SUMMERHEAT

Meeting cooling demands in SUMMER by applying HEAT from cogeneration

Publishable Report

Supported by

Intelligent Energy Europe

Preface

The publishable report is a product of the SUMMERHEAT project
EU Intelligent Energy Europe Programme **EIE-06-194**.

More information on the SUMMERHEAT project is available at:

http://www.eu-summerheat.net

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Contents

1 Basic Project Data

SUMMERHEAT

Coordinator:	Berliner Energieagentur GmbH, Germany
Partners:	Austrian Energy Agency, Austria Fernwärme Wien GesmbH, Austria Cityplan spol. s.r.o., Czech Republic Rhônealpénergie-Environnement, France Energy Consulting Network, Denmark Københavns Energi, Denmark National Energy Conservation Agency, Poland Euroheat & Power, Belgium
Website:	http://www.eu-summerheat.net
Objective:	Increase waste heat usage in summer to improve the economics of cogeneration and the environmental performance of cooling
Benefits:	Increase the share of cogeneration based thermal cooling, reduce primary energy demand and CO_2 emissions
Keywords:	Cogeneration – Waste Heat – Thermal Cooling
Duration:	11/2006 – 12/2008
Budget:	€ 769,253 (EU contribution: 50%)
Contract number:	EIE/06/194/SI2.439979

SUMMERHEAT brought together nine partner organisations from all over Europe to develop strategies for the increased usage of Summerheat in the participating regions. Based on in-depth market analyses of both the supply technologies and the demand side, proposals to improve the framework conditions were developed. Building owners and planners were addressed by a guideline that gives them comprehensive information about Summerheat. Feasibility studies demonstrated the advantages of Summerheat

2 Executive Summary

Background

SUMMERHEAT assessed the political framework and market conditions within the European Union to use waste heat from combined heat and power (CHP) technologies and incineration plants in district heating networks during summer for the operation of cooling applications (chillers). The current low demand for this "Summerheat" is one of the main bottlenecks for an increased use of CHP-technologies and incinerators because it influences the economics of power parks based on combined heat and power (CHP) generation technologies. An increase in CHP plants however is desirable due to their high primary energy (resource) efficiency.

Using Summerheat to operate chillers has several benefits including:

- an improvement of the economics of the power park, of the district heating system in general and of CHP and incineration plants in particular
- a reduction in primary energy demand as it is more energy efficient than standard cooling systems.

Therefore SUMMERHEAT also indirectly supports the reduction of CO_2-emissions in the EU and contributes to a secure supply of energy.

Objectives

- Providing an overview on the current market situation for Summerheat in Europe i.e. identified technologies for thermal cooling, their economic and environmental performance as well as the demand for cooling based on Summerheat
- Specifying the framework conditions in the partner countries including the barriers
- Removing barriers through targeted actions addressing the key actors on national and international level, i.e. presenting recommendations for an efficient policy support
- Building regional cooperation networks between the key actors, e.g. investors, municipalities, district heating suppliers
- Developing a roll-out strategy for an increased use of Summerheat: Implementing a dissemination strategy on international and national level to encourage project development throughout Europe
- Provide best practice examples

Results

The direct outcomes for the seven EU regions that participated in the project include:

- Legislative and political framework descriptions (country reports)
- Market reports regarding the use of Summerheat (utilisation and potential)
- Ecological and economic comparison of Summerheat in comparison with conventional air conditioning application

- One feasibility study for each of the seven regions
- Interaction with key actors from the supply side (investors, project developers, energy utilities, chiller manufacturers) in expert workshops in the seven regions
- For energy supply companies: workshops and support in defining strategies for an increased use of Summerheat
- For policy makers and lobbyists: proposal for effective policies regarding the market conditions for cogeneration technologies and thermal cooling
- For the general public: articles in respective journals and magazines
- For international expert audience: three presentations at Euroheat & Power events and workshops

Outcome

TECHNOLOGY PERSPECTIVE

For the production of cooling using waste heat, single-effect LiBr absorption chillers are the technology of choice. They are a market mature technology and can be operated efficiently even using heat with a temperature of around 90 °C. None of the regions within the project group could identify technological barriers to provide cooling using this technology.

ECOLOGICAL COMPARISON

- Thermal cooling has (significant) advantages over compression cooling: The primary resource factor calculation (PRF) shows (in some cases even significant) ecological advantages of absorption chillers over compression chillers.
- Central applications have advantages over decentral applications: Due to the effects that can be reached through economies of scale (in ecological and economic terms), central solutions should be preferred to decentral solutions wherever possible e.g. in newly built areas or in cities where underground preparations have been undertaken in advance.
- In established urban centres (where grid construction costs are immense) and in areas with too little cooling demand density, decentral solutions should be deployed. As a scenario calculation from Germany shows, ecological advantages over conventional, compression chillers are also prevalent in decentral installations.
- Free cooling combined with central applications reaches the lowest PRF: Free cooling should be used additionally to absorption cooling wherever possible. A district cooling network, centrally supplied with absorption and free cooling as in Copenhagen shows the best environmental performance to all other options calculated within the project team.

ECONOMIC COMPARISON

- Compression cooling has lower production costs up to 500 kW installed capacity and 1000 full-load hours: Within the economic comparisons made, compression chillers generally showed lower production costs (€/kWh) than absorption chillers in small and medium ranges (< 500 kW) of installed capacity and full-load ranges around 1,000 hours. The difference in production costs decreases with the increase in installed capacity and full-load hours. Hence, central absorption chiller installations are more competitive than decentral installations.
- The costs for thermal cooling are mainly dependent on the costs for the investment (i.e. machines) and the price for waste heat.
- The costs for compression cooling are mainly dependent on the operational and maintenance costs.

MARKET ANALYSES

- In all analyzed regions, the cooling demand is expected to increase over the coming decade. To match the cooling demand efficiently, the utilisation of waste heat could play a significant role. None of the involved partners could identify technological barriers for a market development.
- The market analyses show that apart from the price, soft consumer demands matter. Examples include space occupation, noise reductions, as well as maintenance and control requirements. Here, absorption chillers show advantages over compression chillers. Thus, when combining soft and hard factors, centrally installed absorption chillers could become a competitive alternative to compression chillers.

NATIONAL STATUS AND ROLLOUT STRATEGIES

The roll-out of the Summerheat concept varies from region to region. While some regions start with the supply of "cold spots" through central solutions (Vienna, Copenhagen), the majority of partners is pushing for an expansion through decentral solutions (Szczecin, Berlin, Hamburg, Prague, Grenoble). Respective projects have been launched with the energy utilities during the SUMMERHEAT project.

POLICY LEVEL

- Specific legislative support for thermal cooling is not common in the EU. Indirect measures through the support of CHP installations are more common. Supporting CHP should, however, automatically consider a levelling-out of heat demand throughout the year.
- Policy instruments – at European and at national level – for evaluating efficiency of end-user solutions should be based on primary resource factors.
- A level playing field should be created – at EU and national level - for district cooling solutions and local authorities should reduce administrative barriers (i.e. provide licenses, permissions).
- Local authorities should cooperate with industry to engage in proactive energy planning.

3 Introduction

The development of an efficient energy supply within the European Union is a recognized necessity. It is needed to lower the high dependency on energy imports, to counter rising prices for fossil fuels, and to fulfil the obligations for climate protection. The further development of energy efficient CHP is a substantial element for the success of the European energy strategy. The main bottleneck for an increased use of capital-intensive CHP technologies and waste incinerators in district heating systems is the low system load during summer months. Hence, especially in summer the waste heat from CHP-technologies and incineration plants in district heating networks (Summerheat) can be used as a heat source for the operation of chillers.

Within the project, strategies for the increased use of Summerheat were developed for the participating regions. Proposals for improving the framework conditions were addressed to policy makers; building owners and planners were addressed by a guideline that gives them comprehensive information about Summerheat. The work was based on an in-depth market analysis of both the supply technologies and the demand side. Feasibility studies were carried out in all involved regions in order to demonstrate the advantages of Summerheat to interested building owners.

There are many advantages to district cooling compared to traditional cooling systems. Producing cold during summer from surplus heat (Summerheat sourced from CHP plants and incineration plants) generates the following benefits to society:

- Up to 30% fuel savings
- Up to 80% electricity savings
- Up to 65% CO_2 reduction, and
- Removal of HFC/HCFC emissions

District cooling using Summerheat is energy efficient, reduces electricity consumption and may eventually also prevent electricity shortages. Hence, district cooling provides an opportunity to adjust to the standards set by the Kyoto Protocol and to newer, stricter environmental norms for improved local environments.

For energy utilities and supply companies, district cooling is an innovative concept that offers great opportunities to expand and/or diversify their businesses and it fits well into corporate social responsibility policies (i.e. sustainable energy supply). On the one hand, the use of surplus heat from CHP and incineration plants improves the cost efficiency of supplying cooling. On the other hand, suppliers benefit from improved economics of power parks based on combined heat and power generation technologies because the use of Summerheat assures higher efficiency of the energy sources.

The main benefit for consumers is that professional companies assure cooling production and transportation outside the building (safes floor space). District cooling fits well into the general trend of outsourcing building operations. The improved cooling efficiency of a district cooling system compared to the existing compressor-based chillers is a primary motivation. Furthermore, there are no hidden costs because cooling costs are not included in the electricity bill.

The following seven regions have participated in the Summerheat project:

- Berlin and Hamburg (Germany)
- Copenhagen (Denmark)
- Grenoble (France)
- Prague (The Czech Republic)
- Szczecin (Poland)
- Vienna (Austria)

This report presents the following aspects that have been investigated in the different regions:

- **Thermal-driven cooling technologies**: Description of technical solutions to use Summerheat for cooling-systems (chapter 4)
- **An ecological assessment of thermal cooling**: Ecological comparison of identified technical solutions; presentation of the applied methodology (primary resource factor) (chapter 5)
- **An economic assessment of thermal cooling**: Comparison of the cold supply costs of Summerheat with standard cooling-systems (chapter 6)
- **The market - Demand for cooling**: Presentation of the market and its expected development (chapter 7)
- **Summerheat - Perceived customer benefits**: The advantages of district cooling (chapter 8)
- **Political Framework**: Political framework for district cooling (chapter 9)
- **Best Practices**: Presentation of three best practice examples, including evaluation of economic performance, functionality, operator convenience and the transfer potential to other EU-regions (chapter 10)
- **Roadmap to Summerheat** (chapter 11)

4 Thermal-driven cooling technologies: A Review

At present cooling mainly works with electrically operated compressor chillers, which intensify the existing power supply problems such as high peak loads in summer, dependency on power import and higher CO_2 emissions. Cooling systems running with thermal energy from district heating (DH) networks, can work against this trend.

There are several thermal driven cooling technologies, many of which could be used for the production of the required cold based on Summerheat. However, there are several restrictions which limit the technologies that can be applied.

From a technological point of view, there are two different operational principles: absorption and adsorption. In either case they are based on a working pair of a refrigerant and a sorption medium. In the case of absorption, the refrigerant is absorbed by i.e. dissolved in the sorption medium, while it is only adsorbed in the case of adsorption chillers. Currently, there are four different refrigerant-sorption-medium combinations available as shown in the following table.

Principle	A**b**sorption		A**d**sorption	
Type			Closed	Open/DEC
Refrigerant	Water	Ammonia	Water	Air
Sorption medium	Lithium-Bromide	Water	Silicagel	Silicagel or Cellulose/Lithium-Chlorine

Available thermal cooling applications

The first restraint for the usage of any of the listed thermal cooling principles lies in the secondary system i.e. the required in-house infrastructure. In the case of an open adsorption process (DEC), an air condition system is needed to distribute the cooled air in the building. As one of the aims of SUMMERHEAT is to provide cooling also to houses that have no air condition distribution system yet in place, the DEC option is not considered. The requirement is to have a water-based cooling process.

H_2O/NH_3 absorption is not considered as the application is mainly used in industrial and retail cooling applications and not for air conditioning purposes. The refrigerant NH_3 can be cooled down to much lower temperatures than water (down to -60°C). This however also means that the application requires a higher inlet temperature ranging around 110-180°C – which are almost impossible to achieve solely through district heat.

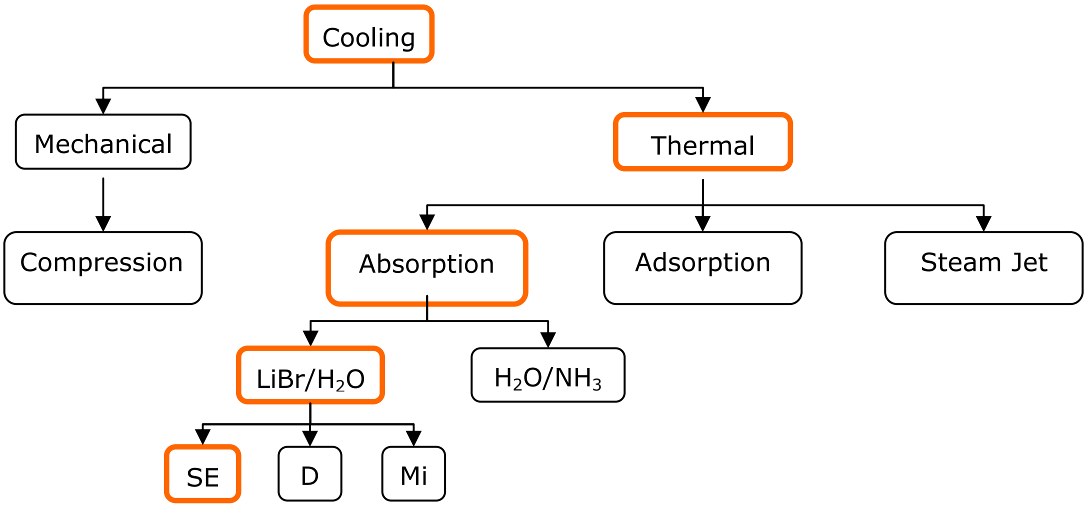
The same applies to double-effect $LiBr/H_2O$ absorption chillers. Here the chiller makes twice usage of the inlet heat. While they have a more beneficial coefficient of performance (COP), their inlet temperature requirement is too high for the sole operation with district heat.

Thus, two options are compared to each other: $H_2O/LiBr$ absorption and H_2O/Silicagel adsorption.

	Thermal				
Technology	Absorption				Adsorption
Type	$LiBr/H_2O$ single-effect	$LiBr/H_2O$ double-effect	$LiBr/H_2O$ single-effect/double-lift	H_2O/NH_3	H_2O/Silicagel
Heat source	warm water, district heat, steam	steam, direct fired	district heat	steam, district heat, solar thermal heat, steam	low heat source is sufficient
Inlet Temperature	75 - 110°C	135 - 200°C	80 - 100°C	100 - 180°C	55 - 90°C
Capacity	(15) 35 kW - 12 MW	200 kW - 6 MW	600 kW - 6 MW	100 kW - 10 MW	50 - 500 kW
COP	0.6 – 0.8	0.9 – 1.3	0.4 – 0.75	0.25 – 0.5	0.5 – 0.7
Price / kW_{th}	1,200 - 200 €	-	> 400 €	1,250 - 400 €	1,500 - 350 €
Space	(1.8) 15 - 96 m^3	17 - 56	25 - 168 m^3	> 50 m^3	12 - 70 m^3
Weight	(0.6) 5 - 41 t	10 - 30 t	15 - 60 t	> 11 t	5 - 25 t
Application	Air-conditioning	Air-conditioning & industrial	Air-conditioning & district cooling	Retailing, industry	Air-conditioning
Market penetration	high	high	small	small	small
# Suppliers	> 8	> 5	Entropie (Patent)	> 2	2

Comparison between different thermal cooling options

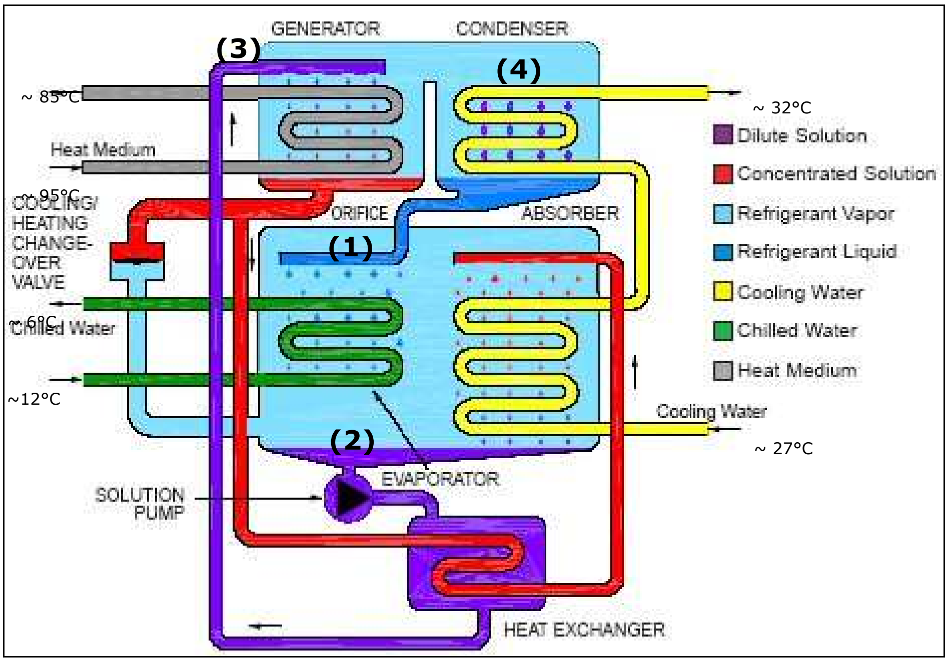
Comparing H_2O/LiBr absorption and H_2O/Silicagel adsorption to each other, it seems that the latter one lacks a high market penetration, the number of suppliers is low, the COP is lower and the space requirement (per kWh) is higher. Hence, the technology of choice analysed here will be single-effect LiBr/H_2O absorption chillers.



Overview: Thermal cooling technologies

Absorption

In comparison to conventional compression chillers where the refrigerant is compressed mechanically, thermal based chillers compress the refrigerant using a heat source. In an absorption chiller this is done in a combined refrigerant-sorption-medium cycle. Electric power is only needed for the operation of the solution pump. The work diagram for the absorption process is shown in the following figure.

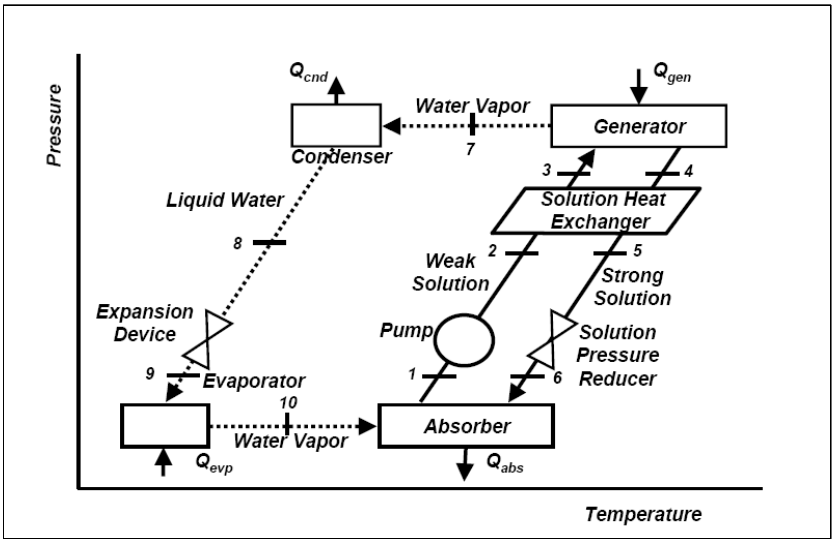


Basic single-effect absorption working cycle[1]

[1] Source: Yazaki Energy Systems Inc., http://www.yazakienergy.com/waterfired.htm (May 22nd, 2007)

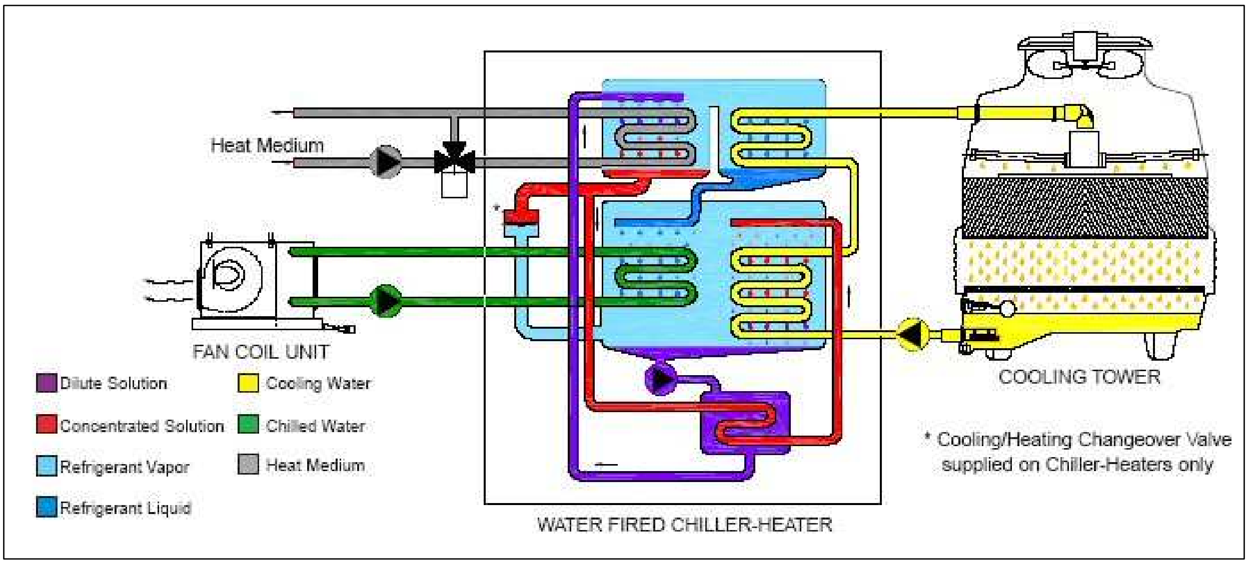
Starting at the evaporator (1), the basic working principle for a H_2O/LiBr absorption chiller is as follows: the refrigerant water is evaporated on a low temperature and pressure level. It is then absorbed by the LiBr sorption solution (2). The diluted solution is then pumped on a higher pressure level where the refrigerant (water) is released as a vapour by applying thermal heat (3). The refrigerant is then condensed i.e. put back into liquid form in the condenser (4). After moving through an expansion valve the liquid refrigerant (water) is vaporised again.

The different temperature and pressure levels as well as heat sources and heat sinks become more obvious when looking at the following temperature-pressure diagram of the process. Here it is obvious that there are two heat sinks (generator and evaporator) as well as two heat sources (condenser and absorber) in the process.



Temperature-pressure diagram of the absorption process

Taking this into consideration, the complete set-up of a single-effect absorption chiller includes a fan-coil unit to distribute the cooling in the respective rooms as well as a cooling tower to get rid of excess process heat. This is relevant for the economic comparison.



Peripheral connection of a single-effect LiBr absorption chiller[2]

Other technical influencing factors for the economic comparison are the heat inlet temperature as well as the COP level. Generally, the hot water cycle has a temperature inlet level between 75-130°C. The higher the inlet temperature, the better the cooling efficiency of the machine. Furthermore, the heat source temperature should be relatively constant.

The ratio between the cooling output and the thermal energy input - the coefficient of performance (COP) - influences the economics of the absorption chillers. Usually COPs are between 0.6-0.8 for single-effect LiBr absorption chillers. However, they depend strongly on the cooling load or cooling capacity utilisation of the absorption chiller, i.e. the machines only reach their highest COP during full load. Therefore the cooling demand has to be well defined for the dimensioning of the chiller to ensure economic viability.

We differentiate between the centralised and the decentralised cooling unit. For the "centralised" solution, the refrigerating machine is not located at the consumption point. It produces chilled water, which is later distributed by dedicated piping to the different buildings. For the "decentralised" solution, the buildings are linked to the heat network and refrigerating machines produce chilled water in the building using hot water from the heat network. The decentralised production of cold is generally preferred when the construction of a cooling network is not feasible.

In sum, SUMMERHEAT compared three different model cases in terms of their ecologic and economic performance:

- Compressor cooling unit (reference model)
- Absorption cooling unit: Central
- Absorption cooling unit: Decentral

[2] Source: Yazaki Energy Systems Inc, http://www.yazakienergy.com/waterfiredapplication.htm (May 22nd, 2007)

5 Summerheat: An ecological assessment

The comparison of very different cooling technologies and primary energy sources is possible when considering the primary energy used in the whole life cycle, from exploitation to waste. Such different technologies cannot be compared in terms of energy efficiency because energy efficiency is related only to the final process of usable energy production. Thus, to compare the efficiency of different heating and cooling systems, a methodology based on Primary Resource Factors (PRF) is commonly used. PRF defines the ratio between net fossil energy consumption and the amount of heating or cooling energy delivered to the building. Low PRF values, therefore, correspond to efficient systems. High PRF values indicate poor efficiency and high CO_2 emissions. Consequently, should systems with low PRF values increase their market share, it would have a significant and positive impact on energy consumption and CO_2 emissions.

The Primary Resource Factor Method

The PRF defines the ratio between the amount of energy used (based on fossil fuels) and the total useful energy supplied e.g. to a building. The calculation method is based on the European standard EN 15316-4-5 and the outputs of the European project ECOHEATCOOL (Intelligent Energy Europe). The European standard EN 15316-4-5 (adopted in October 2005) provides a method of assessing the energy performance of district heating systems through the calculation of the primary energy factor of a specific district heating system.

The standard formula for the calculation of the primary resource factor is:

$$f_P = \frac{Q_F}{Q_C} \cdot f_{P,F}$$

where:

$f_P \rightarrow$ primary resource factor,

$Q_F \rightarrow$ total input energy consumption,

$f_{P,F} \rightarrow$ primary energy factor of the energy carrier (for example fuel) for the whole process chain.

For compressor cooling, the primary resource factor is determined with the following formula:

$$f_{P,DC} = (W_{CC} \,.\, f_{P,elt}) \,/\, Q_{DC,k}$$

where:

$W_{CC} \rightarrow$ electrical energy consumption of the compressor chillers.

To calculate the primary resource factor of district cooling, we first need to establish the PRF for district heating, the input energy for thermal cooling. When comparing the supply of heat and electricity from a CHP plant with the separate production of heat and electricity, the standard PRF formula needs to be adjusted. The superposition principle is valid while it is necessary to keep the same input conditions principle. Consequently, it is necessary to take off the electricity from the cogeneration when we compare the heat distribution from a heat station (HS) and CHP plant.

Thus, the formula to calculate the primary resource factor for district heating is:

$$f_{P,DH} = \frac{\sum_i Q_{F,i} \cdot f_{P,F,i} - W_{CHP} \cdot f_{P,el}}{\sum_j Q_{DH,j}}$$

where:

DH → district heating,

CHP → combined heat and power,

$Q_{F,i}$ → fuel (final energy) input to the heating plants and to the cogeneration plants within the considered system,

$f_{P,F,i}$ → primary resource factor of the fuel (final energy) inputs for the i-unit,

$Q_{DH,j}$ → heat energy consumption measured at the primary side of j-customers substations, i.e. the heat which is provided for district heating and as an input for thermal cooling systems,

W_{CHP} → electricity production of the cogeneration plants of the considered system,

$f_{P,elt}$ → primary resource factor of electrical power.

To calculate the PRF of a district heating scheme, different fixed values are needed for different fuels. The following values have been used in the SUMMERHEAT project:

Kind of fuels	**PRF**
Lignite Coal	1,3
Hard Coal	1,2
Natural Gas	1,1
Oil	1,1
Excess heat e.g. from industrial processing	0,05
Renewable (e.g. wood)	0,1
Waste as Fuel, Landfill Gas	0
District Heating - external	0,654
Free Cooling	0
Electrical Power, European average	2,5

Calculation of PRF for District Cooling

Having calculated the PRF for district heating, the input for the cooling applications, we can now calculate the PRF for district cooling with the following formula:

$$f_{P,DC} = \frac{\sum_i Q_{F,i} \cdot f_{P,f} - W_{CHP} \cdot f_{P,el} - Q_{DH} \cdot f_{P,Q}}{\sum_k Q_{DC,k}}$$

where:

$f_{P,DC}$ → primary resource factor for district cooling

Q_{DH} → total heat production from the considered system provided to the DH grid for heating purposes (measured at the secondary side of CHPs and heating plants) – $Q_{DH} = \Sigma Q_{DH,j} / \eta_{DH}$,

$\Sigma Q_{DH,j}$ → total heat received by customers,

η_{DH} → efficiency of heat distribution system,

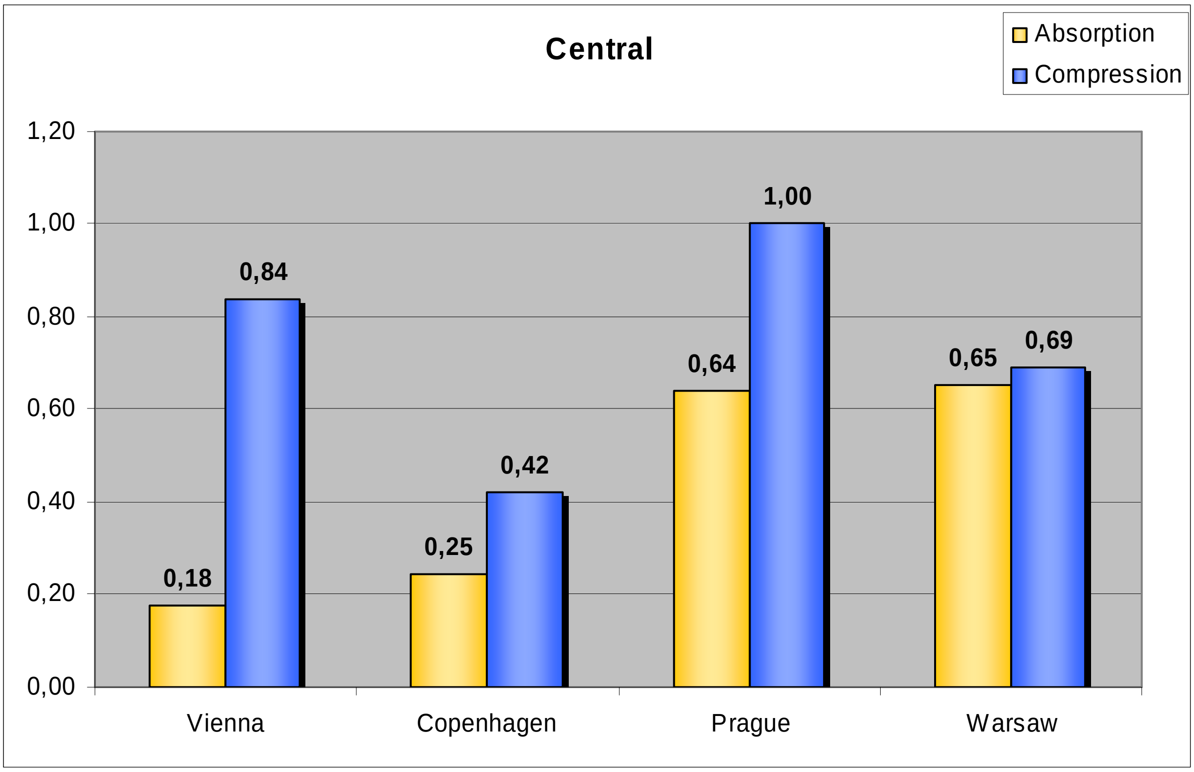
$Q_{DC,k}$ → cooling energy consumption measured at the primary side of customers substations.

For electricity, the primary resource factor of the specific country (power plants mix) or the European average value may be used.

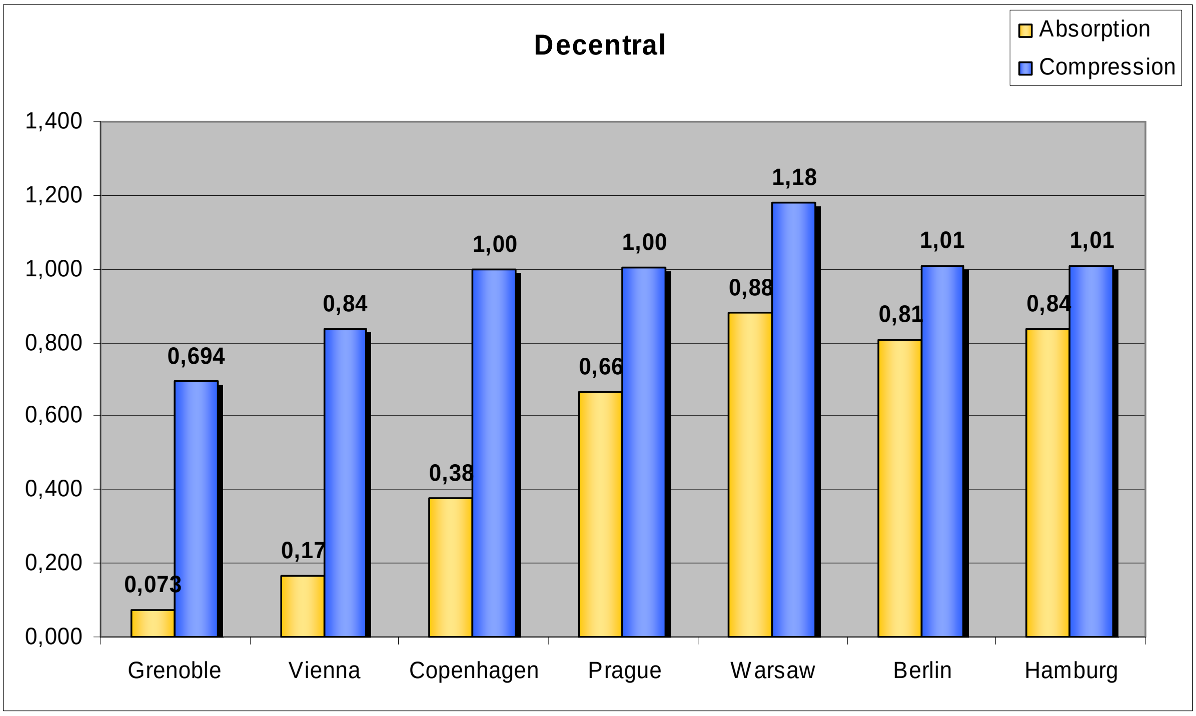
Thermal cooling environmentally beneficial

Every cooling system has its own primary resource factor. Values greater than one indicate a greater total use of fossil fuels than heating or cooling energy is delivered to a building. If the value is less than one, the total consumption of non-renewable energy is less than the energy transferred to the building. If the primary resource factor is lower than zero, less energy is spent than utilized, i.e. no fossil energy is consumed. This may be the case for heat and power cogeneration based on renewable resources such as biogas. These are set equal to zero. Some of the most efficient heating and cooling systems today, particularly when running with renewable energy sources, can achieve a PRF close to zero. It means that heating or cooling does not spend any non-renewable energy sources.

The figures below show PRF values which were calculated for the SUMMMERHEAT partner cities. The figures clearly indicate that thermal cooling (absorption technology) is generally a more efficient and environmentally friendly solution than compressor units. This is particularly true in cities like Vienna and Copenhagen where the district heating systems are based on CHP plants and utilise renewable energy sources. Furthermore, the figures show that central solutions, such as district cooling, are more efficient than decentral solutions.



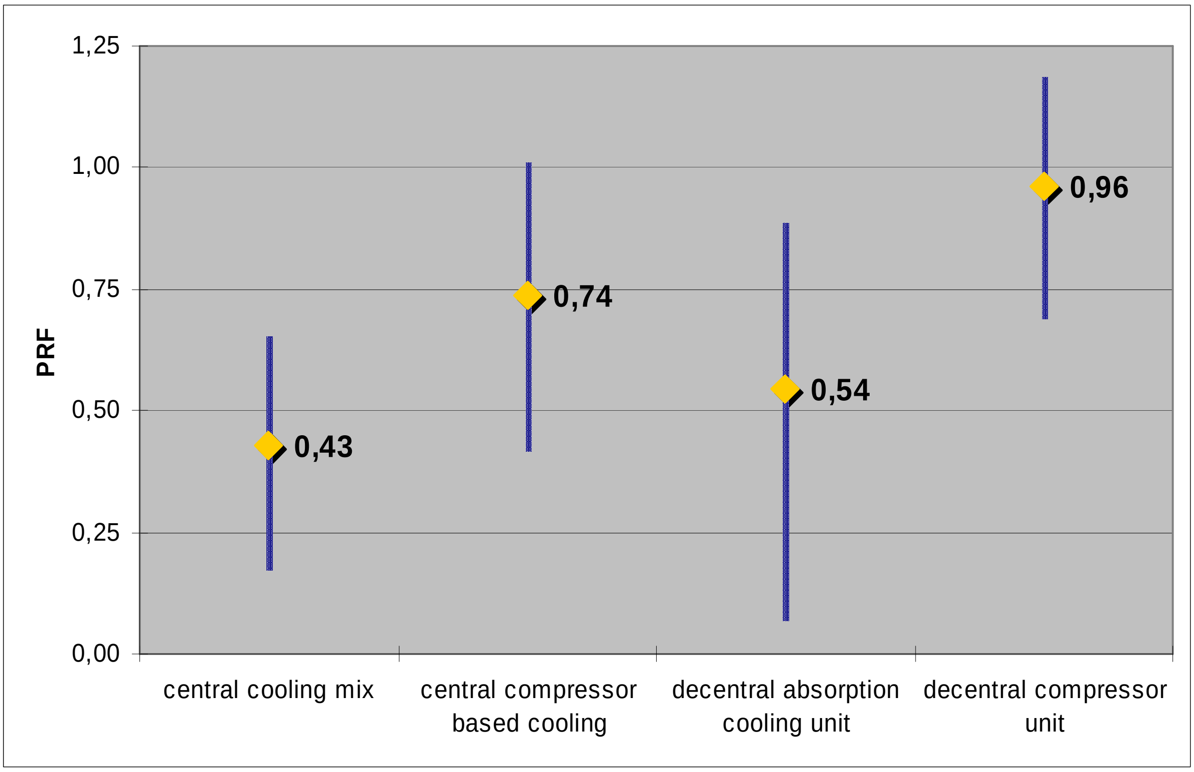
Primary Resource Factors: Comparison between central absorption and compression units



Primary Resource Factors: Comparison between individual absorption and compression cooling units

The figure below shows that an increase of absorption chillers using district heat will lead - in general - to better PRF values than compression chillers using electrical power. The range of PRF values is partly explained with the different PRF for district heating, depending on the primary energy source and the technology (i.e. CHP more efficient).

The PRF value for district cooling may be even better than indicated when considering to seasonal differences: District heat in summer is mainly produced in waste incineration CHP plants. Raising the share of these plants could reduce the PRF summer value for heat to be less than half the PRF winter value.



Primary Resource Factors

Calculation of CO_2 emissions

To assess the environmental performance of thermal cooling compared with conventional cooling technologies, the SUMMERHEAT project developed the PRF methodology. Alternatively, an ecological comparison may be based on the CO_2 emissions of different technologies.

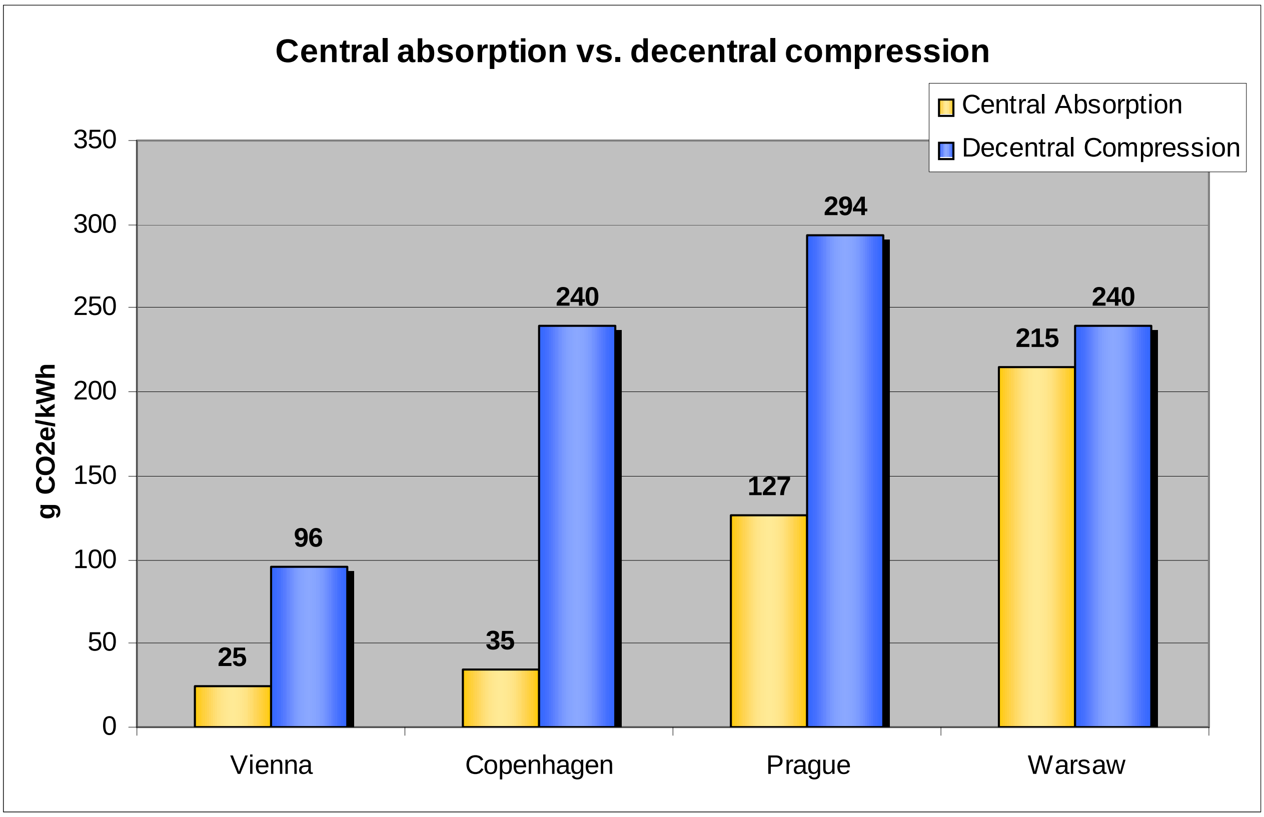
CO_2 emissions are related to the use of fossil fuels and therefore CO_2 emissions are related to the value of the primary resource factor. Total CO_2 emissions of heating or cooling systems are depending on the specific emission factors of the fossil fuels used. Using the following formula:

CO_2 = PRF x specific CO_2 factor,

it is possible to benchmark different heating and cooling technologies. The assessment of cooling systems is based on the same principle as the calculation of the primary resource factors. Lower primary resource factor values mean lower CO_2 emissions, which are almost directly related to the value of the PRF.

The specific emission factors of the fuels used influence and determine the total CO_2 emissions of cooling systems. A high contribution by cogeneration plants, whose electricity generation gets credited for the heat produced, and by waste incineration with a defined CO_2

emission factor of zero, can favour thermal driven cooling systems compared to the electric ones.



CO_2 emissions of central absorption and decentral compression units

Conclusion

The environmental benefit – in terms of primary energy – of the absorption cooling technology using district heating compared with an electric compression solution is especially prevalent when the heat is derived from an incineration or cogeneration plant.

In addition, increasing district cooling instead of compressor chillers avoids a further increase of the power demand. Should conventional compressor chillers cover the increasing cooling demand, a substantial expansion of electricity supply will be required. Thus, already existing problems in the energy supply, such as high peak loads in summer, additional dependence on imports and higher CO_2-emissions would intensify. Instead, utilising district cooling to meet growing demand would level out the peak power demand and use far less electricity. In addition, the required number of sub-stations, and the length and capacity of power cables will be reduced accordingly.

6 Summerheat: An economic assessment

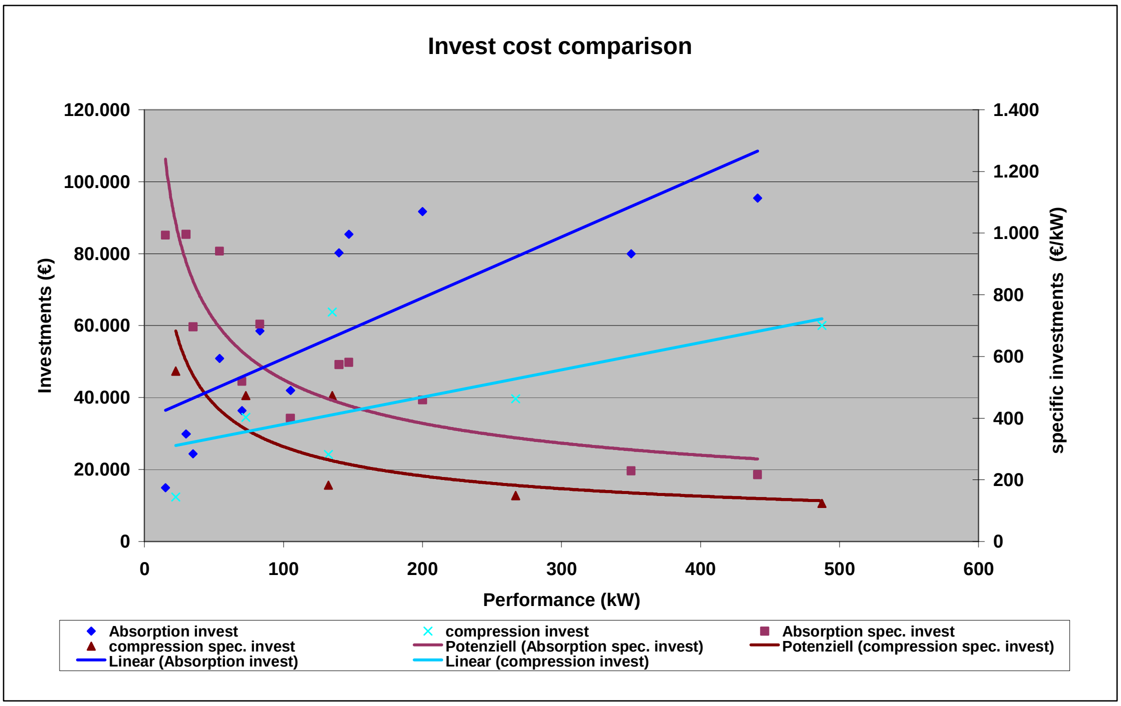
In this section the relevant cost factors regarding both systems, conventional compressor cooling units on the one hand and thermal driven cooling units on the other hand, are presented. The costs for each individual project may vary greatly depending on specifications and requirements like available space, building height, network length and other constraints. Hence, each project must be considered separately and general statements regarding cost are difficult. Nevertheless, we will investigate the key cost parameters for the different technologies in this chapter:

- Investment costs
- Operational costs (heat, electricity, water)
- Maintenance costs

Investment costs

The investment costs consist mainly of the costs for the chiller, the re-cooling tower and peripheral equipment and installation. The costs for the construction of a primary district cooling network in the case of a centralised system are not taken into account in the profitability calculation (these costs may be relatively low in rural areas and very high in urban areas).

A solid comparison between compression and absorption chillers needs two machines of exactly the same performance level. As it is very rare to find the exact same performance range, "fictitious" chillers have been defined at 150 kW. This has been done by using retailer data for both compression and absorption chillers and a regression analysis to define the costs per kW of cooling.



Specific investment costs for chillers

Using the above regressions, 150 kW chillers have the following investment costs[3]:

Absorption (total)	**59,308 €**
Absorption (specific)	**395 € / kW**
Compression (total)	**33,205 €**
Compression (specific)	**233 € / kW**

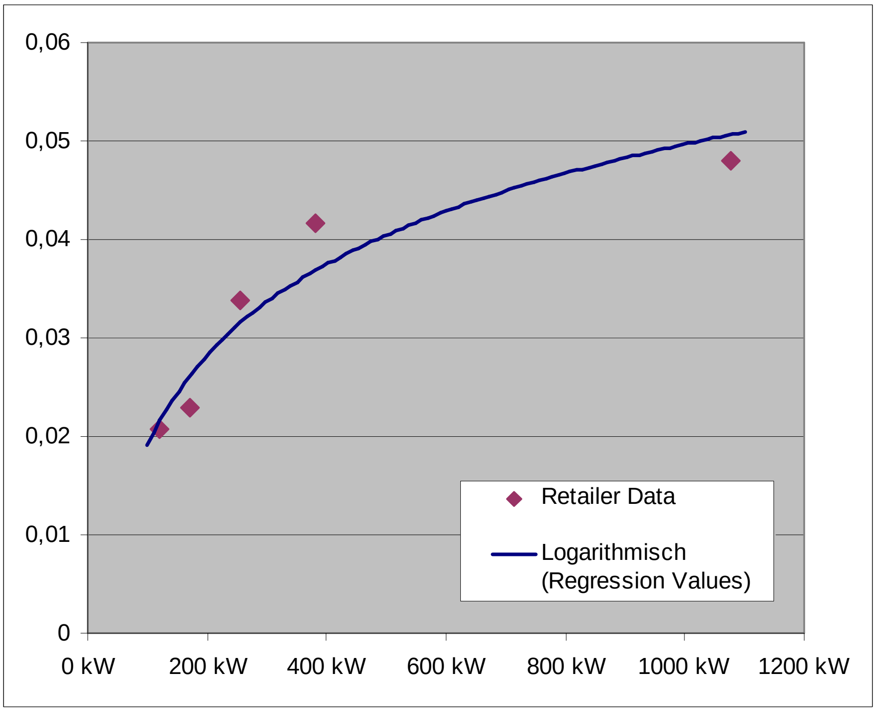
Recooling is an important issue for all cooling technologies. With respect to water cooled chillers an own recooling cycle is needed, which can be realised with open/closed or wet/dry recooling units/towers. The amount of heat that needs to be re-cooled in a cooling tower depends on the chiller. In general it is the following sum:

Amount of re-cooling = cooling load + amount of energy input

The amount of re-cooling for compression chillers is lower than for thermal chillers, due to their relatively high coefficient of performance (COP), hence the relatively lower input energy demand. It was agreed among project partners to use common COP values: COP_{CCU} = 4 for compression and a value of COP_{ACU} = 0.7 for absorption cooling units. This leads to the following dimensioning of the re-cooling tower:

Absorption	**150 kW + (150 kW / 0.7) = 364 kW**
Compression	**150 kW + (150 kW / 4) = 188 kW**

Using retailer data for the costs and dimensions of cooling towers, a logarithmic regression was undertaken to calculate the costs of the "fictitious" cooling towers of 188 kW and 364 kW respectively. The following diagram shows the logarithmic regression upon the retailer data of re-cooling costs per kW. The costs per cooling tower have been determined as 10,238 € for 364 kW and 6,481 € for 188 kW.



Re-cooling costs per kW in a logarithmic regression

[3] German data which is, however, representative for Europe.

The overall calculation input data is shown in the following table:

Model	**Absorption**	**Compression**
Cooling performance	150 kW	150 kW
Energy input	214 kW_h	38 kW_{el}
COP	0.7	4
Investment costs	59,308 €	33,205 €
Specific investment costs	395 €/kW	233 €/kW
Dimension re-cooling tower	364 kW	188 kW
Costs re-cooling tower	10,238 €	6,841 €
Costs peripheral equipment[4]	50,623 €	40,498 €
Specific water consumption	5 m³/MWh	-

Calculation costs

Operation costs (electricity, heat, water)

Another important parameter regarding the efficiency of cooling production is the price of district heat for absorption chillers and the price of electricity for conventional compressor chillers. As the coefficient of performance of thermally driven cooling machines (absorption chillers) is only a fifth to a sixth of that of compression chillers, the energy input required for absorption chillers is significantly higher. Thus, the cost of electricity needs to be respectively higher than the cost of heat to make absorption cooling systems competitive. Primarily, costs for water occur at the recooling cycle when open circuit cooling towers are used and the water is procured from the municipal utility.

The following energy costs for heat, power, and water were used:

	Price in the first year	**Annual price increase**
Heat price [€ cent/kWh]	5,00	1%
Heat base price [€/a]	100,00	1%
Power price [€ cent/kWh]	12,00	2%
Water [€/m³] incl. treatment	2,00	1%

[4] Peripheral equipment includes costs for planning, setting-up, piping systems, fundament installation, noise insulation, electrical integration, and control systems.

Maintenance

Maintenance is very site specific and must be examined for every single object. It includes measures for servicing (preserving the desired status of a system), inspection (determining and assessing the actual status of a system) and for repairs (restoring the desired status of a system). In general lower maintenance costs can be expected for absorption chillers due to fewer moving parts and its relatively simple construction. Their life cycle time is between 20 and 30 years and is typically longer than that of compressor chillers.

Conclusion

As the exemplary comparison of specific cooling costs indicates (see two tables below), at the outlined full-load hour scenarios[5] and the regular price level of input district heat of 5 € cent/kWh, the most economically feasible cooling system is decentralized compressor cooling unit. The calculation lead to the below indicated costs for the specific cooling application:

Type of unit	**Absorption chiller 150 kW, 1,000 full-load hours, 5 € cent/kWh heat**		
1	Energy cost, Water cost in total	15,850	Euro/yr
2	Electricity	-	Euro/yr
3	Heat	-	Euro/yr
4	Water	-	Euro/yr
5	Annual costs of repairing and service in total	2,008	Euro/yr
6	Cost of investments in total	132,186	Euro
7	Annual annuity from investment (6%, 15 years)	13,610	Euro/yr
8	Cooling production cost in total	31,468	Euro/yr
	Specific costs	209.79	Euro/MWh

-

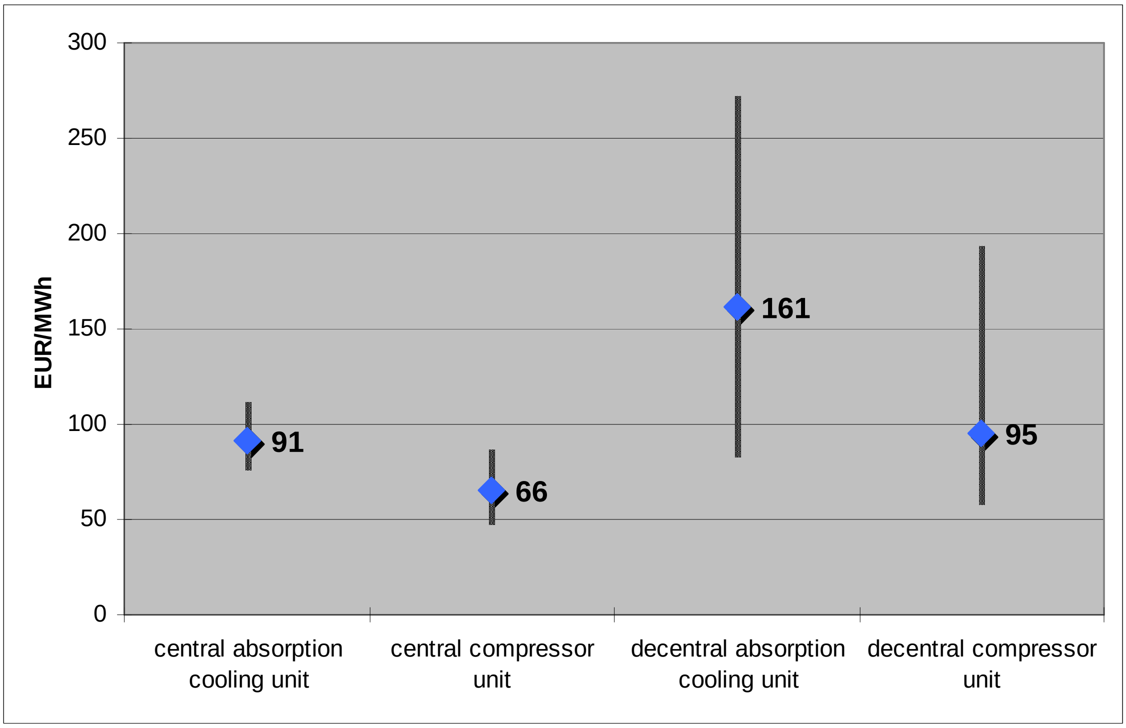
[5] The estimated average full-load hour of a chiller is around 1.000 full-load hours.

Type of unit	**Compression chiller 150 kW, 1,000 full-load hours**		
1	Energy cost, Water cost in total	5,643	Euro/yr
2	Electricity	-	Euro/yr
3	Heat	-	Euro/yr
4	Water	-	Euro/yr
5	Annual costs of repairing and service in total	3,739	Euro/yr
6	Cost of investments in total	88,598	Euro
7	Annual annuity from investment (6%, 15 years)	9,122	Euro/yr
8	Cooling production cost in total	18,505	Euro/yr
	Specific production costs	123.36	Euro/MWh

Explanatory note on the individual rows in the above table:

1. Total cost of energy consumption, sum of row 2,3,4
2. Cost of electricity consumption
3. Cost of heat consumption
4. Cost of water consumption
5. Annual cost of repairing + annual cost of service for all units in total
6. Total investment costs (all units together)
7. Row 5 x annuity factor, annuity factor for 6%, 15 years
8. Sum of row 1,5,7

The above conclusion (based on German data), that decentralised compressor cooling units are economically the most efficient solution, is confirmed in most other EU regions in most circumstances, as the below figure illustrates.



Cooling production costs (excluding network construction costs) based on national technology reports (power: 300 - 500 kW; full-load hours: 1000 h)

To make absorption chillers cost competitive, the price of the input heat has to be dropped significantly and the amount of full-load hours has to be kept high. The economic comparison has shown that only at a high amount of full-load hours and the use of waste heat at 0 €/MWh, absorption chillers become cost competitive per $MWh_{cooling}$ to compression chillers.

In sum, it is difficult to offer Summerheat solutions (absorption chiller) which are price competitive with standard (decentral) compression chillers. In specific circumstances with lower investment costs, centralized absorption systems could be economically feasible.

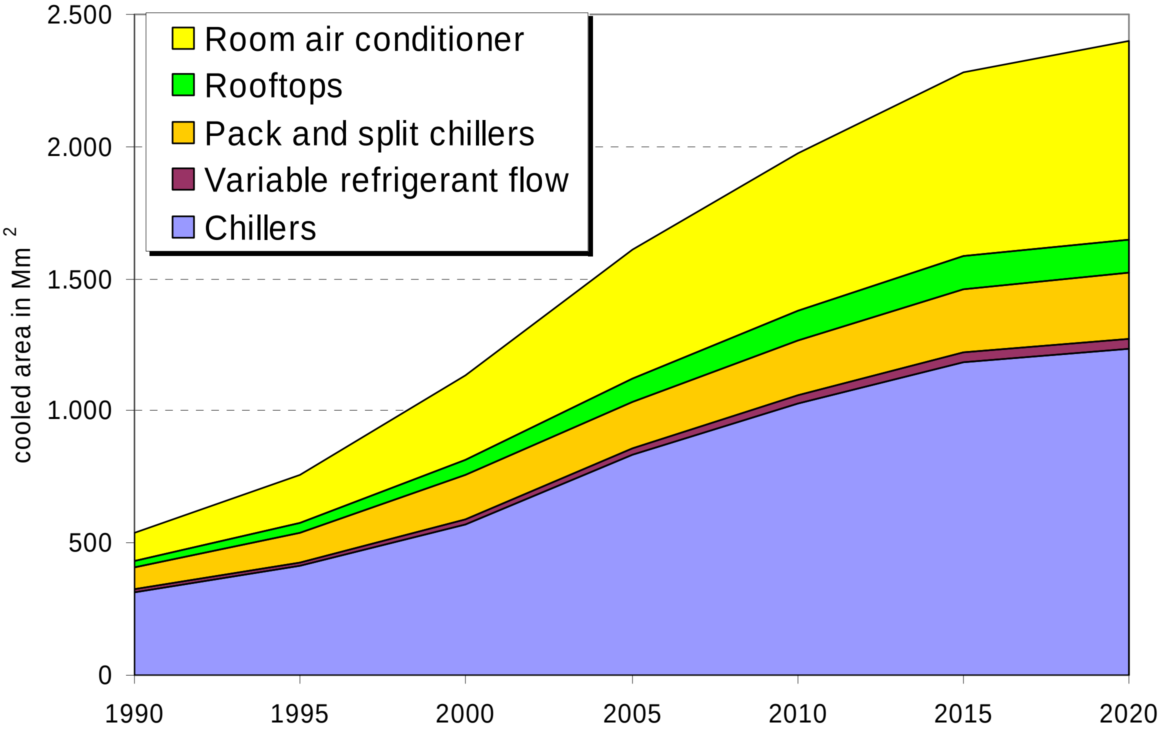
The following factors determine the future competitiveness of district cooling:

- The output of plants and their level of use: examine more thoroughly large cooling demands with long use during the summer (in other words, high full load hours)
- The price of Summerheat as well as the development in the price of electricity
- Development of investment unit costs (production of greater quantities tends to reduce investment unit costs)

7 Demand for cooling

For the coming years national and European studies predict a clear rise in energy consumption for air conditioning and cooling. The amount of useful floor area that is cooled and/or air conditioned has increased in the past few years and this trend will continue.

The European market for air-conditioning (AC) systems was analysed, for example, in the AUDITAC Study (see figure below). In 1990, smaller AC systems (<12 kW) provided cooling for 540 million m² of surface area. This number increased to 1,800 million m² by 2005. A further increase to around 2,400 million m² by 2020 is expected. This would require an energy demand of approximately 115 TWh.



Cooled area in Mm2 (EU15)[6]

[6] Adnot J., et al.: Energy Efficiency and Certification of Central Air Conditioners (EECCAC). Final Report, Volume 2, 2003. http://www.energyagency.at/(de)/publ/pdf/aircondbig_v2.pdf (10/2008)

There are several reasons for the increasing cooling demand, including:

- Changing building designs that include higher insulation standards and increasing glass facade surface areas
- The buildings have higher internal heat benefits due to increasing number of electric appliances (e.g. growing need for cooling of computer rooms)
- Higher comfort demands
- Quantitative increases of office and service buildings
- Majority of new buildings are planned including cooling and air-conditioning possibilities

EU and national legislation intends to reduce or diminish cooling demand in buildings through energy efficient building standards and the utilisation of natural air or water resources for free cooling. The structure of national regulations differs from country to country; they can limit the shift towards active cooling technologies for new buildings, or may set indications and restrictions for existing buildings which need refurbishment. Nevertheless, cooling demand is expected to increase due simply to economic growth. The number of air-conditioning systems installed may increase as building owners and operators aim to compete with neighbouring units with air-conditioning systems. In such circumstances, district cooling, using surplus heat from combined heat and power and incineration plants, is an energy efficient option.

8 Summerheat: Perceived customer benefits

The requirement of the customer in simple terms is and will remain: to receive a service that is price competitive and delivers the expected outcome i.e. 'comfortable indoor climate'. The perceived 'price competitiveness' as compared with alternatives goes beyond price to include the whole service of cooling supply i.e. hard and soft factors. The hard factor, the cooling price for the customer, may vary with the type of model. Customer pricing reflects the divergent investment costs (influenced by the size of the system), the location and the potential network construction costs, on which the models are based. In addition to price, there are a number of soft factors that should be taken into consideration. The below table gives an overview of the benefits of each model. It is clearly shown that district cooling has significant advantages over decentralised cooling – even if the equipment is operated (or contracted) by the energy provider.

There are several clear advantages of connecting to a district cooling system from the customer's perspective. The customer receives an energy service that has a very high reliability (>99% according to the International District Energy Association) because the system is operated 24 hours a day all year round. The customer also remains flexible as to the dimensioning of the system. For example, they are able to increase or reduce the cooling load from the system without having to invest in more capacity. District cooling can be adapted to the customer's office hours and be used at low-load or peak-load without additional costs.

With the connection to district cooling, the property owner outsources the risk and transfers it to the energy provider. In addition, less space is occupied by cooling systems (most often in buildings' basements) which creates options for underground parking and similar benefits for the building owner. Also, as there are no re-cooling appliances or cooling aggregates required in the building itself, architectural benefits are provided by district cooling. The property owner is now able to use the roof for other purposes.

Because problems with HFC and HCFC refrigerants are avoided, district cooling can also be integrated into a company's environmental strategy. Moreover, district cooling is an energy efficient and environmentally sound cooling option. Applying the Summerheat concept may therefore improve a company's reputation as it moves towards becoming CO_2-free.

In sum, advantages of district cooling networks in comparison to conventional central compressor chillers:

- Free space due to elimination of own cold generation systems and recooling systems which are centrally erected
- Positive influence on the architecture and on the general view of the buildings due to elimination of recooling systems or compact air cooled water chillers respectively which are normally installed on the roofs.
- Concentration of noise emissions onto one place and nearly no vibrations.
- Operation and maintenance by professional and specialised staff.
- Less manpower requirement for facility management and no maintenance costs for own cold generation and peripheral systems. Moreover absorption chillers are less maintenance intensive.
- Reliability and comfort, which become more and more important in times of higher demands.
- Elimination of investments in own cold capacities can bring advantages for the determination of rental fees in

highly competitive real estate markets.

- Lower electric peak load due to elimination of own cold generation systems.
- Transparent and calculable costs for cold generation.

	District Cooling	Decentralised cooling	
Supply Option (Chapter 11)	3	2	1
Cooling equipment owned by	Energy provider: ☺	Energy provider: ☺	Customer: $
Investments	By the energy provider: ☺	By the energy provider: ☺	Customer: $
Maintenance by customer	No requirement: ☺ Focus on core activities: ☺	No requirement: ☺ Focus on core activities: ☺	Self-maintenance: $
Operational requirements	None: ☺	Maybe hygienic issues (open re-cooling): 😐	Maybe hygienic issues (open re-cooling): $
Refrigerant	Compression chillers (peak): 😐	No compression chillers: ☺	No compression chillers: ☺
Space occupation	None in the building: ☺	Space required: ☹	Space required: ☹
Architectural benefits	Central re-cooling, additional space on the roof available: ☺	Re-cooling on the premise: ☹	Re-cooling on the premise: ☹
Additional energy requirements	Not for the customer: ☺	Not for the customer: ☺	Distribution / secondary system: ☹
Environmental benefits / CO_2-emission reductions	Most likely ☺	Depending on local factors	Depending on local factors
Reliability	~ 99 %: ☺	~ 80 %: 😐	Own risk: ☹
Noise & vibration	None: ☺	Fewer compared to compression chiller: 😐	Fewer compared to compression chiller: 😐
Market deployment	Mature technology: ☺	Mature technology: ☺	Mature technology: ☺

Perceived customer benefits depending on the operation & business model

Legend from the viewpoint of the potential customer:
☺ great benefit 😐 ok ☹ no benefit $ additional investments required

9 Political Framework

EU Directive on the energy performance of buildings

At the European level, a framework to be transposed and implemented by the EU Member States, is provided by the European Directive on energy performance of buildings (2002/91/EG). It aims to improve the energy performance of buildings by taking into account climatic and local conditions, as well as requirements on indoor climate environments and cost effectiveness. Emphasis is therefore put on measures to increase energy efficiency and on energy savings which directly impact the cooling demand of a building.

The Directive contains explicit terms in Article 5 and 9 which are relevant for cooling applications and the implementation of thermally driven cooling technologies. Accordingly, it refers to air-conditioning and cooling in buildings and therefore to the activities set forth in the SUMMERHEAT project.

Article 5 states that an examination of alternative systems is required. Thus, before construction of new buildings with a total useful area over 1,000 m^2 begins, the technical, environmental and economic feasibility of alternative systems such as district or block heating/cooling, if available, must be considered and taken into account.

This required examination for alternative systems is a strong opportunity for energy utilities to convince future building owners of the advantages of Summerheat.

Article 9 states that Member States shall lay down the necessary measures to establish a regular inspection of air-conditioning systems which have an effectively rated output of more than 12 kW. This inspection shall include an assessment of the air-conditioning efficiency, and the size compared to the cooling requirements of the building. Appropriate advice shall be provided to the users on possible improvements, on the replacement of the air-conditioning system, and on alternative solutions. This also creates a strong opportunity for the efficient Summerheat solution to be introduced to building owners.

Legal framework for district cooling operation

In addition to the aforementioned building regulations and the restrictions on fluorinated greenhouse gases, other legal framework conditions have to be taken into account. Legal requirements for building and operating district heating and cooling networks (e.g. the temperature limit between hot water and superheated networks, pressure thresholds, security requirements etc.) are a core element to be considered. These requirements are very specific to the member state and can have a strong impact on the costs of cooling services.

In addition to technical regulations, the legal status and the objectives of the company or organisation which wants to deliver cooling must be considered. Limits to creating and proposing new services may exist according to country specific conditions. For example, in Denmark until July 2008, municipal district heating companies were legally prohibited to deliver cooling: their economical activities by law were limited to the distribution and sale of heat. The contractual relationship between the local authority and the district heating operating company in France may need similar adaptations to allow for district cooling.

For refrigeration and air-conditioning applications, re-cooling facilities are necessary. These units are subject to numerous requirements on planning, installation and service levels. This applies both to conventional cooling and to the supply of district cooling. In the case of district cooling, however, the measures required are shifted away from the individual onto the district cooling supplier. Environmental and hygienic aspects must be considered when using open, wet or sprinkled re-cooling towers (e.g. in order to impede the growth of legionella bacteria). To a certain extent, this can be considered as a disadvantage for Summerheat use as it requires greater re-cooling capacity. However, depending on the local conditions, other re-cooling techniques can be implemented. For example, ground water, water tables or free cooling using rivers or lakes can serve to discharge the excess heat. However, specific regulations exist for each of these re-cooling options , and need to be taken into account (e.g. limitation of warming ground water or nearby rivers).

Urban Planning

The role of urban planning is crucial to the development of energy services distributed via a network. The applicability of district heating or cooling will depend on the density of land occupation and the variable uses foreseen for that area. In addition, for areas which are to be newly developed, the early choices made for infrastructure will have an important impact on investment costs, especially for district energy networks.

District cooling networks are affiliated with long-lasting, expensive infrastructure. Therefore, close cooperation between the district supply company and the urban development department of the city is obligatory. Particularly relative to new buildings and urban development areas, early involvement of official authorities is required to ensure adequate planning and design of the supply networks.

Political support by local authorities, which may be based on local energy plans, will create a positive backdrop for the public or private real estate developers, so that they may accept the connection to the district heating and cooling grid as an opportunity, but also to a certain extent, as an obligation.

The most promising development areas are those dedicated to tertiary activities or to a mixed use with small and medium sized industries. The higher the density of the floor area in relation to the area of the building site, the better are the conditions for district heating and cooling. For example, in a new development area in Vienna, Austria, the density varies between 1.5 and 2 (gross floor area/gross development area).

10 Best Practices

10.1 Vienna

In Vienna the first district cooling network started its operation in 2007. TownTown is a new area of urban development in the district Erdberg which is still under development. On this site, twenty
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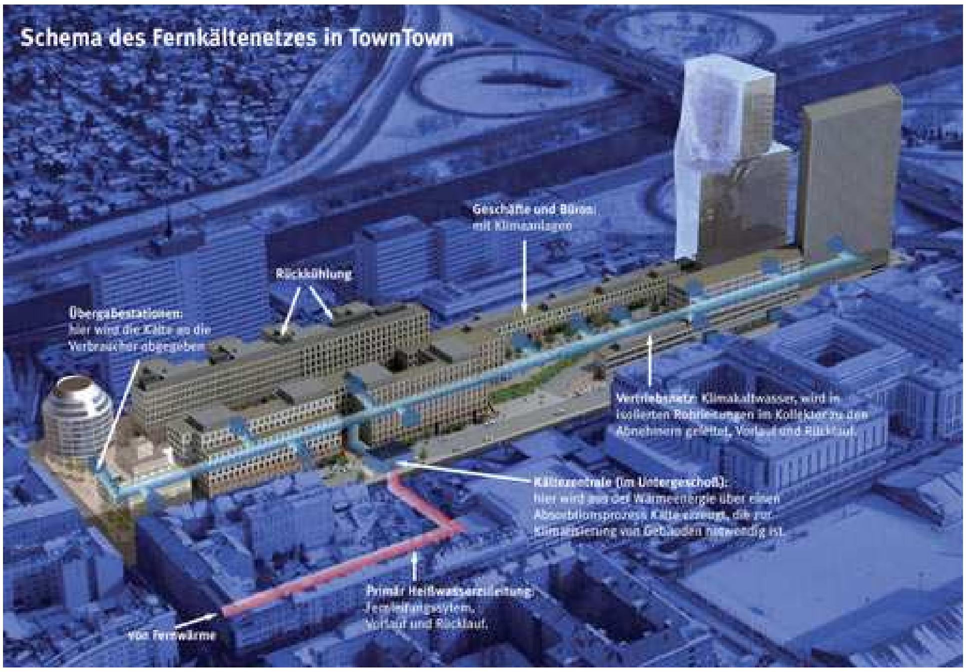
one buildings with a total net floor area of over 100,000 m^2 have been constructed. In addition to offices, there are commercial buildings, restaurants, shops and a hotel



District Cooling, „TownTown" Project, Vienna (Source: Fernwärme Wien GmbH)

In order to meet increasing demand for a comfortable room climate, particularly in shops and offices, an air conditioning system was planned for all components. As an alternative to conventional cooling systems, the local district heat utility (Fernwärme Wien GmbH) drew up a concept for central supply of the whole area by a district cooling network. At its completion, the district cooling plant will be comprised of three absorption and two compressor chillers with a total cooling capacity of 8.4 MW.

This innovative supply concept which combines different technologies contains the following systems:

- Two absorption chillers with a cooling capacity of 2,200 kW each at a given hot water inlet temperature of 90 °C.
- One compressor chiller (centrifugal) with a cooling capacity of 900 kW.
- One free cooling unit (heat exchanger) with a cooling capacity of 500 kW.

Free cooling is especially of interest during the winter, during the transition time between spring and summer, and between summer and autumn. At such transitional times, despite low outdoor temperature, cooling is required due to high solar exposure. Furthermore, rooms which require all-season cooling as a result of high internal loads (e. g. computing equipment) can make use of this cooling system over these periods.

Special characteristics of the cold supply concept

Similar to district heating, a split between base and peak load is carried out for cold generation. Thermally driven chillers cover the base load and the compressor chiller is responsible for supplying the peak load. Additionally, the thermal activation of building structures (a constructional measurement) helps to balance out peak loads.

Pipe systems in the core of the building's main structures, including walls and ceilings, are utilised to influence room climate. By cooling the concrete components of the building, the thermal storage of the mass is harnessed for temperature balance. The thermal activation helps to shift the loads from day time to night time. The load transferred to the evening hours approximately equals the day's cooling load. This technique enables the absorption chillers to run at a constant load over as long a period as possible.

Open circuit cooling towers are used for re-cooling absorption chillers. The re-cooling unit of the compressor chiller is a hybrid cooling tower, which, depending on the outdoor temperature, makes a combination of wet and dry re-cooling possible. The re-cooling medium, a mixture of water and glycol, circulates in a closed cycle within the cooling tower. The ability of the hybrid cooling tower with the re-cooling cycle to be directly connected to the chilled water cycle – bypassing the chillers, is especially noteworthy. This system effectively creates a free cooling operation mode. At appropriately low outdoor temperatures, water can be chilled by cooling the re-cooling water in the hybrid cooling tower with cold air. In this case, little or no operation of the chillers is necessary.

Energy and environmental impact

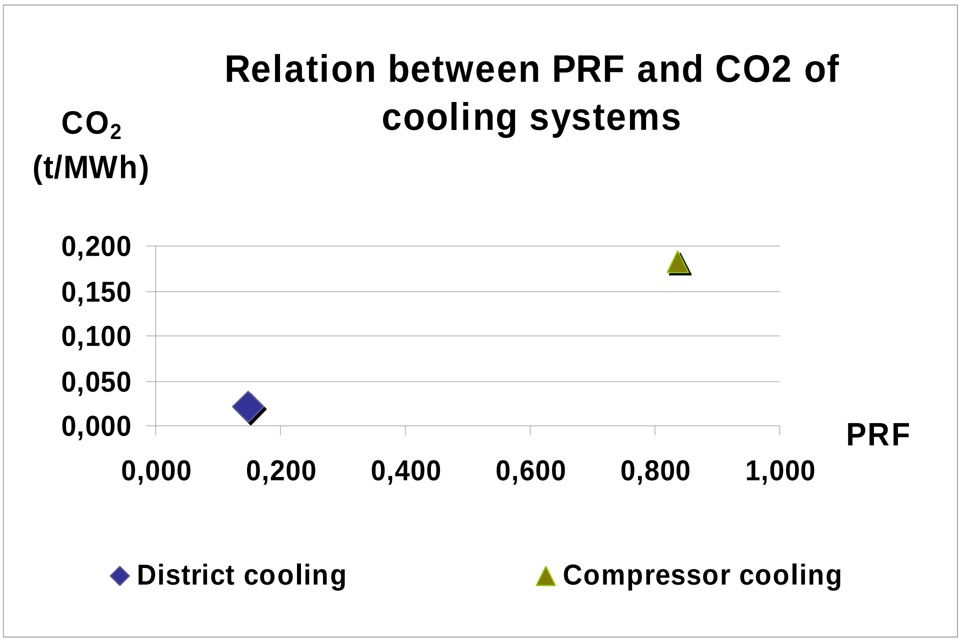
For the environmental analysis of this project, input data of the underlying district heating network of Vienna from May to September (the period responsible for the largest cooling demand) were taken into account.

Waste incineration plants	601 GWh
CHP plants	268 GWh
Peak load boilers	26 GWh

Sources of district heating in Vienna in the period May – September

During the summer, the vast majority of heat is generated by waste incineration plants. This heat source is a low-cost option which also preserves primary resources; its use replaces fossil fuels. Heat from waste incineration is constantly generated throughout the year and therefore sufficiently covers the base load. During the summer, its supply of heat is well-suited for cooling purposes.

The electricity generated in cogeneration plants is credited with the PRF of the electricity supply in the Vienna region. The same value is also applied for the appraisal of conventional chillers.



Comparison of primary resource factors and CO2 emissions for different cooling systems in Vienna

For this example, the environmental impact of different cooling concepts is indicated in the figure above. District cooling shows clear advantages in terms of the primary resource energy factor and CO_2 emissions. District cooling has a much lower primary resource consumption. This is primarily due to the favourable structure of heat generation in Vienna during the summer period. It relates that this district cooling concept is also advantageous in terms of CO_2-emissions.

Conclusion

This functioning best practise example shows that the concept of district cooling is viable in Vienna under appropriate framework conditions. It is an ecologically and environmentally friendly alternative to conventional cooling applications, particularly by its use of existing waste heat potentials.

Further promotion of such local, central supply concepts is justified through the many advantages to the customer. By connecting to a district cooling system they are able to replace their own generation facilities. The energy utility, which operates the district cooling system, aims to offer an economically competitive energy service to customers. In this way, the advantage of district cooling is clear to customers as they consider the costs of owning their own individual compressor chillers.

Success Factors:

- Advantageous PRF and CO_2 emissions for district cooling due to the favourable situation of heat generation in Vienna.
- Market development initiated by the local energy utility
- Identification of cold spots to supply primarily limited urban areas with district cooling
- Long term market perspective
- Customer benefits due to district cooling as energy service

10.2 Copenhagen

Copenhagen Energy is in the process of establishing a district cooling system in the central part of Copenhagen (Kongens Nytorv). A number of owners of commercial buildings and office buildings have shown strong interest in having access to district cooling. For the „Kongens Nytorv project", seventeen potential customers with a total cooling demand of 15.3 MW were identified. Five of the potential customers show a demand which equals 80% of the projected capacity. The annual cooling demand is estimated at 21.8 GWh.

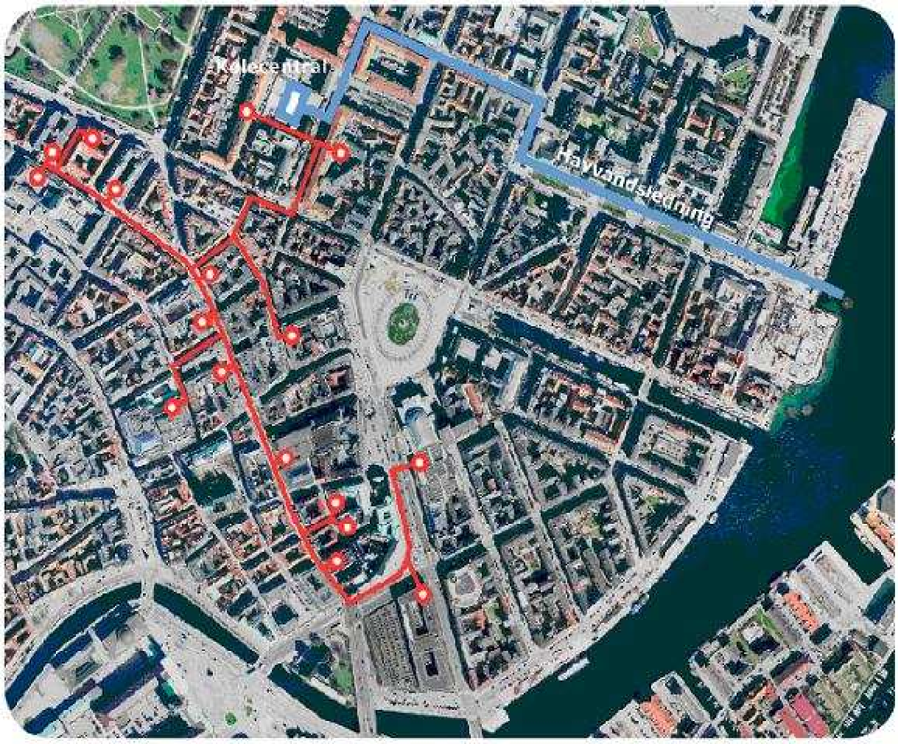


Diagram of the district cooling project in Copenhagen

Study Design

The project includes:

- A cooling production plant comprising 3 ammonia compressor chillers and 1 absorption cooling unit
- A seawater pump station. To the maximum possible extent, the system will utilise sea water for 'free cooling' and pre-cooling
- A district cooling network to provide cooling capacity in buildings

The distribution is to be established as a double-piped system providing cold water to each of the customers (6 °C at consumer sub-stations).

Cooling production	share
Free cooling	29.3%
Electrical chiller	42.4%
Absorption chiller	28.3%
Total cooling production	**100.0%**

Composition of cooling production

Energy balance GWh/year	OUTPUT Cooling	INPUT Electricity	INPUT Heat
Free cooling	6.49	0.22	
Electrical chiller	9.37	0.95	
Absorption chiller	6.26	0.02	5.69
Losses	-0.32		
Distribution		0.14	
Auxiliary		0.23	
Total	**21.80**	**1.56**	**5.69**

The energy balance of the District Cooling System

Electricity and fuel savings

The Design Study (KE plant) indicates a reduction in electricity consumption of 5.6 GWh (approximately 80%).

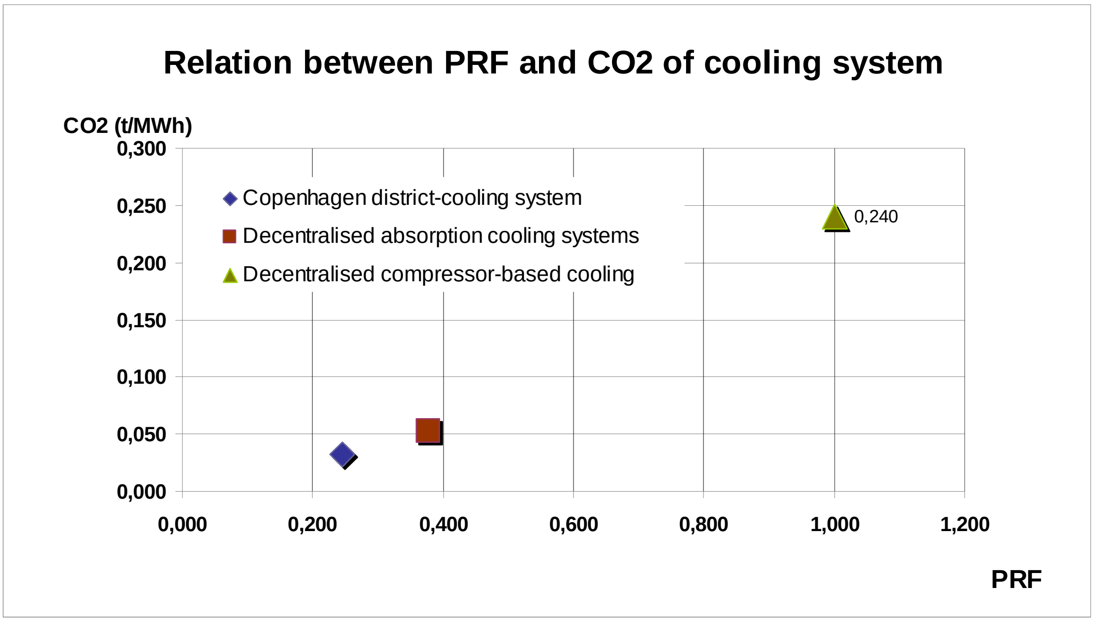
The use of centralised compressor units will reduce electricity consumption by more than 50%.

This reduction is due to the improved energy performance of central, larger compressors as compared to smaller, decentralised units.

Furthermore, calculations show that CO_2 emissions will be reduced by 3,000 tons.

Environmental Impact

District cooling shows clear advantages in terms of the primary energy resource factor and CO_2 emissions. Its primary resource consumption is much lower than alternatives, which is primarily due to the favourable structure of heat generation in Copenhagen during the summer period. It relates that district cooling is also advantageous in terms of CO_2-emissions.



Comparison of primary resource factors and CO2 emissions for different cooling systems in Copenhagen

Conclusion

Analysis of the district cooling project in Copenhagen indicates that, under appropriate framework conditions, it has good viability. Moreover, it represents an ecologically and environmentally friendly alternative to conventional cooling applications.

Although it is not yet possible to connect to a district cooling grid, Copenhagen Energy has experienced a growing interest in district cooling from potential customers in the Copenhagen area. District cooling has caught the attention of many commercial building owners. In addition, office building and real estate managers are now making inquiries to Copenhagen Energy to investigate their possibilities of becoming District Cooling customers.

The main motivation for these potential customers is the improved overall cooling economy of a district cooling system compared to existing compressor-based chillers.

Success Factors:

- Access to free cooling (Hafenwasser)
- Municipal requirement (to energy company) to reduce energy demand by 1% p.a.
- Identification of cold spots
- District heating system is historically based on steam i.e. higher supply temperatures (180-300°C) lead to higher cooling machine efficiencies and therefore better overall environmental efficiency

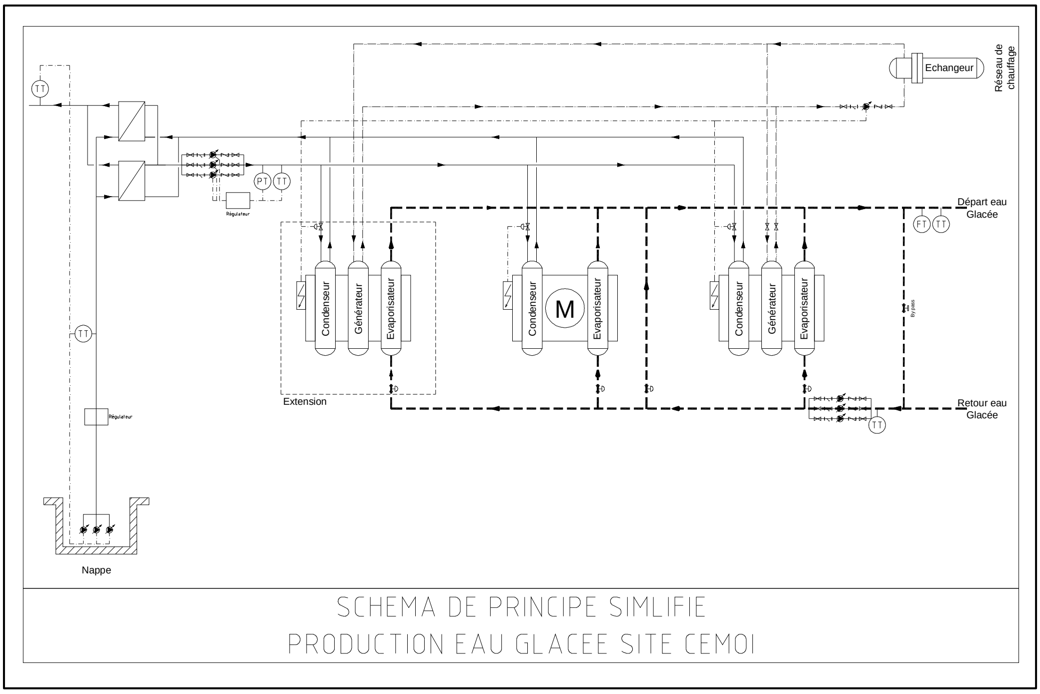
10.3 Grenoble

The CEMOI site contains buildings originally used by a chocolate manufacturer operating from 1920 until the early 1970's. This property of 13,000 m^2 was bought by the Town of Grenoble and in 1979 was converted into a business centre containing offices, workshops and warehouses.

In the framework of the Bouchayer-Viallet district's development plan, the Town of Grenoble began to reallocate buildings in order to incorporate firms from multimedia and software sectors. In the context of these plans, a building area of about 7,500 m^2 will be supplied from a decentralised district cooling system.

The district heating network of Grenoble's inter-municipal district heating company (CCIAG) supplies the Bouchayer-Viallet district and will supply heat, cold water for cooling needs and air conditioning of the CEMOI site.

The technical concept of the cold production



A simplified scheme representing the production of cold water CEMOI site

The cold production plant, based in a technical room of the building, consists of an absorption group of 300 kW and a compression group of 200 kW (scheduled for January 2010).

At a later stage an extension of the installed refrigerating power in line with the development of demand is foreseen (with a second absorption group of 300 to 500 kW).

The condensers of the refrigerating machines (absorption and compression) will be cooled with the water table, found between 3.50m and 4m.

Energy and environmental impact

During summer, cold production by absorption will utilise surplus heat from the incineration of domestic waste in Grenoble (UIOM Athanor). The annual cooling energy demand has been estimated at 680 MWh: 450 MWh for the summer period (May to September) and 230 MWh for the winter period. This cooling production consumes 690 MWh of heat and 75 MWh of electricity (not including the operation of auxiliary equipment).

The environmental impact (in terms of greenhouse gases and primary energy) of this project was estimated using primary resources factors (PRF) and CO_2 emissions factors. The results are presented in the table below.

These two criteria (use of the primary resource and CO_2 emissions) show the advantages of cold production from the district heating network of Grenoble (supplied by the UIOM- Incineration plant for domestic waste). Operation of the future plant will save about 359 MWh of primary energy per year (-61%) and will avoid about 3.6 tons of CO_2 emissions annually (-42%).

Cold production mode	PRF (Primary resource factor)	Factor CO_2 gCO_2/kWh cold	Primary energy consumed MWh/ year	Emissions CO_2 t/ year
Compression machine (COP of 3)	0.86	13	585	8.8
Absorption machine on the DH network of Grenoble in summer	0.073	5	50	3.4
67% absorption and 33 % compression	0.332	7.6	226	5.2
Savings (primary energy or CO_2)			359	3.6

Environmental impact of the Grenoble project in terms of primary resource factor (PRF) and CO_2 emissions factors.

Supply services for users and cost estimates

The cooling energy consumed per user is measured by an energy meter which is installed at the entrance of each rented surface. This serves as the basis for invoicing.

Prices are made up of two parts: 1) a fixed amount proportional to the requested power and 2) an amount proportional to the consumed cooling energy. The costs for cooling of the tertiary buildings of the CEMOI site is estimated to be a total of 10-12€/m^2/year excluding taxes (value is for June 2008 on the basis of a consumption of 100 kWh/m^2/year).

This estimate includes costs for: cold water production plant investment; the energy (heating and electricity) necessary for the cold production; the distribution network, maintenance, reparations and the renewal of equipment. The user receives cold water without investment or maintenance costs linked to the production of cooling.

These costs are comparable with cold production by compression (taking into account investment costs, and operation and maintenance costs).

Conclusion

The District Heating Company of Grenoble has been a major stakeholder in the town planning for more than 50 years. It therefore recognises the value of high performing solutions regarding energy and the environment. This project will allow for a positive return of experiences within the French energy context.

11 Roadmap to Summerheat

Choosing an adequate Summerheat cold supply option

When considering the use of surplus heat from CHP and incineration plants to supply district heating (DH) systems to produce cooling, there are several ways to incorporate absorption chillers or any thermally driven cooling technology.

Identification of the most attractive supply option for the specific application requires an integrated technical and economic approach involving cooling demands, energy efficiency considerations, environmental concerns and due emphasis on financial viability and cooling costs.

The necessary analyses involves all system components; from the technical equipment in buildings to the generation of cold, its impact on the generation and distribution of district heat and the derived environmental benefits of the system.

Central or decentralised cold generation

A fundamental distinction must be made between district cooling (DC) and thermally driven cooling technologies in terms of their implementation and operation. There are two main concepts:

- Concept 1: Central cold generation
- Concept 2: Decentralised cold generation

Both are considered district cooling.

The distinction between the two types of cold generation is of decisive importance with respect to technical feasibility and particularly to the assessment of economic profitability.

This analysis can either be carried out from the perspective of the building owner or of the energy utility entering into the district cooling business.

Decentralised cold generation

District heating is provided to customers and cold is produced locally, in a decentralised manner often in or at customers' buildings. A variety of cold production technologies including thermally driven absorption chillers may be used.

Operator of the local production of cold: owner of building, the local energy utility or an external service operator.

Central cold generation

Chilled water for cooling and air-conditioning purposes is centrally generated at one site (District Cooling plant) by means of absorption cooling, eventually combined with compressor-based cooling and free cooling. It is subsequently distributed as cold to customers via a dedicated District Cooling network.

Coverage: Supply of locally limited areas ranging from a few hectares up to several square kilometres.

Operator of the DC network: typically a local energy utility.

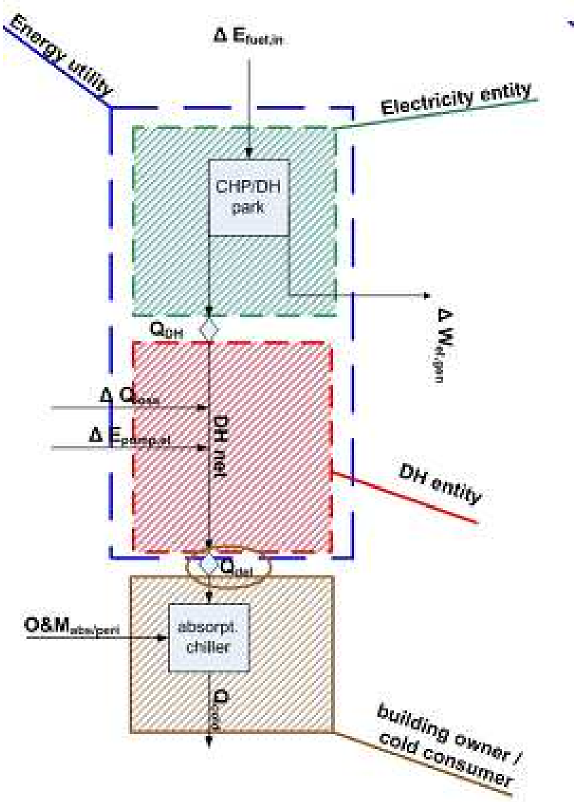
Choosing supply option

This section presents **three different supply options** and aims to illustrate the relevant system boundaries and the substantial aspects therein.

- Supply option 1: Selling heat for Decentralised cold generation
- Supply option 2: Selling cold from Decentralised cold generation
- Supply option 3: Selling cold from Central cold generation

Option 1: Selling heat for decentralised cold generation

The local energy utility (or the district heat provider) sells heat to customers (building owners) that use the heat for generation of cold with thermally driven absorption chillers. These chillers are owned and operated by the customers themselves.



Technical integration of absorption chillers:

Needed technical analysis:

- Required DH supply temperature for absorption chillers
- Dimension of heat junction
- Defined temperature difference of DH (inlet – outlet) that may be prescribed
- Impact on DH return temperature

Implications for the Heat supplier / Energy Utility

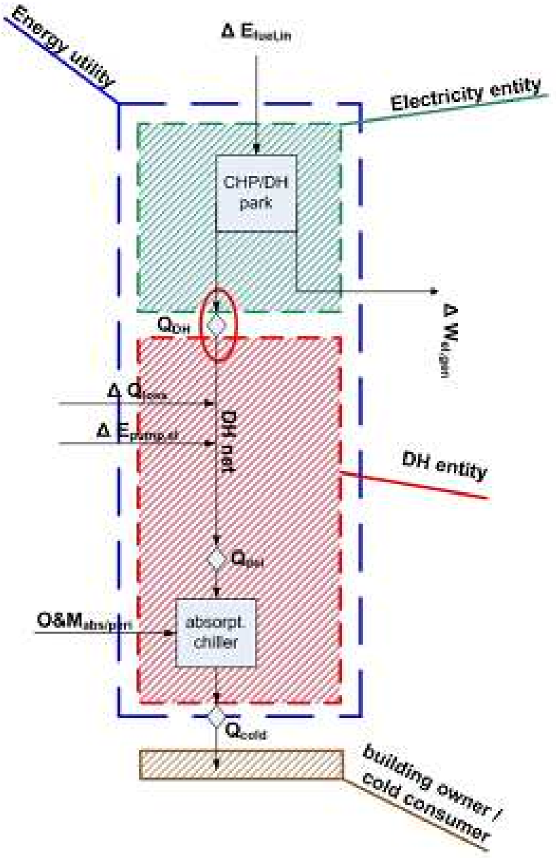
- Impacts of technical integration of absorption chillers on the heat distribution network and generation plant
- DH temperatures, mass flow and heat capacities required at chillers

Financial and Economic Analysis for Option 1

- Financial analysis: building owners / end consumer
  - Overall economic analysis: investments, costs of heat, operation and maintenance (O&M) costs for chillers and peripheral equipment borne by building owner;
  - Sensitivity: Impact of heat supply price for customers, and;
  - Investment decision by building owner / end customer.
- Financial analysis: Energy Utility / District heat supplier
  - Sale of additional heat, and;
  - Financial impacts on heat distribution and generation plant caused by the technical integration of an absorption chiller.

Option 2: Selling cold from decentralised cold generation

The local energy utility (or the district heat supplier) owns and operates the district heating network and decentralised chillers. The utility sells cold in the form of chilled water to the building owners/cold costumers.



Technical integration of absorption chillers:

Needed technical analysis:

- Required DH supply temperature for absorption chillers
- Dimension of heat junction
- Impact on DH return temperature

Implications for the Heat supplier / Energy Utility

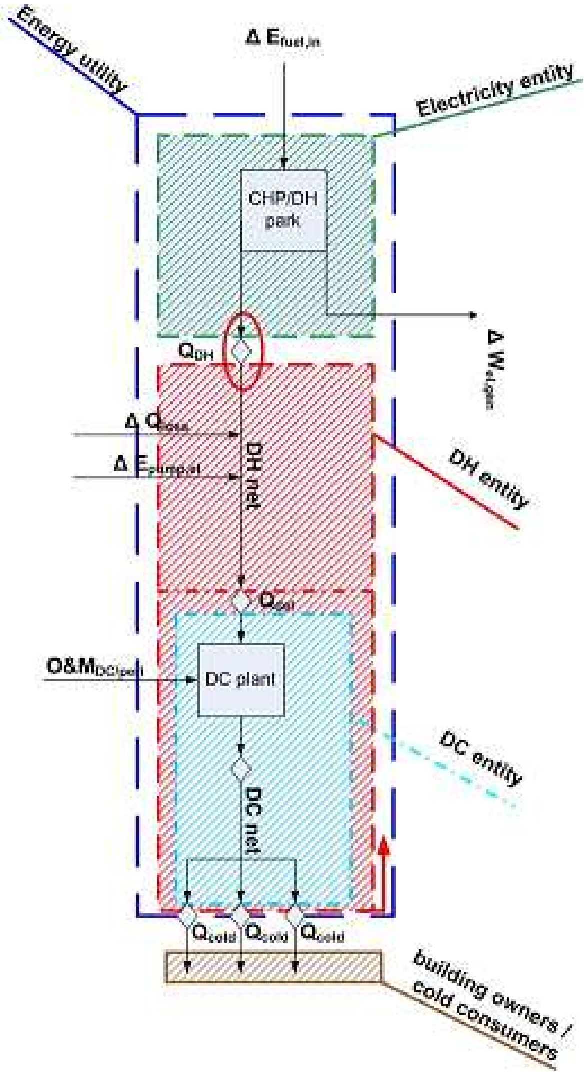
- Impacts of technical integration of absorption chillers on the heat distribution network and generation plant
- DH temperatures, mass flow and heat capacities required at chillers

Financial and Economic Analysis for Option 2

- Financial analysis: District heat supplier/cold supplier (in case of separate entities)
  - Sale of cold;
  - Overall economic analysis: investments, costs of heat, operation and maintenance (O&M) costs for chillers and peripheral equipment;
  - Financial impacts on heat distribution and generation plant caused by the technical integration of an absorption chiller;
  - Impact of the transfer price for heat between the heat generation supplier and the DH supplier, and;
  - Investment decision by energy utility (district heating supplier) or cold supplier.
- Financial analysis: building owners
  - Sensitivity: Competitive cold supply price for customers.

Option 3: Selling cold from central cold generation

The local energy utility (or the district heating supplier) owns and operates central chillers and sells cold in the form of chilled water to the building owners/cold consumers. Cold is delivered through a District Cooling network.



Technical integration of absorption chillers:

- Required DH supply, temperature for absorption chillers
- Dimension of heat junction
- Impact of cooling load on DH return temperature

Implications for the Heat supplier / Energy Utility

- Establishment of District Cooling plant(s).
- Establishment of an adequate connection from District Heating network to the District Cooling plant.
- Establishment and dimensioning of District Cooling network.
- Impacts of technical integration of DC plants on the heat distribution network and generation plant.
- DH temperatures, mass flow and heat capacities required at chillers.

Financial and Economic Analysis for Option 3

- Financial analysis: District Heating supplier / District Cooling supplier (in case of separate entities)
  - Selling cold,
  - Overall economic analysis: investments, costs of heat, operation and maintenance (O&M) costs for chillers and peripheral equipment,
  - Financial impacts on heat distribution and generation park caused by technical integration of absorption chiller,
  - Impact of transfer price for heat between heat generation entity and DH supplier, and;
  - Investment decision by the energy utility (district heating supplier) or the cold supplier.
- Financial analysis: building owners
  - Sensitivity: Competitive cold supply price for customers.

Rollout strategy for implementing heat driven absorption chillers

1. Assess the availability of heat in the period of cooling demand

- Analyse the heat and CHP generation plants
  - Heat sources
  - Operation modes during summer
- Identify future waste heat potentials

2. Assess relevant framework conditions including the administrative, legal and financial aspects of District Cooling

- Examine alternative cooling systems according to European Directive on Energy Performance of Buildings (Article 5)
- Involve urban/municipal planning and development departments for the expansion of long-term heat and cold network infrastructure, particularly in new development areas
- Financial support for thermally driven cooling technologies
- Financial support for long-term infrastructure
- Legal organisation of DC entity

3. Outline the supply concept preferred

- Identify potential cold customers/district cooling areas (concentration of cold demand = cold demand/surface of area)
- Supply concept: Selling heat for decentralised cold generation
- Supply concept: Selling cold from decentralised cold generation
- Supply concept: Selling cold from central cold generation
- Integration of other cold generation technologies (compression, free cooling)
- Analyse the possibilities and facilities for re-cooling

4. Outline the installation and operation of thermally driven chillers

- Consider the technical building equipment and how its parameters fit with a thermally driven cooling technology
- Operation and maintenance (O&M) costs for absorption chillers (district cooling plant) and peripheral equipment
- Dimensioning DC main supply pipes for final stage (in the case of central cold generation)

5. Analyse the technical impacts on the upstream heat distribution network, generation facilities and their financial effects

- Required DH supply temperature for absorption chiller Dimension of heat junction for decentralised/central installation of absorption chillers
- Impact on mass flow
- Impact on DH return temperature (temperature difference of DH may be prescribed in the case of decentralized end customer operations)
- Effects on DH losses (ΔQ_{loss})
- Effects on energy demand for pumping in the DH network ($\Delta E_{pump,el}$)
- Impact on operation mode of CHP during summer
- Effects on electricity output due to heat extraction on a higher temperature level ($\Delta W_{el,gen}$)
- Effects on energy input at heat generation park ($\Delta E_{fuel,in}$)

6. Analyse environmental aspects related to DC/use of Summerheat

- Compare the input of primary resource and the CO_2-emisions for different technologies
- Assess the municipal/regional/national commitment to thermally driven cooling (e. g. in terms of environmental action plans, etc.)
- Assess the development of conventional refrigerants within framework conditions and their impacts on the cooling sector

7. Make economic calculations from the corresponding viewpoint

- Consider the financial and techno-economic aspects from above
- E.g. Calculate the specific costs of cold production should heat be purchased for cooling (from a customer's perspective)
- E.g. Utilise an investment appraisal method if cold is being sold (from an energy utility's perspective)

8. Promote customer based criteria/benefits when offering district cooling or heat for cooling respectively

- Cold as energy service
- Advantages linked with the supply of cold from district cooling networks

9. Consider implementing district cooling/supply of Summerheat

- Initiate the planning and implementing phase

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