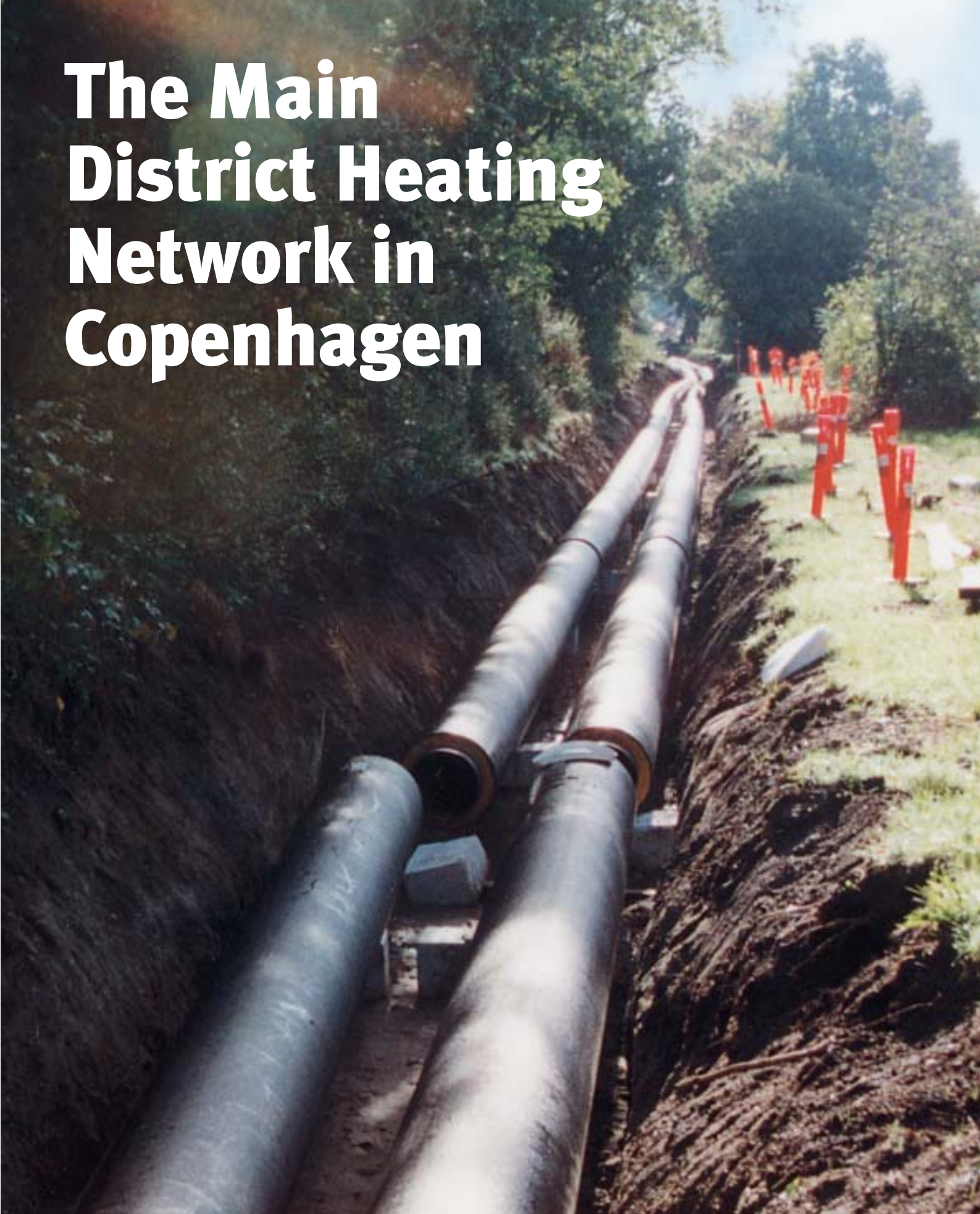
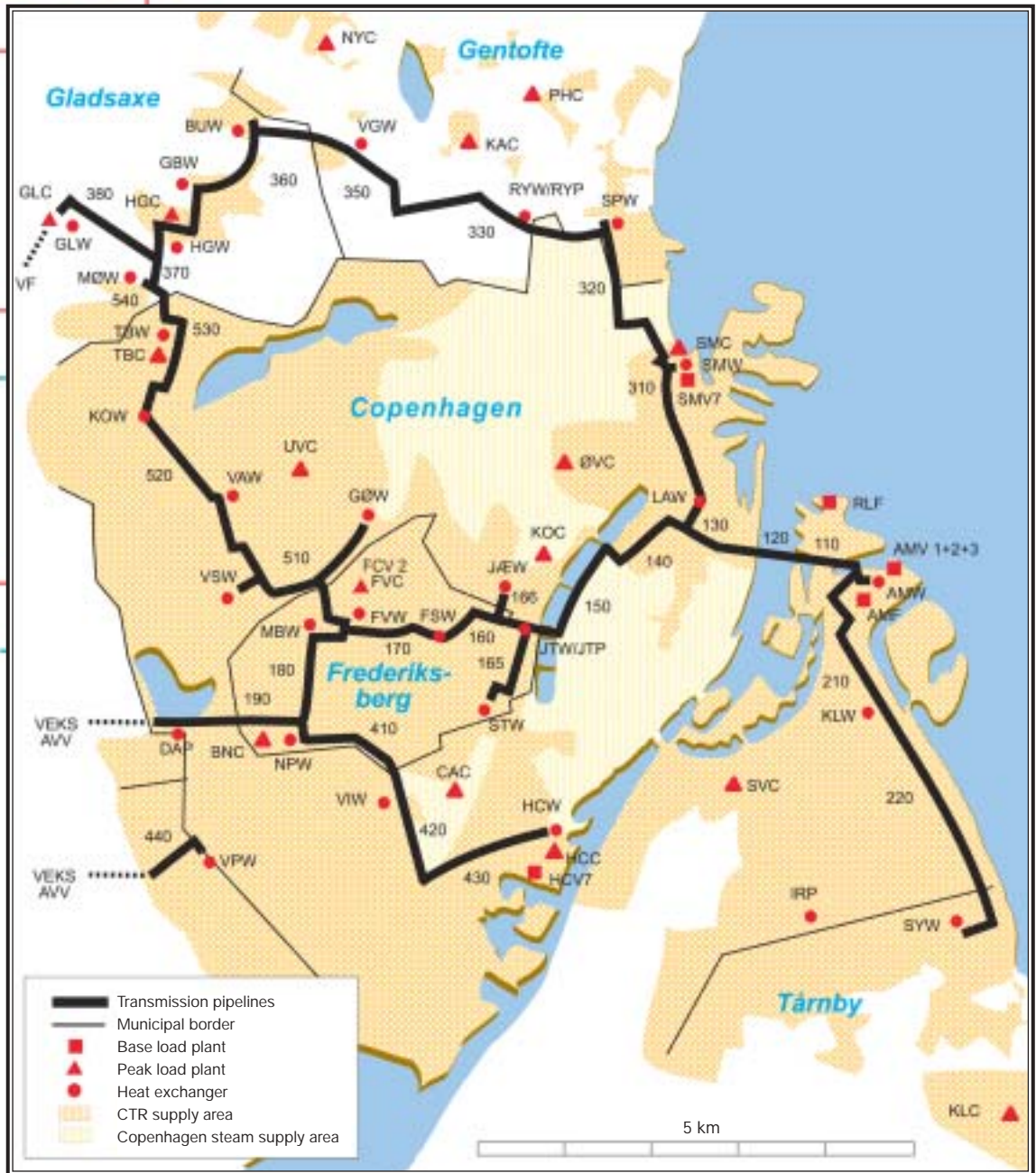


The Main District Heating Network in Copenhagen





CTR – the Metropolitan Copenhagen Heating Transmission Company – is a partnership of the municipalities of Frederiksberg, Gentofte, Gladsaxe, Copenhagen and Tårnby. The company purchase heat from refuse incineration plants and combined heat and power plants in the metropolitan area and transport it – sometimes together with heat from CTR’s

own peak load units – to delivery points in the municipalities involved. Fully extended it will be possible to supply about 275,000 households. CTR’s staff counting 24 members is responsible for new construction works, running and maintaining the whole transmission system. The company’s annual turnover is approximately 1½ billion DKK.

Management

Board of Directors and Committees

CTR’s board of directors represents the five municipalities involved in the partnership. The Municipality of Copenhagen appoints four of the eight members of the board and the other municipalities each appoints one member.

Two advisory committees are attached to the board to deal with all economic and technical matters arising during the running of the project.

These committees are called the Contact Committee and the Technical Committee, respectively, and are made up of leading local government officials from the municipalities involved in the partnership.

The supply of heat will be divided as follows: 69% will go to the largest partner municipality (Copenhagen), and 3.5% to the smallest (Gladsaxe), while the other

municipalities receive 16% (Frederiksberg), 6.5% (Gentofte) and 5.0% (Taaenby).

At present, with the construction phase – to all intents and purposes – nearing completion, the annual number of meetings held by the board and the two advisory committees is four.

Administration and Operation

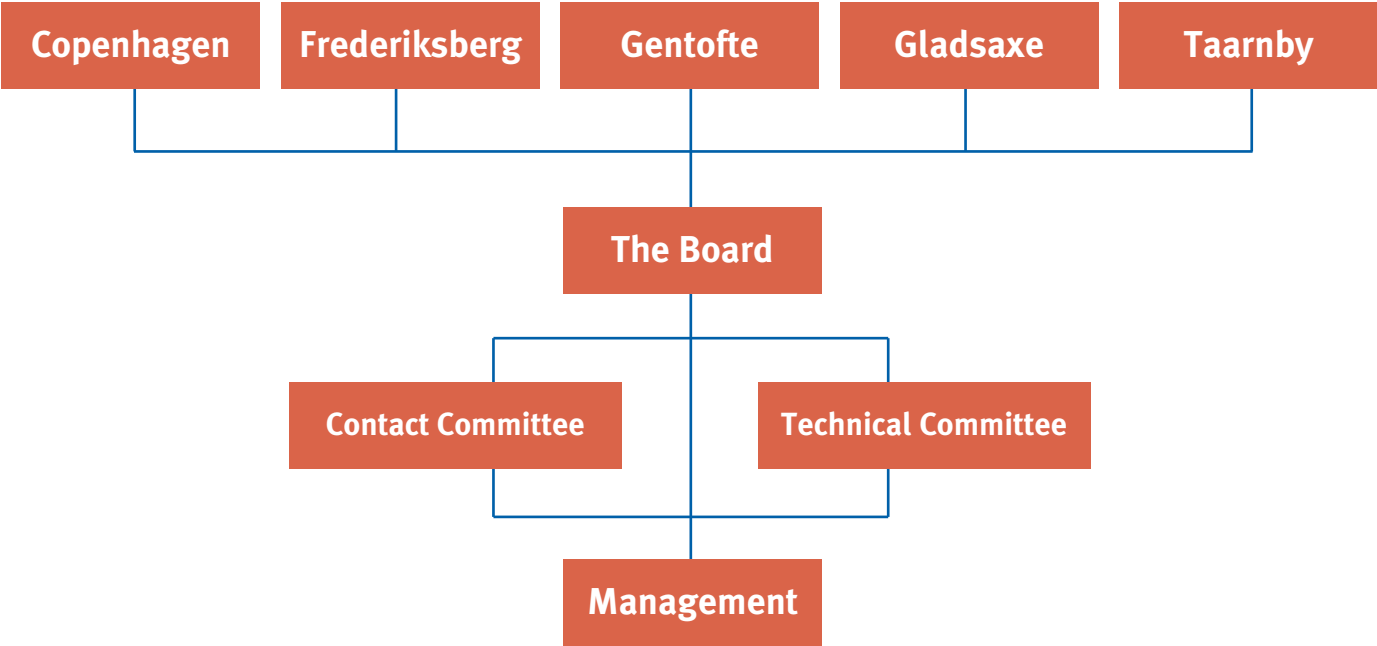
A president and a vicepresident carry out the day-to-day management of the company.

There are 22 other members of staff associated with the running of the transmission network. These members of staff are divided up into two groups: 14 members of staff in CTR’s administration department and 8 engineers (working a 24-hour shift system) in the central control room.

Furthermore, a number of agreements have been reached with the individual partner municipalities’ operational organisations where-

by these organisations have responsibility for carrying out the day-to-day maintenance and monitoring of CTR’s pipe network and stations. Finally, an ‘in-house advisory’ engineering firm is linked to the project. This is the Danish consultant engineering firm Ramboell. While construction work was at its highest level it gave employment to more than two hundred of this firm’s staff. Today, the annual demand for specialist engineering and consultant advice can be met by less than a dozen men.

CTR’s administration	16
CTR’s control room	8
Municipal operational personnel	26
Consultants, etc.	10
Total	60





PHOTOS: GRAFISK HIMMEL

District Heating in Denmark

Collective energy supply, heat sources, legislation

The Energy Supply of the Future

'The future is not what it was'. So said Mark Twain almost 100 years ago, and many of today's research workers would be quick to agree with him. Pollution on a global scale, natural disasters, global warming and an ozone layer in ruins – this is what we face if we continue on our present course.

Human needs – for food, fuel and other natural resources – threaten to alter our planet just as, for example, the burning of fossil fuels threatens to alter the balance of the atmosphere. Time and time again, at international conferences and in innumerable reports, it has been stressed that it is essential that global agreement be reached on a sustainable energy production model.

One of the most urgent global challenges is centred on the necessity of halting the current ever-increasing rate of energy consumption. Energy savings and increased energy efficiency seem to figure among the best means to achieving this end.

In this regard, an attractive solution is provided by the combined production of heat and electricity – also known as CHP. This is based on the fact that CHP-based district heating makes it possible to increase the total efficiency of the heating process by more than 100% – whilst at the same time more than halving the associated pollution. The conclusion is that CHP and district heating benefits fuel flexibility, energy savings and pollution reduction.



MAD COW STUDIO POLFOTO

Collective Energy Supplies

In Danish energy policies, the utilization of CHP has been given the highest priority since the beginning of the 1970's. Around the turn of the century CHP met more than half of the total Danish energy demand.

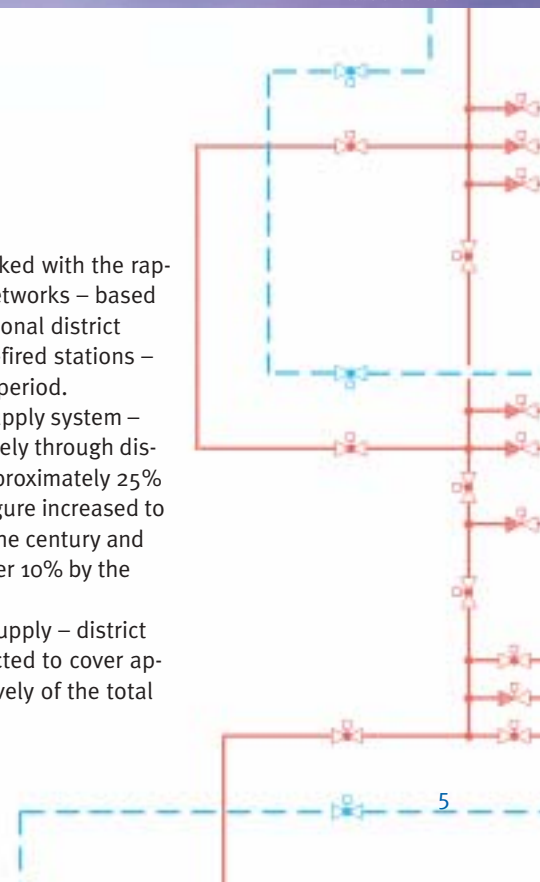
The district heating networks of various sizes already established have already proved themselves to be both extremely versatile and successful. The size of these networks ranges from those supplying 100-150 households, to very large, integrated installations supplying heat to up to 500,000 households.

The results achieved so far as a result of following this line have also been impressive: Danish energy consumption for space heating (pr. m²) has been more than halved, falling from approximately 100 kWh (341 x 10³ BTU) in 1972 to below 50 kWh (170 x 10³ BTU) today.

These results are inextricably linked with the rapid expansion of collective supply networks – based on supplies from CHP plants, traditional district heating installations or natural gas-fired stations – that has occurred during the same period.

In 1972, the communal energy supply system – delivering supplies, at that time, solely through district heating networks – covered approximately 25% of the total heating demand. This figure increased to more than 70% around the turn of the century and that looks set to increase by a further 10% by the year 2010.

At that point, the two forms of supply – district heating and natural gas – are expected to cover approximately 60% and 20% respectively of the total Danish demand for space heating.





District Heating

But what, exactly, is district heating? Briefly, district heating can be described as the supply of heat and hot water to a number of buildings with different owners from one central plant. The heat that is produced at this plant is circulated as hot water to the consumers' homes via an insulated, dual pipe system.

The heat is transported – in the form of hot water – to the consumers through delivery flow pipes. Once this water has radiated its heat, the colder water is returned, via return flow pipes, to the plant, where it is reheated.

Any kind of fuel, and any source of surplus heat that can heat water to a temperature of approximately 100°C (212°F) can be used in a

district heating system. Heating plants, CHP plants, refuse incineration stations and industrial companies are major heat producers and are those most commonly used to supply heat for district heating systems. Occasionally, several of these plants are linked together by a network of pipes.

In such cases, the network of pipes will consist of large-bore pipes (transmission pipes) linking the major plants to residential areas, and pipes with smaller bores (division or distribution pipes) carrying supplies to the individual consumers. The heat is transferred from the transmission network to the distribution network using heat exchangers.

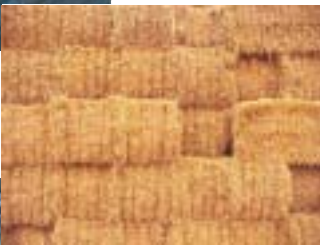
Heat Sources

The basis for the establishment of the existing district heating networks has, primarily, been cheap energy from the simultaneous production of heat and electricity (CHP), refuse incineration or the combustion of heavy fuel oils, respectively coal, burned in the production plants instead of light fuel oil burned in individual boilers.

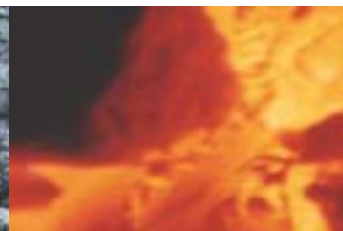
CHP has developed especially in and around major cities, not least due to the obvious ad-

vantages for energy supply (lower fuel consumption), for the economy (lower fuel costs) and for the environment (less local pollution and reduced CO₂-emissions, etc.)

As a new stage of development, a number of smaller, decentral CHP plants have been introduced in regional towns. The aim is that these plants should run exclusively on nationally produced fuels – primarily natural gas, but also, to a lesser extent, straw, wood chip and bio-fuels.



Incineration, coal, straw, gas and heavy fuel oil – some of the most important sources



Moreover, research is being carried out into the possibility of establishing a more systematic exploitation of various forms of renewable energy, including and in particular geothermal energy.

In order of priority, the fuels used in the majority of Danish CHP plants and district heating

stations are natural gas, oil and coal. This order of priority stems mainly from a concerted political effort aimed at replacing oil with natural gas/coal as the major source of energy supply in the 1980's, while at the same time encouraging the expansion of natural gas as an energy source.

Heat Supply Legislation

Development in Denmark during the past few decades has been characterized by the exceedingly rapid growth of collective energy systems. The roots of this development can be traced back to the various energy policy guidelines and the legislation adopted by the Danish Parliament, the 'Folketing', from the middle of the 1970's onwards.

The overall target here was to 'promote the most socio-economical use of energy for supplying buildings with heat and hot water, while at the same time reducing the dependence of

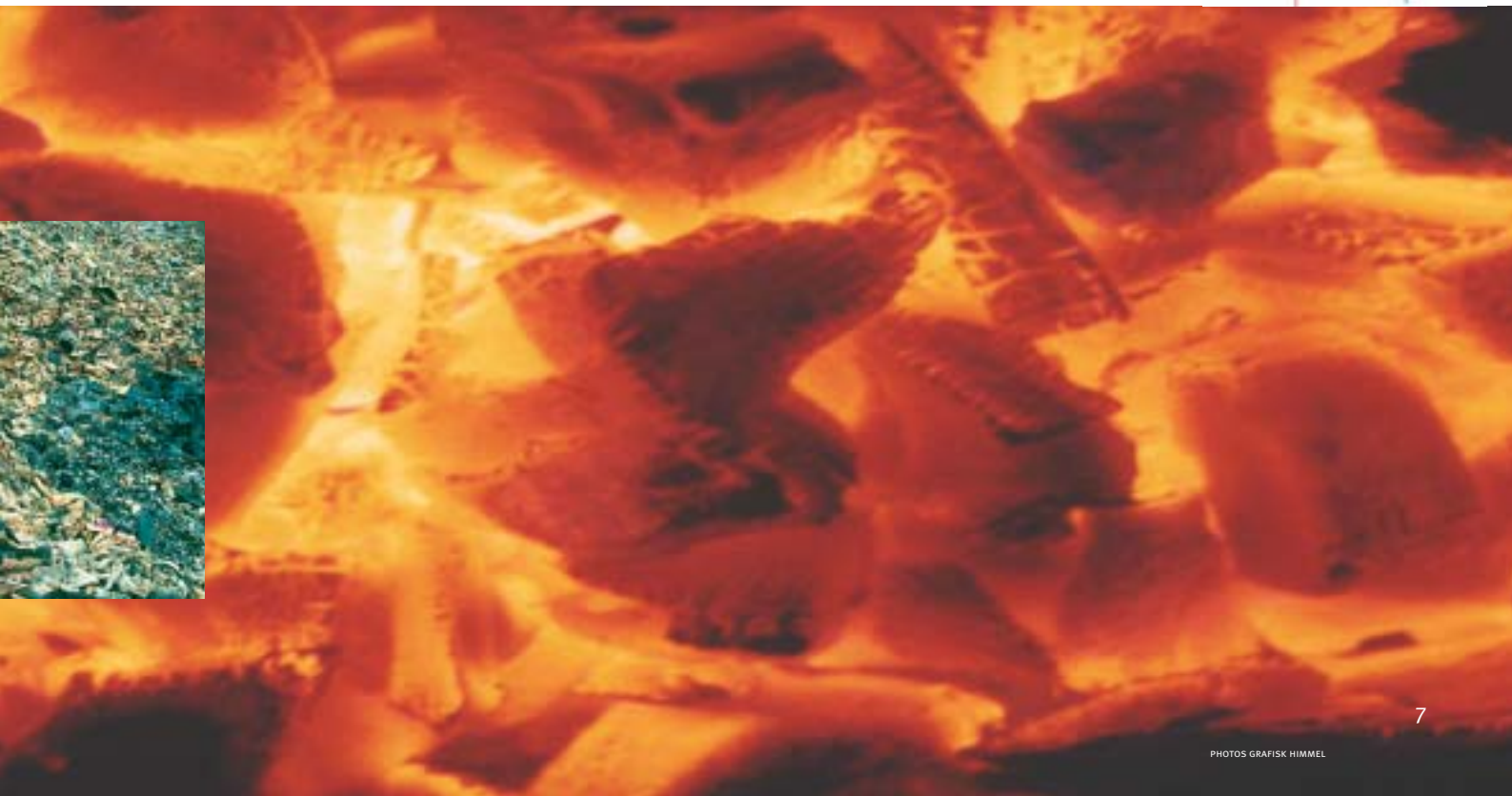
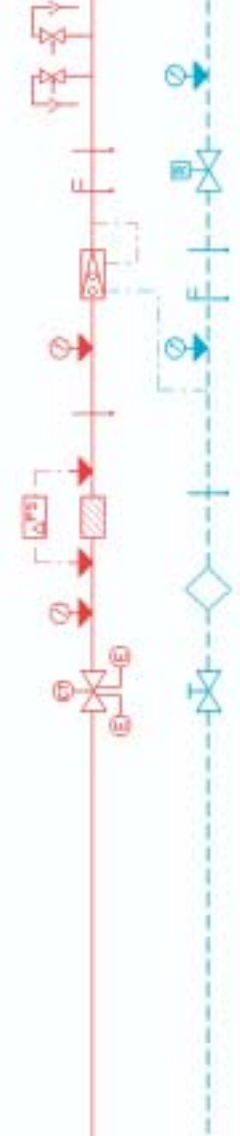
the energy supply industry on oil'.

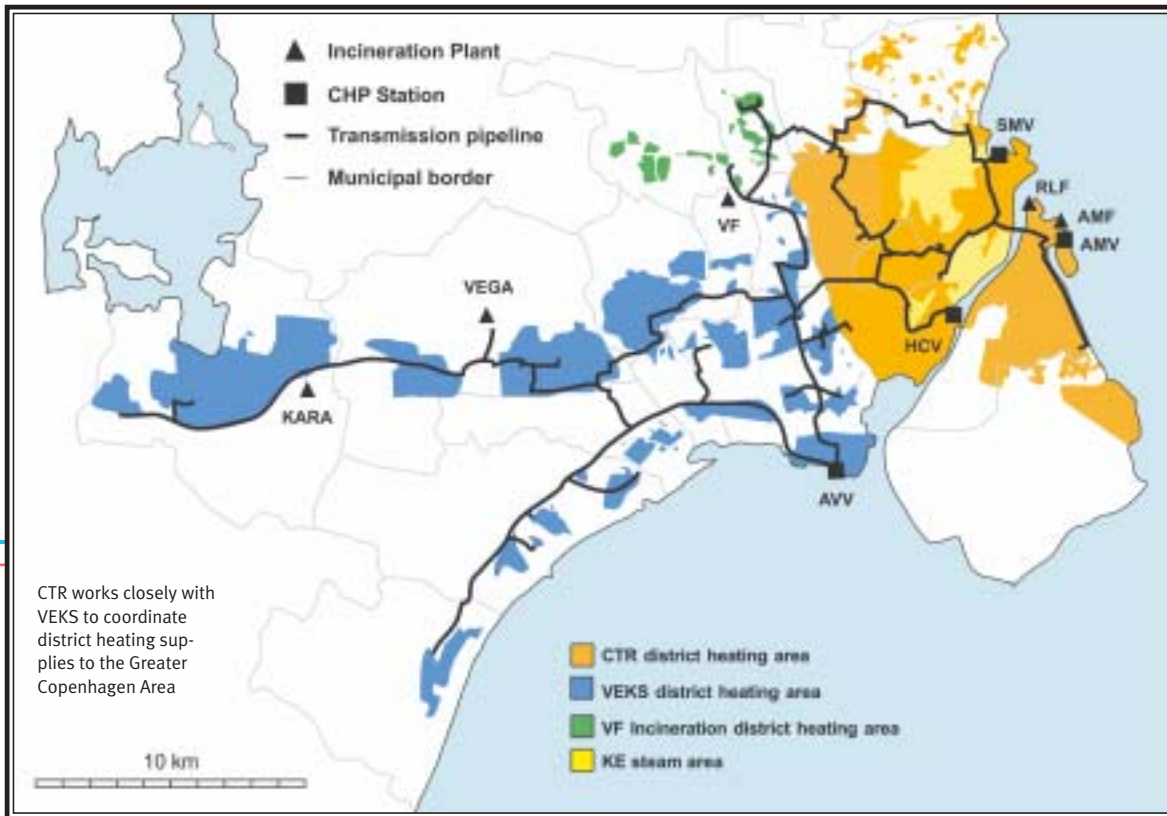
In addition to this, more and more importance has been attached to environmental considerations. In a subsequent review of heat supply legislation it is specifically stated 'the utilization of energy must be carried out in the best possible way from both an economic and an environmental point of view'. At the same time it is clearly stated that any further adaptation of heat supply systems should, as far as possible, incorporate the combined production of heat and electricity.

Mapping out Heat Demand

The actual planning of energy supplies in the various local regions has been carried out at municipal level. Collectivity in heat supplies has included giving higher priority to natural

gas and district heating systems; indeed, the final goal was to use these two sources to cover 75% of the total national heating demand at the turn of the century.





Energy Plan

CTR – the transmission company of five municipalities – heat and hot water to 275,000 households

The Greater Copenhagen Area

The expansion of district heating was naturally given the highest priority in the heavily urbanized Greater Copenhagen Area. In this area, small-scale district heating networks were already present at a time when electricity production was faced with the need to expand by building two new power stations to produce 330 MJ/s (1.126×10^6 BTU/h) each. It was found that these two stations could be constructed so as to run as co-ordinated CHP Units.

It was therefore decided to establish a coherent district heating transmission network for the entire Greater Copenhagen Area. However, it was also decided that it would be best to divide the supply area

between two major transmission companies – CTR (Centralkommunernes Transmissionselskab I/S) and VEKS (Vestegnens Kraftvarmeselskab I/S). These two companies' pipe networks should be connected internally, so that heat could be exchanged in the most advantageous manner possible, from a socio-economic point of view.

In the central area of the region, five municipalities joined forces to create a communal district heating transmission network. On February 29th 1984, the Municipalities of Frederiksberg, Gentofte, Gladsaxe, Copenhagen and Taaenby founded the partnership CTR – Centralkommunernes Transmissionselskab I/S (the Metropolitan Copenhagen Heating Transmission Company).

The company's first assignment was to plan, set up and finance a communal district heating transmission network. Today, the company's

primary area of activity is the running of the network.

This includes:

- Buying heat from heat production units (CHP plants and refuse incineration stations)
- Producing heat on the company's own account during peak load periods and operating back-up units
- Transporting heat through the transmission network
- Selling the heat to the municipalities involved and to VEKS.

The transportation of the heat from the various delivery points (heat exchanger stations) out in the municipalities to the individual consumers does not fall under the auspices of the company's area of responsibility, but is carried out by local organisations (distribution companies).

Differences in Heat Consumption

At the start, the degree of familiarity with the concept of district heating varied greatly between the five municipalities involved in the CTR partnership, a situation mirrored by the extent to which district heating systems were present in each of the municipalities.

The municipalities of Frederiksberg and Copenhagen had already been supplying heat to a considerable number of customers via district heating networks for many years, and these networks were subsequently expanded.

However, in the three 'outer' municipalities (Gentofte, Gladsaxe and Tårnby), district heating supplies were first introduced with the appearance of the CTR project, and it was therefore

necessary to establish completely new district heating networks in these areas.

Similarly there are major differences in the amount of heat used by the individual municipalities. It is expected that the Municipality of Copenhagen will take 69% of the total heat production while the Municipality of Frederiksberg will take 16%, the Municipality of Gentofte 6.5%, the Municipality of Tårnby 5% and the Municipality of Gladsaxe 3.5%.

A section of the existing district heating network in the municipality of Copenhagen is still steam-based. The aim is in time to convert these steam-based networks to hot water-based networks.



PHOTO GRAFISK HIMMEL



Customer Base

The customer base for the supply of district heating in the various areas primarily comprises major consumers such as housing units, public institutions, schools, sports' halls, industrial companies, etc. Legislation has also been passed requiring all new buildings and existing buildings with a heating requirement of more than 250 kW (852.5×10^3 BTU/h) (equivalent to the consumption of 25-30 households) to be connected to the communal energy supply network.

Moreover, some municipalities – including the Municipality of Copenhagen – have decided to extend the compulsory connection order to cover buildings with a heating requirement lower than 250 kW (852.5×10^3 BTU/h), i.e. private housing, etc. In the outer regions of the Greater Copenhagen Area residential areas are primarily supplied with natural gas.

All in all, a coverage level of 90-98% is expected within CTR's area of supply.

The Extent of the Project

The final goal for the expansion of the heat supply system within the CTR area is to supply district heating to 275,000 households – i.e. 3/4 of a million people – in 2009. This is equivalent to a gross annual heat demand of approx. 19,000 TJ/year (18×10^{12} BTU/year).

To achieve this goal, a 54 km (34 mile) long network of pipes has been laid and equipped with 26 heat exchanger stations (two of which feature two-way supply), three booster pump

stations, 14 peak load units and a computer-based control, monitoring and regulation installation. In addition to these, various tunnels have been built including a 1.6 km (1 mile) long tunnel under the port of Copenhagen.

These constructions – with the exception of a small number of peak load units – were carried out over a period of six years, stretching from December 1984 to May 1990.

An Attractive Heat Supply System

From the start, it was planned that the municipalities involved in the partnership should be connected to the CTR network in stages starting from Autumn 1986 and finishing towards the end of 2002. The rate of connections to the network has, to all intents and purposes, matched the timetable; indeed, connections in some municipalities have occurred ahead of schedule. A number of legislative initiatives, such as the

above-mentioned connection orders, together with various subsidy schemes, etc. have facilitated this process.

In conjunction with the appreciably cheaper production method made possible by the combined exploitation of heat and electricity, this has resulted in district heating becoming an exceptionally competitive form of heat supply.

An added bonus is that, over the course of the



ARUNAS KLUPSAS POLFOTO

CTR secure the comfort for 275,000 families

past few years, consumers generally have become increasingly aware of the environmental and other advantages associated with this particular form of heat supply. This awareness has been supported by numerous national and regional information campaigns.

The Heat Production



Part of Avedøre 2 plant

PHOTO ENERGI E2

Heat Production Units

95% of the heat demand within CTR's area of supply is covered by the surplus heat produced by seven production installations – including four CHP plants (the Amagerværk, the Avedøreværk, the H.C. Ørsted Værk and the Svanemølleværk) and three refuse incineration stations (I/S Amagerforbrænding, I/S Vestforbrænding and Rensningsanlæg Lynetten).

CTR has the disposal over a capacity amounted to 1,314 MJ/s ($4,500 \times 10^6$ BTU/h) on these so-called base load units.

The remaining 5% of the heat required is produced by 16 local district heating stations built to use oil or natural gas. These stations are used partly to cover the peak load periods – a few hundred hours a year – and partly as back-up units to cover interruptions in the supply from the major suppliers. The supply from these stations is sent either to the transmission network or directly to the local distribution networks. The total demand for heat in peak load periods amounts to 800 MJ/s ($2,730 \times 10^6$ BTU/h). A major part of this demand is covered by production from plants that formerly – i.e. before

the transmission net was established – acted as production units on the distribution side.

A useful addition to the heat production capacity directly associated with the CTR system is the possibility of transferring heat from the Avedøreværk via VEKS – CTR's sister company to the west. Supplies in the opposite direction can also take place, i.e. from the heat production units in CTR's area to VEKS.

Finally, the two accumulator tanks located on the Avedøreværk site add to the optimisation of the complete district heating system. These tanks, with a total capacity of 44,000 m³ (11,660,000 US gallons), collect any surplus hot water and keep it in reserve for those times of the day when demand is at its highest. This means that, to a certain extent, the purchase of heat can be adapted and regulated according to the varying levels of electricity production during the day. The maximum drainage capacity of the two tanks has been set at 330 MJ/s ($1,126 \times 10^6$ BTU/h).

An accumulator tank has been installed at Amager plant as well.

Accessible Production Capacity for the Greater Copenhagen Area Combined Heat and Power

Net capacity	MJ/s Heat	MW Electricity
CHP Plants		
Amagerværket, Unit 1	190	136
Amagerværket, Unit 2	190	136
Amagerværket, Unit 3	330	250
Avedøreværket, Unit 1	330	250
Avedøreværket, Unit 2	480	480
Steam 'pool'	175	85
Incineration stations		
I/S Amagerforbrænding	82	28
I/S Vestforbrænding	105	14
Others	64	14
Oil/natural gas fired peak production		
	1,300	
Heat accumulators		
	330	

Amager plant



PHOTO ENERGI E2



Avedøre 1+2 plant and the two accumulator tanks (in the middle behind the plant)

PHOTO ENERGI E2

Production Planning

The system concept – i.e. the division of production, transmission and distribution into three separate areas – plays a very important role in the optimisation of the production of the entire district heating system. It is this division that makes it possible to select the most economically and environmentally advantageous form of production for the system as a whole.

The refuse incineration plants are in op-

eration all the hours of the year to dispose of the necessary amount of refuse. The heat production from these plants has first priority because the alternative is to cool the heat away. It is therefore both environmentally as well as economic a large advantage to use these heat deliveries in the district heating system.

The remaining heat need is to the greatest extent as possible covered with heat

produced in the CHP plants in the area. Energy E2 carries through the operation of these plants in interaction with the need/the market for electricity production. In that way the economic and environmental impacts can be optimized for the total electricity and heat system.

CTR's heat demand estimates are drawn up on the basis of forecasts from the Danish Meteorological Office.

The Transmission Network



Transmission, steel-in-steel pipes leaving Avedore plant

PHOTO ENERGI E2



Temperature/Pressure

Technically speaking, the transmission network is constructed as a system with a maximum supply temperature of 120°C (248°F) and a maximum operational pressure of 25 bar (350 psi). For normal operation conditions, however, the working temperature and pressure have been set at 90-115°C (194-239°F) and 16-24 bar (224-336 psi) respectively. These levels are adjusted according to the season.

The return temperature in the transmission network lies typically between 50 and 60°C (122-140°F).

Pipes

A large section of the 54 km (34 mile) long pipe network has been laid as a ring. The decision to build the network in this form was based on a number of considerations regarding the economics of operation and the reliability of supply. The ring system makes it possible to draw heat from the most economical production unit at any one time and to reverse the direction of the heat flow should a pipe rupture or a power station's supply be interrupted.

The pipe network is also linked with the VEKS system – the corresponding network in the westerly part of the Greater Copenhagen Area – and surplus heat and reserve capacity from one area can therefore be used in the other.

The pipe network itself has been laid using steel pipes with diameters ranging from 250-800 mm (10-32 inches). Most of these pipes (32 km (20 miles)) are pre-insulated pipes with plastic jackets, but pre-insulated pipes with steel jackets (3 km (2 miles)) and pipes laid in concrete channels (17 km (10 miles)) have also been used. Finally, there are a number of tunnels (2 km (1.5 miles)) containing up to 4 pipes.

The different types of pipes have been used in the following situations:

- Pre-insulated pipes with plastic jackets were used primarily where the construction work was relatively straightforward, i.e. long straight stretches with pipe diameters not exceeding 700 mm (28 inches).
- Steel-in-steel pipes were used for special (wet) constructions or where the pipes were to run above the ground.
- Pipes were laid in concrete channels in streets where a complicated system of underground supply pipes had already been laid.

Generally speaking, the district heating pipes have been laid in the ground on a bed of drained aggregate. The pipe insulation incorporates moisture sensors and, should the insulation material become damp, an alarm is activated in the central control room and the presence of moisture is registered before it can cause damage to the pipeline.

The total carrying capacity of the pipe system is 20,000 m³ (5,300,000 US gallons). At peak periods, this amount of water is circulated through the system every two hours.



The pipe network going down deep ...



... under the harbour ...



... under the heavy traffic ...



... under the railway system



Pumps in connection with the heat exchanger stations ensure the continuous circulation of the water in the transmission network

Heat Exchangers and Pump Stations

In CTR's heat exchanger stations, the heat is transferred to the local distribution networks which transport it on to consumers. This transfer takes place through the medium of plate heat exchangers in which the mean-temperature difference between the transmission and distribution sides – also known as the primary and secondary sides – has been set at 7.5°C (14°F).

The CTR project as a whole comprises 26 heat exchanger stations. Two of these stations supply two municipalities. The majority of these stations have been laid underground, and the number of stations and their geographical locations has been chosen with a view to achieving the best possible technical and economic solution for the entire district heating system.

The installed heat exchanger effect amounts to approximately 1,900 MJ/s (6,500 x 10⁶ BTU/h).

Some of the heat exchanger stations include pumps – so-called booster pumps – as well as heat exchangers.

These pumps ensure the continuous circulation of the water in the

transmission network. Moreover, an independent pump station has been built on the boundary between CTR's and VEKS' systems. It has

been calculated that the total effect of the system's pump stations amounts to 6,000 kW (8,000 HP).



The 26 heat exchangers is the dividing line between CTR and the municipal companies

The Operation of the System

The Computer System

The nerve centre of the CTR system is an operation centre that is manned 24 hours a day. From here, the heat supply is monitored and regulated using advanced computer technology that transports alarm signals, measurements, etc. from throughout the network.

The Control, Regulation and Monitoring – CRM – installation has approx. 10,000 signals possible to inform about the process. In this way, the operation centre monitors the production, transportation and delivery of the heat to the various delivery points.

In reality, the CRM installation comprises six main stations – CTR's central control room and five municipal main stations – and approximately 30 sub-stations.

Each of the municipal main stations is responsible for seeing to the actual operation and maintenance of those parts of the system that have been established in its municipality. This includes the close monitoring of a number of sub-stations (installed in heat exchanger and pump stations, in the production units and, in one case, at a measuring station).

In this way, all process control functions take place in independent sub-stations which can be operated independently from the rest of the system and which can carry out automatic regulation and sequence control.

Communications between the stations are carried out by an 80 km (50 mile) long fibre optic network. For security reasons, this network has been built as a double ring.



Highly trained engineers monitor CTR's transmission network 24 hours a day





An exceptionally detailed regulation of the temperature of the system can lead to appreciably large savings



Operational Optimisation

Operational reliability, forecasting, exploitation of inexpensive energy production and optimisation of energy production are all important elements in the overall operational planning carried out in CTR's central control room.

As many of the daily control room tasks as possible have been automated. It is therefore possible to carry out the planned operations whilst continuously adapting these operations according to the currently applicable conditions, using a number of operation plans that have been installed in the computers. This means that the operational personnel's primary task is limited to intervening should abnormal operating conditions (alarms) arise.

The control room's most important tasks can be briefly summarised as follows:

- controlling production from the base and peak load units

- controlling reference points for main, booster, and heat exchanger stations
- controlling the delivery temperatures from the individual plants
- controlling supplementary water deliveries to the distribution networks, emergency functions (intervention, control, shut-down), reporting and operational optimisation.

In this regard, operational optimisation in particular features as a very special and demanding area. The main principle here is that the most inexpensive production unit must always come on-line first, and that the units used must only run for as long as is absolutely necessary.

The large number of plants available to controllers means that during peak load periods they have to tap into supplies from a large number of different units, albeit many of them only briefly.

Optimisation of Energy

Another important area of work is the optimisation of the total energy consumption. An exceptionally detailed regulation of the temperature of the system can lead to appreciably large savings.

If the delivery temperature is lowered by as little as a single degree Celsius, savings of several million Danish Crowns (DKK) per annum can be achieved in the form of reduced fuel consumption. From an environmental point of view, this gives an added bonus in that the level of pollutant emissions falls correspondingly.

The control, regulation and monitoring of

the supply from CTR's transmission network are mostly carried out – as described above – from the consoles in the central control room. The extensive use of computers has made it possible for a staff numbering only 24 to run the heat supply.

However, when the computer installation's many functions were set up, high priority was given to ensuring that man and machine should work in harmony. At the end of the day it is still human evaluation that forms the basis for the final decision.

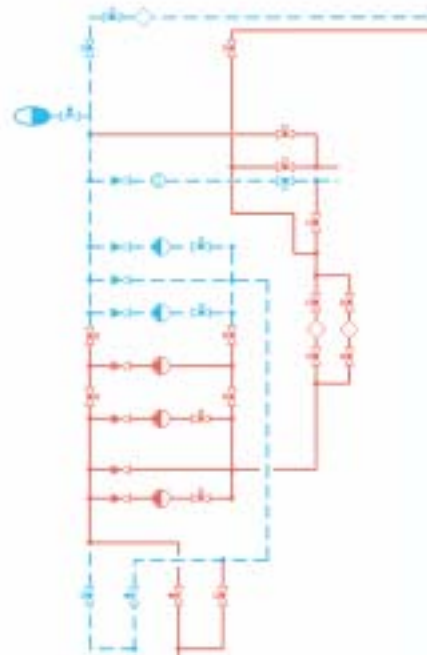
Maintenance

The actual maintenance of the transmission system is also computer-controlled. In this case, what is known as a distributed computer system is used. This means that CTR can collect data concerning the overall control and co-ordination of the various activities while the municipal operational organisations – with whom agreements have been reached concerning the day-to-day monitoring and maintenance of those parts of the system that have been established in the individual municipalities – can communicate directly with the system through local terminals.

Maintenance activities are divided into two groups: preventative maintenance and remedial maintenance (i.e. actual repairs). All in all, these covers approximately 5,000 different ac-

tivities a year – or, economically speaking, accounts for approximately 1% of the total cost of the system. This sum includes the various service contracts that have been drawn up with sub-contractors (for pumps, plate heat exchangers, boiler installations, measuring equipment, etc.).

Moreover, the maintenance system is also linked with CTR's computer-controlled spare parts system, so that a run on any particular type of spare part is registered immediately. Subsequent to this registration, messages are sent to CTR's accounts system so that the maintenance costs are paid and the relevant entries into the accounts are made immediately as a matter of course.



Preventative maintenance and remedial maintenance (i.e. actual repairs) accounts for approximately 1% of the total cost of the system



PHOTO ENERGI E2

The Environment

– oil consumption savings of 290,000 tons per annum

Tangible Environmental Improvements

The collectivisation of heat supplies has shown itself to be an important means of reducing the adverse effects of energy consumption on the surrounding environment.

This effect has been achieved primarily through a more efficient exploitation of fuel's inherent energy. This is particularly applicable to supply systems that use surplus heat from the production of electricity and/or from industrial production, from refuse incineration stations and from bio-fuels and other sources of renewable energy. The expansion of district heating systems using, in particular, these last types of fuel is making an important contribution to the reduction of fossil fuel consumption.

For example, in Denmark, energy consumption per m² has fallen by more than 50% since the beginning of the 1970's. This reduction has occurred at the same time as collective supply systems have expanded from covering approximately 25% of the total amount of energy used for space heating in 1972 to covering up to 70% at the turn of the century.

During the same period, emissions of carbon dioxide (CO₂) and sulphur dioxide (SO₂) have fallen dramatically. This is due, first and foremost, to the more efficient exploitation of energy, but is also due to improved firing techniques, more efficient smoke purification systems and the use of fuels with a lower sulphur content.

Nationally, CO₂ emissions have fallen by approximately 14% year 2002 compared with year 1990. A corresponding reduction in SO₂ emissions has also been recorded. In CTR's area of supply alone, the concentration of SO₂ has fallen to approximately 40% of the level it reached in the mid 1980's (as measured at the centre of the area of supply) – falling from approximately 46 µg/m³ in 1985 to approximately 16 µg/m³ in 2000.

The CTR system has saved approximately 290,000 tons of oil per year and has reduced SO₂ emissions by two thirds and CO₂ emissions by approximately 50%.

Moreover, reductions in the volume of nitrogen compound emissions of up to 80-90% are the results in plants fitted with NO_x-reducing equipment.

The Economy

The Construction Budget

The construction budget for the entire project currently stands at DKK 3.0 billion (460 mill. US\$, 1 US\$ = 6.5 DKK) at current prices. Foreign currency loans have been

taken out to finance a large part of these considerable investments.

The major part of these investments was made in 1986-87 where construction

work was at its highest level. In the latter half of the 1990's, activities has been mainly centred around the continued expansion of the system's peak load capacity.

The Cost of Heat

CTR sells heat at the heat exchanger stations to the municipalities involved at a pool price. The price level for the heat has been calculated on the principle that the operations budget should balance in the year 2009. Furthermore it is assumed that the price, in fixed prices, will remain constant until this point.

After the year 2009 – or if the investments in construction have been repaid in full before that – the price charged by the

company for the heat will be set according to the principle that the operations budget should balance from year to year.

CTR's pool price comprises a fixed effect charge and a variable energy charge. The effect charge covers fixed costs such as the producers' fixed charges, wages, administration costs and loan repayments. The energy charge covers the actual cost of fuel, the cost of running pumps and other variable operational costs.

The size of the fixed charge has been set in advance – based on the estimated heat demand in the individual municipalities on completion of the system – and, as such, is paid regardless of the actual level of heat consumption. On the other hand, the variable charge is paid in accordance with the number of heat units that have actually been used.

The Purchase of Heat

From the point of view of the supplier of the heat, the main principle behind the agreements made is that the individual suppliers put their production apparatus at CTR's disposal and agree to supply the heat CTR needs. In return, CTR covers the fixed cost of material depreciation, and pays interest charges and operational, maintenance and administration costs. Furthermore – in case heat is delivered – CTR covers the costs for fuel, variable operation and maintenance costs as well as the state taxes that are imposed on the heat producers.

When buying from CHP plants, the company also covers any additional costs relating to the production of electricity that the plant may have incurred by supplying heat to CTR at times when there from an economic point of view is no need for the electricity production.

At the same time, it has also been agreed that 'the CHP advantage' (the fuel savings) should fall out in favour of heating during the first years (i.e. until the investments made in construction have been repaid in full). This advantage should subse-

quently be divided equally between heating and electricity production. The division has come into force for all plants except the newly built Avedoerevaerk 2.

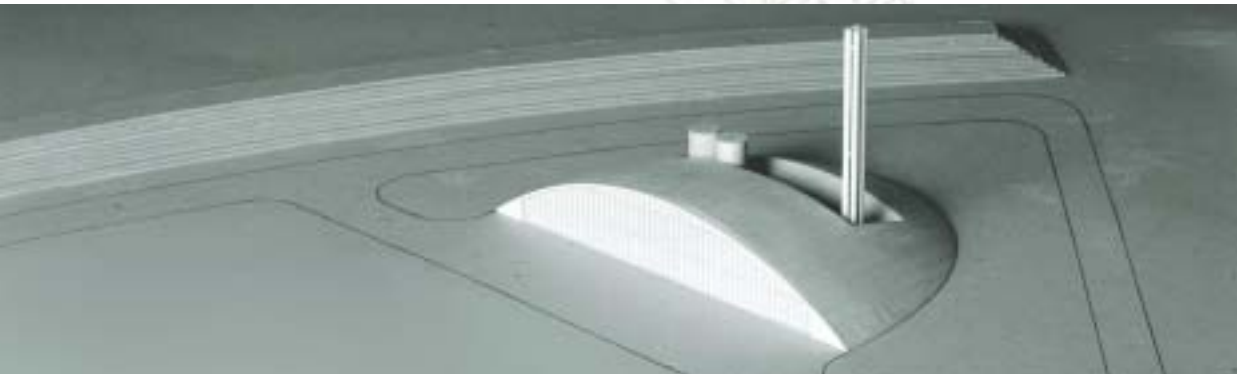
The level of CTR's pool price exclusive of taxes has remained relatively stable since the first stretches of the pipe system were taken into use in the autumn of 1986. Prices have only varied by a few percent.

If this price for heat (the wholesale price) is compared with the price paid by the consumer it can be seen that the local

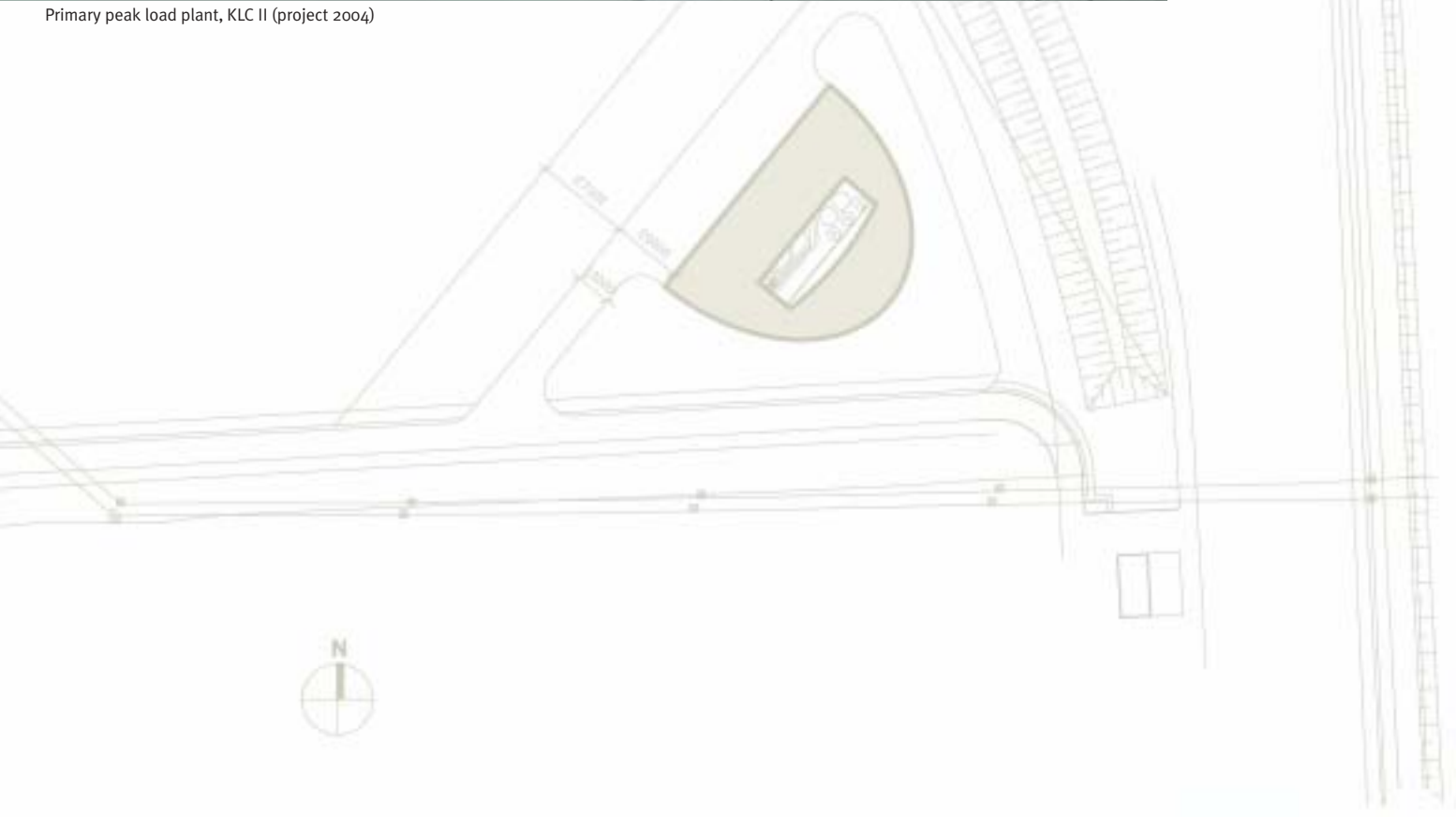
distribution networks charge roughly double. If you, however include the taxes the changes in the heat price have been striking over the last 10 to 15 years. From the start of the operation in 1986 where only taxes on oil existed taxes on coal, natural gas, heat from refuse incineration and the fuel savings on the combined production have been introduced. This means that the burden of taxes has risen from 10 per cent of the pool price in 1986 to more than 50 per cent to day.

Facts about CTR when the System is Completed in 2009

Estimated gross annual demand for heat	19,000 TJ	(18.0 x 10 ¹² BTU)
Basic load capacity	1,236 MJ/s	(4,200 x 10 ⁶ BTU/h)
Peak load capacity	725 MJ/s	(2,500 x 10 ⁶ BTU/h)
Transmission network length, double pipes	54 km	(34 miles)
Heat exchanger systems (26) installed effect	1,900 MJ/s	(6,500 x 10 ⁶ BTU/h)
Booster pump station (3) installed effect	6,000 kW	(8,000 HP)
Maximum flow temperature	120 °C	(248°F)
Operating pressure	25 bar	(350 psi)
Construction costs	3.0 bill. DKK	(460 mill. US\$)



Primary peak load plant, KLC II (project 2004)



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