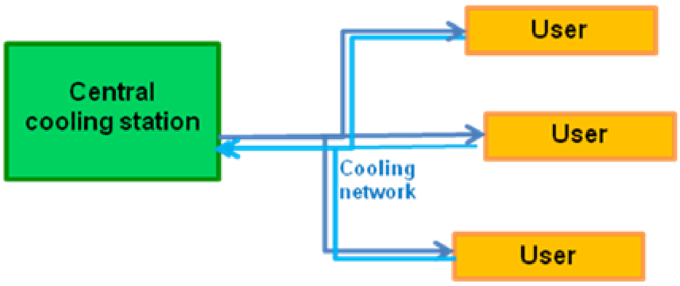

Figure: Real district cooling system

- "**Hot**" district cooling system, in which a district heating network is used to provide thermal power to local sorption chillers (i.e. absorption or adsorption units), which provide cooling power to the user.

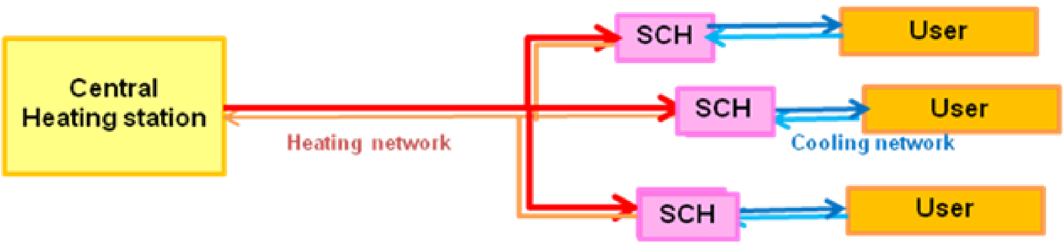

Figure: Hot district cooling system with sorption chillers (SCH)

In the “real” district cooling system a combination of free cooling (from underground water, lake or sea), compression chillers and sorption chillers can be used to produce cold water. Dedicated pipework is needed to transport the cold fluid (generally @ 6-7°C) from the central cooling station to the user. This pipework needs particular care in insulation to avoid condensation on the metallic surfaces, from which corrosion can occur. Insulation is also needed to minimise thermal losses. In most applications, the main cooling network is coupled with the end user by means of a heat exchanger normally referred to as a substation or energy transfer station (ETS).

It is necessary to take into account that in most situations buildings and HVAC equipment already exist. Therefore, when introducing DC systems, it is important to consider how to match these requirements in the future as the DC system must provide cooling power according to temperature, mass flow and nominal power. This can be done by lowering the supply temperature that enables the use of existing building-bound systems. An alternative is to upgrade or rebuild the end user system by increasing the heat exchanger surface or introducing additional high temperature equipment such as baffles. Despite additional investment, the upgrading alternative is normally the most common as it enables higher efficiency for the system with long-term energy savings.

Unlike DH networks, DC temperature differences between supply and return are much lower (6°-10°C compared to 20°-50°C). This means that in order to provide the same thermal power, for a DC network you need a much higher flow rate and consequently the diameter of the pipe must be larger and so the network cost will be significantly higher than for a DH network. Therefore DC systems are never used on small capacity installations or in an area of low cooling power density as the investment will be much too high.

3.3 Production of District Cooling

District cooling can be produced in different ways. The technology chosen depends on a range of parameters such as economic factors, local energy systems, the natural resources available and urban strategy.

3.3.1 Production

In the production plant, one or a combination of the following production and storage techniques are the most common.

Combining district heating/cooling
"Surplus cooling" can be used from heat pumps that are originally intended for production of district heat, operating on, for instance, seawater or waste water. By connecting the cold side of the heat pumps to a district-cooling system, the heat pumps can be used for simultaneous production of heat and cold.

Absorption chillers
Absorption chillers use heat as their primary energy and not electrical power as is the case for conventional compression chillers. The benefits of this technology compared to conventional chillers are that electrical power consumption is dramatically reduced and primary energy is used more efficiently. Surplus heat from, among others, municipal waste incineration, industrial processes and power production may be used for cooling production by the integration of an absorption chiller into the plant.

Cooling production can also be distributed in local areas or buildings using the district heating system as the distributor of the waste heat to the local absorption chiller. This can imply higher distribution temperatures in the district heating system during the summer. This consequence must be fully analysed before using this distribution solution.

As heat demand is seasonal and low during the summer, cooling production through an absorption chiller enables an increase in the efficiency of the plant by using excess heat that is available while displacing less environmentally friendly alternatives.

"Free cooling"
This refers to the extraction of available cold water. It can be compared to the use of geothermal energy in district heating systems. The cold water required to cool buildings can be found in oceans, lakes, rivers or aquifers.

Using heat exchangers the cold is transferred to the distribution network and delivered to the customers where it is used in the cooling infrastructure of the building. The maximum cooling temperature delivered to customers can be guaranteed with - if needed - additional cold from different sources.
Such a system can be developed when the water temperature is cold enough and when the plant is close to the buildings where the water is transported. The advantage of free cooling is that it offers cooling on a renewable basis.

Such schemes exist in Europe (Stockholm, Helsinki) and North America (Toronto).

Industrial chillers
Highly efficient industrial chillers can be added as part of the production mix to secure outgoing temperatures and redundancy, and/or for peak capacity.

3.3.2 Storage

To increase efficiency and reliability, these cooling sources and production techniques are often combined with different kinds of storage solutions, such as:

Seasonal storage
Often performed as an aquifer solution, where free cooling in winter is stored for use during the summer period.

Night to day storage
Often performed as ice or water storage solutions. Overcapacity during the night is stored for use during daytime.

3.3.3 Distribution

In a district cooling network, the chilled water is distributed to buildings where it loses its cold content, thus cooling down the building temperature; the warmed up water is then returned to the central production facility. The supply temperature is normally between 6°C and 7°C, but an ice mixture of 0°C is used in some cases. The typical temperature in the return pipe is 12°C -17°C. The supply of cooling to the user can also be done through a district heating system coupled to absorption chillers at the user's location.

3.3.4 Substation or Energy Transfer Station (ETS)

The customer interface or the "substation" is usually an indirect connection via a heat exchanger - the same technology as for district heating. The substation is not only the connection point and the contract boundary between the supplier and the customer but also a digital connection for measurement of the cooling delivery.

This information is also used for energy services to the customer such as energy declarations, alarms and benchmarking information.

4 Why choose District Cooling?

……according to the DC Industry

In this section we have collected most of the arguments used by the DC industry when promoting District Cooling technology. By understanding their arguments it is easier to prepare and present the local alternative for the client.
Therefore, please note that everything stated here represents the views of the District Energy establishment.

4.1 Benefits for society

The following five areas are normally seen as the main societal benefits by the District Energy business

- The environment
- Security of supply
- Infrastructure savings
- Economics
- Improved building value

4.1.1 The environment

CO_2 reduction

The reduction in CO_2 emissions by using district cooling comes from several sources, namely:

- Reduced electrical power consumption due to improved energy efficiency when producing cooling (high COP or SSEER). Depending on how the electricity is produced, a saving in CO_2 emissions of between 350 and 950 kg/kWh electric power can be achieved.
- Reduced need for cooling capacity due to centralised production synergies (a power factor between 0.7 and 0.9 is normal for large district cooling systems). A consequence of less demand is of course less cooling produced, which results in less electrical power needed, with savings as mentioned above.
- Centralised equipment needs less refrigerant. This, together with better possibilities to control leakage from the equipment, results in much lower emissions.

	DC alternative	Local alternative	Comments
Cooling energy supply GWh/year	100	100	
Seasonal system performance SSEER	18	3	DC alternative uses free cooling and waste heat
Electrical power consumption GWh/year	5.55	33.33	Energy supply / electrical power consumption
Necessary production capacity, MW	87 (52 MW Mech 35 MW ABS)	100	Centralised production synergies gives a power factor of 0.87 for DC
Free cooling from deep lake system, MW	15	-	
Emissions of CO_2 tons/year	5378	32,297	Calculation based on 969 g CO_2/kWh for electrical power production
Refrigerant charge in kg	17,160	33,000	Refrigerant charge per kW cooling capacity is set at 0.33 kg/kW for both alternatives
Estimated annual refrigerant leakage in kg/year	172(1)	2475(2)	1) Industrial O&M structure guarantees low leakages rates, here set at 1%/year. 2) Average European leakage rate is estimated at 7.5%/year

Figure: Example of performance figures for the alternatives DC vs. local production

Phase-out of refrigerants, HCFC & HFC

In line with the above, less refrigerant is needed for the same end-user demand for cooling comfort.

Centralisation into a few production units also enables the operator to choose more industrial designed equipment with a higher environmental profile, i.e. ammonia, carbon dioxide or at least centrifugal chillers with high COP and SSEER.

Improving the local environment

Larger plants located in more industrialised areas based on free cooling solutions combined with highly efficient chiller units result in:

- less cooling water for the cooling towers
- fewer water treatment chemicals
- smaller footprint for the dry coolers
- fewer units which create less noise

4.1.2 Security of supply

Avoid summer electricity peaks

For efficiency reasons DC always needs less electricity power at peak conditions. As a consequence normal summer peaks can be avoided. This is a problem mostly seen “south of the Alps”, i.e. in Greece, Italy, Spain (and France). In this area electricity grids are stretched to their limits during summer time. By using DC this problem is significantly reduced.

An example is given in the figure below.

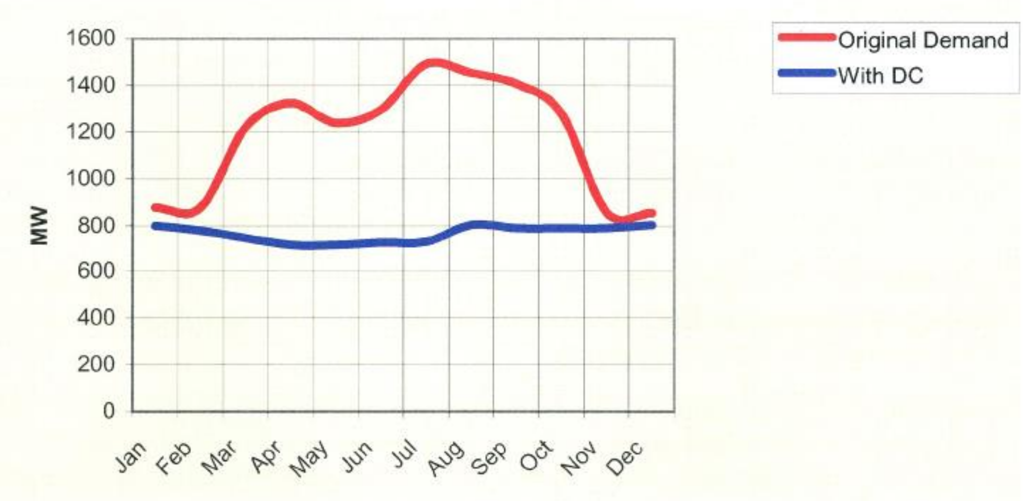

Figure: Comparison of electricity demand using DC and traditionally produced A/C

4.1.3 Infrastructure savings

If handled correctly, massive savings can be made in infrastructure costs. As mentioned later in this report (4.2.1) coordinated installation of utilities such as DC grid, gas, IT communication, potable and sewage water makes the actual cost of DC very low. Moreover the simultaneity factor, normally between 0.7 and 0.9, results in huge advantages compared to the local alternative.

Key infrastructure savings are normally:

- Massive reduction in demand for electrical power (see figure above)
- Reduced demand for water and sewage
- Possibilities for reusing TSW, grey or irrigation water

4.1.4 Economy

The following arguments are normally used when promoting district cooling systems.

Lower operational costs

DC will always have a lower operational cost for the end-user compared to the local traditional alternative.

Less price risk

By having long-term fixed price agreements, the end-user always knows what to expect. It is therefore easy to predict costs when doing annual planning.

Clear cost profile, no "hidden costs"

DC operators always claim there are no hidden costs, something that can always be discussed.

Carefree service with very high reliability

What the end-user sees is the substation (or Energy Transfer station, ETS), compared to a traditional A/C installation. The need for maintenance and the risk of down-time tend to be much lower than with the local alternative. DC operators claim to have 99.6% reliability, equal to 35 hours per year.

4.1.5 Improved building value

Contribution to improved local environment – architecture, noise, chemicals

By using internal substations instead of traditional chiller solutions with external dry coolers or cooling towers, architectural, noise and chemical problems can be avoided.

Flexible adjustment of supply to demand, both comfort and process cooling

With proper planning when dimensioning the distribution grid supplying the end-user's substation, very high flexibility in supply capacity is achieved. Adjustment of supplied cooling capacity can be made simply by adding or reducing the number of heat exchanger plates in the substation. In comparison, the local alternative will most likely involve the installation of an additional chiller with all its auxiliary equipment in order to increase cooling capacity.

Floor space savings

By avoiding locally installed chillers, controls, dry coolers or cooling towers, significant floor space savings can be made, floor space that in many cases can be upgraded and rented out at a premium price.

Solution for replacement or phased-out HCFC or HFC in cooling systems

By using free cooling or high efficiency cooling systems, the need for traditional cooling systems can be avoided or greatly reduced, thus minimising the use of synthetic refrigerants such as HCFCs or HFCs.

4.2 Influencing factors – when is district cooling competitive?

In order for a district cooling project to be competitive, a number of factors have to be checked and confirmed before it starts. Normally this is done by an external consultant in the form of a feasibility study.

4.2.1 The Energy Deal

You could say that "the energy deal" sums up the infrastructural business case of the project. What can be expected in terms of quality, availability and price of water supply, electricity, etc.? What agreements can be expected regarding connection of the end-user? Can one expect a mandatory connection or does the DC operator have to fight for each and every contract? Mandatory connections are mostly seen in Green Field projects, while individual contracts are more common in established areas such as existing towns.

Last but not least, you check for different types of synergies or simultaneity factors linked to the project. When laying down the distribution system, can this be coordinated with other media systems or services such as gas, communication, sewage water etc. If so, major savings and synergies can be found where several operators share the costs of installation.

4.2.2 The Market

Development schedule

Over what period and at what pace will the building-up of the system take place? This will have an influence on cash flow and financing of the project.

End-user configuration – residential/office/commercial
Density of cooling demand

What type of customers will the DC system support? The ideal is to have few customers with high needs in a narrow area.

What is the market demand for product quality (temperature and security of supply)? This will have an impact on system design; for example, banks and computer centres have much higher demands on quality and security of supply than a traditional office building or shopping mall.

Location of production – flexibility and creativity

Here you look into physical conditions of the project.

- Where can I place the production unit(s)?
    - Centralised or decentralised production
- How do I reach the customers?
- Where can I expand the business?

4.2.3 Quality, availability and price of energy sources

This is an extremely important area having a major impact on the decision to start a district cooling project. In order to be competitive, a district cooling system must achieve the same or a significantly higher performance compared to the local alternative.
The following four areas are always looked into and evaluated.

Free Cooling – "Free Heating"

What is there to find and use in the near surroundings?

- Lake/river/sea water
- Outside or exhaust air
- Waste heat or heat recovery

Storage

- Seasonal storage – aquifer
- Day storage – TES

Electrical power supply

- Availability – is the power supply infrastructure in place?
- Flat rate or differentiated tariffs

Potable/Sewage/Grey water

- Quality / Availability / Price

4.2.4 Economics

The economics of a district cooling project are of course very complex. Investments are huge and the payback time long. You have several uncertainties that can affect both investment costs and income, something that finally will have an effect on payback time and the profitability of the project.
Evaluation and planning of a district cooling project therefore have to be undertaken very thoroughly.

Investments

Investments are normally divided into these three main areas

- Production
- Distribution
- Substation or Energy Transfer Stations (ETS)

Costs

- Project costs
- Operation and maintenance costs
- Energy costs

Income

- Connection fee, EUR/kW or TR
  A one-off cost to finance the installation and connection of the substation
- Capacity fee, EUR/kW or TR, year
  Annual fee based on agreed cooling (or heating) capacity
- Energy fee, EUR/MWh
  Consumption fee based on actual supply
- Yearly fixed fee, EUR/year
  Could be used instead of, or as a complement to the energy fee

The pricing principle of an energy company is to safeguard the investment as much as possible. This is mostly done by offering a high connection and capacity fee, and a lower energy fee. By doing this they are always sure of getting their investment back.

4.2.5 Cost comparison District Cooling vs. local alternative

When district cooling operators make the comparison between their own solution and the local traditional solution, the following areas are considered.

DC system	Local system
- Connection fee EUR / kW or TR (one-off fee) - Capacity fee EUR / kW or TR (yearly) - Energy fee EUR / MWh (actual consumption)	- Investment New investment Reinvestment - Operation cost o Fixed *Organisation* *Rents* o Flexible *Energy consumption* *Consumables* *- Cooling water* *- Oil* - Maintenance cost Service Renovation Re-fitting

4.3 Competitiveness of District Cooling vs. conventional A/C system

As stated above, a District Cooling system needs to achieve the same or a significantly higher performance compared to the local alternative in order to be competitive. One way to argue in favour of the DC alternative is to compare different production methods. The illustration below shows how DC companies present the efficiency of different types of cooling units or systems.

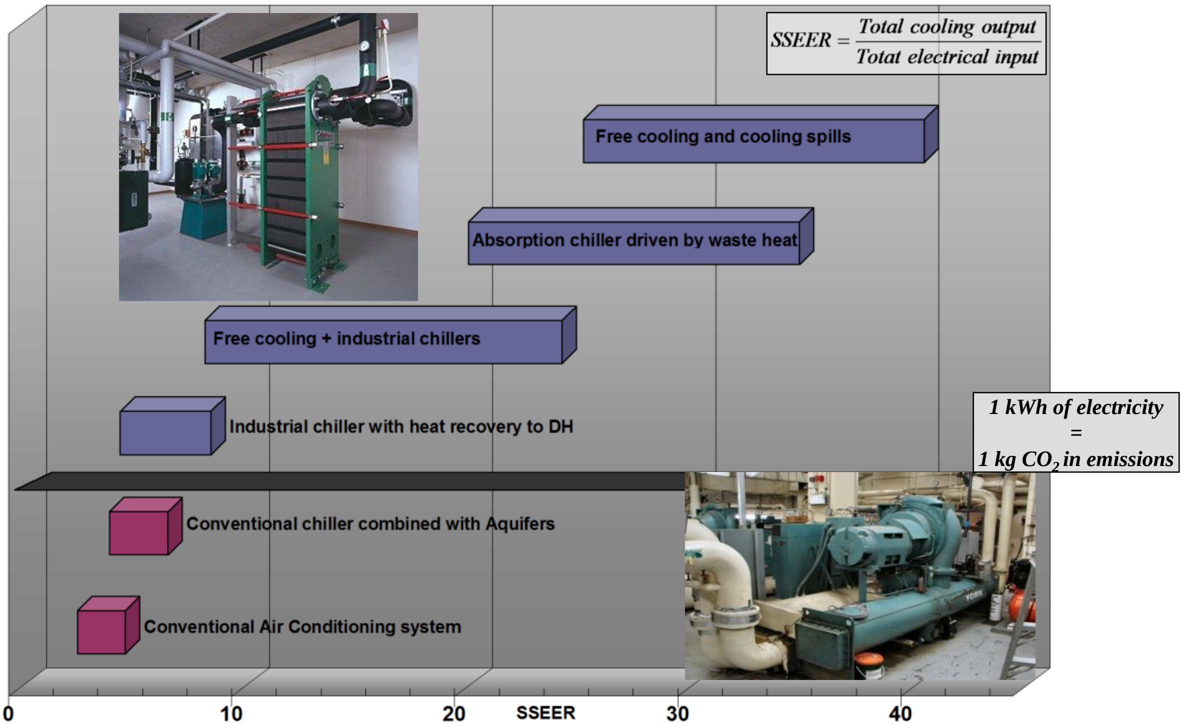

Figure: Comparison in COP for various production systems

It should once again be noted that the figures presented above are those given by the DC industry. Therefore, when arguing for a local alternative, consideration must be given to the specific performance of selected equipment.