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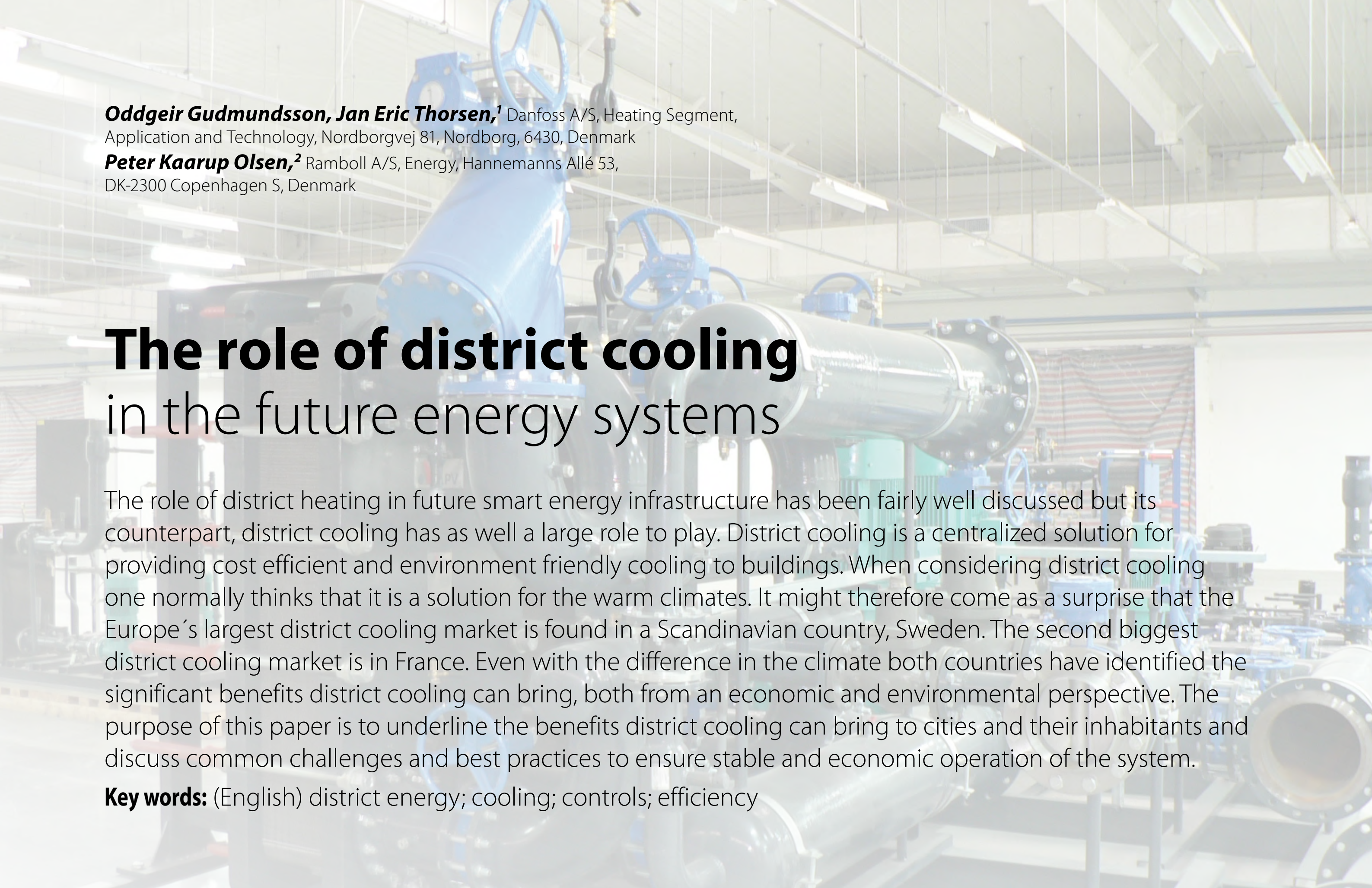

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The role of district cooling in the future energy systems

The role of district heating in future smart energy infrastructure has been fairly well discussed but its counterpart, district cooling has as well a large role to play. District cooling is a centralized solution for providing cost efficient and environment friendly cooling to buildings. When considering district cooling one normally thinks that it is a solution for the warm climates. It might therefore come as a surprise that the Europe´s largest district cooling market is found in a Scandinavian country, Sweden. The second biggest district cooling market is in France. Even with the difference in the climate both countries have identified the significant benefits district cooling can bring, both from an economic and environmental perspective. The purpose of this paper is to underline the benefits district cooling can bring to cities and their inhabitants and discuss common challenges and best practices to ensure stable and economic operation of the system.

Key words: (English) district energy; cooling; controls; efficiency

1. Introduction

Cooling energy demand within Europe is today low compared to countries like U.S. and Japan. In U.S. the commercial and residential cooling saturation is 80% and 65% respectively, in Japan it is 100% and 85% respectively [3]. Europe on the other hand has cooling saturation of only 27% and 5% respectively [1].

1.1 European market prospects

The cooling demand in Europe is therefore expected to rise significantly. Key parameters that influence the cooling demand are building design, internal heat loads, heat island effects, and comfort reasons. Given the current low cooling energy demand saturation in Europe gives the perfect opportunity for establishing district cooling system and avoiding investment in conventionally small scale and decentralized electric driven compressor chillers. By not relying on decentralized approach's significant primary energy usage, greenhouse gas emissions and peak electricity demand can be avoided. Experience in the U.S. shows that fouling is a common problem in chillers, according to the HPAC Engineering webpage the average fouling in water-cooled chillers creates a 17% increase in energy consumption. This is not a surprise as a biofilm of only 150 microns (0,15 mm), which is so small that it is typically over looked, causes 5.3% increased energy consumption in cooling tower based chillers [2].

District cooling is about outsourcing of cooling units in buildings to an external cooling utility which has high focus on the performance and efficiency of the cooling plants. Once the cooling utility has been formed it will establish a pipe network for connecting multiple buildings to one or more cooling sources using various resources for generating the cooling. Cooled water is circulated from the cooling sources to the buildings, where heat exchangers are used to extract heat from its cooling system, and then back again to the cooling sources to be cooled again. Both the property owner and the environment benefit from this. In addition to monetary and environment benefits there is an added supply security for the building owners.

Although the first district cooling systems were introduced in the 1930's for cooling of the Rockefeller Center in New York and U.S. Capital Buildings in Washington DC district cooling in Europe took its first steps in 1990s. In Europe district cooling has shown an exponential growth where it has been established, until the local market has been saturated. Even though district cooling is reaching its 30 years anniversary in Europe it is still a rather unknown solution and has a market share of about 1% or 3 TWh/year [3]. Considering that Swedish district cooling system alone delivers almost 1 TWh/year [4] the growth potential is enormous.

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There are many reasons why municipalities and energy companies have started up district cooling schemes. Reasons that are commonly named are a) synergies with existing district heating systems, b) increased utilization of existing combined heat and power (CHP) plants during the summer, c) new development on the market, d) existing high cooling demand and e) demand for more green energy profiles, both at the utility and potential consumers. Almost all energy companies that have district cooling systems mention these points which imply that there is a business and market driven approach.

Currently the main markets for district cooling in Europe are commercial buildings, which typically need large connection capacities and cooling throughout the year.

2. District cooling

2.1 Arguments for district cooling

Urbanisation, globalisation and rising cooling demands have led to an increased interest in the environmental and economic benefits of district cooling.

Similarly as with district heating the main driving power of district cooling comes through economy of scale, its indifference on the origin of the cooling and its ability to maximize the operational efficiency across multiple cooling sources by taking advantages of simultaneity of demands, which would be impossible to accomplish on a building level. This makes it more cost effective than locally based cooling such as central air conditioning.

Besides the above mentioned power drivers there are multiple alternative benefits, the frequently mentioned are:

- District cooling substations require significantly smaller space than building level chillers and thus frees up valuable space in the building. Further, cooling towers can be removed from for example rooftops.
- District cooling typically results in significantly higher energy efficiency through greater flexibility of optimizing cooling production over time and cooling sources.
- District cooling substations are relatively simple and well proven technology through decades of usage in district heating systems, thus resulting in lower maintenance costs than building level cooling units.
- District cooling both reduces and optimizes electrical loads over the day, leading to significantly reduced electrical peaks. Thus a reduction of energy usage is achieved through greater efficiency. This makes it possible to utilize free cooling or heat driven cooling units. This leads to optimization by decoupling demand and production by utilizing large scale thermal storage. An example of a seasonal storage is ATES (Aquifer Thermal Energy Storage) which opens up a possibility for storing large amounts of free cooling available at certain periods of the year for optimizing the production in peak demand periods.
- District cooling reduces HFC handling.
- District cooling is a silent system - no noise at the building which increases the comfort for users.
- District cooling has architectural advantages, i.e. no need to consider cooling fans, chillers and other auxiliary systems.
- District cooling has been shown to contribute to higher building value through its multiple benefits.
- District cooling has less demand for technical staff on building level (building owners / operators)
- District cooling is environmental beneficial
- District cooling increases energy security by utilizing local sources and maximizing efficiency of all cooling units.
- District cooling is a very resilient technology. The system can be operated from all cooling sources. The system can quickly adapt to fuel price pressure through pooled cooling sources and multi-fuel plants.
- With co-production of district heating with heat pumps, it can be possible to achieve very compatible heating and cooling tariffs.

2.2 Technological benefits of district cooling in terms of savings for Europe

District cooling can greatly reduce the peak power demand during the cooling season. A great example was documented in Cleveland in 1994/95, see Figure 1.

According to [1] district cooling in Europe could avoid electrical capacity requirements of 50 GWe and corresponding new investments of 30 billion Euro in the power infrastructure. These saved 30 billion investment would account for approximately 40-50% of the investment required for establishing the required district cooling infrastructure. Further, district cooling would save 50-60 TWhe per year,

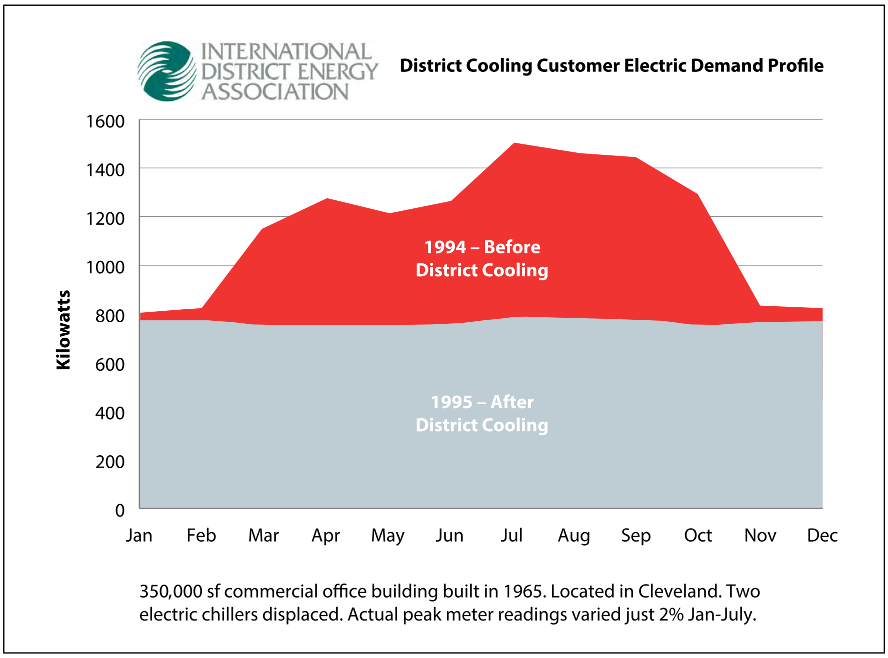

FIGURE 1: Example of how district cooling could change the electrical demand profile across the year [5]

equivalent to power consumption of Greece. In terms of CO_2 emissions district cooling would avoid 40-60 million tons of CO_2 emissions per year (15% of Europe's share in the Kyoto protocol).

On country level can as an example be mentioned Cooling Plan Denmark [6], which states that the potential for district cooling in the country of Denmark is estimated to be about 2.4 GW cooling. This would result in an enormous socio-economic saving of approx. 1.3 billion EUR.

A district heating and cooling system could look like shown below.

The district cooling consumer interfaces are industrial prefabricated and typically offered on a frame in one or multiple sections, depending on the size.

3. Common challenges

There are number of common challenges when running district cooling systems, below are few of the most commonly mentioned are:

- Large upfront investments when few cooling costumer agreements are made / few cooling customers connected
- Finding space for the district cooling facilities: Technical components (in a building), thermal storage, pipe tracing (large dimensions) can pose challenges, especially in city centre areas
- Ensuring noise reduction of very large chillers / heat pumps. This challenge can be solved with sufficient insulation components
- Low temperature difference between the supply and return, commonly known as low dT syndrome.

All of those challenges can be overcome by sticking to good preparation work, known solutions and focused operation.

4. Driving factors for district cooling

A common nominator for district cooling system is the strong growth once it is started, the growth typically continues until the market is fully saturated few years later. Great examples can be seen in Stockholm and Helsinki.

Driving factors behind the general strong growth seen when district cooling systems are constructed are:

- Increasing affordability, due to its high efficiency compared to standalone units.
- Shifts in comfort culture, behavioural patterns and consumer expectation
- Increase in internal heat loads (computers etc.)
- Increase in urban heat island phenomenon and a general trend towards higher temperatures
- Perception that comfort cooling contribute to higher productivity
- Movement towards universal building designs which are poorly adapted to the local climatic conditions

Market experience from US shows that once 20% of the office space in a city is air conditioned it sets the rental value and un-cooled space can only be rented out at discount price.

5. Conclusions

It is a fact already today more energy in the world is used to cool buildings then heating buildings. The energy need for cooling is also expected to grow in the future along with higher comfort requirements from emerging markets. To fulfil the growing cooling demand more and more countries are realizing that district cooling provides a simple, easy and cost efficient way to

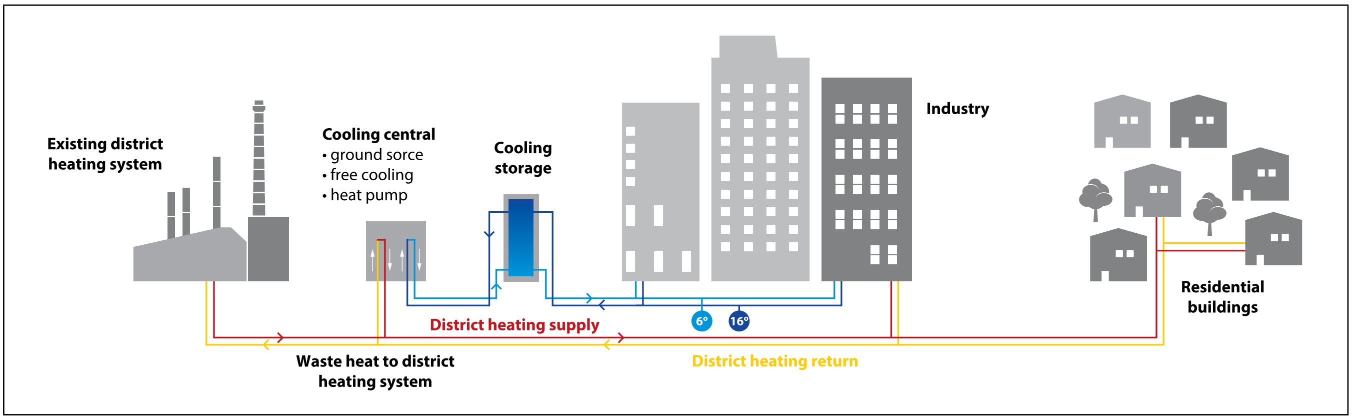

FIGURE 2: Supply concept for combined district cooling and heating

FIGURE 3: Typical prefabricated indirect substation for district cooling

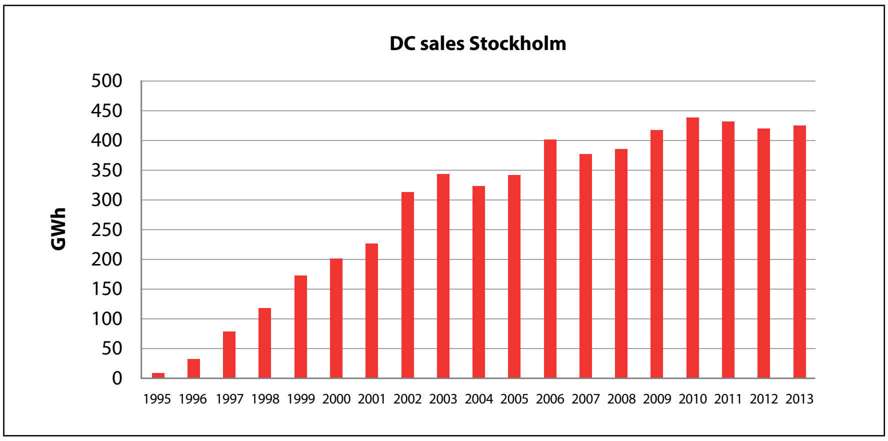

FIGURE 4: District cooling growth in Stockholm, Sweden [3]

provide cooling with high quality and consistent comfort. Further benefits of district cooling are that it provides the ultimate means to take advantage of renewable energy sources in a cost and environmentally efficient way.

In cases where an existing district heating system have been in a city it has proven to be rather simple to start district cooling systems, because the consumers then know the technology and the benefits it brings. It has further been shown that even in colder regions, like Sweden and Finland, district cooling can be very economically attractive, which should give a good indication on the attractiveness in warmer regions.

High focus needs to be put on planning, designing, building and operating the district cooling systems to avoid running into a situation that can greatly impact the cost efficiency of the whole system. By adhering to best practices the future of district cooling is bright.

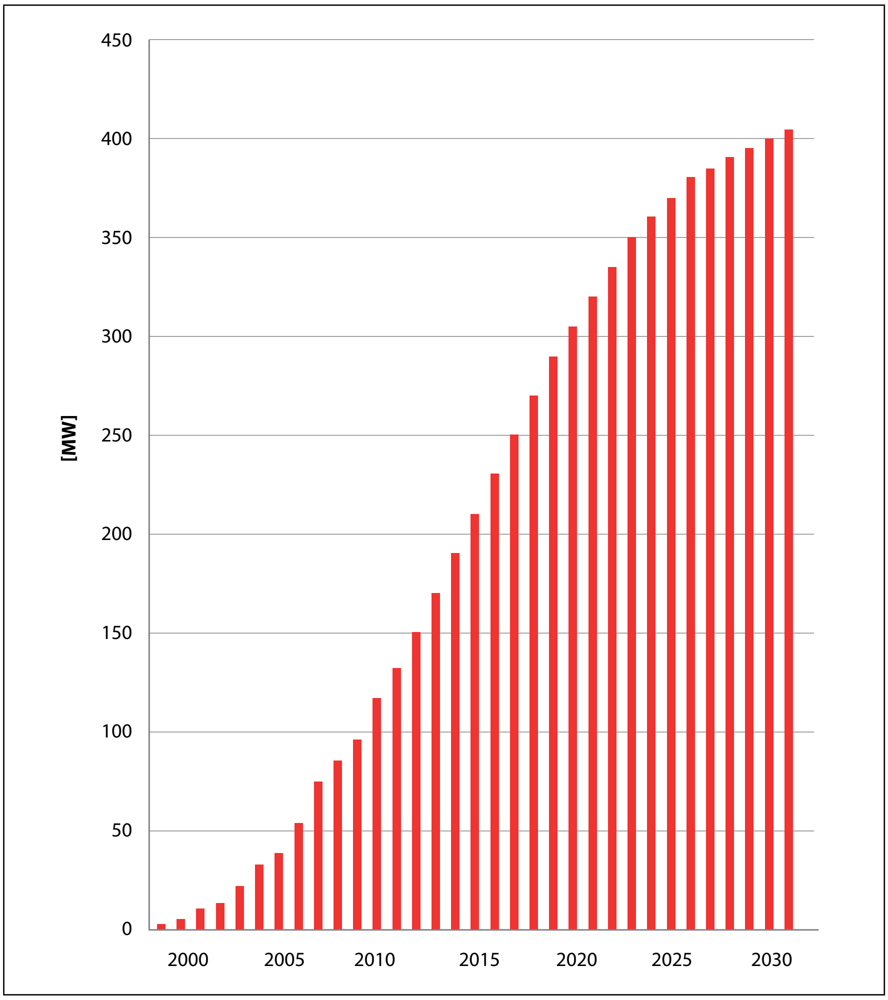

FIGURE 5: District cooling growth in Helsinki, Finland, from 1998 to 2012 and project growth to 2030 [3]

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