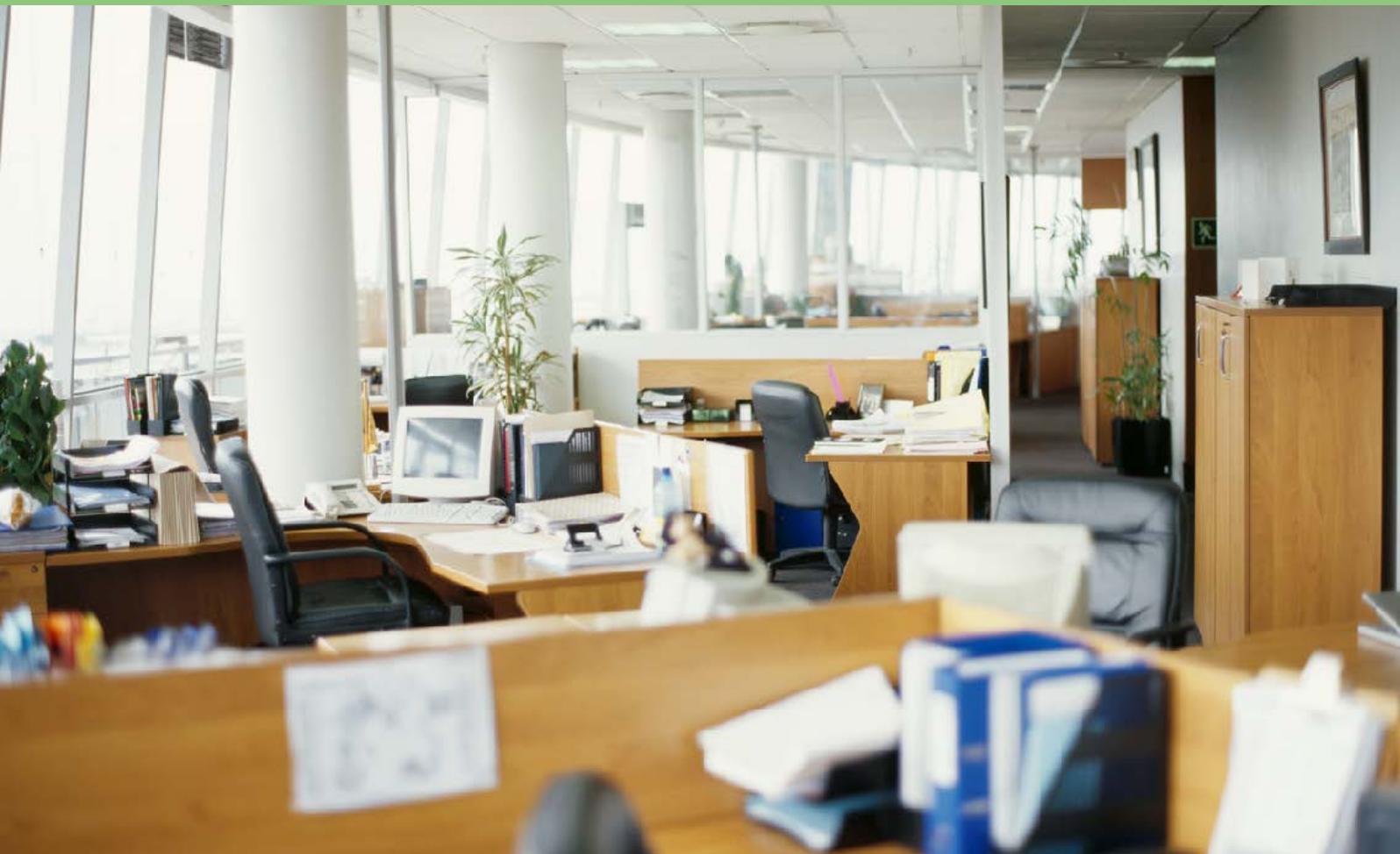




Rescue

RENEWABLE SMART COOLING FOR URBAN EUROPE



Best practice examples of District Cooling systems



Co-funded by the Intelligent Energy Europe
Programme of the European Union

This report was elaborated in the
framework of the RESCUE project
co-funded by the Intelligent Energy
Europe Programme of the
European Union

Report prepared by:



DISCLAIMER

The sole responsibility for the content of this report lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither the EASME nor the European Commission are responsible for any use that may be made of the information contained therein.

Content

1	Preface.....	4	
2	Project description	4	
3	Nomenclature.....	6	
4	Summary.....	7	
5	Background.....	8	
6	Selection of different systems.....	9	
7	District Cooling system and technical practices	10	
7.1	Key drivers - why District Cooling has been developed	10	
7.2	Technical aspects.....	11	
7.3	Why was the specific technical solution chosen	11	
7.3.1	<i>Paris</i>	12	
7.3.2	<i>Vienna</i>	13	
7.3.3	<i>Stockholm</i>	14	
7.3.4	<i>Solna / Sundbyberg</i>	16	
7.3.5	<i>Helsinki</i>	17	
7.3.6	<i>Växjö</i>	18	
8	Lesson learnt - Good practices	19	
8.1	Market driven development	19	
8.2	Robustness and flexibility in production ..	20	
8.3	Stakeholders and Financial issues	22	
8.4	Distribution practices, early actions.....	22	
9	Lesson learnt - Barriers and common failures	23	
9.1	Too low market focus.....	23	
9.2	Access and interest from top management	23	
9.3	Overestimation of customers cooling demand	24	

9.4	Choose the optimal production solution for the DC system	24
9.5	Too little attention on ΔT risks	25
9.6	Lack of respect for the time plan.....	26
9.7	To little focus on permit issues.....	26
9.8	Pipes surveillance system not adapted for cooling distribution	26
10	Final discussion.....	26
11	Key Performance Indicators	27
11.1	Market indicators	27
11.2	Technology/ sourcing indicators	27
11.3	Environmental indicators	28
12	Bibliography.....	29

1 PREFACE

This report has been elaborated within the RESCUE (Renewable Smart Cooling in Urban Europe) project. This IEE (Intelligent Energy Europe) co-funded project is scheduled from June 2012 to May 2015.

The sole responsibility for the content of this report lies with the authors. It does not necessarily reflect the opinion of the European Community. The European Commission is not responsible for any use that may be made of the information contained therein.

Project Coordinator: Prof. Clemens Felsmann, Technische Universität Dresden, Professorship of Building Energy Systems and Heat supply

Principal Authors of this report: Henrik Frohm, Anders Tvärne from Capital Cooling Energy Service AB, Sweden. Kostu Koski from Helsinki Energy, Finland.

With Contribution by the RESCUE partners:

- TU Dresden (www.tu@dresden.de)
- Capital Cooling Energy Service AB (www.capitalcooling.se)
- Climespace (www.climespace.fr)
- Helsinki Energy (www.helen.fi)
- AGFW (www.agfw.de)
- Euroheat & Power (www.euroheat.org)
- ICLEI Europe (www.iclei-europe.org)
- Regional Energy Agency of Liguria (www.areliguria.it)

If you would like to know more about RESCUE project please visit our website www.rescue@project.eu.

2 PROJECT DESCRIPTION

Cooling energy demand within Europe, especially in urban regions, is rising significantly, mainly caused by building design, internal heat loads, heat island effects, and comfort reasons. If served conventionally using small scale and distributed electric driven compressor chillers this would result in a significant rise of primary energy consumption, greenhouse gas emissions and peak electricity demand.

The RESCUE project focuses on the key challenges for further development and implementation of District Cooling (DC) using low and zero carbon emitting sources, thereby enabling local communities to reap the environmental and economic benefits of this mature technology. Although DC allows the application of high efficient industrial chillers or absorption chillers driven by waste heat it is estimated that DC market share today is about 1–2 % in the service sector (which is about 3 TWh) but less than 1 % of the

total present existing European cooling market including residential sector. The main steps to extend the use of smart, energy efficient and renewable DC Systems are:

1. Dissemination of essential background information.
2. Decision making based on (pre-) feasibility studies exploring cooling options.
3. Implementation, Monitoring and Optimization.

The RESCUE project focuses on steps 1 and 2 within the project duration addressing main actors and target groups, i.e. Local Authorities (LA), utility companies, building owners, and the financing sector. The main project objectives are as follows:

- Promote district cooling as a sustainable energy solution with a potential.
- Increase familiarity and reliability of information available to decision makers and local authorities about the DC business.
- Improve networking activities and experience exchange.

A key action of the project is to provide a number of target cities with a decision-making support package assisting local authorities to account for DC in their planning policies and to guide them when looking for cooling options fitting best to their Sustainable Energy Action Plan (SEAP).

Key outputs and main deliverables of the project, available to the public, are:

- An impact calculator which shows the key figures in comparison between Central and Distributed solutions.
- A set of guidelines and handbooks related to the DC business and the decision making process.
- Reports describing the cooling energy market, the energy performance evaluation as well as DC best practice and show cases.

The RESCUE project consists of seven Work Packages (WP), whereas WPs 1, 6 and 7 are dedicated for project management and communication, WP2 is dedicated to conducting a market survey for cooling in Europe and to establish how DC can contribute to the 20-20-20 targets. WP3 is to showcase examples of DC systems in Europe in order to demonstrate their performance and to provide details on the use of renewable energy sources (RES), improvements in energy efficiency and CO₂-savings. Within WP4 a “Decision Making Support Package” is developed, applied and enhanced to guide and assist LA in their decision processes regarding cooling issues in local energy concepts. The purpose of WP 5 is to provide practical information related to start-up of DC systems and the DC business in general.

3 NOMENCLATURE

Abbreviation	Description
AC	Air Conditioning
CHP	Combined Heat and Power
CoM	Covenant of Mayors
DC	District Cooling
DCS	District Cooling System
DH	District Heating
EC	European Commission
ECI	European Cooling Index
LA	Local Authorities
LCC	Life Cycle Cost
LG	Local Government
PEF	Primary Energy Factor
RES	Renewable Energy Sources
SEAP	Sustainable Energy Action Plan
WP	Work Package
NZEB	Nearly Zero Energy Buildings

This report is based on collected information and experience from two Southern and four Northern Europe District Cooling (DC) systems which represent typical cases that can be seen across Europe. Many DC systems have now been in operation for around 20 years. From these systems a lot of useful information related to the early period of cooling business is very valuable for the cities that are considering their own District Cooling system.

One common feature of the six DC systems is that they all utilise natural cooling resources to some extent (sea, lake or river), thereby greatly improving their performance. Still, natural cooling sources are not a must-have in order to develop DC systems. However, it should also be noted that major cities in Europe are usually located near lakes, seas and rivers, and therefore a huge potential was identified for developing sustainable DC solutions.

There are many reasons why municipalities and energy companies in the selected six DC systems have started up District Cooling schemes, the most common reasons given by the interviewed DC providers are:

- Top management that believes in the District Cooling business
- Competition – be able to sell both heating and cooling
- A new sustainable and environmental product on the market
- Sight of a potential profitable business
- Sell more district heating and to be able to produce electricity longer in the summer period
- The aesthetic concept of a city as re-cooling devices disfigures facades and roofs. Among other aspects: health, reducing noise and removing cooling towers from the city centre.

It is very important to understand and identify smart local solutions based on the local conditions. For all six examples of DC systems described in this report, the choice of the DC production technology was based on the locally available sources. The production mix was optimised for local conditions and is based on calculated development plans. The key in all systems depicted in this report is covering cooling demand at a local market. It is essential to understand the whole market potential so the right technical solution that is feasible can be evaluated in order to be able to present a competitive District Cooling solution. Successful DC systems are not only dependent on the smart choice of technical solutions, but possibly even more on a strong sales and market focus during the development phase.

A more detailed description of the DC system in Paris, Vienna, Stockholm, Solna/Sundbyberg, Helsinki and Växjö can be found in respective sections of this report.

A common success factor for the examples is that key stakeholders had clear roles in the DC development schemes. The local energy companies have been able to develop the DC scheme with their own cash flow and then use loans from local, regional, national or European institutions, like EIB or Green loans. Many of the companies have also introduced front fees (access fees) to lower their negative cash flows.

In general, lessons learnt from the successful DC system development schemes can be listed as follows:

- *A High Market Focus Access* is essential to develop a successful DC Business.
- Secure the connection of key customers first.
- *Access and interest from top management*: it is crucial to have the upper hand of the progress of the project development. Implementing adequate steering and control models at an early stage is absolutely necessary. Efficient decision processes and interest from the top management is needed.
- *Overestimation of customer cooling demand* is a common mistake that should be avoided by evaluating demand carefully.
- *An optimal production solution for the DC system* should be chosen, taking into account the locally available sources and local conditions.
- Always pay attention to *the temperature differential (ΔT) risks*
- It is important to keep the *time plan* on track.
- Always give high importance to *permitting issues* is also a common and costly mistake that delays the system development
- The *pipe surveillance system* has to be adapted for cooling distribution, with special requirements compared to heating distribution.

5 BACKGROUND

There are several cities operating DC systems around Europe. Many systems have now been in operation for around 20 years. A lot of useful information related to the early period of cooling business can be given by these systems. They can be of high value for the cities that consider developing their own District Cooling system and are interested in key issues to address when starting to develop a DC system.

This report is based on collected information and experience of a few selected systems both from Central and Northern Europe and will represent typical cases that can be seen across Europe, taking into account the characteristics of different locations at which the various sources (river, sea, lake, etc.) are available to produce cooling. The scale of municipalities will be from large cities to mid-sized towns. The focus is put on technology – outlining good practices and what makes these systems “good”.

The focus in this report is put on the period when district cooling is being established, it is not focused on the experiences in operation. However, some advice is included on issues that need attention on future operation.

6 SELECTION OF DIFFERENT SYSTEMS

Five types of systems around Europe are covered in this report:

- Large and small
- Northern, Central and Southern systems
- Different technical solutions

In order to fulfil this aim six different DC systems have been described as the main source of information, see Table 1. Some general experience from other projects and cities has also been included into the report.

City 4)	Country	Inner city inhabitants (approx.)	North / South	Starting year of DC supply	Technical solution for DC supply
Paris 1)	France	2 200 000	Central (South)	1978	Electrical chillers, river, Geothermal and grey water Heat Pumps,
Vienna	Austria	1 700 000	Central (South)	2009	Absorption, electrical chillers, river
Stockholm 2)	Sweden	900 000	North	1995	Sea water, heat pumps, electrical chillers
Solna / Sundbyberg	Sweden	110 000	North	1995	Sea water, heat pumps, electrical chillers
Helsinki	Finland	700 000	North	1998	Sea water, absorption, heat pumps, electrical chillers
Växjö 3)	Sweden	60 000	North	2011	Absorption, electrical chillers and lake

Table 1: List of different types of DC systems described in this report.

Note 1: The system in Paris is operated by Climespace. (Outside of Paris, one more district cooling system can be found in the La Defence area.)

Note 2: The Stockholm system is here only showing info regarding the main, large central system (Fortum also operates a number of mid and small DC systems, which are not included here.)

Note 3: The Växjö system use un-insulated pipes (on the return) located in lakes for connecting different areas. Natural cooling is then achieved by the un-insulated pipes function as a heat exchanger.

Note 4: An alternative to the systems of Helsinki, Växjö and Solna/Sundbyberg would be the cities of Gothenburg, Helsingborg, Halmstad, Linköping, Borås, Umeå, Lund and Jönköping, all from Sweden. Experiences, results and conclusions would be similar from these cities as from the ones Rescue chose to include.

The ambition was initially to include a system from the South of Europe. However there are very few systems there that have experience to share as good practices. Most of the Southern Europe DC systems are small and not growing or showing low development indications. The financial situation in south of Europe is presently not a foundation for project development. The DC systems in both Barcelona and Lisbon have limited resources and, for various reasons, not a possibility to participate as sources of information and experience in this project. Cities in Germany and Italy are also excluded since there are no cities with DC schemes that are interested in sharing information. The DC schemes are also very few in these countries. However, a positive point is that cities in these countries are very good potentials for target cities of developing DC, with support from Rescue.

The focus will therefore be on DC systems in in North and Central Europe countries. The Rescue project is convinced that experience from systems there will best serve the scope in this report.

An interesting fact to observe is that six systems that have been chosen have some kind of natural cooling included, sea, lake or river. This is very natural if there are locally available sources of cold water, at least some part of the year. DC systems are excellent in utilising local sustainable sources and solutions. However it is not a deal breaker that natural cooling must be available if DC should be developed.

The fact that all DC systems that have been analysed do have natural cooling is not so surprising; the history of a city and why people have gathered there in the past shows that it was because of the geographical aspect, and more specifically, the presence of water. Today, many of the cities in Europe are located near the coast, near lakes or near rivers. So from a DC perspective it is actually a huge potential for developing sustainable DC solutions.

7 DISTRICT COOLING SYSTEM AND TECHNICAL PRACTICES

7.1 KEY DRIVERS - WHY DISTRICT COOLING HAS BEEN DEVELOPED

There are many reasons why municipalities and energy companies have started up District Cooling schemes but here is a summary of the most common reasons from the interview DC providers ((Tvärne, Anders; Capital Cooling) 2014):

- Top management that believes in the District Cooling business
- Competition – be able to sell both heating and cooling (e.g. in comparison with heat pumps).
- New interesting product(s) on the market
- Outlook of a potential profitable business
- Sell more DH and to be able to produce electricity longer in the summer period

- A new sustainable product that strengthens the company's environmental profile
- Demand from building owners (these serve as DC customers then) possibly caused by restrictions from the municipality (concerning facades and re-cooling devices)

Almost all energy companies that have DC systems tell this story and this means that there is a lot business and market driven approach. Additionally, district cooling assists to improve the environmental profile of the company. In Sweden and in Finland, a strong driving force has been the competition on District Heating from heat pumps and the ability to produce more electricity during summer period using excess heat.

7.2 TECHNICAL ASPECTS

Actually there are no major differences if a DC system is located in the North or South of Europe, if it is a small or a large system or the choice of technical solution. The main objective is to understand and to satisfy a customer market demand DC operates on a local market. The common driver is that the system design and technical solution is based on local conditions. Then it is important to understand and identify smart solutions available on the market. If the system shall be successful, the management skills of developing the business are essential. The business analysis should include optimisation of the prevailing technical options.

A key issue is to find and utilise production facilities near the market. Long transition pipes should be avoided.

The first step is to identify all possible sources of natural cooling. The next step is to identify possibility of waste energy. It can be from industrial processes, waste incineration or heat from CHP plants and then used as heat for absorption chillers. Apart from that, high efficiency electrical chillers are also used. If there is a demand of a DH system, heat pumps can also be a solution.

It is very rare that DC systems utilising natural cooling will have unlimited sources of cooling. None of the ones described here have. The source of natural cooling does not provide enough energy or the temperature is not low enough over time. Every system must have a mix of different cooling production solutions to be able to deliver the quality the customers demand.

The sources of natural cooling are basically huge storages of cold energy. For peak reasons or capacity in transition pipes, the systems often use storages (day and night). Then operations can be reduced with electrical chillers during peak in day time. Cold-water storage is also valuable for restarting a system after an electrical power failure etc.

7.3 WHY WAS THE SPECIFIC TECHNICAL SOLUTION CHOSEN

For all of the examples of DC systems described in the following section, the choice of the DC production has been based on locally available sources. The production needs to be optimised in respect to local conditions and calculated development plans. Normally it takes many years to develop DC systems. The development period depends on both customer's interest to actually connect and the utility companies scheduling. A planned phasing in respect to what is financial possible sets the framework for the development plan.

District cooling is characterised by high investments and low operational costs. It is financially tough to build simultaneously both the network and production plants. A smart use of simple temporary solutions

can bridge the gap between the customer demand and the time when the customer can be connected to the main network.

When DC has been accepted on the local market, even more customers can be interested in DC. It can also not be excluded that the cooling market actually could have been under-estimated. A second expansion phase will be possible. The production capacity will in that case probably not be sufficient. It cannot be excluded that totally new market conditions may prevail. This could lead into a different technical optimal solution compared to the first phase. It is therefore very important that each project is analysed as a new project. Therefore, experiences from other projects must be evaluated very carefully before being implemented. Risk assessments and security of supply studies have also been included.

7.3.1 PARIS

The Paris District Cooling dates back to 1968, at the time when the Paris City council decided to renovate an area in which the shopping centre of Forum Les Halles was to be built. A centralised heating and cooling system has been adopted as technical solution to recover the energy, to avoid electricity peaks and to ensure security of power supply to the consumers in the area.

In order for the district energy system to be economically feasible, it needed to supply other buildings and hence, the Louvre museum has been connected to the system.

Due to its central city location, far from any natural resource, the technology solution chosen was the installation of electrical centrifugal chillers with cooling towers installed on the top of the building and the ice energy storage.

Believing in the technology and in an increase of the cooling demand, in the 1991, Climespace became a shareholder with the idea to expand the existing District Cooling system.

As the system expanded, with the increasing number of new clients' connections, the installation of other energy plants such as Opera and the increase of the distribution network, etc. it became economically feasible.

In fact, river water provides better thermal performance for heat rejection when compared to a cooling tower, due to its temperature stability and better specific heat capacity, and offers the opportunity to exploit free cooling which led to the construction of 3 others energy plants.

Paris is a very dense city and the location to accommodate the plants also posed some constraints, which led to alternative solutions. This case is better represented by the construction of Canada energy plant, which has been created completely underground or Tokyo energy plant which was built under Tokyo palace and required structural adaptation in order to build the plant underground the building.

With the increase of technology and the discovery of large geothermal energy source in Paris, Climespace has recently constructed an energy plant that uses geothermal energy.

Through the means of heat pumps and the synergy with CPCU, that operates the District Heating system of Paris, the energy plant is capable to provide simultaneously heating and cooling energy for DH and DC.

Legislation in France also influenced the technical solution adopted for cooling production such as the restriction of the use of ammonia as a cooling refrigerant.

Another important factor was that in the city centre of Paris there are not any incinerator plants what excluded the use of surplus heat.

Paris has a very developed underground tunnel which in some areas created some advantages by facilitating the poses of pipework whereas in some others it poses some constraint due to the limited space available.

Climespace is currently installing an energy plant in the Paris City Council building that uses the Paris grey water system as a source of heat rejection and recuperation which by means of reversible heat pumps will be capable of producing cooling and heating.

As shown in *Figure 1* , Climespace now operates 3 separate District Cooling Systems. Each system consists of at least 2 energy plants to provide and deliver the chilled water. This corresponds to a decentralised approach of the energy production, implying the dynamic operation of the plants of the same network.

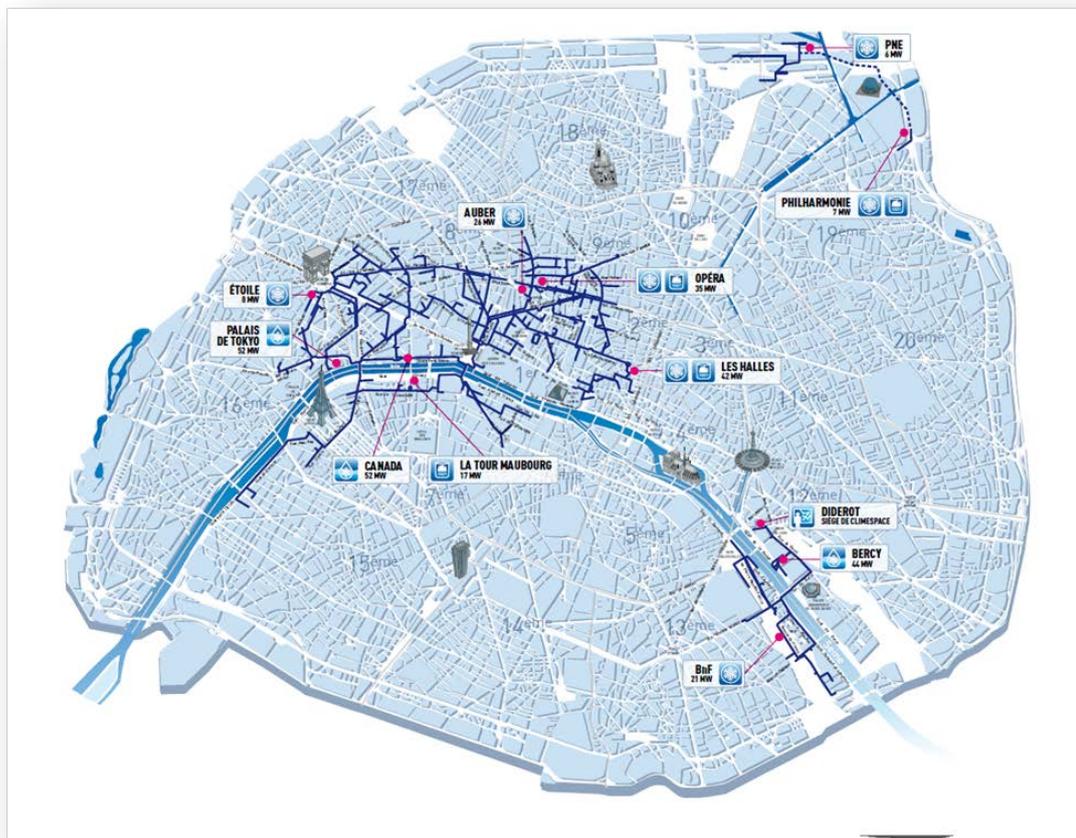


Figure 1: Paris District cooling system (Source (Climespace, 2013))

7.3.2 VIENNA

There are a few main quarter stones that set the framework for the cooling market in Austria and especially in Vienna. There is electricity peak production demand in the summer period. For these peaks, fossil fuel is used. However, the global EU framework leads to a need of reducing the use of fossil fuels.

The floor area for office is increasing in Vienna. According to the Executive Office for Strategic Energy Affairs, the floor area will grow by 18 % between 2005 and 2030. Most of this additional space will be built, by default, already fully or partially air-conditioned. The trend is also clear that the cooling demand is increasing in current office buildings.

Connected to the existing DH system, there were a few customers that for many years have used local absorption chillers (driven by heat from DH network). The business had been sleeping for years with no indication of any interest from the stakeholders.

Feasibility studies identified areas of cooling demand with an interesting potential for developing full scale DC system. A system design study showed options for mixed production with natural cooling, absorption chillers and electrical chillers. The decision to develop district cooling was taken in 2006.

Fernwärme Wien has long experience with waste incineration at the Spittelau plant. The base load for DH in Vienna is based on this plant. In the summer period there was a surplus of waste leading to cooling demand to get rid of excess heat when the heat demand was too low. This could now be used for heat driven absorption chillers. In the spring period the flow in the river Danube is high and the water temperature is then cold enough for DC supply. Accordingly, natural cooling can be used during parts of the year. During periods when the air is cool enough, additional free cooling can also be produced. Remaining DC is produced with electrical chillers.

Expansions to other areas will use similar concepts as in Spittelau DCP. New production capacity is developed in Rudolfstiftung Hospital, Reingasse, TownTown office complex, Krankenhaus Nord and Central railway station. All these units use a mix of natural cooling, absorption chillers and electrical chillers. The approach is to develop local DC islands. Some are integrated with nearby DC islands. With a number of production sites near local demands the need for large DC transition pipes is reduced.

7.3.3 STOCKHOLM

Stockholm is located at the Baltic Sea. Utilising deep sea water is of course the base source of DC. The depth of the sea in the harbour and sea water temperature variations during the year result in a supplementary need to cool the sea water for the DC supply. Existing large heat pumps could be used for securing the supply temperature as well as as peak production. The heat pumps use sea water. Initially, the city centre DC projects were aiming on a market corresponding to a capacity of 60 MW. For the city system it was aimed at a capacity possible to transfer in pipes that could be located inside an existing tunnel.

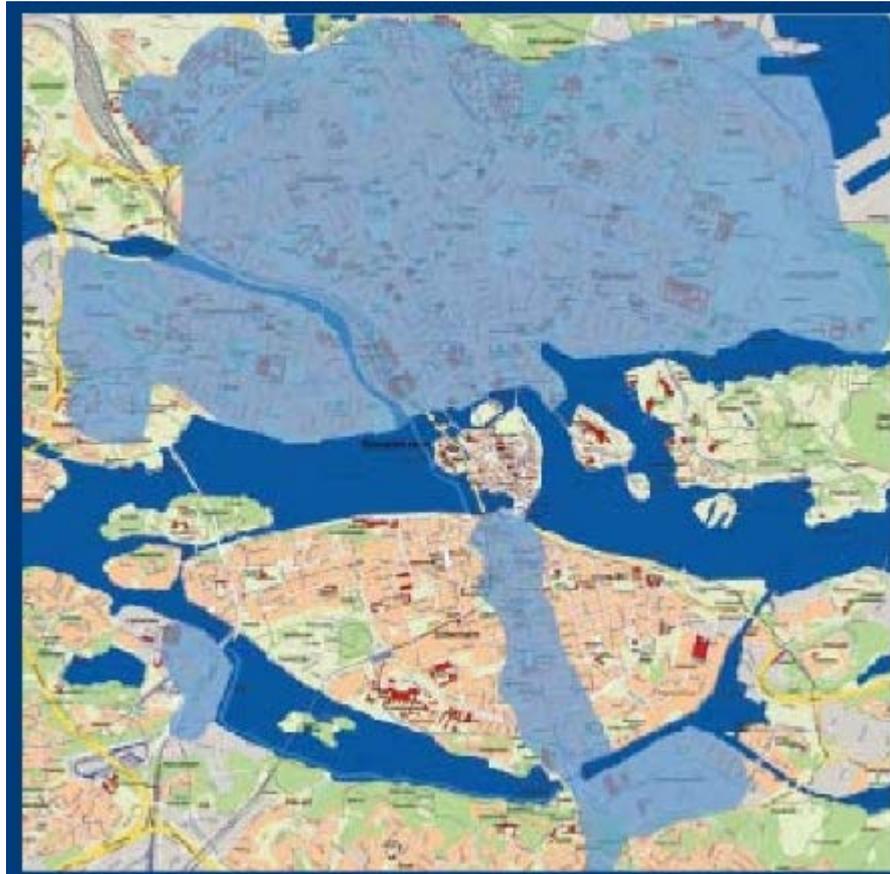


Figure 2: District Cooling system in Stockholm (Fortum Värme AB)

The successful growth of the system led to a higher demand from the customers. A second north complementary transmission network and extra production capacity has therefore also been built. Local aquifer storage has been utilised in the city centre. The blue marked areas in Figure 2 show the areas now served by DC in Stockholm city area.

For the second area of Södermalm, there was a separate DC system built up a few years after the initial city centre system. In the Södermalm DC system, existing heat pumps in Hammarbyverket were used. The Södermalm and the city centre system are now connected by pipes located in the lake Mälaren.

The west area of Kungsholmen has been connected to the city centre's system with DC pipes under a bridge. In Kungsholmen rock tunnel, cold water storage has been built. There are plans to include the second sea water intake into the system in order to boost the capacity.

A separate mid size DC system using heat pumps is also operated in Kista, the Swedish IT centre. Apart from this a few small satellites in gallerias/malls are also operated by Fortum.

The use of production by heat pumps and not by absorption chillers is from a historical perspective a natural development path. The heat pumps were already installations in operation. Utilising energy from both the hot and cold side is then very cost efficient. At the time of the design in 1994 the electricity price levels in Sweden were then lower than today's market prices. Neither the emissions trade system, nor the

Swedish green electricity certificates exist. The energy taxation was not in favour of operating CHP plants. Compared to 1994 the electricity production from CHP in Sweden has increased by 250-300 %.

Stockholm has had waste incineration plant with energy recovery to District Heating since 1970. The capacity has of course increased since then. The waste incineration plant is not close to the DC production locations. The DH network do have bottlenecks plus also that the base load demand is higher than what the waste incineration can produce. If absorption chillers would be used in the city centre system it would therefore be supplied with other, more expensive sources than waste incineration.

7.3.4 SOLNA / SUNDBYBERG

Norrenergi operates the DC system in Solna and Sundbyberg, which are two communities located in the North of Stockholm. The DC system was planned at the same time as the Stockholm system in 1994.

Norrenergi also had large existing heat pumps (treating sewage water) in their DC production. Heat pumps were the initial technology to utilise for the DC production. When the DC system had reached a market penetration as well as a capacity large enough, a sea water supply system was feasible.

Now, electrical chillers are also included in the production for peak and reserve. A cold water storage (CWS) is also included in the production facilities and located at the production site, Solnaverket. When the cooling demand is low, during nights, the CWS is charged with the sea water for natural cooling. When the DC pipe system is inter-connected, operation with electrical chillers for day time peaks can be reduced.

Further expansion of the DC system will also be utilised by adding chillers at the DH plant in Sundbybergsverket. The sea water pipe system is already utilised at the maximum capacity.

The DH system is also operated by Norrenergi. There is not any industrial waste energy included in the DH production. There is no CHP plant included in the production of DH. Absorption chillers are therefore not an interesting alternative for DC production.



Figure 3: Layout of DC distribution system in Solna/Sundbyberg and location of DCPs. (Norrenergi AB)

The approach on developing DC in Solna/Sundbyberg was to start with utilising energy also from the cold side of existing heat pumps. The waste heat used in the heat pumps is treated sewage-water. One of the Stockholm area main sewage tunnels is close to the Sundbyberg production plant. The sewage water does have a rather constant flow during the year.

Area 1 in Figure 3 was in the first stage developed with the mix of heat pumps and electrical chillers. With the success of providing district cooling, the waste energy (in the heat pumps) was utilised to maximum capacity. For any new customer, the dependency on electrical chillers was too high.

Area 2 in Figure 3 is covering one of the most expensive areas for developing office surfaces. These modern commercial buildings do all need AC, so DC is an attractive product in the area. For this area sea water cooling was possible to develop.

When integrating area 2 with area 1, more of natural cooling (sea water) could also be boosted into area 1. Since the cooling from existing heat pumps in area 1 already was used to the maximum. With the interconnection of the two areas the production with sea water cooling could be raised with the use of the CWS.

7.3.5 HELSINKI

Helsinki Figure 4 is the capital of Finland with around 700 000 inhabitants and located by the Baltic Sea. The experience of district energy supply in Helsinki has a long history, starting in 1953. DH was a success from the beginning. District cooling supply started in 1998. The implementation of DC was easy as real estate owners were already experienced with DH. The DC production is a mix of sea water cooling (natural cooling for 6 months of the year), absorption chillers and heat pumps.

More than 80 % of production is based on energy that otherwise would be wasted.



Figure 4. City centre of Helsinki. (Koski, Kostj; Helsinki Energia OY)

The Katri Vala heating and cooling plant is the largest in the world to use heat pumps to produce District Heat and District Cooling from purified sewage water and sea water. Its output is 60 MW of District Cooling and 90 MW of District Heating. The DH capacity would fit to supply heat to a small town. The plant is located in a rocky space and in the tunnels underneath the Katri Vala park in the district of Sörnäinen.

The second DC plant use is located at the Salmisaari cooling centre and has a capacity of 10x3.5 MW absorption chillers and two compressor chillers. The heat source for the absorption technology is +85°C District heating water.

The production mix is chosen to utilise the local energy sources efficiently. Figure 5 show the mix of DC production from both Katri Vala and Salmisaari DC plants. The photo shows one of the heat pumps 18 MW heat and 12 MW cooling.

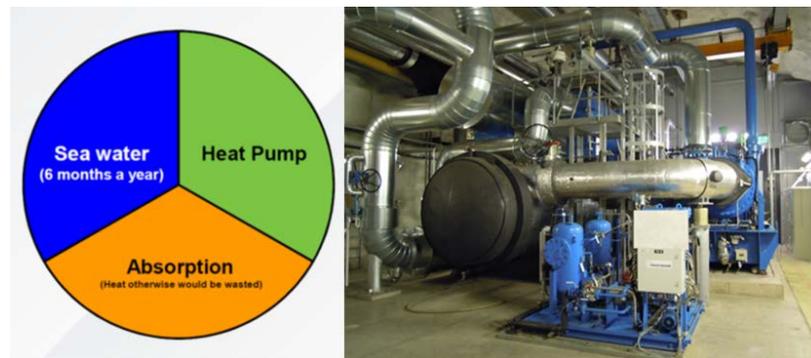


Figure 5. Production in Helsinki (Koski, Kost; Helsinki Energia OY)

7.3.6 VÄXJÖ

Växjö is a small city with a population of only 60,000 in the city centre. The location of Växjö is inland in an area of good availability of biomass waste from the local forestry. A biomass CHP plant was taken in operation in 1997. Today, over 90 % of all district heat is produced by biomass.

A number of key-customers that were already connected District Heating indicated an interest in supply of District Cooling. Växjö is a spread out city and a few lakes are nearby. All the lakes are shallow, so only surface water is available for cooling purposes. The lakes are beneficial for distribution purposes because of the lower investments cost for lake location instead of ordinary ground constructions.

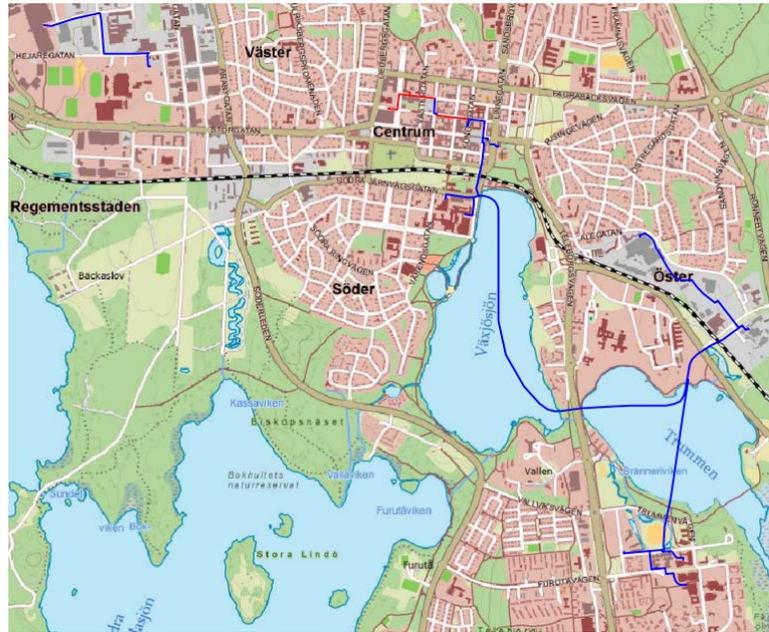


Figure 6. DC distribution system in Växjö. (Växjö Energi AB, 2012)

Figure 6 shows the DC distribution system in Växjö. The DC distribution system use uninsulated pipes (on the return) located in lakes for connecting different areas. The uninsulated pipes function as a heat exchanger. The water from the lake is then taken up by the DC pipes. (So it is not an open – “once through” – open lake water system, with separate lake water pipes.).

The City of Växjö aims to become a fossil fuel-free municipality. Sustainable production of electricity with biomass is encouraged. District Heating is now produced in a biomass CHP plant build in 1997. A new biomass CHP plant was taken into operation at the end of 2014. In Sweden and Norway there is a market that aims at introducing sustainable production of electricity, “electricity certificates” (Elcert). New CHP plants with biomass can then during a period of 15 years achieve Elcert. The level of Elcert is set by the price on market place, by auctioning. It is now attractive to produce electricity during the summer period, and then CHP combined with heat driven absorption chiller is a feasible option for District Cooling.

8 LESSON LEARNT - GOOD PRACTICES

8.1 MARKET DRIVEN DEVELOPMENT

The common success factor for successful DC schemes is their strong focus on market and sales during the development phase.

The DC product is mainly meant for commercial facilities and official buildings. It is therefore important to identify the market needs and understand market challenges. What are each customer’s specific needs? The District Cooling offer has to be equal or lower priced than the alternatives when all benefits are added. A higher price level linked to the added values is often hard to succeed in selling.

Successful district cooling system is profitable. However, it must be remembered that DC is an infrastructure. Infrastructure investments are characterised by high initial investments, slow long term but steady income.

The key is satisfying the local market demand. It is essential to understand the whole market potential so the right technical solution that is feasible can be evaluated in order to be able to come up with a competitive District Cooling solution.

Securing key customers is essential. The DC distribution system is expensive. Customers located along the pipe routing are essential to connect. If not it will be difficult to achieve a high DC saturation. However there is a possibility to move up on the value chain with additional services, see Figure 7.

Not securing a high enough penetration rate before investment decision will lead into a high profit dip during the first years.

Some customers can be supplied with temporary solutions so they do not have to invest in their own on-site local cooling solutions that would block DC connection for many years to come.

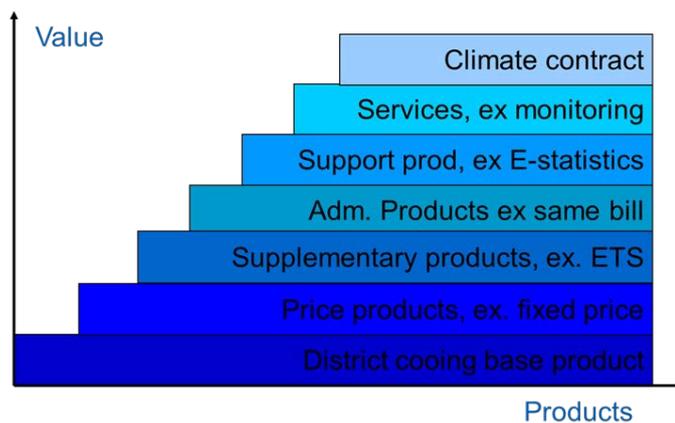


Figure 8: Value chain (Frohm, Henrik; Capital Cooling)

8.2 ROBUSTNESS AND FLEXIBILITY IN PRODUCTION

The choice for this technical solution and a specific production mix for a DC scheme always depend on local energy sources and conditions.

The basic business foundations for DC are linked to capacity costs and less on energy related costs. The successful DC business is characterized by having sufficient production capacity. With local solutions customers do need stand-by redundant capacity in each building.

It is important to have the knowledge of current realistic cooling demands in different types of buildings when establishing a DC business. Too high capacity estimations will lead to huge fixed costs. Experience is that many customers report over estimations on customer demand, usually evaluated from consultants. The knowledge of the current maximum capacity need for a building is often unknown. That is not the same as the number of chillers in the building reduced by the reserve capacity need. Investment

decisions in DC production capacity solely based on customers calculations is a risk of standing with too much unused capacity and high capital expenditures.

Energy Efficiency

To be able to cover the high capital costs for distribution of a DC system, principles of the economy of scale should be applied and the production system has to be energy efficient. Establishing a small DC system can be financially challenging, if potential customers are located far from each other the DC pipe distribution system will be expensive.

High energy efficiency can be reached by using free natural cooling sources as, lake, river or seawater or by using waste heat from CHP, industrial processes or waste heat for absorption chillers, see Figure 9.

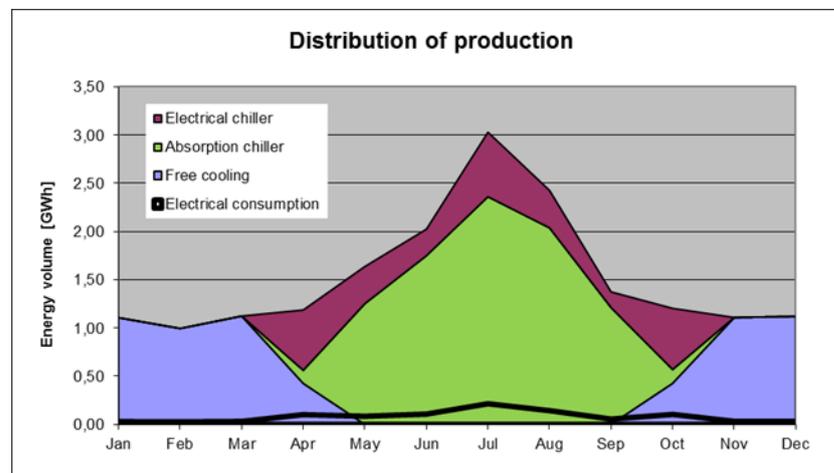


Figure 9. Energy balance for a District Cooling system. (Frohm, Henrik; Capital Cooling)

If high energy efficiency is reached, the primary energy factor will be low and the DC product will have a stronger environmental profile than the competitors on the market and the product will be easier to sell. However even with a strong PEF it is essential to offer a competitive price level in order to succeed with the DC business.

To be able to get a profitable DC scheme, it is essential that area is quite dense so the cooling demands will be high enough and that the connection speed is high to be able to cope with the high capital costs.

Using a benchmark on market demand per meter of distribution (kW/m of piping) will give an indication whether it is economically feasible to deliver DC to a certain area. This benchmark value will vary for each local market, depending on production costs, ECI etc. but should in most cases not be lower than 2 kW/m.

8.3 STAKEHOLDERS AND FINANCIAL ISSUES

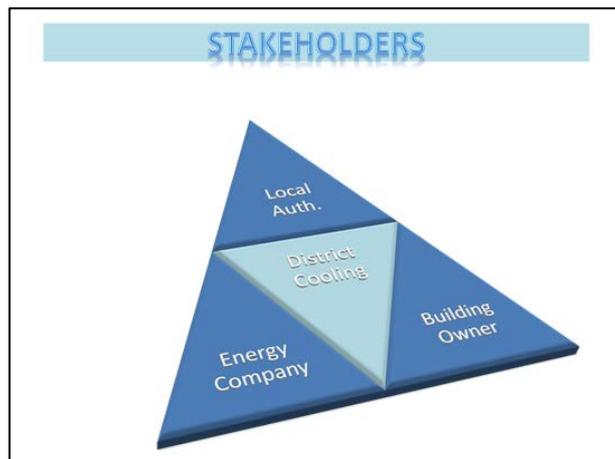


Figure 10. Stakeholders in a DC Scheme. (Frohm, Henrik; Capital Cooling)

One common success factor for the good practice examples is that the key stakeholders, see Figure 10, have had clear roles and where the local authority and local municipality/energy company have taken a clear role in developing the DC scheme. The local energy company has been able to develop the DC scheme with its own cash flow and then been able to use beneficial loans, from for example EIB or Green loans. Many of the companies have also introduced connection fees (access fees) to lower their negative cash flows in the start-up phase, Figure 11 show an example of the impact of the cash-flow by using an access fee, on a typical 60 MW DC system.

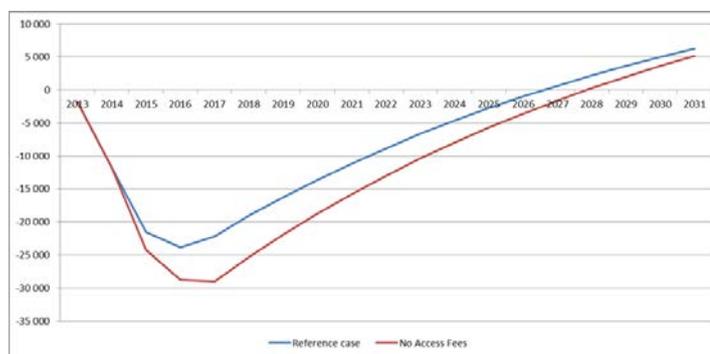


Figure 11. Cash flow for a DC scheme. (Frohm, Henrik; Capital Cooling)

8.4 DISTRIBUTION PRACTICES, EARLY ACTIONS

The investment in a DC distribution system is often in the same range as the investments in the production plants. It is essential with a smart initial planning in order to save costs. What has been buried in the ground already is extremely expensive to replace later on. Identifying possible bottlenecks and obstacles in the early planning is essential in order to reduce the risk of costly surprises. Routing where the civil works are cheaper can lead to huge cost savings.

A DC pipe system is generally complex and need redundancy supply with alternative routings (loops). Considerations for start-up planning operations also need attention. Due to the complexity it is essential to implement the pipe system into a hydraulic model at an early stage.

Strategic decisions on quality measures can be taken in the planning stage. One important issue is the type of pipe material in respect to, pressure requirements, temperature losses etc. Pre-insulated steel pipes are the most common type. Certified pipes according to the EN253 standard are then recommended. Linked to EN253 a lot of other normative standards do also apply.

Trenchless excavation methods or laying pipes directly on the bottom of lakes and seas can often lead to smart solutions and cost saving.

One often early identified obstacle when presenting leads of District Cooling systems is the disturbance on traffic during the excavations, this is especially common in cities with no experience of district energy. One common question is often how to handle the disturbance of digging up the roads. However the time for having open excavations is actually of a limited time frame. A control question can often be how was handled the construction work for new or refurbished infrastructure distribution lines in the street.

The disturbance on traffic can often be limited. One example is the use of temporary bridges that can reduce inconveniences.

A planning with minimising time for open excavations is recommended. There are also good examples on information during the construction works; "Excuse the mess. We are building for sustainable DC".

There are cities with local legislation that limits time for open excavations. Checking local regulations is therefore recommended. Being forced to build very short distances before back-filling will lead to high costs. It will also complicate pressure testing of welds, joints and preservation actions linked to the filling up system with water.

9 LESSON LEARNT - BARRIERS AND COMMON FAILURES

9.1 TOO LOW MARKET FOCUS

Focus too much on the technical issues on the DC scheme and too little on the market. This leads to a technically superb DC system but with poor profitability because of low incomes per year. A common failure is often that the technical solution for the production of DC is chosen before the feasibility study stage. Not evaluating the impact of different options will not lead to an optimal solution.

9.2 ACCESS AND INTEREST FROM TOP MANAGEMENT

A common failure is a misjudgement of the needed management resources. It is very important to have control over the progress of the development of the project. Implementing adequate steering and control models at an early stage is absolutely necessary.

When a new product is set on the market, a lot of fast decisions have to be made and then a efficient decision process and interest from the top management is needed.

With auditing the progress early warning can steer the project on track again. Repeating expensive mistakes can be avoided. It is essential to identify problems early and giving attention to them. Letting problems wait will only escalate them.

9.3 OVERESTIMATION OF CUSTOMERS COOLING DEMAND

It has been mentioned earlier in this report the risk of overestimating cooling capacity demands. Most property owners do not have a clear knowledge of their cooling demand. However, their knowledge of the maximum peak demand is more common than their knowledge regarding their annual cooling energy usage.

At contract negotiations, customers often report a higher demand than they actually have, based on their installed capacity but forgetting originally installed back-up capacity.

An overestimation of the peak demand may lead to overinvestments in the DC production plant and distribution network. If this is balanced by a higher connection fee from the customer, based on the customer building's stated peak demand, the negative effects become less for the producer. Using a transparent connection fee linked to capacity is recommended.

Overestimation of the annual cooling energy usage is worse and may have a serious impact on project economics if too high annual income is calculated and not realised in practice. However, by benchmarking with other similar customers in other projects, climate data and careful inventory of the properties many uncertainties can be clarified.

9.4 CHOOSE THE OPTIMAL PRODUCTION SOLUTION FOR THE DC SYSTEM

"Decentralised absorption chiller solutions". Some energy companies in Sweden, Austria and Germany have started cooling business by providing decentralised absorption chiller solutions. Examples can be found in cities like Gothenburg, Vienna, Berlin, Düsseldorf and Munich. Some cities also have stand-alone installations of small local institutional solutions in airports.

A decentralised absorption chiller solution stands for an absorption chiller driven by heat from the current District Heating network is located in a sub-area or in the customers' buildings. The idea with this solution is to avoid installation of a DC pipe network. Initially it sounds great, however there are issues that must be considered.

There are some advantages with this solution:

- Excess capacity in the production of District Heating system can be used.
- Positive on the electricity balance. Electricity for chillers can be avoided and higher CHP production possibility.
- Environmental strength due to saving electricity that would otherwise power chillers.
- Avoiding investments in a District Cooling network

But these advantages are balanced by disadvantages which often are disregarded:

- The District Heating network temperature is in general lower than required for operation of absorption chillers during the summer season with high cooling demand. The network temperature must be raised resulting in increased energy losses.
- Low ΔT in the District Heating circuit driving the absorption chiller; will damage the District Heating network return temperature. This will decrease heat recovery in the flue gas condenser and make it generally harder to use waste energy and heat pumps for District Heating production. Higher return temperature also leads to reduced power production in CHP-plants.
- The customer will lose the added value associated with District Cooling connections; simplicity, flexibility, saving local space and improved local environmental conditions.
- Difficult to achieve profitability in the local small business

- Complicated permitting issues
- Need of placing cooling towers on a roof top. Since COP for absorption chillers is lower, the cooling towers will be much larger than for electrical chillers
- Always need reserve chillers on site compared to District Cooling

One general observation is that providing cooling by decentralised absorption does not lead to a market penetration and the business usually is stagnant. The cooling deliveries never correspond to the potential each city has. Cities with large scale DC and only 100,000 inhabitants have cooling market shares that cities with 1,000,000 inhabitants and using decentralised absorption have hard time to reach. No energy company providing only decentralised absorption presented positive financial results.

Institutional District Cooling (stand-alone solutions for one customer) like airports are generally hard to integrate into larger District Cooling systems, due to the distance to other customers.

Providing decentralised absorption should only be used for customers that are not reachable within the DC network. The conditions are also that the energy company must have a stable large scale DC business. Only then is it possible to distribute fixed costs on many customers.

The second problem is keeping competence in the utility company on a non-expanding product. The interest of working with cooling will be low. Expanding and challenging assignments are always more interesting than business as usual. There are even cases when the energy company only sell heat to the customer. It is not known how much is used for heating and cooling. The customers then need to solve all O&M themselves. Basically it is then just the same case as having their-own alternative chiller solution.

9.5 TOO LITTLE ATTENTION ON ΔT RISKS

Lack of quality control on approving customer's installations and reducing low ΔT problems is hard to correct at a later stage since the project team will be occupied with other on-going activities. When a customer shows too low return temperature, a prompt action is required. Do not wait until it is too late and the system suffers from lack of capacity due to too high flow and low return temperature.

Many examples exist of systems where the supplier initially not focuses on the ΔT , for the first customers. The pipe system still has no capacity limitations. It can even be so that the supplier is so eager on connecting customers that they do not deal with the problem.

It is essential to have technical requirements for DC connections. Technical requirements on how the building should be connected to the DC system. Adaptation of the building cooling systems must have high attention and be enforced. No DC system is better than the return temperature that the customer's installations perform.

Too low ΔT in a DC-system have mainly three negative consequences; lack of capacity in the distribution network, high pumping energy costs and reduced utilisation of natural cooling resources. This leads to higher costs, decreased efficiency and lower environmental benefits.

A DC-system with bottlenecks due to excessive flow will restrict possibilities of connecting future customers and hereby reducing the potential income. Natural cooling resources, such as lake- or sea water, etc., will also be limited.

9.6 LACK OF RESPECT FOR THE TIME PLAN

The process to develop a DC system is long with a number of milestones on the way. The time-plan shall be realistic. If it is realistic there is no reason not to follow it.

It is recommended to hang up the time plan on activities that are possible to influence, such as; “send in permit application” instead of “permit application approved”. Then it is also possible to work with a slightly aggressive time plan.

A usual situation is that the start of an activity is dependent of the end of another activity, but it is also so that in many cases it is possible to start a new activity although some uncertainties remain from previous activities.

Work hard to reach identified milestones in time, in case of delays; see if activities planned for a later stage can be started up earlier.

9.7 TO LITTLE FOCUS ON PERMIT ISSUES

When a DC-project involves circulation of sea-, lake- or river water one or more environmental permits are required. One of the prerequisites will be that an Environmental Impact Assessment study is carried out and presented, the recommendation is to start immediately with the EIS.

Important input data is annual and maximum water flow, temperatures, construction period, etc. Make sure that the volumes of water, temperature differences, etc. applied for are sufficient but make sure that, especially the temperature program, does not exceed existing regulations.

Start the permit activities immediately and make sure that the personnel or consultants which are handling the activities have the necessary knowledge and time available.

9.8 PIPES SURVEILLANCE SYSTEM NOT ADAPTED FOR COOLING DISTRIBUTION

If steel pipes with PUR insulation and HDPE jacket pipe are used for the distribution network the built-in surveillance system must be adapted for cooling. It has shown that traditional surveillance systems with uninsulated copper wires moulded into the foam give too many false alarms when used for cold water pipes. In surveillance systems for cooling water pipes are insulated wires on fixed distance between each other used; moisture is detected by measuring the change of impedance between the wires.

10 FINAL DISCUSSION

In all the good practise cities all had their share of both good practices, barriers and failures.

The main thing that is common for all the DC schemes are, that to be able to get it profitable three things are needed:

- Strong market focus so that the right capacity and energy are sold to the customers to the correct price.
- Chosen technology that is optimal for the local conditions. It has been flexible and robust so it can grow with the market demand and also survive changes in prices for

energy sources. Key issues for this is using local energy sources and “Economy of scale” to maintain a low (Opex) operation expenditures.

- Strong local stakeholders that have believed in the DC product and made it happen. The municipality or the local energy companies have been able to develop the product with its own cash flow.

Cities that have successfully developed DC schemes have had a long experience in distributed energy (District Heating). This knowledge should also not be underestimated. Both the customers and the cities know the local energy company and trust the DH product. They know that it works, so why should DC be any different? The LA and local energy company also have longstanding experience in distributed energy and then the step to develop DC is not that high. This can be one reason why for example Paris has a District Cooling system and London does not.

11 KEY PERFORMANCE INDICATORS

What kind of technical solution and business concept that are used to develop a DC scheme is as said much depending on the local conditions in form of market density, local energy sources and the cost of using these sources.

For cities/ municipalities that are interested in study a DC scheme already in operation should study a city that have the same conditions as the good practice system has.

11.1 MARKET INDICATORS

The city or a part of the city should be in the right size and density. This means that there should be a high density of cooling demand on a limited ground area as the good practice cities have.

Key performance indicator: [number of inhabitants]

- Market potential, rough estimate of the total cooling potential in the city area
 - Key performance indicator: [MW]
- How does the outdoor climate affects the comfort cooling demand in the city
 - Key performance indicator: ECI (European Cooling Index) [-]

11.2 TECHNOLOGY/ SOURCING INDICATORS

Does the prospect city have an access to any natural cooling sources as sea, river or lake water as some of the good practise cities have. The city may also have access to some kind of waste heat from CHP, industrial process or waste incineration.

- Possible energy source to utilise
 - Key performance indicator: Type of source, ex. Sea water [-]

The city/ municipality can be densely populated with buildings with high cooling demand or the cooling demand can be more widely spread in the city area.

- Length of distribution system
 - Key performance indicator: Distribution system length [km]

11.3 ENVIRONMENTAL INDICATORS

The DC product must have a better environmental profile and performance than the alternatives.

- High environmental performance of the DC product.
 - Key performance indicators:
 - Primary Energy Factor (PEF), [-]
 - Carbon dioxide emissions, [kg/MWh]

From a cooling perspective the primary energy and carbon dioxide emissions are the most important indicators due to the fact that RES is already considered in non-renewable primary energy factors and is not required as separate criteria. For more information about environmental factors from a cooling perspective see (Rescue-project, 2013).

Climespace. (2013).

Fortum Värme AB. (n.d.).

Frohm, Henrik; Capital Cooling. (n.d.).

Koski, Kostj; Helsinki Energia OY. (n.d.). Finland.

Norrenergi AB. (n.d.). Retrieved from www.norrenergi.se

Rescue-project. (2013). *Environmental factors from a cooling perspective*. Stockholm: Rescue-project.

Tvärne, Anders; Capital Cooling. (n.d.).

Växjö Energi AB. (2012). www.veab.se. Retrieved from
<http://www.veab.se/Fjaerrkyla/Utbyggnadsplaner.aspx>

APPENDIX 1: Description of the six selected good practice systems

Paris

Vienna

Stockholm

Solna/Sundbyberg

Helsinki

Växjö