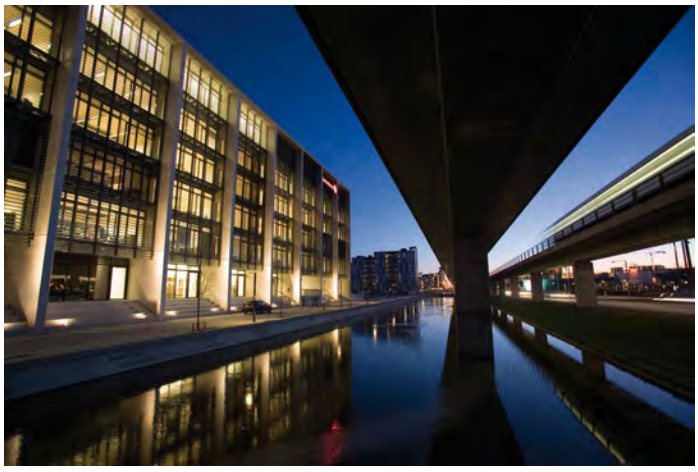
Application for the
'Global District Energy Climate Award'

Copenhagen
District Heating System

Operated by Copenhagen Energy Ltd.



September 2009

Location: **Copenhagen, Denmark**

Owner: **Municipality of Copenhagen**

Ownership: **Public-owned limited company**

Applicant:

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Content

1 Photos and illustration of system facilities

1.1 The Copenhagen District Heating system

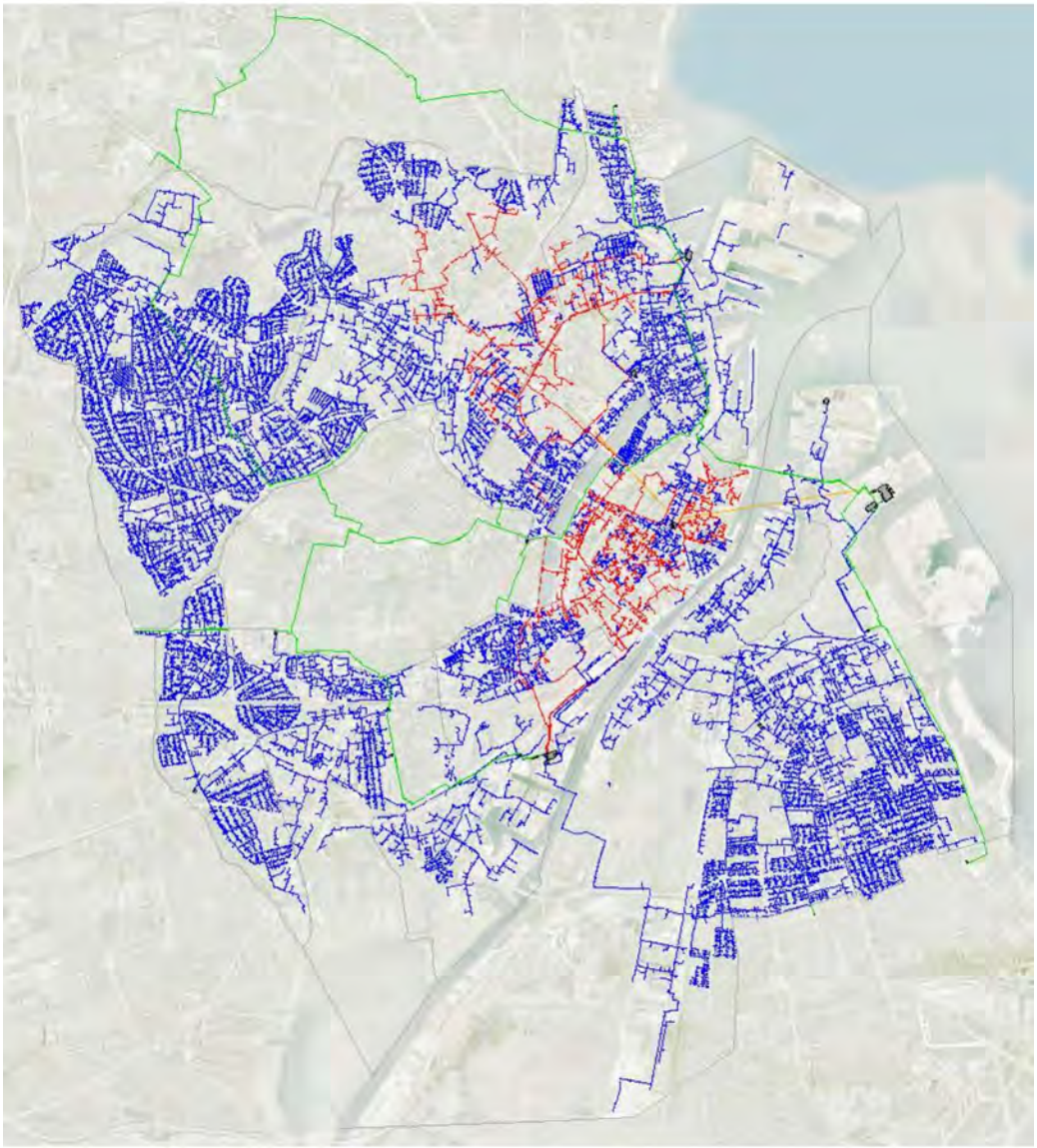


Illustration 1: The Copenhagen District Heating (DH) System. The heat distrubution is operated by Copenhagen Energy Ltd.[1], whereas the transmission system is operated by CTR[2]. The green lines symbolises tranmissions pipes, the blue are water-based distribution pipes and the red lines are steam-based destribution pipes.

[1] Copenhagen Energy (Københavns Energi). Non-profit public shareholding company owned by the Municipality of Copenhagen; http://www.ke.dk

[2] The Transmission System in Copenhagen is operated by CTR, Metropolitan Copenhagen Heat Transmission Company, of which the Municipality of Copenhagen owns 70%.

1.2 Modern DH

Illustration 2: District heating pre-insulated S-curve piping

Illustration 3: Construction of new pipe lines in Central Copenhagen

Illustration 4: Modern efficient DH substations

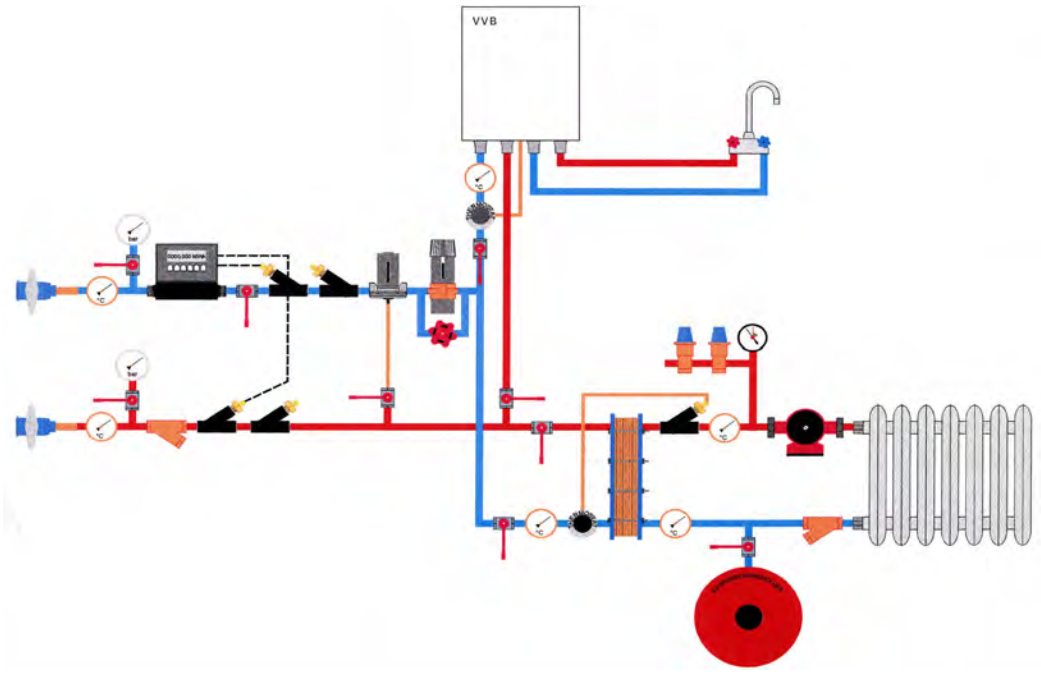


Illustration 5: Typical substation configuration

Illustration 6: From the construction of the district heating tunnel under Copenhagen Harbour

Illustration 7: The drilling crew

1.3 Surplus heat from efficient Combined Heat and Power production (CHP)

Illustration 8: Avedøre Multifuel Cogeneration Plant owned by DONG Energy A/S[3]

Avedøre Multifuel CHP Plant	
Avedøre 1	
Capacity, heat [MJ/s]	330
Capacity, power [MW]	250 (Condensing)
Fuels	Gas, wood pellets, straw and fuel oil
Avedøre 2	
Capacity, heat [MJ/s]	570
Capacity, power [MW]	570 (Condensing)
Fuels	Gas, wood pellets, straw and fuel oil

[3] From Dong Energy A/S: http://www.dongenergy.com/EN/Media/image%20gallery/Pages/Image_gallery.aspx

Illustration 9: Amager Waste Incineration Plant is owned by the municipalities of Dragør, Frederiksberg, Hvidovre, København and Tårnby AMF [4]

Amager Waste Incineration Plant	
Capacity, heat [MJ/s]	120
Capacity, power [MW]	29
Fuels	Municipal waste

[4] Amagerforbrænding A/S; http://www.amfor.dk/Om_os/Presserum/Billedmateriale/Anlaegget.aspx

2 The Copenhagen District Heating system

Copenhagen Energy A/S is a non-profit public owned limited company, having a turnover of approx. 370 million EUR and employing approx. 190 people in its DH division.

Vision: **Copenhagen Energy** aims at being the leading utility in Denmark

Mission:

- **Copenhagen Energy** supplies customers with water, sewage, district heating, district cooling and town gas[5]
- **Copenhagen Energy** ensures effective supply of high quality at lowest possible price and high security of supply
- **Copenhagen Energy** improves the city environment

The DH system in Copenhagen was initiated in the mid 1920'ies and the 1,500 km double-piped net now covers more than 98% of the demand for heating in the municipal of Copenhagen, providing heat for more than 30.000 customer (approx. 500,000 inhabitants). Through time the system has developed in two tracks, partly in the form of a water-based DH system and partly in the form of a steam-based system.

The steam-based system was developed because hospitals and industries in the city needed steam in different processes. The steam was supplied from in DH systems and private houses and compartment buildings close to the steam-based system was connected to these systems.

Only very few DH systems in the European Union still have a steam-based DH network. The steam-based system in Copenhagen covers one-fourth of the total heat demand in the city, mainly supplying major customers in the central parts of Copenhagen. The main part of the steam-based network in Copenhagen was build before 1950, and it has not been expanded since 1980, approximately 30 years ago. Copenhagen Energy has started to convert the steam-based system to a water-based system, and it is decided that the conversion will be finished in 2025.

2.1 Framework drivers

2.1.1 Legal framework

The Danish legal framework governing power and heat production, environmental standards and energy planning requirements is in the historical context considered a dominant driver for Denmark's (and Copenhagen's) high degree of combined heat and power production (CHP), and thereby also the high degree of district heating.

After the energy crisis in the 1970'ies, a massive development of district heating from CHP took place in the metropolitan area. Power production plants were converted from oil to coal, new CHP plants were commissioned and a large-scale national heat planning

[5] Town gas is natural gas mixed with air supply to households for cooking purposes.

process were carried out in order to expand the use of surplus heat from power production as well as the use of natural gas.

The heat supply act from 1979 enabled municipalities to define certain areas for district heating[6] and make it mandatory for owners of real estate to connect to district heating in these areas (obligation to connect).

Whether you are connected or not, you have to pay your share of the investment in the district-heating network. This framework condition and the way it is enforced makes DH the far cheapest option for the consumers living in such areas. The basic idea behind this type of regulation is to make the consumer's choice of heating source in line with the most beneficial primary heating source for society. As a result of the obligation to connect, the total connection to DH in the municipality of Copenhagen has increased to 98 %.

As the DH system based on CHP in Copenhagen was established and the costumers were connected to DH the overall efficiency raised and the costs to consumers were reduced. Hence, it has been a very effective and successful initiative in order to save energy and to reduce the overall dependence on imported oil. The heat supply act from 1979 also stated that heating companies are non-profit companies, the price of heat is the cost of the heat production and the distribution to the user. This is still the bases of the district heating in Denmark today.

In a system that works according to the principles described above, and when the majority of the customers are reliant on the supply of district heating, the supply companies has in return - according to Danish law – an obligation to deliver the necessary heat at the lowest possible price, without including profit or dividend to the owner of the DH company.

Economy and security of supply were the main concerns when the district heating system was expanded in the 1980'ies, and from the beginning of the 90'ies the environment became a main concern as well.

Natural gas, biomass and other renewables were introduced in the heat and power production.1993 the Danish Government decided that electricity sector in Denmark should produce electricity from 1.4 million tonnes straw and woodchips, and two of the plants in greater Copenhagen agreed to participate in the fulfilment of the obligation.

The development towards more renewables continues in the future, where biomass-fired CHP and waste incineration are considered main elements in a sustainable energy system in Copenhagen. Waste incineration now covers approx. 30 % of the heat demand in the municipal of Copenhagen.

Subsidies and energy taxes are today the main drivers of the ongoing process of getting more biomass to the CHP plants of greater Copenhagen. Subsidies are given to electricity production based on biomass, and heat production based on fossil fuels are taxed heavily. There is no tax on heat produced from biomass. As well as the exchanges of CO2-quotas on the European emission market, these subsidies and taxes makes CHP production based on biomass more economically feasible than CHP production based on fossil fuels.

Within the last few years the municipal of Copenhagen has made initiatives concerning the energy consumption and greenhouse gas emissions of the municipal. The initiatives are announced in the Copenhagen Climate Plan[7]. The climate plan targets the

[6] Usually called zoning

[7] Copenhagen Climate Plan, issued by The Municipality of Copenhagen; see also:

Copenhagen district heating system to play a major role in the efforts on achieving the 2015 goal of a CO_2 emission reduction of 20% and the 2025 goal of being CO_2 neutral.

2.1.2 Cultural framework

In the Danish society there has been and still is a strong tradition of forming collectives of different kinds. This tradition dates back to the mid/late 18-century. Around 1860 the first collectives were formed around bulk purchase of consumer goods and around 1880 the first collective for investment in technology for dairy product manufacturing was formed.

Very likely, the traditions on forming collectives has made it easier by political decisions to enforce collective solutions as district heating. The DH concept is commonly accepted by the population, not least because it underpins the political tradition to create incentives that would benefit the society and pave the way for collective energy systems.

2.2 The DH network

Directly and via the CTR, Metropolitan Copenhagen Heat Transmission Company[8], Copenhagen Energy has access to heat from CHP plants. The Municipality of Copenhagen owns 70 % of the liabilities of the CTR, whereas the remaining 30 % is owned by the surrounding municipalities. Illustration 10 shows Copenhagen Energy's DH network and the DH transmissions networks.

The investments in the DH network in greater Copenhagen since the 1980'is was financed by the fuel reductions by CHP production compared to separate heat and electricity production (app. 30 %). In contracts between the CHP plant owners and the heating companies, the fuel reduction, and thereby the cost reduction, in the first 12 years of the plant's production, was given to the heat companies. After the 12 years the fuel reduction is divided equally between the heat companies and the plant owner.

Due to this the non-profit heat companies could expand the DH system. Today 98 % of the heat demand in the municipality of Copenhagen is supplied by DH, mainly based on the CHP plants and waste incineration. Illustration 12 shows the percentage of customers connected to the DH system in the municipality of Copenhagen from 1970 to 2008.

http://www.kk.dk/sitecore/content/Subsites/Klima/SubsiteFrontpage/HvadGoerKoebenhavnsKommune/KoebenhavnsKommunesklimaplan.aspx

[8] CTR: Metropolitan Copenhagen Heating Transmission Company; http://www.ctr.dk/en/home.aspx

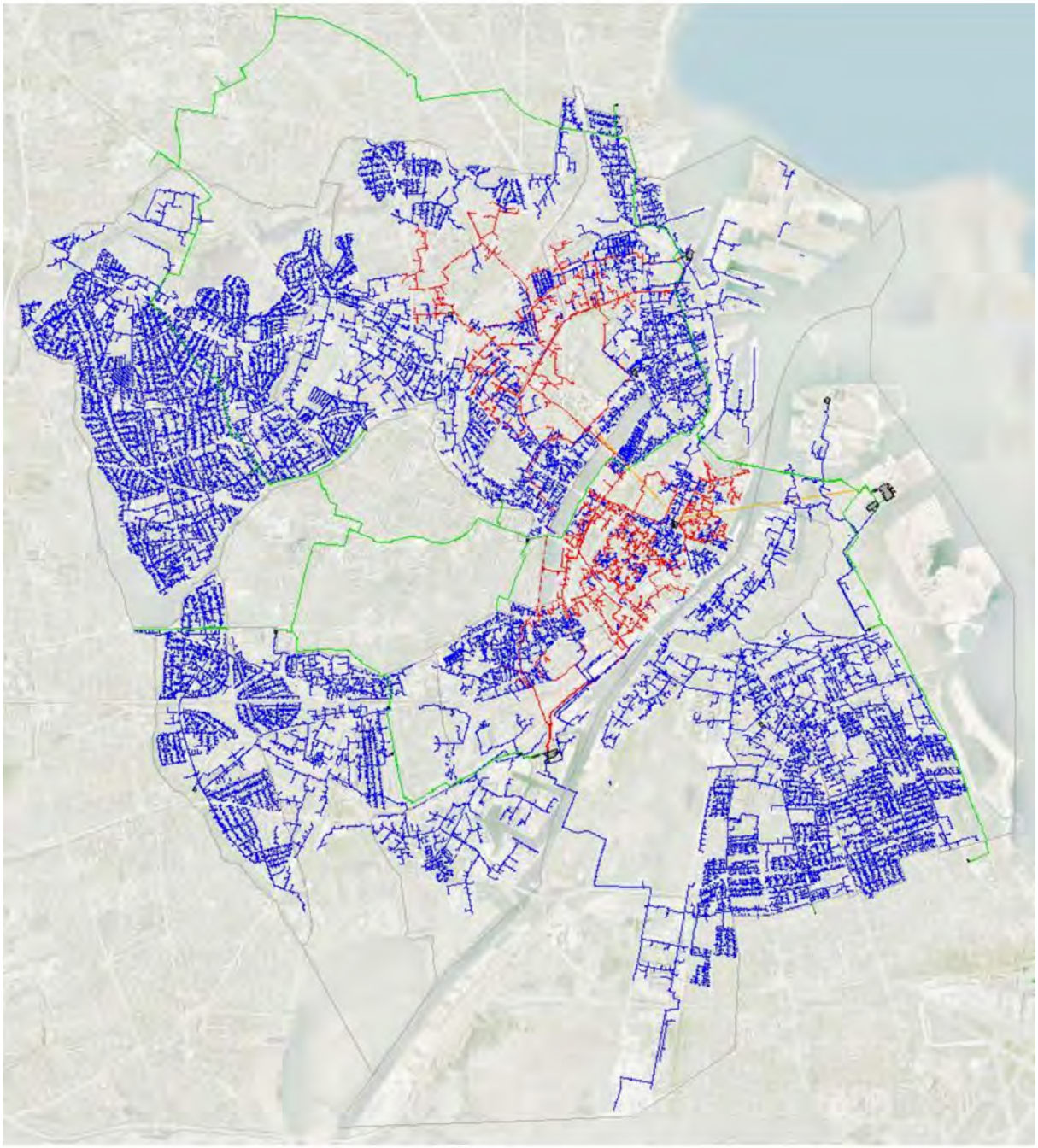


Illustration 10: The Copenhagen DH System. The heat distrubution is operated by Copenhagen Energy Ltd.[9], whereas the transmission system is operated by CTR[10]. The green lines symbolises tranmissions pipes, the blue are water-based distribution pipes and the red lines are steam-based destribution pipes.

[9] Copenhagen Energy (Københavns Energi). Non-profit public shareholding company owned by the Municipality of Copenhagen; http://www.ke.dk

[10] The Transmission System in Copenhagen is operated by CTR, Metropolitan Copenhagen Heat Transmission Company, of which the Municipality of Copenhagen owns 70 %.

Copenhagen DH system - Key figures (average year)	
Number of customers[11]	31,300
Of which water-based DH	30,000
Of which steam-based DH	1,300
DH network (double piped)	1,500 km
Of which water-based DH	1,370 km
Of which steam-based DH	130 km
DH design capacity (at customers)	4,800 MW
Of which water-based DH	3,900 MW
Of which steam-based DH	900 MW
Major heat exchanger substations	25
DH production	19,500 TJ (5,400 GWh)
Of which water-based DH	14,500 TJ (4,000 GWh
Of which steam-based DH	5,000 TJ (1,400 GWh)

Illustration 11: Copenhagen DH system – Key figures

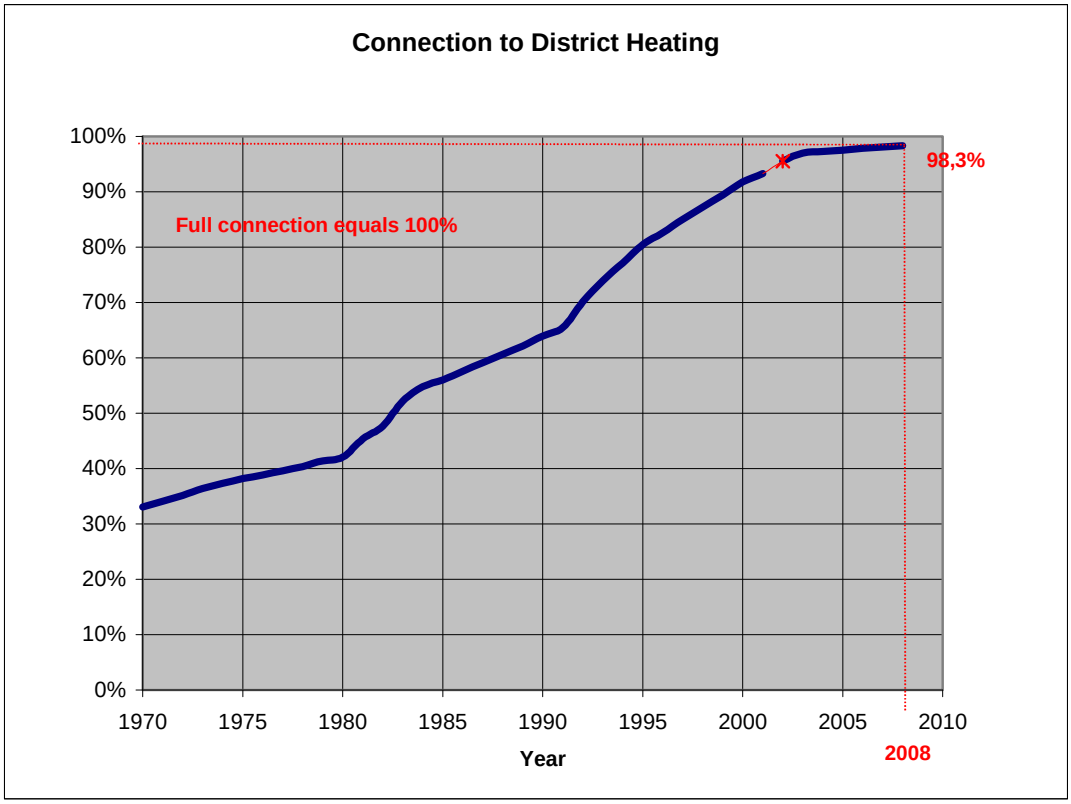


Illustration 12: Connection to the Copenhagen DH system – percentage of heat demand

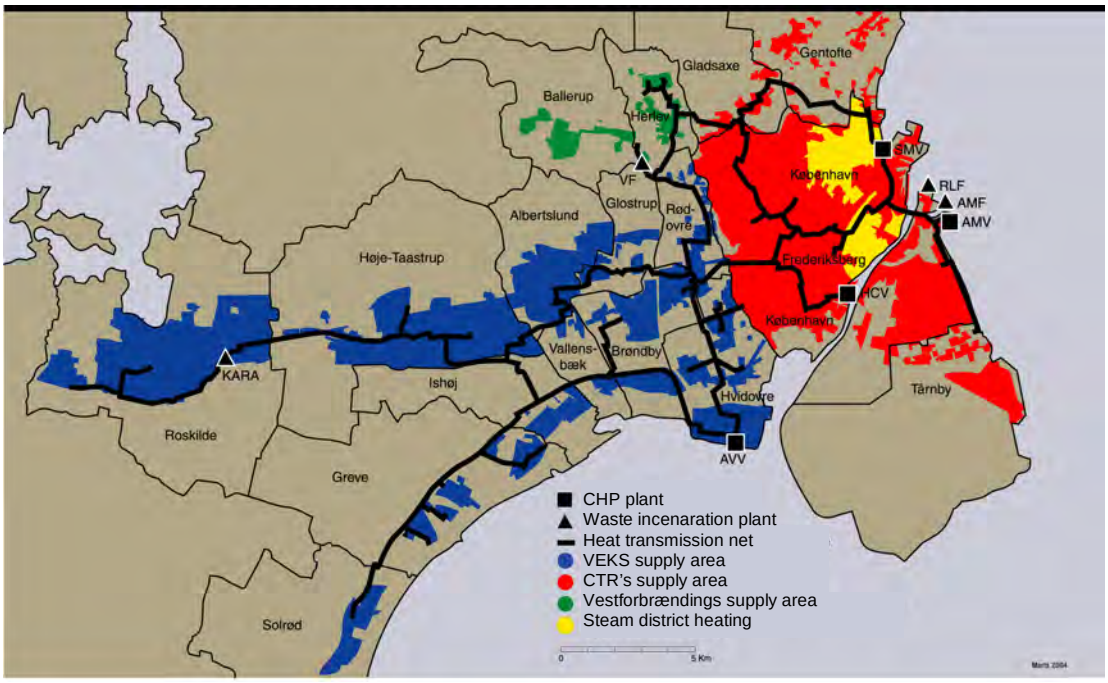
The DH system in Copenhagen covers approximately 98% of the heat demand for heating and hot water purposes, hence covering the heat demand for a building stock of roughly 35.5 mill. square meters, being equivalent to roughly 500,000 inhabitants[12].

[11] Compartment buildings is also defined as one costumer.

Even though the amount of customers supplied by DH already is high, Copenhagen Energy still receives request to be connected.

2.3 Heat production configuration

The Copenhagen district heating system is operated as a part of the very large coherent district heating system in greater Copenhagen, covering Copenhagen and 15 smaller municipalities. Two large heat transmission companies, CTR and VEKS[13], transports heat from the large CHP plants to the local distribution system. Below the greater Copenhagen DH system is showed.



The district heating system in greater Copenhagen is one of the largest district heating systems in the world, with a yearly heat consumption of approximately 33,000 TJ[14]. The share delivered to the municipality of Copenhagen is about 55 % of the total heat consumption.

The main part of district heating for Copenhagen is delivered from 10 CHP plants with the total capacity of app. 2,000 MW heat. The rest of the heat demand is supplied by a number of heat only boilers for peak load production .

[12] Københavns Kommune - Klimaplan 2015, Bygninger, November 2008, page 8 http://statistikbanken.dk/statbank5a/default.asp?w=1152 and http://www.kk.dk/sitecore/content/Subsites/Klima/SubsiteFrontpage/HvadGoerKoebenhavnsKommune/~/media/491B1EC4F6B14FC9A31F9373AA54F02D.ashx , page 73

[13] VEKS: http://www.veks.dk/default.aspx?sc_lang=en

[14] Including heat loss in the DH system.

Unit name	MW heat, maximum	MW Electricity, maximum	Fuels	Year of construction
AVV1	330	250	Coal	1990
AVV2	570	570	Gas, wood pellets, fuel-oil and straw	2001
SMV7	138	71	Gas	1995
HCV8	42	24	Gas	2004
HCV7	224	88	Gas and fuel-oil	1994
AMV1	250	80	Wood pellets, straw pellets (Coal for backup)	2009
AMV3	330	250	Coal	1989
AMF	120	29	Waste	1991-2001 (4 boilers & 2 turbines)
KARA	12	71	Waste	1970-2005
VF	31	219	Waste	1976-?
TOTAL	**2047**	**1652**		

Illustration 13: Heat production configuration

In 2005 a geothermal demonstration plant was established. Surplus heat from the large waste water treatment plant in Copenhagen is also exploited.

As shown above the DH system in Copenhagen receives its heat supply from many different units with different technical data and using different fuels. Because of this the system is very flexible, has a high level of security of supply and is less vulnerable to fluctuating world market prices. The energy system (heat and power) is operated in a manner that gives the best economic performance, thus as a common optimization of production of heat and electricity. Based on a forecast, for every day it is estimated what CHP stations should be in operation, reflecting the estimated heat demand, fuel prices and electricity prices.

In 2009 a new CHP plant at Amager is commissioned: AMV1. As the first plant in Denmark AMV1 has a requirement of a minimum percentage of biomass-based CHP production. The subsidies for biomass-based electricity production, the lack of energy taxes on biomass-based heat production and the CO2-quota costs on coal-based production will make the costs of biomass-based CHP production at AMV1 lower than coal-based production. Thus AMV1 will be a mainly biomass-fired CHP plant, with coal as a backup fuel.

At the same time Copenhagen Energy is commissioning a tunnel with steam pipes from AMV1 to the steam-based DH system in the centre of Copenhagen. AMV1 is build to supply the steam-based DH system in Copenhagen through this tunnel. Building the new biomass-fired plant for the steam-based system, has made it possible to close older and inefficient gas-fired plants in Copenhagen.

Copenhagen Energy is in the process of converting the steam-based DH system to a water-based DH system, therefore the tunnel from AMV1 also contain water pipes. As the steam-based system is converted, the water pipes can supply the new water-based parts in the system. The steam pipes in the tunnel will be used for hot water, as the steam-based system is converted. AMV1 can be extended with a low pressure turbine, making the electricity production at the plant higher, and making it possible for AMV1 to produce water-based DH instead of steam-based DH.

2.3.1 Planning the daily heat production

With the liberalization of the electricity market in Europe the CHP plants and some of the heat boilers in greater Copenhagen are owned by the liberalized power companies, DONG Energy and Vattenfall. Thereby the DH system is supplied by two large thermal electricity and heat producers. The two thermal energy producers must not know of the production at each others plants, according to the competition rules in the electricity market. Therefore it is difficult to optimize the heat and electricity production in the CHP plants in the DH system in greater Copenhagen.

The heat companies of greater Copenhagen, Copenhagen Energy, CTR and VEKS[15], made an analysis of the optimization of heat and electricity production in the greater Copenhagen. The analysis showed that a continued total optimization of electricity and heat production (load dispatch) in greater Copenhagen, was a much cheaper way of supplying the system compared to other daily production planning routines.

The only ones with the total overview of the energy system in greater Copenhagen to make the total optimization of the heat and electricity production is the heating companies, not trading in the electricity market and buying heat from both thermal energy producers and waste incineration. Therefore the heat companies and the power companies, made a contract, stating the routines for making a total optimization of the heat and electricity production in greater Copenhagen, hour per hour at the lowest possible cost. To perform the daily optimization of the heat production hour per hour, the heat companies of greater Copenhagen established VLE.

VLE handles the daily planning of the heat production. The optimization routine is based on calculations of the total cost of heat and electricity production in the plants in greater Copenhagen, and on a day ahead communication between the power companies and VLE. The power companies calculate a heat cost curve for the whole next day depending on the electricity price, fuel prices and availability of the plants. VLE calculates the optimal distribution of heat production, between the two power companies. The power companies sends back the optimal plan for production the heat order, and marginal cost of heat regulation of every plant, every hour. Based on the marginal heat costs of the plants, VLE regulate the two heat production plans to a physical possible plan by addressing the transmission-bottlenecks in the DH system and technical abilities of the plants and the DH system. Three times a day the heat plan is regulated with new marginal heat costs, based on electricity price in the electricity after-markets an the deviations from the heat demand forecasts.

Because of the differences between the steam based and water based DH system, the optimization handles 3 products: electricity, water-based heat and steam-based heat. Handling all 3 products in the daily optimization is the only way ensure the total optimization.

Within the DH system in greater Copenhagen there are three heat storage facilities. Two is located at Avedøre CHP plant and the last one at the Amager CHP plant. The heat storage facility basically works like a huge thermo. The heat storage in Amager has the capacity to store 24,000 m^3 of hot water. The heat storages is used in the optimization of the electricity production and heat production from the CHP plants. It is possible to produce the electricity in the peak hours of the electricity demand by charging and

[15] VEKS: http://www.veks.dk/default.aspx?sc_lang=en

discharging the heat storage. This makes it possible to full fill the heat demand every hour and produce the electricity when the electricity price is high. A part of the heat storage capacity is used for heat regulation if the heat demand deviates from the forecast of the heat demand .

2.4 Steam Conversion 2025: Converting steam customers to water- based heating

Having the aim of reducing environmental impact, reducing heat losses and of reaching even higher efficiencies and better economy for the CHP production, one of the major development projects during 2009 to 2025 will be the substitution of the steam-based DH network with a new water-based DH network. The rationales behind the conversion to a water-based system are:

- Low efficiency in distribution in steam-based system
- Lower electricity efficiency in CHP plants producing steam-based DH
- Higher CO2 emissions

Analyses have shown that the conversion worth 350 million EUR will benefit the district heating system, making the conversion viable in financial terms as well as in terms of socio-economy. The project will save more than 1,100 PJ primary energy and reduce CO2-emissions by more than 125,000 ton/year.

3 Energy and environmental achievements

3.1 DH is lowering primary energy use

Cogeneration of heat and electricity production (CHP) use app. 30 % less fuel compared the same amount of heat and power produced in separate heat and electricity plants.

The heat consumption in the DH system of Copenhagen Energy was 17,400 TJ in 2008. Below the fuel consumption for the heat production distributed on the different fuel types are seen.

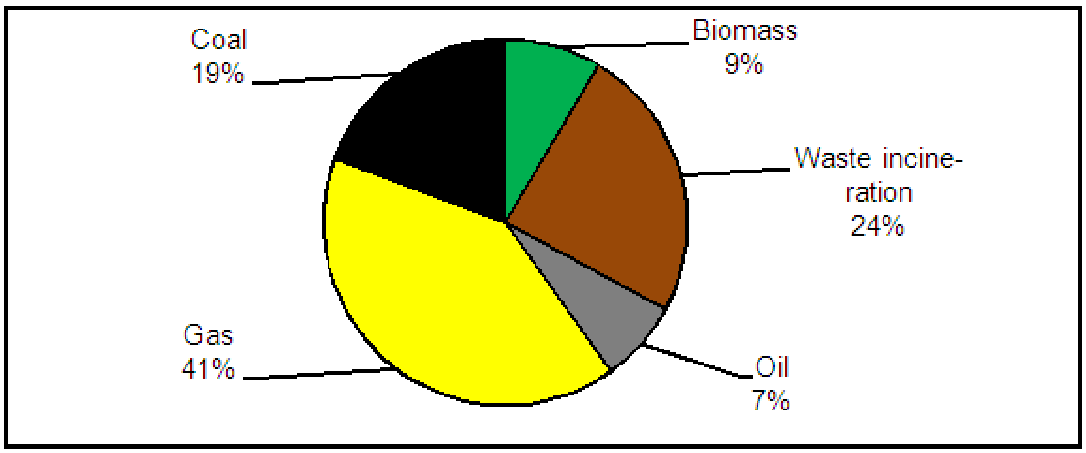


Illustration 14: The fuel mix in the heat production for the municipality of Copenhagen in 2008, calculatede with the 200 %-methode .

The DH system in the municipality of Copenhagen was in 2008 supplied by 33 % biomass and waste incineration. Waste incineration is considered CO_2-neutral, apart from the plastic in the waste.

The gas consumption in the fuel mix in mostly used in CHP plants supplying the steam-based system in the centre of Copenhagen. In the future biomass-based steam production for the steam-based system from AMV1 will lower the amount of gas in the heat supply.

The tunnel from Amager to the steam system also makes it possible to get steam from the waste incineration plant at Amager to the steam-based system, raising the amount of heat from waste incineration in the municipality.

3.2 Lowering CO2 emissions

The CHP-based DH system in greater Copenhagen lowers the CO_2 emission of the heat production compared to individual oil- and natural-gas boilers.

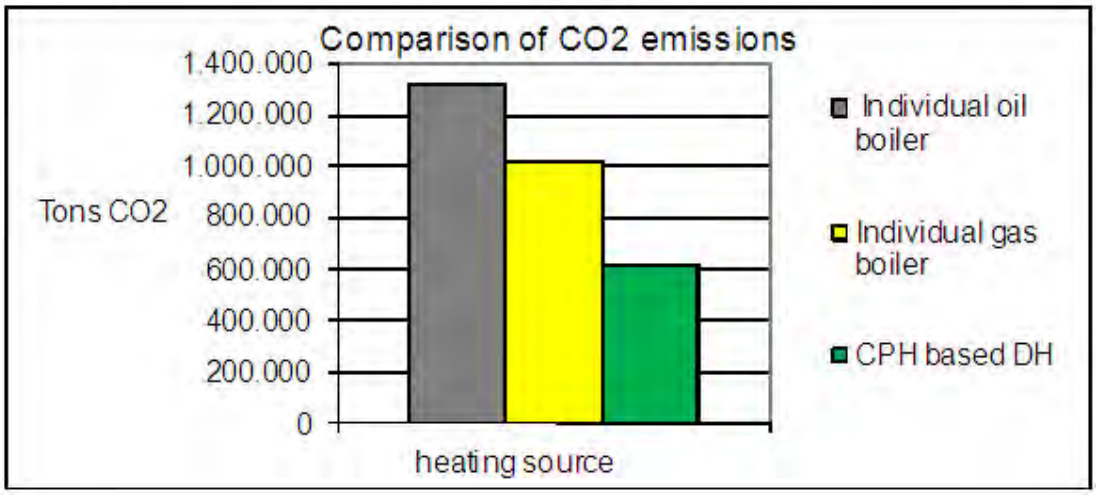


Illustration 15: District heating has reduced CO_2 by 40 – 50 %

The environmental impact of the DH consumption compared with oil- and gas boilers clearly shows the reduction in CO_2 has been substantial. Compared with the oil or gas boiler alternatives the reduction is 40 - 50 %.

3.3 Environmental compliance

Copenhagen Energy conduct environmental management that is certified according to the EMAS and the ISO14001 standards. This ensures that the supply company is in compliance with all environmental laws and that the company is conducting its business according to the highest international standards.

3.4 Increasing energy performance of existing buildings

Induced by law, Copenhagen Energy has the obligation to reduce demand side energy consumptions by 42 GWh per year for the period 2006-2013, which constitutes approximately 0.8 % of the annual heat production. Stronger national requirements to DH companies may be imposed in near future.

Consequently, Copenhagen Energy offers energy saving services to the customers in the range of building insulation and similar, electricity savings (pumps and lighting). KE has entered into cooperation with external companies involved in retrofitting of heating installations etc.

The main target areas are energy savings related to:

- New customers
- Conversion of substations to water-based heating
- Insulation of pipes and valves

3.4.1 Climate+

The Municipality of Copenhagen has initialised the Climate+ initiative, being a network for companies who wants to reduce their CO2-emissions.

The approximately 40.000 businesses in Copenhagen use 70 % of the city's electricity consumption and 35 % of its heating consumption. The goal in Copenhagen is to have 6000 members by 2015 and to reduce the emissions by 20 %. Members of the network receive offers such as coaching, workshops and different kinds of inspirational meetings.

The various offers are oriented towards different businesses such as industry, shops, hotels, restaurants, offices etc. Furthermore the network offers free energy audits through Copenhagen Energy.

3.5 Sustainable heating for new building stock

The Municipality of Copenhagen has a strong focus on sustainable city planning, as reflected in the Copenhagen Climate Plan[16]. The municipality has engaged in a partnership with Copenhagen Energy who will take an active part in the analyses of sustainable heating options for new building stock that will meet the strictest requirements set out in the Danish Building regulation 2008: 'Low-energy Class 1' in the municipality. The coloured areas, exceeding 8 million square meters on the map below illustrate the new development, representing around 20 % of the total building stock when realised.

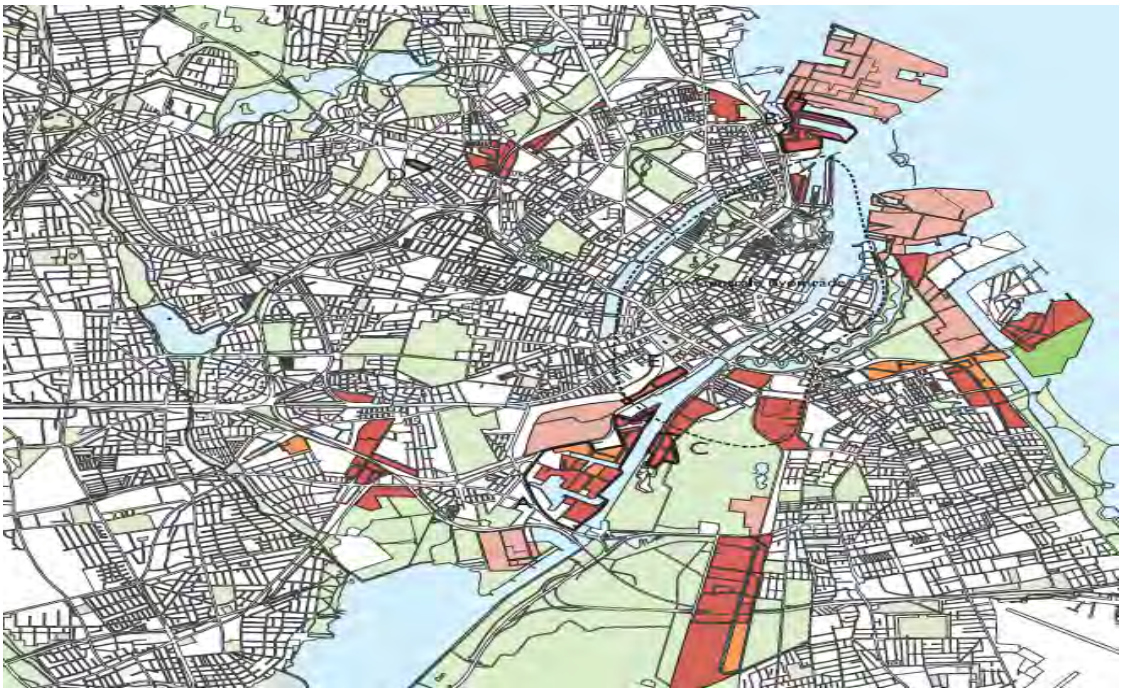


Illustration 16: Map of new development areas in Copenhagen (coloured areas)

In the latest analysis of Copenhagen Energy, District heating has proven superior to other individual heating alternatives, when it comes to environmental impact, socio-economy and consumer economy. This is mainly due to the significant use of renewable fuels for DH and the energy efficiency of Combined Heat and Power (CHP) production. Today the

[16] Copenhagen Climate Plan: English version available at: http://www.kk.dk/sitecore/content/Subsites/Klima/SubsiteFrontpage/HvadGoerKoebenhavnsKommune/KoebenhavnsKommunesklimaplan.aspx

water-based DH production of greater Copenhagen is based on app. 45 % renewable energy from biomass and waste.

For the alternative scenario the following technologies were considered:

- Small scale biomass boiler with a local distribution net
- Solar panels and a geothermal heat pump for each building

The small scale biomass boiler was opted out, due to the fact that much greater economy of scale would be achieved by incineration of biomass in the large CHP plants. Solar panels for domestic hot water in summer was ruled out because combined with necessary additional technologies having to cover the remaining part of the season, investments became too high. Heat supplied from a geothermal heat pump was chosen as the best alternative. Due to lack of space for renewable technology in dense city areas, more expensive geothermal rods had to be applied in stead of horizontal pipes. Furthermore, an electrical boiler for each building was required as back up - all in all resulting in a more expensive solution. The alternative scenario also turned out to be less environmentally viable, due to the electricity required for the heat pump, supplied from the collective power system.

1. District Heating scenario

2. Alternative scenario: Geothermal heat pump

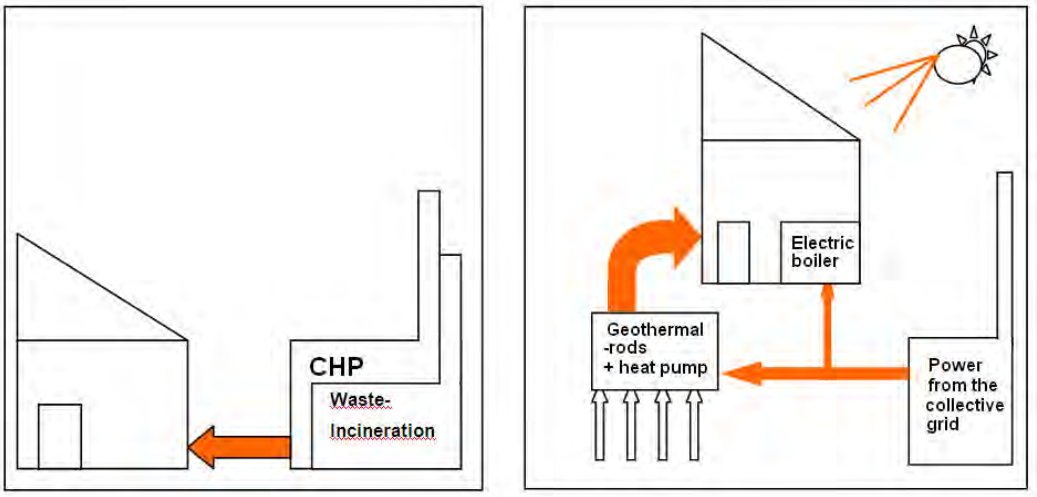


Illustration 17: Centralised DH supply compared with local geothermal heat pump

The analysis thus highlighted a number of issues related to sustainable heat supply in city areas:

- Lack of space for RES technology in densely built city areas
- Present renewable energy technologies are costly and can often not exploit economies of scale advantages
- Further analyses of the potential advantages from combining local renewable technologies and collective DH are relevant

4 Innovative technological solutions

4.1 Economic optimisation of heat production

Much efforts are put into economic optimisation of heat production. Since the heat production is strongly integrated with the power production in CHP plants, and hence for Denmark the balancing of demand and production in the liberalised power production regime is done through the Nord Pool Spot[17] power exchange.

Thus the exercise of economic optimisation is very complicated and will reflect the behaviour of power market actors in the liberalised market.

Not least due to environmental and economic concerns, Copenhagen Energy is focused on this optimisation and has applied the rather advanced Balmorel model for simulation of the power and heat market and subsequently also to form the basis for heat contracting.

The Balmorel model[18] is the most detailed simulation tool describing the Nordic market for electricity and the DH market in greater Copenhagen. The model is basically an economic optimisation model, that optimises heat and electricity production in overall economic terms. The tool include models of the CHP and power generation capacities and their technical and economic performance, covering Denmark and all surrounding states including capacities of interconnection etc. In this way the model will simulate the behaviour of the power market, taking into account the bindings to heat production, given by CHP plants.

Priorities found by Balmorel simulations forms the basis for everyday heat production optimisation and the model has played a major role in the analyses done in the **Heat Plan Greater Copenhagen 2025**.

4.2 DH net optimisation

As a district heating company, Copenhagen Energy has the need continuously to:

- Make overall design of the district heating network and improve its operation
- Make detailed design of the district heating network
- Detect malfunctions and potential for improvements in the district heating network

Overall design of district heating network is done with respect to areas with new customer and in the planning of renovation of the network, but not least in the ongoing major 'From Steam to Water' project, where the existing 130 km DH system operated on steam will be substituted by a new DH system operated on hot water.

In this respect, simulations of the district heating network is made aiming at ensuring low heat losses, low energy consumption for pumping and a sound operation of the new network, thus giving also lowest possible environmental impact.

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[17] http://www.nordpool.com/en/

[18] The Balmoral model has been developed to model and analyse the Baltic region's energy sector with main focus on the electricity and district heating sectors.
See: http://www.energinet.dk/en/menu/Planning/Analysis+models/Balmorel/Balmoral.htm

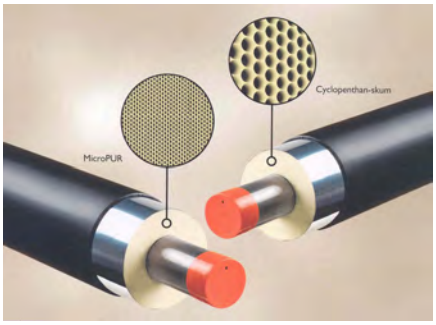


Illustration 18: Using new and better pipe insulation

The conversion from steam to water calls for a considerable amount of simulations in order to obtain the most optimal system as possible. Calculations are made both on the existing system (2009), the future system (2025) and for all the years in between, where the two parallel systems will be operated concurrently.

The detailed net design focuses parts of the net close to customers and design of pump stations, valves, pipes and heat exchanges. The overall design and the detailed design is often made together to ensure robustness and energy efficiency.

Real-time simulations are used get knowledge on the dynamic response of the DH system and for hydraulic optimisation of the system and thereby detect malfunctions and assess the potential for improvements in the district heating network. The simulations incorporate data for the net from

For the simulations, Copenhagen Energy uses the TERMIS software[19], which is an advanced and a powerful calculation-tool for simulating district heating system operation. The TERMIS software imports data from the fully developed GIS system, covering all DH elements in the network, as pipes, valves, heat exchangers etc.. For the real-time simulations data on the net is imported from a central data monitoring system using a sample rate of 15-minutes.

4.3 Adaptive control of DH supply temperature

Historical measurements have shown that the supply temperature in the district heating system tend to be higher than necessary, thus increasing the heat losses and operational costs in the system.

In order to adjust the supply temperature to the lowest possible, a temperature optimisation method has been introduced. The method encompasses two steps:

- Load forecast (MW) produced by the PRESS software on the basis of historical data from the SCADA system, in the form of supply temperature, return temperature, flow, load, outdoor temperature and wind speed together with weather forecast data.

[19] http://www.7t.dk/termis/default.asp

- Deriving a 144 hours supply temperature forecast from the load forecast and a TERMIS model of the district heating system by using the TERMIS Temperature Optimisation Module.

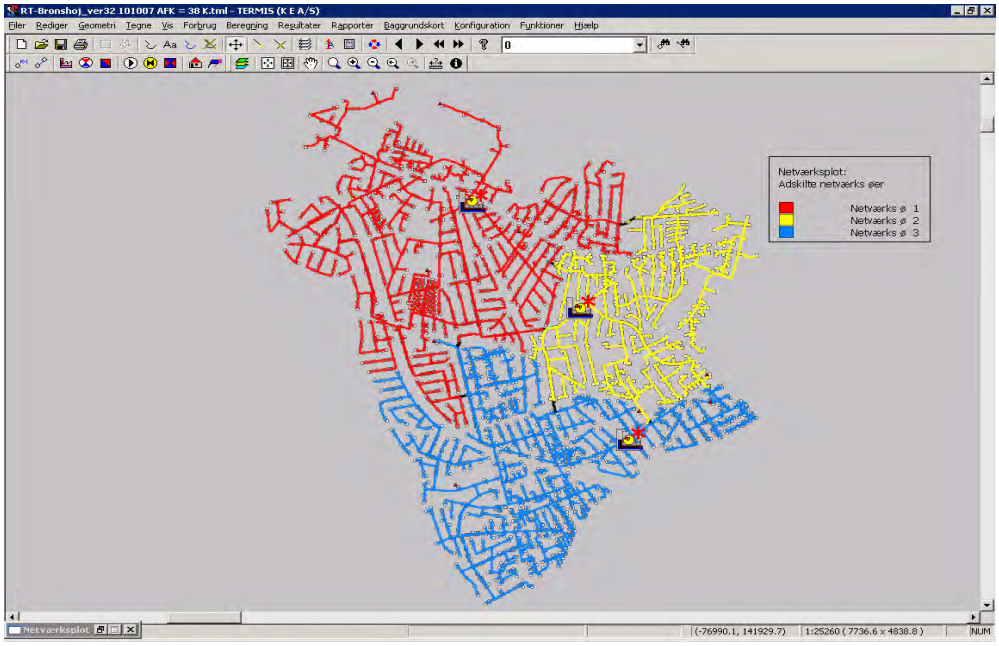


Illustration 19: TERMIS Model for load forecasting in three local areas of Copenhagen

The temperature optimisation module takes into account the accumulated energy in the net, and the changes needed as a result of the weather forecast. It takes into account the common operational changes, such as valves being opened or closed, large consumers with varying consumption, and variations during weekends and holidays and as well unusual operational interruptions.

4.4 Remote metering of DH substations

A pilot project on remote metering covers 1800 major customers, and will be expanded with 4700 minor customers in the supply area of Amager in the following years. The metering include consumption of energy, flow and temperatures. Major customers are equipped with remote metering by means of telecommunication, whereas simpler communications are in place at the minor customers.

Illustration 20: Different types of meters used in DH installations through the years.

Apart from metering the system is also used for monitoring of substations, aiming at detection of malfunctions and improvement of the performance of the substation; e.g. reduction of return temperature.

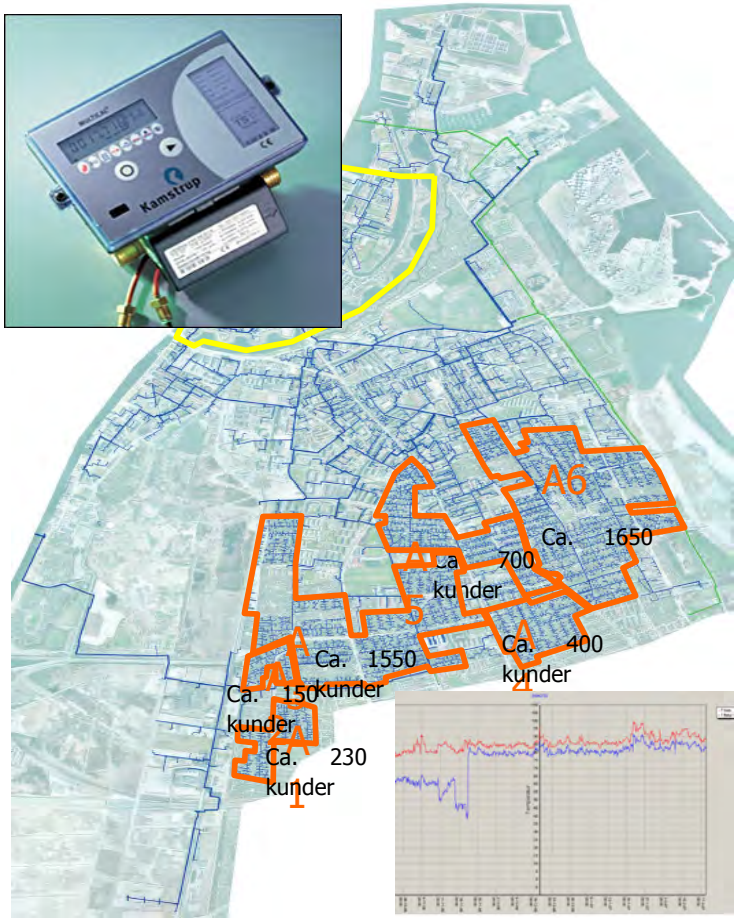


Illustration 21: The geographical aree for pilot remote metering project

The results from the pilot project point out a number of advantages:

- The metering becomes easier and will in the long run reduce costs of metering
- The remote metering can be used to detect insufficient performance and give hints on possible improvements

4.5 Geothermal heat

Copenhagen Energy owns a geothermal test plant together with other district heating and power sector actors – located at the Amager CHP plant's site.

The geothermal plant utilises the temperature of 73 °C, at 2,6 km below the earths surface, to produce heat. With a 700kW pump that has been lowering into the hole, the water is pumped up to the surface. Three absorption pumps, operated on steam from the Amager CHP plant, raise the district heating supply temperature so that it can be utilised in the DH network. The plant has an overall heat production capacity of 25 MW of which 13 MW is geothermal.

4.6 Solar DH

Copenhagen Energy is installing a demonstration solar plant, that will deliver solar heat to the DH system in Amager.

The investment of 0,8 million EUR in the solar DH demonstration plant include 490 square meter of solar panels, a heat storage and a heat pump. The plant has a capacity of 280 kW and will deliver district heating to the DH network by the end of 2009.
In the demonstration project the solar panels are connected to a large heat storage tank and a heat pump. In the storage tank the heated water from the solar panels can be stored to the time of use. With the heat pump the temperature of the water from the solar panels or the storage tank can be raised before the heat is delivered to the DH system. Until now, solar heat has only been applied in a few smaller DH systems, where solar heating supplies most of the heat during the summer, the spring and the fall.

Although solar DH will compete with waste incineration during summer, it is expected that experience will be gathered from the demonstration plant, that may show the way to further initiatives, and in the long run eventually lead to methods of storing waste for later incineration during winter.

4.7 Exploitation of District Cooling

A District Cooling (DC) project in central Copenhagen around the Kongens Nytorv square, hence abbreviated the 'Kongens Nytorv project' is under construction. The first consumer was connected in the summer of 2009 supplied from interim centrals. In the sprig of 2010 a new cooling plant, with the capacity of 15 MW, will be in operation.

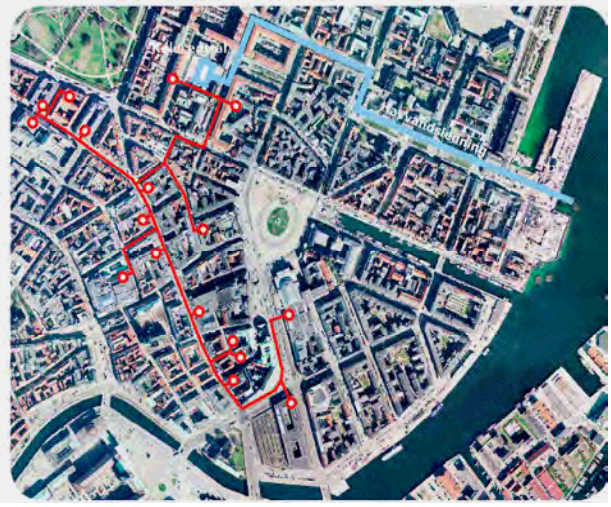


Illustration 22: District Cooling in Central Copenhagen, the Kongens Nytorv project.

Copenhagen Energy is in the process of establishing a district cooling system in central Copenhagen in the Kongens Nytorv area. The project stand upon a survey, mapping potential customers including investigations of existing air-conditioning systems, need for renovation taking into account the age of the system, technology, maintenance level and subsequently the prevailing cooling costs.

A number of owners of commercial buildings and office buildings have shown strong interest in having access to district cooling and for the Kongens Nytorv project seventeen potential customers has been identified having in total a cooling demand of 15,3 MW. Five of the potential customers show a demand equalling 80% of the this projected capacity. These five major customers all have existing central cooling plants. Most of the smaller customers do not have a central cooling plant in place, and will thus need to establish such.

When fully implemented during 2010-2013, the pilot district cooling system will supply the customers with approx. 22.000 GWh's of cold per year. It has been given high priority to design the production in the most sustainable way. Therefore the system uses free cooling and absorption chillers on surplus heat from CHP plants to a high extent.

Cooling production	**share**
Free cooling	29,3%
Electrical chiller	42,4%
Absorption chiller	28,3%
Total cooling production	**100,0%**

Illustration 23: The cooling production in the Kongens Nytorv pilot project

Since the implementation of the project started new consumers have shown interest in being connected to the DC system. The demand from these consumers add 10 MW to the demand.

A new DC project is planned to cover the area around the Town Hall Square. This project will be the same size as the Kongens Nytorv project.

5 Governing Strategies and Challenges

5.1 Copenhagen Climate Plan 2025

With the Copenhagen Climate Plan, The Municipality of Copenhagen has set the target of a 20% CO2-reduction by 2015 in comparison with the 2005 emissions of 2.500.000 t CO2/y, and the vision for Copenhagen to be completely CO2-neutral by 2025.

The plan incorporates Climate Action Initiatives for the following areas[20]:

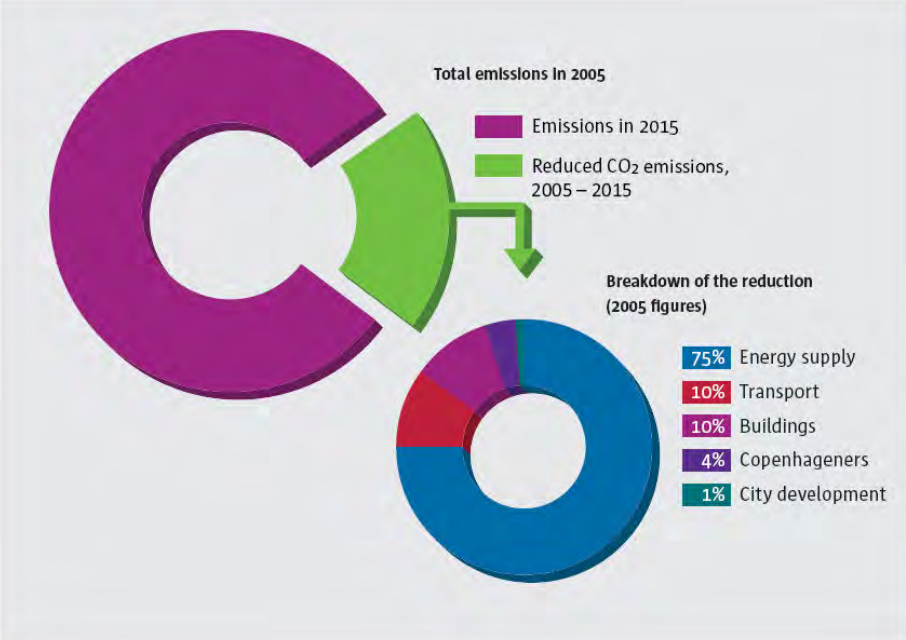


Illustration 24: The Copenhagen Climate Plan – 2015 targets

The Municipality of Copenhagen has furthermore identified 7 specific initiatives[21] with regards to the energy system in Copenhagen:

- Renewable energy replaces coal at Amager power station Unit 1, converting 100% to biomass (wood chips)
- Renewable energy replaces coal at Amager power station Unit 3, converting at least 40% to biomass (wood chips)
- New combined heat and power station is constructed, based on renewable energy.

20 http://www.kk.dk/sitecore/content/Subsites/Klima/SubsiteFrontpage/HvadGoerKoebenhavnsKommune/~/media/F14B427B54874117A430DE1AD08B3879.ashx, page 5

21 For further initiatives see the short English version of the Climate Plan at: http://www.kk.dk/sitecore/content/Subsites/Klima/SubsiteFrontpage/HvadGoerKoebenhavnsKommune/~/media/F14B427B54874117A430DE1AD08B3879.ashx

- Heating with geothermal energy is increased six-fold by expanding the demonstration geothermal facility at Margretheholm.
- The efficiency is improved at waste incineration plants by introducing flue gas condensation units.
- The district-heating network is modernised to reduce heat losses from the pipes.

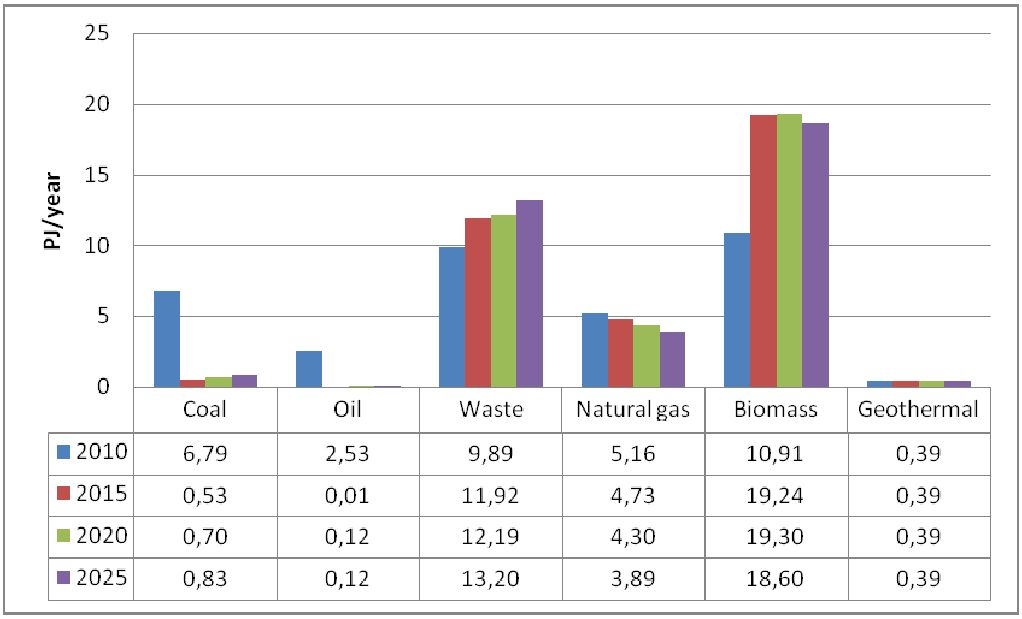
5.2 Heat Plan Greater Copenhagen 2025

That district heating is essential for reaching climate goals is demonstrated in the Heat Plan for the greater Copenhagen area that was presented in the 'Heat Plan Greater Copenhagen – 2025', in September 2009[22].

The plan analyses the future heat supply for the Greater Copenhagen. The plan contains scenarios for the heat supply by 2015, 2020, 2025 and 2050. Elements in the scenarios are energy savings in the existing building stock, high exploitation of waste and a vast utilisation of biomass on existing CHP plants.

Based on present and future regulatory framework and an evaluation of future technologies; the Heat Plan projects 4 scenarios for the heat supply system in the metropolitan area by 2025.

The analysis shows that already from 2015 biomass will play a major role, substituting coal and oil.



	Coal	Oil	Waste	Natural gas	Biomass	Geothermal
2010	6,79	2,53	9,89	5,16	10,91	0,39
2015	0,53	0,01	11,92	4,73	19,24	0,39
2020	0,70	0,12	12,19	4,30	19,30	0,39
2025	0,83	0,12	13,20	3,89	18,60	0,39

Illustration 25: District heating production distributed on fuels – reference scenario

The scenarios contain a doubling of present share of renewable energy in the heat supply, equivalent to an objective of 70 % renewable energy in the district heating system by

[22] More information at: **www.varmeplanhovedstaden.dk**

2025. One scenario requires the heat supply to be solely based on renewable energy resources and waste incineration, equivalent to an 87 % CO2-free system by 2025.

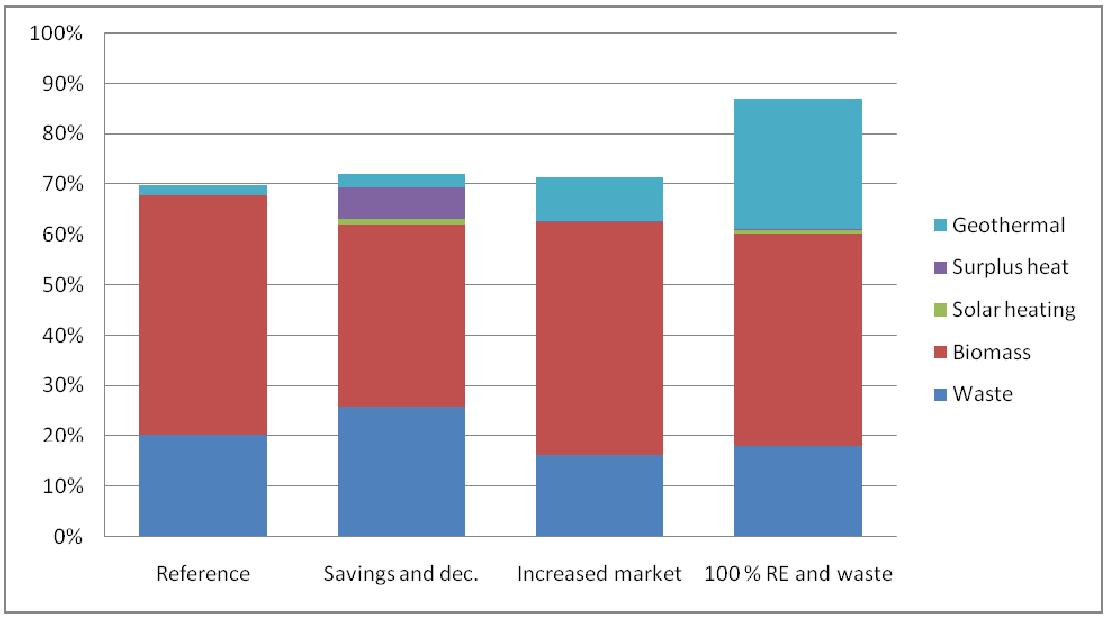


Illustration 26: Share of renewable energy by 2025 for different scenarios

The analyses shows it will be both possible and economically feasible to rapidly and massively convert from coal to biomass in the CHP plants, mainly because of subsidies for biomass-based power production and no energy taxes on biomass-based heat production. Such a conversion should be followed by a gradual long term conversion to other kinds of renewable energy in the system, as experiences with these technologies are obtained.

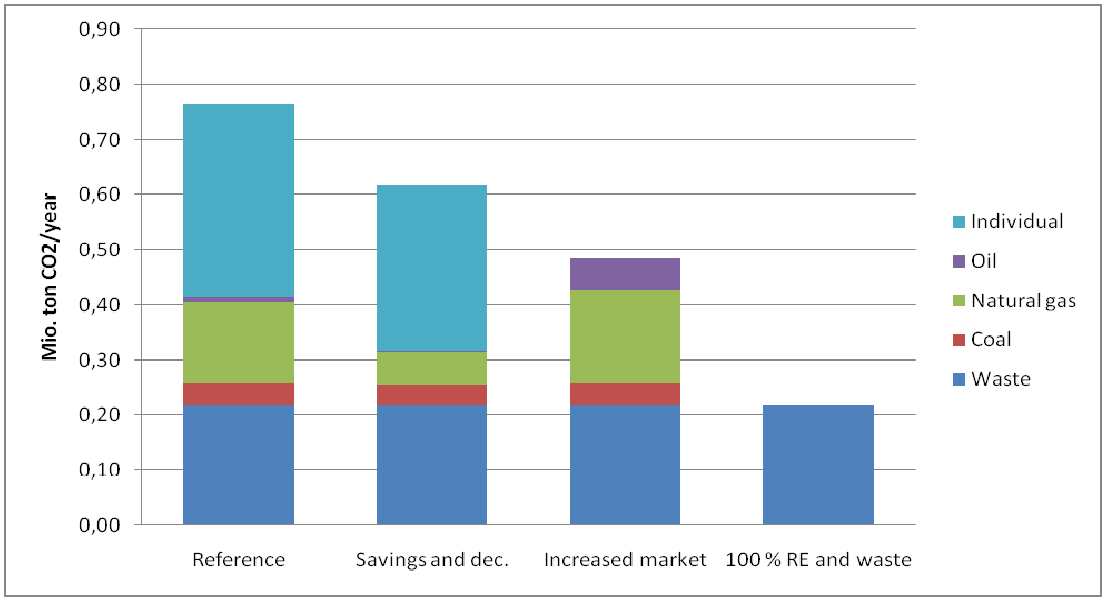


Illustration 27: Total CO2-emission. Heating in Greater Copenhagen by 2025 for different scenarios.

The scenarios demonstrate it is feasible to extend the district heating networks by converting apartment houses and commercial customers in the areas supplied with natural gas to district heating. Apart from the economic benefits this will also bring about substantially lower CO2-emmissions

Finally the Heat Plan shows that steps should be taken to reduce bottlenecks in the heat transmission system in the region and to adapt heat production to the seasonal variation of heat consumption. This could for example be done by temporary storage of waste in order to use it at times of bigger value to the system. Other kinds of seasonal storage of heat could be utilized as well.

The different scenarios in the Heat Plan Greater Copenhagen 2025 show that both from a societal point of view and a company point of view a higher renewable energy penetration is feasible. The fuel mix for the scenarios with maximum share of renewable energy and with the minimum share of renewable energy is shown below.

These scenarios show that it is possible by 2025 to reduce the use of fossil fuels to between 28 and 13 percent. The scenarios furthermore show that there are different ways of integrating more RE into the system.

Based on Heat Plan Greater Copenhagen, the target set out for Copenhagen Energy is to obtain a 100 % share of renewables and waste incineration heat in the DH system by 2025. The current share of renewables is 35 %. Exploitation of the District Cooling Potential

An assessment has been made of potential sites for further development of district cooling in the Municipality of Copenhagen.

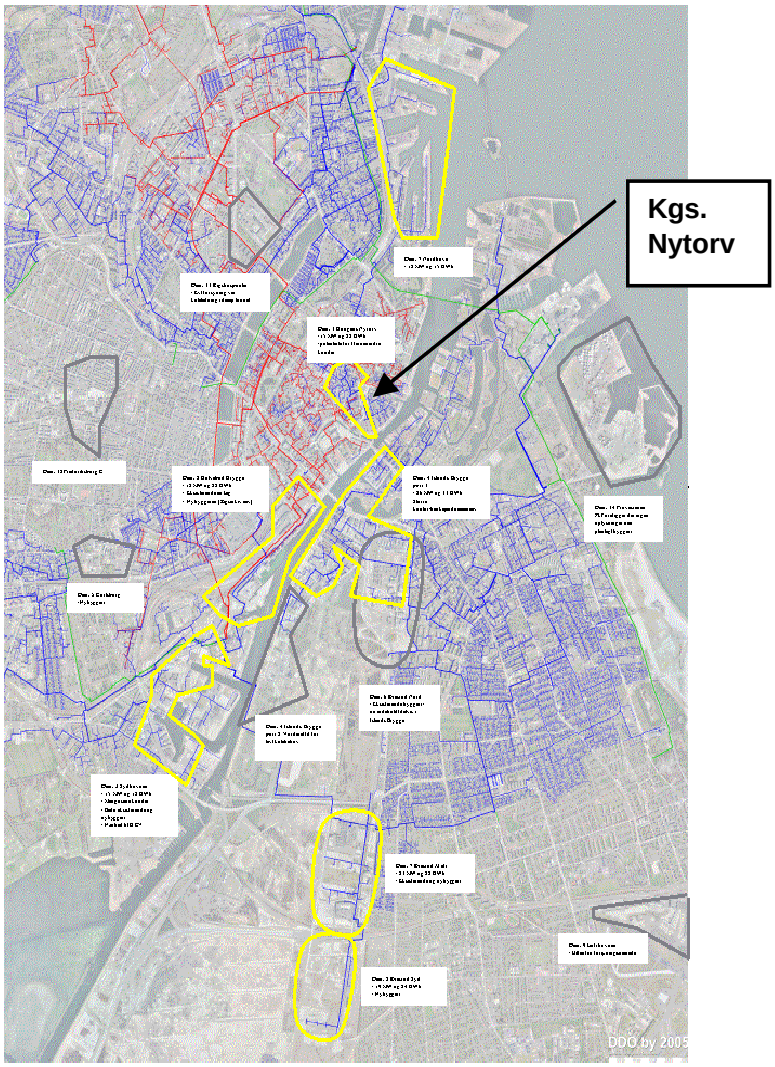


Illustration 28: Potential areas for district cooling

Fifteen potential areas have been identified of which seven (marked yellow) are considered feasible at the moment. These seven sites have together a cooling demand of approx. 150 MW (cooling production capacity), thus forming the potential for district cooling in Copenhagen.

6 Customer relations

6.1 Customer retention efforts

In many areas, the Danish Energy Policy reflects socio-economic concerns, being a cornerstone for the strategies and the development of the Danish energy sector. The governing policies since the 1960'ties have been featuring district heating as the way to obtain a high share of CHP production and thus to establish a high flexibility to different fuels, i.e. coal, waste, biomass and gas.

By law, the municipalities have the obligation to undertake heat planning, and to make sure that heating of buildings is done in the most economic way for the society. To avoid costly competition between energy carriers in the same area as e.g. competition between district heating and gas, the municipality defines through zoning how heating shall be provided in different areas of the municipality.

Hence, the zoning forms the basis for optimal district heating systems. The municipality may then reinforce efficient operation of district heating, by making it mandatory for building owners to connect to the district heating system, as it has also been done in the Municipality of Copenhagen. There are obvious exemptions from the general provisions, which may be applied to certain buildings, like building from the middle-age and similar building, where architectural reasons may prevent installation of a central heating system in the building.

New buildings meeting the Building Code's low-energy requirements may be exempted from connection to district heating. Nevertheless, in most cases owners of such new low-energy buildings want to be connected to district heating.

By 2009, although more than 98% of the heating demand in Copenhagen is provided by district heating, the number is still growing as every month new customers in the existing building stock apply for DH.

6.2 Marketing efforts and communication

6.2.1 Customer Centre

Copenhagen Energy has established a professional customer centre. This is the entry point, where dedicated people serve the customers. In most cases the centre is able to answer and take action. The centre is further supported by specialist in the various departments.

6.2.2 The Copenhagen Energy website

The website of Copenhagen Energy, accessible at www.ke.dk, plays a growing role in the interaction with customers, although the Customer Centre still is the dominant communication point.

Through the website the customers have access to:

- Online entering of readings from their heat meter (upload)
- Publications on Energy Saving Measures etc.
- All relevant provisions and terms related to delivery of district heating
- News on coming development; plans for the future etc.
- Annual Reports
- Videos on district heating
- District heating tariffs

Illustration 29: Main page of www.ke.dk

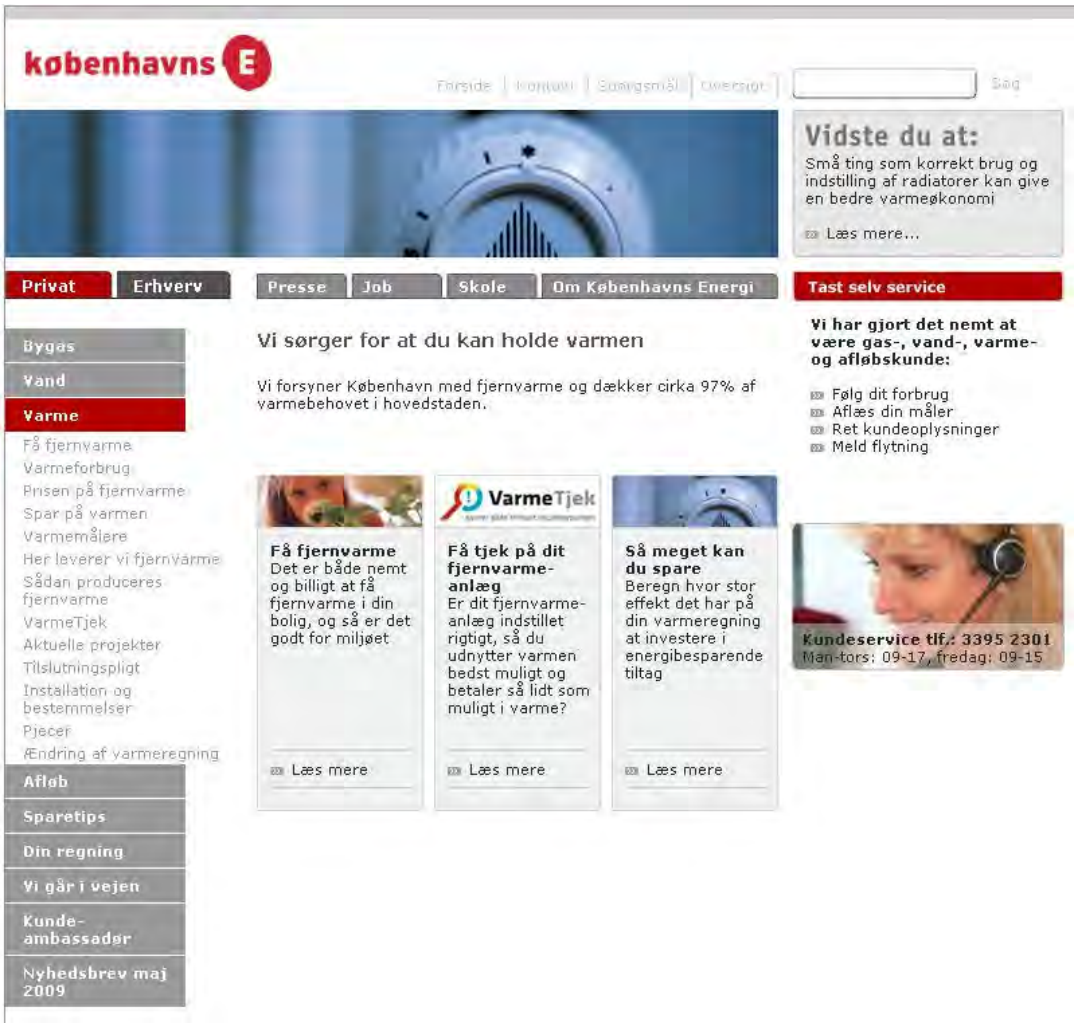


Illustration 30: The District Heating page

6.2.3 The 'Customer Ambassador'

Customers have access to a 'Customer Ambassador' by phone and in writing by e-mail or by letter. If a customer is unsatisfied with the handling of his/her case in one of the Copenhagen Energy departments, the customer may ask the ambassador to intervene. In this respect, the role of the ambassador is to examine the case and make sure that the customer is treated thoroughly and fair. In this respect, the role of the ambassador is to help the customer in her/his dialogue with Copenhagen Energy.

Illustration 31: Our Customer Ambassador

The ambassador may also be contacted with all kind of complaints or suggestion for improvements that then will be directed to the relevant department in Copenhagen Energy.

6.2.4 Metering and billing

In order to reduce the administrative burdens and hence costs, Copenhagen Energy in most cases only read the meters every second year. Smaller and medium **customers read the meters themselves** in the years in-between. In practice, the customers use the Internet or post the readings to Copenhagen Energy, where the numbers are used directly for the billing.

This scheme has now been used during many years, and the experience is good. A quality check is performed on the readings reported by the customers in order to check the validity of the customer readings.

Since a pilot project in the Amager region on **remote metering** has proven to be successful. it is expected that during the following decades remote metering will be introduced all over. Not least, remote metering offers the possibility of introducing the next generation of customer services, by using the readings for energy saving purposes.

Copenhagen Energy apply a **three-tier tariff**:

- Capacity tariff
- Heat consumption tariff
- Cooling tariff (low return temperature)

The typical customer bill shows that 20 – 25 % of the payment is for capacity and 75-80 % is for heat consumption including taxes. The average annual cooling of the supply temperature is calculated and will influence the price per energy unit, as shown below.

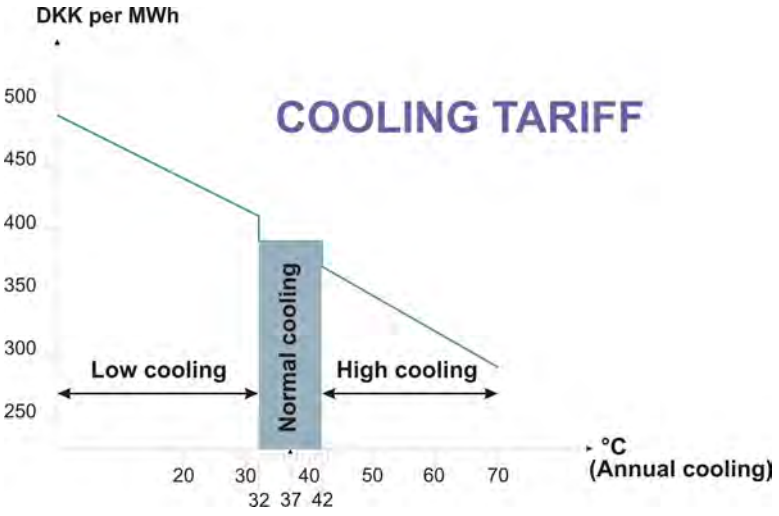


Illustration 32: The impact of cooling (differential temperature) on the heat consumption tariff

Copenhagen Energy provide the customers with detailed and informative invoices, which include the development in consumption during the past four years. In the annual invoice the scheduled prepayments done by the customer during the year is subtracted.

6.2.5 Demand Side Energy Savings

In addition to the direct customer services offered by Copenhagen Energy, also a vast number of publications focusing energy savings at the customers are available in hard copy or through the Internet[23].

Title: 'Efficient cooling is good economy'

Title: 'A leaking hot water storage is expensive'

Title: 'Keep track of the heat'

Title: 'Guide to your DH substation'

Title: 'DH in Copenhagen'

Title: 'How to connect to district heating'

[23] See: http://www.ke.dk/portal/page/portal/Privat/Varme/Brochurer?page=475

Title: ’Questionnaire for connection to DH’

Title: ’When the heating season is over’

Bygningsår før 1979
Udfyld felterne herunder med aktuelle data:

Boligareal:	150 m^2
Indetemperatur:	22 °C
Vinduestype:	Termoglas
Loftisolering:	100 mm.

Udfyld felterne herunder med kommende informationer:

Kommende opvarmet boligareal:	150 m^2
Kommende indetemperatur:	20 °C
Kommende vinduestype:	Energiglas
Efterisolering på loft med:	-- Vælg --
Installation af termostatventiler:	Nej

Beregn Nulstil

Resultat

Kommende loftisoleringstykkelse:	**100** mm.
Nuværende årlige forbrug (ca.):	**24,98** MWh
Kommende årlige forbrug (ca.):	**20,35** MWh
Årlig besparelse i MWh (ca.):	**4,63** MWh
Årlig besparelse i kr. (ca.):	**2.478** kr.
Besparelse i procent:	**19** %

6.2.6 Green Account Emission Calculator

As a service to the customers of Copenhagen Energy an emission calculator can be downloaded from the Internet[24]. The calculator is mainly intended as a tool for green accounting, covering CO2, SO2 and NOx emissions from the district heating consumption, including system heat losses. In this way the customer only has to enter the yearly consumption of heat from their bill in order to find out their yearly emissions. The result is illustrated graphically and in a print friendly format.

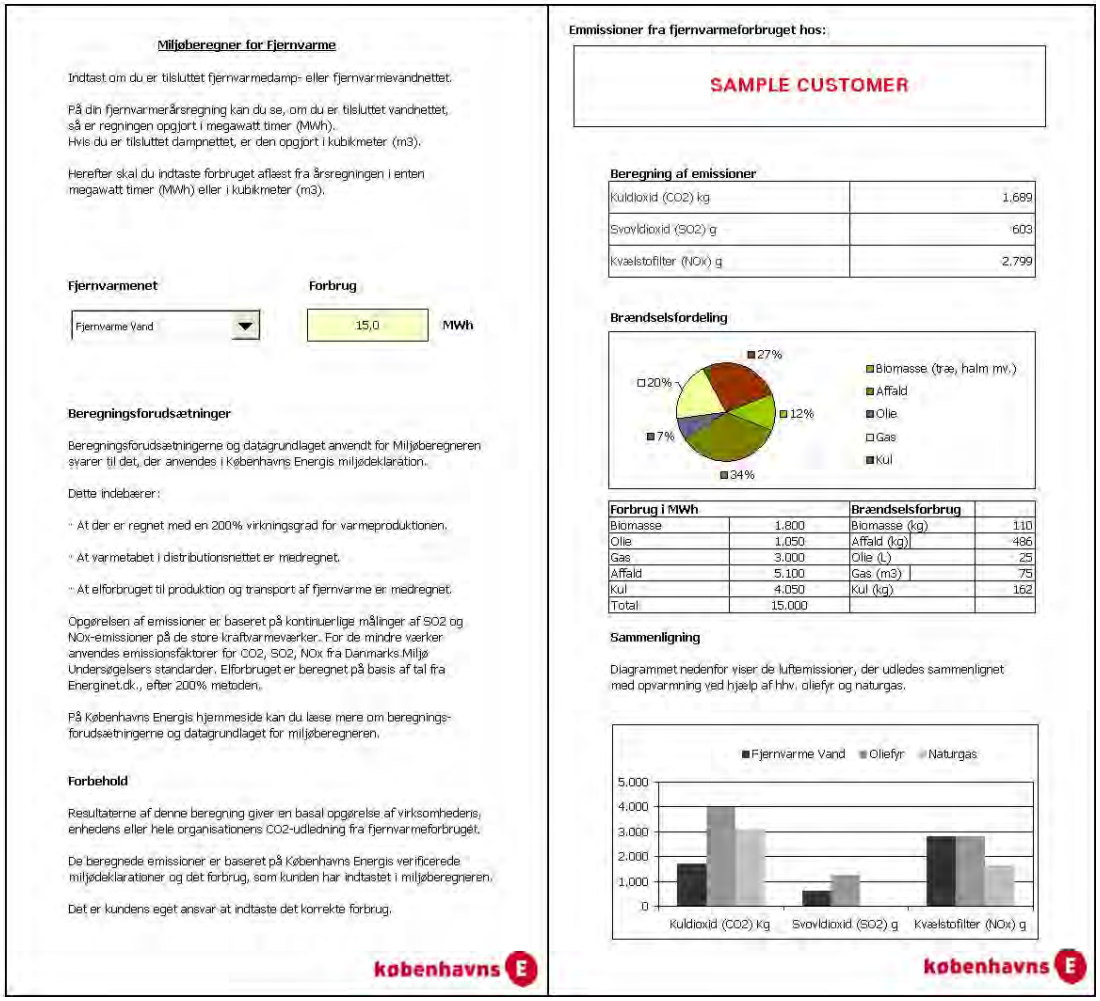


Illustration 33: Emission calculator for Green Accounting

24 http://www.ke.dk/portal/page/portal/Om_KE/Københavns%20Energi%20og%20miljøet/Beregn_miljoeudledninger?page=726

6.2.7 Events

The **Energy Day** will take place 25 September 2009. The Municipality of Copenhagen and Copenhagen Energy is actively involved in the programme for the Energy Day, inviting the public to visit:

- The new district cooling plant in central Copenhagen
- The biggest peak load steam plant (200 ton/hour)
- The Energy and Water Shop (see in other section)

6.2.8 'Energy and Water Shop' – an offer to school classes

Together with Copenhagen Energy, the Municipality of Copenhagen in 1997 established an 'Energy and Water shop'[25] that school classes from Copenhagen visit in order to get hands-on technical experience with energy and water installations.

Illustration 34: The website of the 'Energy and Water Shop'

The Energy and Water Shop is a part of the Green School initiative[26] that focuses on giving children a good understanding of important elements in a sustainable development.

[25] Energi- og Vandværkstedet; http://www.groen-skole.dk/vandverk.htm

[26] Grøn Skole; http://www.groen-skole.dk/

Illustration 35: One of the games in the 'Energy and Water Shop'

Illustration 36: A model of the Copenhagen energy system

At the moment the Green School is featuring Children's Climate Forum the week before COP15 in December 2009 in Copenhagen[27], where children from 42 countries will take part and their stay will be hosted by the schools in Copenhagen.

[27] See: http://en.cop15.dk/news/view+news?newsid=1698

Illustration 37: Promotion of the 'Childrens Climate Forum' to be held late November in Copenhagen

6.3 Customer satisfaction

During March 2007 a major Stakeholder Survey[28] covering a wide range of issues was finalised by external consultants. One of the benchmarks focused on stakeholders' perceptions regarding Copenhagen Energy.

The question was 'To what extent do you perceive that the following values characterize Copenhagen Energy' as to:

- Efficiency?
- Customer service?
- Environmental concern?
- Innovation?
- Trustworthiness?
- Bureaucracy?

The scores should be between 1 and 10 (1: to a little extent; 5: to a medium extent; 10: to a very high extent)
In general the scores turned out to be higher than 5 (medium extent), not least regarding environmental concerns, where the highest score of 7,4 was given by professional building administrators, and where also private households gave a score of more than 7,0.

[28] The Stakeholder Survey was conducted by Aalund/COWI

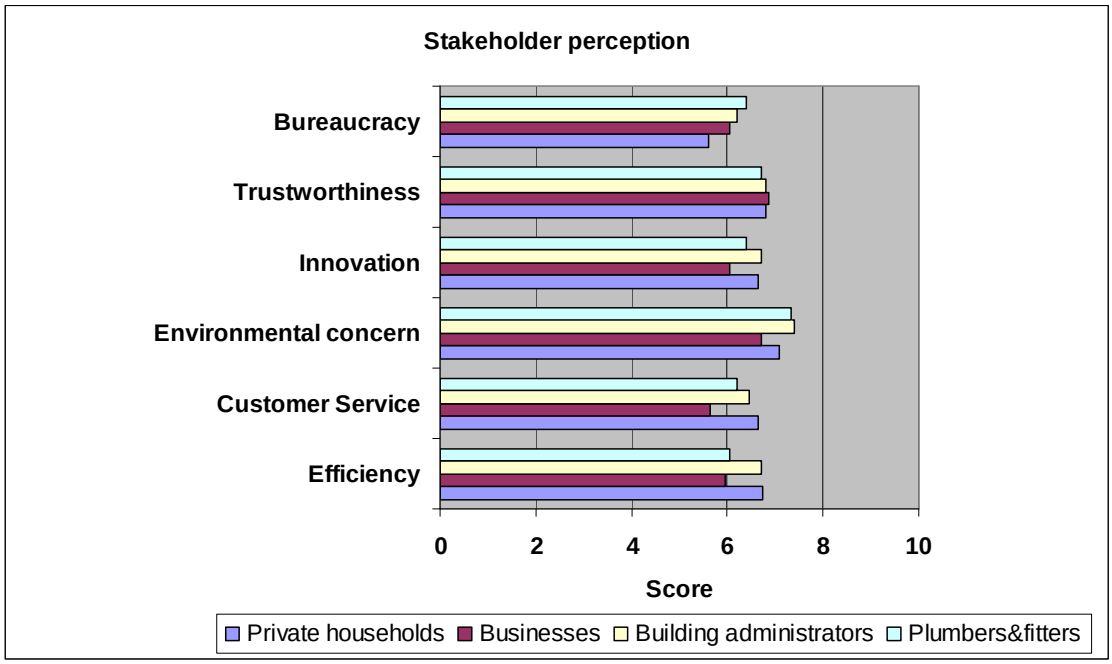


Illustration 38: Stakeholder perception - 2007

Although this shows potential for improvements, it is still considered to be a reasonably good evaluation.