GENERAL DISTRIBUTION

OCDE/GD(94)22

OECD ENVIRONMENT MONOGRAPHS

NO. 85

COGENERATION, DISTRICT HEATING AND URBAN ENVIRONMENT

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Paris 1994

FOREWORD

In 1991 the OECD Group on Urban Affairs launched a programme to promote more efficient and equitable use of energy in cities with the following objectives: evaluation of innovative urban practices and instruments; improvement of the concept of measuring energy efficiency and providing linkages for improved information exchange. As a result of this programme a handbook on "Good Practice in Urban Energy Management" will be published by the OECD. The present report which covers good local practice and policies in the field of cogeneration and district heating schemes is one of the six contributions to this handbook.

TABLE OF CONTENTS

1. INTRODUCTION

"Environmental Improvement Through Urban Energy Management" is a complementary and at the same time necessary effort to achieve sustainable development.

With the aim to promote more efficient and equitable use of energy in cities the OECD Group on Urban Affairs in 1991 launched a programme having the following objectives:

1. Evaluation of innovative urban practices and instruments;

2. Improvement of the concept of measuring energy efficiency;

3. Providing linkages for improved information exchange.

The project focuses on those issues of energy provision and its environmental impact which are most likely linked to urban design.

One of the key issues for Local Authorities in meeting the Global Challenge of energy and the environment has been presented by the OECD as:

"The need to exploit fully the potential of combined heat and power (CHP) and district heating (DH). A major reason for the development of CHP systems and DH systems lies in the technologically more efficient conversion of primary resources into usable final energy forms, heat and electricity. Fuel inputs are saved, operational costs lowered and environmental impacts reduced. The expansion of CHP and DH systems to their optimal size requires comprehensive urban planning. High initial investment costs need to be seen in the context of a long term perspective and take into account both economic and environmental costs and benefits".

Cities representing about 70 per cent of the European population are an effective entry to the establishment of an empirical basis within the field of DH and CHP systems. Closer contact between cities for the exchange of experiences should therefore be promoted.

However, it is a fact that the development of DH and CHP systems has been very different within the different OECD countries and that efforts are still needed to unveil the major obstacles for increased dissemination of these technologies ensuring improved energy efficiency and urban environment.

As a result of the mentioned OECD programme a handbook on "Good Practice in Urban Energy Management" will be published by the OECD. The main objective of this will be to provide advice on what best combines the elements of different disciplines to provide energy to cities efficiently and with a minimum impact on the environment.

The present report presenting good local practice and policies in the field of cogeneration and DH schemes is one of the 6 contributions to the OECD Handbook.

The topic has recently been dealt with in a series of articles published in the magazine Energy Policy. These articles give a profound overview of both technical and political aspects related to development of CHP and DH and presents practical experiences from several countries.

In 1991 the World Energy Council published a report on "District Heating/Combined Heat and Power, Decisive factors for a successful use -- as learnt from experiences". A number of case stories are presented in this report and general conclusions as regards legal and political aspects as well as technical and environmental implications are summarized.

Finally the Commission of the European Communities in 1990 carried out a project on Energy and Urban Environment called the CITIES-project.

This project evaluated experiences within the following aspects:

-- urban energy supply systems;

-- urban waste management;

-- information and marketing;

-- management of municipal building and vehicles stock;

-- integrative urban energy concepts

for selected cities within the 12 EC member states.

The present report has to a large extent been based on these 3 publications.

Initially a short summary of the historical and geographical development of CHP and DH within the OECD countries is given and the general factors behind the development are commented.

Secondly the environmental aspects of CHP and DH are discussed in general terms and finally the factors deciding successful development of CHP and DH are evaluated on the basis of practical experiences and good local practice from a number of representative case stories.

2. COGENERATION AND DISTRICT HEATING DEVELOPMENT IN OECD COUNTRIES

Over the last two decades CHP production by public utilities and private industry has undergone profound developments in most of the countries of the Organisation for Economic Cooperation and Development (OECD). Technological evolution and changes in the regulatory environment have fostered the introduction of CHP and DH. Achievements in the OECD countries, however, have not been uniform and have depended to a large extent on government policies and differences in energy markets.

Outside the industrial sector, the joint production of electricity and heat has to be seen in close connection with the supply of DH. CHP in public utilities, either on a large scale or in smaller units operated by communities, allows the efficient use of the heat which is otherwise a waste product of thermal electricity generation. As the development of DH networks is highly capital intensive - about three-quarters of the total supply costs are investments in the necessary physical infrastructure - some intervention by governments or local authorities has been required to facilitate its market entry and to protect against detrimental effects of competition.

Particularly in response to the oil price shocks in the early and late 1970s, governments sought to exploit more fully the energy security impacts of CHP and DH. OECD member countries have applied different policy instruments in various degrees to support the momentum induced by increased energy prices. These measures ranged from regulation to financial incentives and mechanisms for the enhancement of market conditions.

Since the 1980s, energy price developments have tended to reduce the economic rationale for investments in CHP and DH. Decreased prices of oil and natural gas generally have lessened the economics of large infrastructure projects, such as DH.

In recent years environmental concerns related to the production and use of energy have renewed interest in some countries regarding DH and CHP. Several OECD Member countries see CHP production and DH systems as priority areas for their energy and environmental policies. Energy efficiency and the possibility of using natural gas and biofuels make these technologies attractive from an energy policy as well as an environmental point of view.

DH and CHP development is significantly different from one country to the other (see Figures 1 and 2 on the following page).

While cogeneration in industry can be found throughout the OECD, CHP in the utility sector is concentrated in only a limited number of OECD countries, such as Austria, Denmark, Finland, Sweden, Switzerland and Germany. As DH is closely linked to the development of utility CHP production, these countries also have relatively extensive DH systems. For the OECD as a whole the contribution of DH to energy consumption in the residential sector was about 1 per cent in 1989. Undoubtedly there is a very large potential technically ready for installing CHP units: every energy consumption centre (urban area) where heat and power are demanded at about the same place and at about the same time, is a candidate.

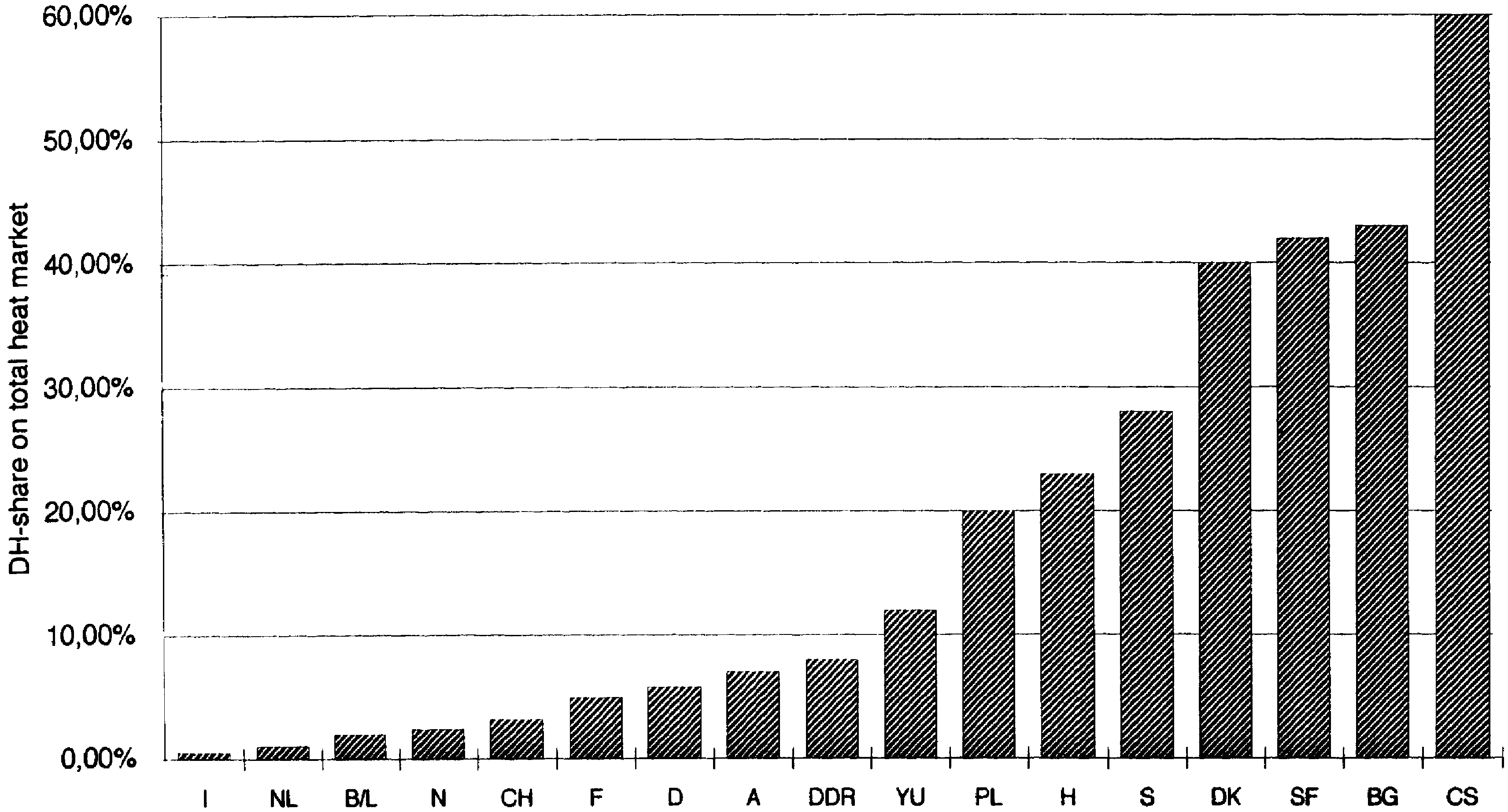
Physical and technical opportunities also need to stand the test of economic feasibility. Here many projects fail because of mismatching heat and power loads; disparate energy price evolutions of fossil fuels, and of heat and electricity; insufficient scales or utilization times etc. The set of economic CHP applications therefore is significantly smaller than the set of technically feasible CHP.

Unfortunately, in many areas, not even the economic potential can be realized because of institutional barriers as e.g. the well-known pay back gap between decentralized and centralized decision making about energy projects, regulatory prescriptions, unequal tariff conditions imposed on independent generators by monopolistic power companies, discriminatory discounted tariffs for large electricity consumers pending towards self-generation etc.

The discussion about CHP has revolved mostly around the measures and means necessary to match institutional and economic aspects.

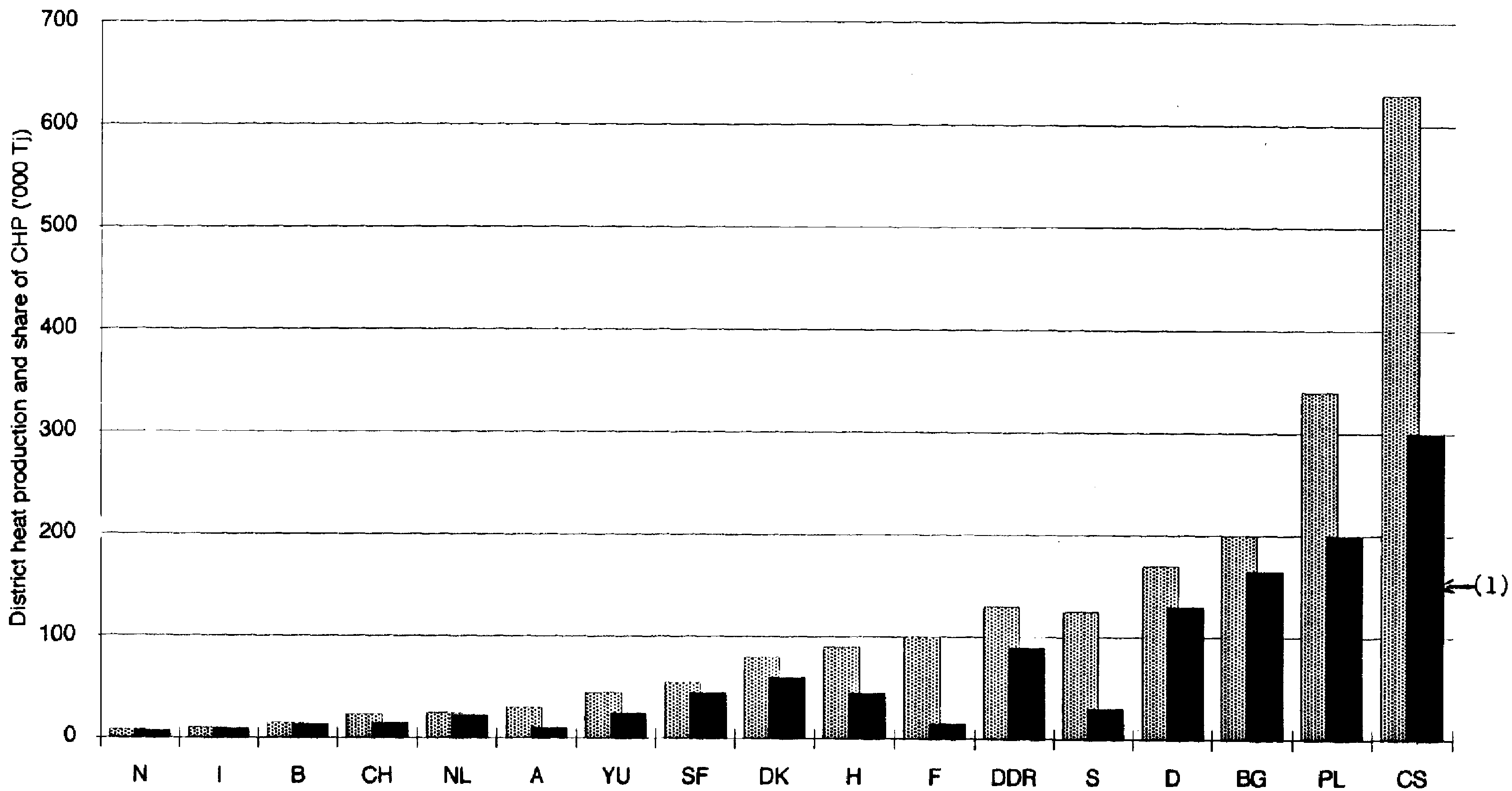
Experience indicates that the type of economic and political system is a most decisive factor in the effective use of DH and CHP. Admittedly, the most widespread use of DH and CHP is found in the countries with a centrally planned economy in which the delivery of heat, and to some degree also electricity, has been considered a social commodity (fig. 1 and 2). Those countries or companies who advocate short pay back periods for investments in CHP/DH systems have not been very successful in establishing such systems due to their unattractive commercial return.

Fig. 1 - District heat share of the total space and water heating consumption



Source: District Heating Yearbook 1991, Unichal

Fig. 2 - District heat delivered and share of cogenerated heat (1)



Source: District Heating Yearbook 1991, Unichal

In other words a global, long-term energy policy that shelters options with long pay back periods from alternating market forces is needed. Energy planning with due consideration to DH and CHP is more than just a paper blueprint. The planning process and its realization must be supported by skilled utilities, manufacturers, engineering/contracting companies etc. In some countries a flourishing CHP/DH industry is a solid base to keep the CHP option standing against other powerful energy interests.

Industrial and commercial CHP generally cannot fall back on similar well organized and well funded interest groups. The crucial issue seems to be a more equitable access for independent generators to the power market, in order to be assured of the right tariffs for buying and selling electricity and of back up capacity at real cost. For several decades industrial CHP generators were dependent on the rule setting of centrally organized electricity companies. They could not compete with the growing power of the seemingly inexhaustible economies of scale of the nuclear and coal fired base load stations. In the 1980s major shifts have occurred. There is a trend towards more competition in the power business, generally supported and sometimes headed by regulatory and official authorities (e.g. the EC). Environmental policies favour energy conservation and, therefore, also CHP.

3. COGENERATION, DISTRICT HEATING AND URBAN ENVIRONMENT

Handling and conversion of any kind of energy implies an environmental impact. In assessing the environmental position of CHP/DH systems it is necessary to compare them with other energy systems.

The impact of CHP on polluting emissions depends on 3 clusters of parameters:

- the CHP process itself and the DH system;
- the heat generation process which is displaced by the heat from the cogeneration process;
- the electricity generation process being replaced by the cogeneration process.

Fig. 3 illustrates an example of energy flow and conversion factors for two comparable situations.

The left side illustrates a situation of electricity supply based on conventional power production and heat supply based on individual boilers.

The right side represents heat and electricity supply from a CHP plant and a DH system.

The total fuel saving from producing 1 MJ of utilized energy thus amounts to 0.32 MJ. Considering heat as a marginal production in the CHP plant the marginal heat efficiency factor would be 1.28.

The attainable energy savings when switching from individual heating or traditional DH based on boilers to CHP based DH are very much depending on the specific plants and the specific circumstances.

On average a total fuel saving of 25-30 per cent is realistic assuming proper conditions as regards the DH market and connection ratios.

If the fuels are the same before and after the introduction of CHP, some of the emissions will be reduced proportionally with the energy saving, i.e. CO_2 and SO_2. Others, especially NO_x, depend on the combustion process, and increased NO_x emissions therefore might occur in the CHP situation.

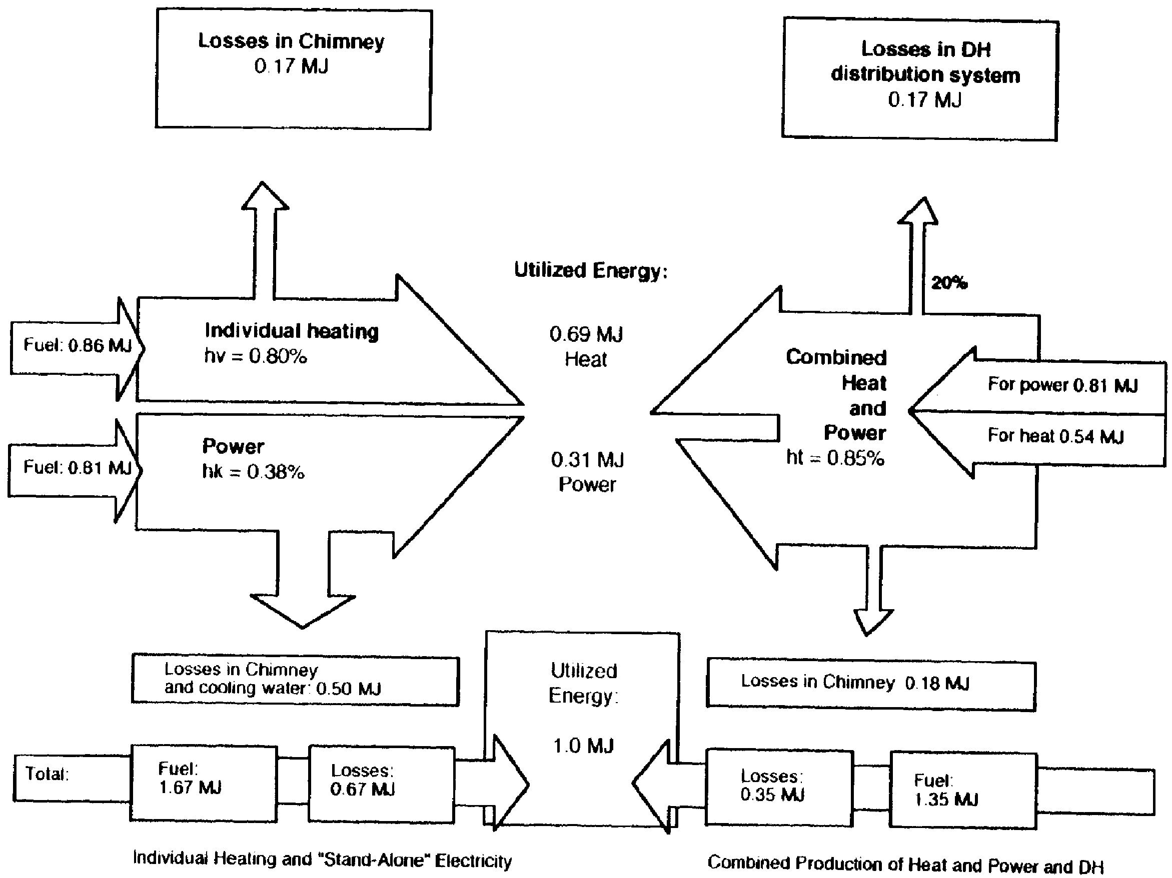


Fig. 3 - Energy Flow Diagram for individual Production of Heat and Power compared to combined heat and power production

Introduction of CHP in the heat market is in many cases connected to a switch from high quality fuels as gas and light oil to lower quality fuels as coal and biomass. Using less costly fuels might be necessary in order to ensure the economic viability of the CHP project and finance the increased investment.

A change from gas and light oil to coal, however, may neutralize the environmental gains caused by the energy savings as emissions of pollutants are increased due to the higher content of carbon and sulphur in coal.

The opposite situation might also occur if existing fuels like oil and coal are substituted by higher quality fuels like natural gas. Introduction of CHP in that case would result in improved environment both due to use of cleaner fuels and reduced fuel consumption.

In some cases CHP is used in combination with local renewable energy resources and domestic waste. Environmental benefits of CHP in such cases can be further increased since renewable sources especially as regards CO_2 emission have a positive environmental impact. Utilizing energy from domestic waste also contributes to the environment in reducing the waste problem and allowing for conservation of other fuels. Waste, however, may unit a number of special pollutants requiring flue gas cleaning.

A clear picture of the environmental consequences of CHP is not possible on a general basis. The general picture often will be an environmental improvement. Centralization of heat production however allows for more effective cleaning of the flue gas at reduced costs and high dispersion of pollutants due to high chimneys. This is an important experience, when compared to heating from individual boilers where cleaning of flue gasses is non existing and chimneys are low.

To estimate possible health effects on the population due to the emitted pollutants, ground level concentrations (GLCs) have to be determined. A comparison of concentration limits worked out by health authorities and by scientific institutions leads to some important conclusions.

GLCs are highly dependent upon topological and meteorological conditions. For realistic assessments the local circumstances have to be taken into account.

For general considerations, a model town may be used in which different space heating systems with different positions and heights of the emission sources are defined.

In order to obtain an appreciation of the absolute values of the GLCs for the various space heating systems of a model town (or special area), at first the emissions of each system have to be calculated. Then, by using a dispersion calculation for each system, the relation between emissions and GLCs can be estimated.

Average mean values for the ratio between emissions and GLCs are given in the literature. Ratios for different space heating systems have been calculated -- all related to small individual heating furnaces, as shown in Table 1.

Table 1. **The GLC-factor for different boilers related to small individual boilers**

Small boilers	Medium boilers	Large boilers		Very large boilers
		Industry	CHP plants	Power Stations and CHP plants
1	0.4	0.3	0.01	0.004

Table 1 clearly shows one of the environmental side effects from substituting individual combustion with controlled emission from tall chimneys. The GLCs of the local pollutants will be reduced at least by a factor of 100, and thus reducing health risks.

Therefore, heat supply from modern CHP plants generally leads to considerably smaller emissions compared to decentralised individual heating applications.

And the resulting GLCs are, due to the higher chimneys, in some cases even more than 100 times less. For a number of air pollutants the specific emission rates are relatively well known, but not so for a series of hydro carbon and other organic compounds with low GLCs limits (if they even exist). But also for these substances there is a tendency for the specific emission from large fuel burning facilities to be very much lower than from individual heating systems.

4. GOOD LOCAL PRACTICE AND POLICIES

4.1 General criteria

CHP and DH systems are successful if they:

-- ensure heating and electricity prices competitive with alternative supply systems;

-- ensure a technical and economic reliable energy supply to all connected consumers under different external conditions as e.g. climate, energy crisis both caused by economic problems and actual resource problems;

-- have a good local reputation resulting in a high connection rate again ensuring a good economy as invested capital is fully utilized and paid for;

-- improve the environment both locally and globally.

The success can be measured through:

-- evaluation of the total costs of the entire supply system from production to end use;

-- evaluation of the technical standard and efficiency of the system;

-- evaluation of the connection rate;

-- evaluation of the environmental effect of the system.

Due to the fact that both the technologies and the political and economic aspects are quite different, the evaluation of urban DH and CHP systems should distinguish between three categories:

- industrial CHP
- integrated CHP/DH systems in larger cities
- decentralized CHP/DH systems in smaller cities and villages.

4.2 Experiences from different OECD countries

Possibilities for actions and degrees of freedom for cities to provide energy efficiently and with a minimum impact on the environment through development of CHP and DH schemes depends, among others, on the following aspects:

-- framework for the energy planning activities and energy policies (energy planning, environmental planning or urban planning);

-- market related conditions as import dependence and availability of different energy sources as e.g. nuclear and hydropower, coal and natural gas;

-- organization and ownership of supplier systems, i.e. decision structures;

-- financial possibilities or constraints;

-- energy pricing and competition between different energy sources;

-- socio-cultural environment and traditions for collective supply systems.

Some specific characteristics in different countries as regards industrial and public CHP development are summarized below.

Industrial cogeneration

Market factors are the main parameters for development of industrial cogeneration. Costs of competing fuels; availability of waste products which can be used as fuel in the boilers; load requirements both for electricity and heat; cost for peak load electricity; the price of back up electricity and revenues achieved from surplus electricity sold to the public grid are elements to be included in the decision process. Regulation of the utility industry is also important, particularly for the last two parameters. Industry usually design CHP facilities to be cost-effective for internal demand. However, any additional revenue which could be collected from selling excess capacity and energy supports the industrial cogeneration investments.

Technological development is another major factor which has favoured the introduction of industrial CHP. The increased efficiency of generation technologies and their cost degression, together with favourable price differentials against purchased fuels, have strongly supported the development of cogeneration over the last two decades.

Industrial CHP is an economically attractive option, particularly where large heat loads exist, such as in the chemical, primary metals or food and paper and pulp industries. However, structural shifts in industry can influence the scope of industrial cogeneration. Reduced heat requirements due to declines in the basic metals industry or the impacts of energy-efficient technologies which have reduced heat demand in industry, ultimately reduce the scope for cogeneration. Integration of industrial CHP in urban areas where the possibilities of selling excess heat or electricity are present is a way towards robust development for industrial CHP. The political and legal framework, however, has to be appropriate.

Below a brief description for several European countries highlights the factors behind development of industrial CHP.

Italy. In 1990 industrial cogeneration increased 3.2 per cent and reached 16 TWh, which is about 7 per cent of total consumption in 1990. The total industrial capacity is about 4500 MW. Cogeneration is concentrated in the chemicals industry (60 per cent), followed by the paper and pulp industry (10 per cent). 725 GWh of electricity was produced in CHP plants of public utilities. Such production has increased by about 15 per cent per year over the last decade. The heat output is used primarily for DH. A promotion law of 1982 provided contributions for cogeneration and heat recovery for about 650 billion Lire in the period 1981/1987. The financial incentive was 30 per cent of the plant expected cost including the CHP and the whole transmission and distribution network. A valuable revision of the promotional law to fulfil some of the targets specified in the PEN (National Energetic Plan) permit financial incentives up to 40 per cent of capital cost for cogeneration plants and up to 50 per cent for DH transmission and distribution network. Promotion strategies are adopted according to which a large part of the connection costs is to be born by the distribution utility.

Ireland. The total industrial CHP capacity in 1990 was 60 MW, generating about 4.8 per cent of industrial electricity consumption. Industry estimates that there is a further potential for an additional capacity of 129 MW, which could be exploited under current economic conditions. Irish law, however, does not allow industrial generators to sell surplus electricity to any company except the state-controlled supply board (ESB), though they may sell surplus steam or hot water.

Spain. CHP production has grown from a 1.6 per cent share of power generation in 1986 to 3.6 per cent in 1990. At the end of 1990 the total industrial cogeneration capacity was 962 MW; the full potential for cogeneration in the industrial sector has been estimated at 2000 MW. In 1988 and 1989 42 new cogeneration plants with a total capacity of more than 200 MW came into operation. Applications are concentrated in the refinery industry. Over 100 CHP units have been installed in Spain. Most of these are gas fuelled, which is partially a result of future cuts in the supply of subsidized domestic coal due to production targets imposed by European Community regulations and the fact that as environmental restrictions become more stringent, using coal becomes an expensive alternative.

The Netherlands. Industrial CHP capacity amounting to 184 MW was completed in 1988; this brought the total capacity to about 2.2 GW. These plants now generate over 15 per cent of the country’s electricity. The central government has been subsidising CHP up to 1987 through various instruments:

- giving grants for feasibility studies (50 per cent);
- supporting demonstration projects for new techniques;
- giving promotion grants for CHP production units. If more than 90 per cent of the produced heat is used for space heating , 40 per cent of the total investment is subsidised. For other users the maximum support is 25 per cent.

A project office was instituted in 1988 to promote the implementation of CHP, mainly in cooperation between utilities and users of heat. The project office is supported by several energy organisations in the Netherlands and the Ministry of Economic Affairs, which provides the necessary financing (1.6 mill. NLG in 1988). Manpower is provided by the participating organisations. Activities concern industry as well as small-scale CHP.The government hopes that as a result of its support programme, around 900 MW of additional new CHP capacity will be added by 1995.

Public utilities and DH

Although not necessarily linked, DH systems and CHP production of public utilities have a close affinity. In many cases the heat produced by power plants is sold to local DH companies or directly to end-users. Furthermore, electric utilities and DH companies are in most countries (particularly in Europe), directly or indirectly owned or controlled by public entities, such as municipalities. In addition to public CHP facilities, heat is also provided by heat plants or in small-scale CHP units which can supply smaller building units or villages. Such installations are often operated by building owners or cooperatives.

Economic parameters as well as regulation are important factors which influence the introduction of DH and CHP production by public utilities. Other factors that foster the application of DH systems are the density of the population and climatic as well as geographical conditions. It is, therefore, not surprising that the largest DH systems can be found in Scandinavian and central European countries.

Economic factors include the costs of competing heat supply options, such as gas and oil, and the resource endowment of the country (the availability of natural gas is an example). The installation of DH networks usually entails high investment costs. About 70 per cent to 80 per cent of the total supply costs are fixed costs for production, transmission and distribution of DH. Compared to other supply options the share of variable fuel costs is much lower. DH activities are therefore usually not undertaken by the private sector or independently without governmental support.

Several governments in the OECD countries have tried to reduce the long-term risk of such infrastructure investments. Regulatory provisions were applied to facilitate the market entrance against competing fuels or heating systems and to guarantee DH companies a sufficiently high consumer connection rate to make their investments profitable. Direct and indirect financial support was often used, such as grants or access to public capital, which is usually cheaper than commercial bank loans.

Though economic considerations have fostered the introduction of DH networks, particularly in cases where relatively cheap heat load from CHP plants has been available or where prices of competing fuels have led to favourable prices differentials, regulatory support has generally been the major factor for the promotion of DH networks. The active role of regional and local administrations, such as communities, has also supported the implementation and extension of CHP/DH systems. Austria, Finland, Sweden, Germany and Denmark are examples of countries with such a fruitful relationship between local authorities and public utilities, including DH-companies.

Since the mid-1980s, however, energy price developments have been less favourable for the extension of DH. The downward trend of the price of oil and natural gas has made connections to the DH network less attractive for consumers. Price developments have often caused economic losses to the operating companies or municipalities. Further regulatory support may be required to guarantee the economic viability by, for example, maintaining a sufficiently high connection rate.

In ***western Germany*** there are about 200 DH supply companies which operate 500 networks totalling 10,000 km. In the last 10 years, DH has expanded at a rate of around 3 per cent per year. More than 70 per cent of the heat supplied by these networks comes from CHP plants which also produce about 4 per cent of the electricity demand. DH accounts for about 9 per cent of the space heating market, equalling to 4.7 per cent of the total final consumption by households and small-scale consumers. Between 1988 and 1989 the heat capacity increased by 898 MW i.e. 2.6 per cent. In 1988 coal provided 41 per cent, natural gas 36 per cent and oil 14 per cent of the heat generated. The Federal and Länder Governments support the introduction and expansion of DH. A programme for investments 1977-81 funded 680 million German mark (DM) by federal and regional authorities to extend DH in urban centres. Subsidies of up to 35 per cent of the investment costs were granted on request. A programme for coal fired CHP stations and DH expansion, launched in 1981 ended in 1987, made 1200 million DM available for the promotion of CHP/DH. The maximum subsidy granted was also 35 per cent, but usually the actual figure paid as subsidies was considerably lower.An Investment Premiums Legislation 1982-1990 stated subsidies of 7.5 per cent of investment costs of CHP, refuse incineration plants, heat pumps and heat-only-peak-load stations. Furthermore, a subsidy of 180 DM/kW is paid to all power plants using domestic German hard coal. CHP plants can be subsidized up to 300 DM/kW gross output. In general, an amount of 50 billion DM has been paid in subsidies between 1975 and 1982. DH has received 1,600 million of this sum (to be compared with a total investment in the same period of 5,200 DM).

Austria provided in 1989 about 7,5 per cent of low temperature heat demand and about 3 per cent of TFC through DH. Total investments by DH supply companies increased substantially, by about 68 per cent. During the 70's, the Federal Government began to support new DH production and supply systems. Subsidies were given to investments, producers were given "soft loans" (reduced interest), and the users were given tax allowances.The total investment support to 374 projects amounted to about 4.5 billion Austrian schillings up to 1987. Interest subsidies were 3 per cent, and investment support amounted to 12 per cent. Since 1st April, 1987 these were reduced to 2 per cent and 8 per cent respectively. Since 1990 the subsidies have been reduced. Depending on the special circumstances DH-systems are sponsored by the government and local authorities. The governmental contribution lies between 6 per cent and 10 per cent of investment costs provided. The local authorities contribute one third. (That means overall sponsorship lies between 8 per cent and 13.3 per cent of investment costs).

Denmark's government and local authorities strongly promote the expansion of DH. The building up of successful DH systems since the 1920's was based on local decisions and voluntary connections to the supply systems. These DH systems were economically self-supporting. Where the potential for CHP existed, the conversion and link-up of the power stations was undertaken only when justified by heat demand as well as revenue potential derived from the utilisation of otherwise wasted energy. In 1989 42 per cent of total heat demand for buildings was provided by DH systems either supplied by CHP plants or heat production facilities. One decade earlier the share was only 25 per cent. The promotion of the DH systems range from tax incentives for CHP companies, to direct and indirect subsidies and regulation. Municipalities are required to elaborate plans for the development of the supply infrastructure and DH and natural gas networks are given priority in towns and conurbations. Indirectly, the electricity consumers have subsidies the extension of CHP plants and transmission systems by giving all advantages from the combined production of heat and electricity to the heat consumers for 12-13 years which is the assumed period to finance the expensive transmission and distribution pipeline system.All extra costs involved in CHP plants - investments as well as running costs and lost electricity production -- is paid by the heat consumers in order that no electricity consumers shall suffer from the combined production. Denmark has experienced significant efficiency improvements of space heating. In 1972 approximately 1.3 GJ/m² heated area were required, whereas in 1989, due to the widespread introduction of CHP/DH and also improved insulation, heat requirements dropped to 0.7 GJ per year for heating.A special programme of support for research, development, and demonstration has been financed by the Ministry of Energy and in many cases with co-financing from the European Community. A total number of 132 projects have cost more than 1.3 billion DKK for development of pipelines, rehabilitation of existing systems, control equipment, metering, low temperature systems, renewable energy sources, etc.

In ***Sweden*** strong governmental support has also led to substantial increases of DH consumption over the last decade. In Sweden the output of DH plants tripled between 1970 and 1985. No general subsidies to CHP/DH have been allocated. However, five temporary government programmes have been instituted between 1981 and 1986 regulating subsidies to CHP/DH investments, among others:

- Grants to replace oil or to conserve energy (1981-82). Subsidies to investments in DH production plants (especially those using domestic fuels) and heat pumps. An amount of about 50 million Swedish kroner (Skr).

- Grants to DH distribution, peat fired plants, etc. (1983). 10 per cent grants amounting to 215 million Skr were given to DH pipelines ordered in 1983. About 200 million Skr was given to new peat fired CHP plants.

- 15 CHP/DH coal fired plants received in total 194 million Skr (1983) for desulphurisation equipment.

- New DH production plants using domestic fuel received 74 million Skr and new heat pumps for 129 million Skr. New consumers of DH connected in 1984 could get a connection subsidy of 108 Skr/kW connected. The total amount of such connections was 88 million Skr.

- As grants to energy investments (1985-86) new DH production plants using domestic fuels received 29 million Skr, and concerning investments for flue gas cleaning 42 million Skr were granted as subsidies.

- Environmental taxes on the emissions of SO_2 and CO_2 were introduced in 1991 and a tax on the emission of NO_x became effective in 1992.

4.3 Urban case stories

Examples of good local practice can be found within many of the OECD countries.

In connection with the 12 CITIES project on Energy and Urban Environment financed and published by the EC at the beginning of 1991 specific case stories within urban DH/CHP systems were presented for the following cities:

-- Odense, Denmark
-- Manheim, Germany
-- Torino, Italy
-- Esch/Alzette, Luxembourg
-- Amsterdam, The Netherlands
-- Newcastle-upon-Tyne, United Kingdom

Typically the two first mentioned cities represent good local practice within integrated DH/CHP systems in larger urban areas. The examples from Italy, Luxembourg, the Netherlands and United Kingdom represent smaller decentralized CHP units for public buildings and industrial purposes. The example of Torino describes good experiences with the development of DH poles with CHP plants leading to significant energy savings and environmental improvements.

The World Energy Council in June 1991 released a report on "District Heating/Combined Heat and Power, Decisive factors for a successful use -- as learnt from experiences".

This report presents case stories from the following cities:

- Budapest, Hungary
- The Greater Copenhagen Area, Denmark
- Helsinki, Finland
- City of Paris, France
- The City of Prague, Czechoslovakia
- Seoul, Republic of Korea
- Västerås, Sweden
- Warszawa, Poland
- A Dutch Combined-Cycle Medium-size System, Purmerend

Apart from the last mentioned case, which is an example of new CHP technology in a city of less than 100,000 inhabitants, all these cases represent good success stories for large integrated CHP/DH systems in large cities.

Some of these stories are summarised in the following paragraphs.

Odense

Odense is the 3rd largest city in Denmark with 175,000 inhabitants. The DH system supplies 95 per cent of all its potential consumers. The DH system, totalling 8,880 TJ in 1988, is almost entirely (93 per cent) provided by Fynsværket, a CHP plant built in Odense in 1953. The DH company is owned and operated by the Municipality.The total energy efficiency of the system is high, due to an overall high conversion efficiency, high connection ratio, and a well managed distribution network. Compared to a situation with conventional condensing power plants the cogeneration is generating an estimated annual energy saving of 1000 TJ. The development of this situation has been supported by City Council decisions since the second oil crisis in 1979. Furthermore, energy savings in the city have been supported, and despite very low consumer prices domestic heat consumption has declined by 28 per cent during the past ten years. Energy consumption in public buildings has successfully been targeted in order to reduce consumption. Likewise a renovation plan for the network has been launched at a total investment of 484 million DKK, financed by energy savings and saved repair expenses. The city of Odense has combined an effective supply strategy based on cogeneration with reductions in energy demand, significantly reducing the total energy consumption, supporting the environmental aims of the Odense energy policy of reducing the impact of energy supply in the city.

Mannheim

Mannheim (Germany) has 300,000 inhabitants with an annual primary energy consumption (excluding transportation) of 9.4 billion kWh. The urban energy policy is guided by the Integrative Urban Energy Concept of 1983, in which costs, security of supplies and environmental concerns are the main objectives. Included in this policy is the aim to expand the supply systems of DH and natural gas and to further utilize cogeneration, waste, and side heat. This expansion is supported by advertising, information and financial assistance to consumers connecting the supply system. Some DH has existed in Mannheim since 1938, but in 1977 a DH programme was launched, pointing out DH preferred areas, based on geographic criteria, heat density etc. Combined with the above mentioned support measures, this programme has resulted in increased coverage by DH, up to 38 per cent of all residential units and 26 per cent of total demand for final energy. A major part of the heat to the DH is supplied from a CHP plant, Heizkraftwerk Nord, based on waste, natural gas and oil. The energy produced on waste now amounts to 18 per cent of the DH. From an environmental perspective the emissions of pollutants have been reduced through reduced fuel consumption, cleaner fuels, and improved cleaning facilities.

Torino

Energy National policy in Italy aims at reducing energy consumption and, in this context, strongly supports the use of CHP. A recent government decision permits municipal energy companies and private producers to sell to the National Utility Company (ENEL) the surplus electricity arising from cogeneration. Torino has decided to develop a rational energy policy including energy saving programmes. Three districts in Torino have implemented DH networks, leading to significant energy savings. This is especially the case where the network is linked to CHP. These projects have been supported by technical assistance form the Technical Team, a team charged by the City Administration. Environmental concerns are an important motivation behind the urban energy policy programme of Torino, seeking to improve air quality in the city through rational energy consumption.

Amsterdam

The Dutch energy supply is dominated by natural gas. Energy savings play an important and successful part in Dutch energy policy, especially the National Insulation Program, whereas introduction of DH often has met difficulties due to the widespread use of natural gas. In Amsterdam some 80 per cent of the energy consumption is covered by natural gas. Recently, the Dutch utility sector has been reorganized and local distribution companies have been allowed to install small power units and to buy from remote producers. This enlarged policy space in Amsterdam has been used to achieve peak saving, to promote renewable energies and to save energy. The Energy Company Amsterdam is implementing a programme for the installation of small scale CHP units. With a maximum pay-back period of 8 years, projects totalling 150 MW have been identified. The current plan foresees the installation of 100 MW CHP in hospitals, large apartment blocks and some large public buildings over a 15 year period.

Esch/Alzette

Esch, Luxembourg, has 25,000 inhabitants, and is primarily supplied with natural gas and oil. In 1988 a company, SURRE, was formed, with the aim of identifying projects for DH and to provide turn-key plants. The DH plant at the Brill School is the first project undertaken, and it consists of three building complexes supplied from CHP plants. The electricity produced is fed into the public grid. The use of primary energy is reduced by 32 per cent, and the emissions of particulates is reduced by 70 per cent, N_20 by 25 per cent, CO_2 by 45 per cent, and SO_2 by 75 per cent. The project is economically highly viable, with an internal expected rate of return of 19 per cent given a lifespan of 15 years. Another project has been identified and is under construction.

Helsinki

DH in Helsinki started in 1952 when the first consumers was connected to a steam network. At the beginning, the steam network supplied heat to business and residential buildings as well as industrial premises. The first hot-water system was established five years later in 1957. To begin with, it had only 27 consumers and a maximum heat output of 12 MW. Today, only 17 consumers are still using steam. The DH system in Helsinki is owned and operated by the Helsinki Energy Board, which is one of the public utilities of the city of Helsinki. As the main task of the Energy Board is to supply the consumers in the Helsinki area with both electricity and heat, CHP is a very important part of the energy production. It means that more than 80 per cent of the heat production today is from back-pressure processes and has its share of an overall fuel efficiency of 80 per cent. Today, about 90 per cent of the energy for heating purposes in the Helsinki area is supplied from the DH system, delivering DH to more than 400,000 inhabitants by a system with a total length of 850 km. The total planning and the daily control of the entire production, transmission and distribution of the DH system is done at the Central Control Centre. This centralised control functions improves the reliability and economy of DH. The Energy Board’s tariffs are based on the recommendations of the Finnish DH Association, which states that charges should be roughly the same in years with cold and mild weather. Due to the increase in the amount of connected consumers and the general reduction of the fuel prices, the real price of DH has fallen to the level it was ten to fifteen years ago.

City of Paris

In Europe, the largest interconnected DH system using steam as the heat carrier is found in Paris. The system is operated by the limited company -- formed in 1928 -- Compagnie Parisienne de Chauffage Urbain (C.P.C.U.) concessioned by the city of Paris to produce and distribute heat. The shares are owned by:

• Paris city	33.5%
• Electricité de France	25.8%
• Société Lyonnaise des Eaux	25.8%
• Société Générale des Eaux	7.4%

and various other shareholders including the personnel. The turnover before tax reaches about 1 billion Ffr. More than 300 km of pipelines supply heat to about 1 million people, resident inhabitants, or people employed in public and private offices, shops, hospitals, industries, etc. More than one quarter of the total needs of the city of Paris for heat is supplied by C.P.C.U. A total of about 20 PJ is produced in 8 heating plants based on coal (45 per cent), gas and heavy fuel oil (10 per cent) totalling 55 per cent of the 20 PJ. The rest is produced mainly by 3 urban refuse incineration plants which burn 2 million tons of household refuse from 5 million inhabitants of the greater Paris district. CHP was another source of energy (up to 11.3 per cent) through extraction of steam from the suburban EdF power station of Vitry. This source was abandoned in 1988 when, as a consequence of the expansion of its nuclear facilities, EdF limited the use of the coal fired Vitry station to only few hundreds of hours during peak period. At the consumer's premises steam may be used directly for industrialized applications in laundries, breweries and hospitals. For households, shops, department stores and office buildings, steam-to-hot water exchangers are installed in substations belonging to the consumers. The steam produced is sold for urban heating to a production cost based on coal prices. The income from elimination of garbage is roughly a little more than half the prices which should have to be paid.

5. EXPERIENCE LEARNT

Based on the case stories some basic conditions for the success of DH and CHP can be outlined.

- **Stable long term economic conditions.** DH and CHP systems are long term, capital intensive, constructions. In order to reach sound economic solutions the long term economic conditions for these systems must be as stable and foreseeable as possible. Capital costs amount to 75 per cent of total cost of consumer prices, whereas the fuel costs varies down to 25 per cent of the total costs. Compared to individual heating the consumer prices of DH thus are relatively independent of energy prices. In situations of fluctuating or even declining real energy prices consumers will hesitate to connect to the DH network, and heat companies will subsequently hesitate to expand DH or establish CHP. A risk which should be decreased through policy and follow-up initiatives.

- **Adequate heat and electricity market.** The necessary heat market, i.e. the heat consumption, the heat density, and the geographic conditions must be available. This is important both in order to ensure economic viability and to reduce heat losses in the distribution system. Likewise technical, legal and organizational admittance to the power system must be available on acceptable conditions.

- **A high connection ratio.** The marginal costs of connecting more consumers to the DH system are limited. High connection ratios in existing and new DH systems are therefore energy-wise and economically important.

- **Maintenance and technological improvements.** Experiences from older DH and CHP systems prove the importance of ongoing maintenance and modernization of the systems by utilization of technological improvements in order to reduce energy consumption and energy losses and improve the long term economy.

The above-mentioned conditions for successful development of DH and CHP are not always met, giving rise to especially economic difficulties. Declining fuel prices may reduce the economic benefits for the DH consumers, induce some customers to disconnect and turn to individual heating, prevent others from connecting, and thus further increasing the economic difficulties of the DH company and the remaining consumers. A vicious circle of increasing consumer rates and decreasing connection ratios has been established. In this circle losses of energy efficiency will occur, often adversely affecting the environment.

Examples show that a number of policies at local and national level as well as organizational improvements can be implemented to ensure the basic conditions for DH, supporting the development of DH and the utilization of CHP in order to reach both economic, energy and environmental gains.

- **Tax, subsidy and regulatory support.** Adequate state and local policies in some cases have made up for problems related to short term prices fluctuations through taxes and subsidies and through regulation.
- Energy taxation. Taxes on energy can level out fluctuations in consumer prices when world market prices are fluctuating and face consumers and decision markers with more stable, long term, prices.
- Subsidies. Subsidies in the form of soft loans and grants to consumers and/or heat companies have been used in many countries to reduce investment costs, support maintenance and modernisation, and to speed up the connection of consumers to the network.
- Regulation. In some cases national governments have permitted local authorities to force consumers within a specified time span to connect to the DH system in order to improve the economy and energy efficiency.

- **Market planning and sharing.** Inappropriate competition between different heat supply systems within the same area may jeopardize the economy of the system. Competing supply systems may further reduce the energy efficiency of DH, since connection ratios may be low. To avoid these problems, in several cases markets have been geographically shared between different supply systems through planning efforts by state or local authorities.

- **Heat and electricity relations.** Utilization of CHP establishes a close physical relation between the electricity production and the heat production. This relation on the production side must be met on the demand side, allowing for the utilization of both energy products. Access to larger DH systems and to the public electricity grid often serves to increase the flexibility of the system and thus allowing the introduction of CHP production. The need for flexibility puts requirements on the legal framework and on the cooperation between the electricity side and the heat side.
- Legal access to sell energy products. Industries, larger dwelling complexes, institutions like schools, hospitals, etc., utilizing cogeneration must have legal access to sell surplus heat to the DH company and surplus electricity to the electricity company.
- Heat companies utilizing CHP production must also have legal access to sell electricity to the public electricity grid.
- Close cooperation with the electricity companies. Whether industrial CHP plants or plants owned by heat companies appropriate terms and tariffs on the exchange of electricity are important.

- **Official support.** The support of public authorities is often important for the success of DH and CHP. Quick connection of public buildings to DH networks can valuably contribute to the economy of the system. Coordinating the physical planning in municipalities with the development of the DH systems can also strengthen the economy of the DH company and lower the consumer rates.

6. EXCHANGE AND DISSEMINATION OF EXPERIENCES

The most effective promoter of CHP/DH will be the continued interest in saving energy resources and reduce pollution of the environment. Supported by public opinion and by the authorities, national as well as international support to further extension of existing systems and establishment of new systems can be foreseen. In view of the fluctuating oil prices, energy policies will continue to reduce the dependency upon oil, and, at least for a considerable time, turn to natural gas and coal as the primary fossil fuel resources.

A close cooperation between industries, public authorities and utilities is an important factor for a future use of CHP production. Sharing the experience obtained on an international basis is of great importance for the most efficient use of energy and for improvement of the environment.

To fulfil the overall objective, i.e. expansion of CHP and DH systems to their optimal size within but also outside the OECD world e.g. in Eastern Europe, it is of great importance to exchange experiences and to build the future development on an up to date experience basis. Although difficult in practice new developments should continue from an established experienced base and avoid reinventing the wheel.

As mentioned in the introduction, the literature on the subject is very rich. Technical aspects, policies and experiences have been presented in many publications and several workshops and conferences have been held where experts and decision makers have had the opportunity to exchange experiences.

Although still reluctant in some countries, the results of increased dissemination of information and good experiences from CHP and DH systems are beginning to show as actual developments of new systems and improvements within existing systems all over Western Europe.

The energy problems in Eastern Europe are now in focus. CHP and DH are widely extended in Eastern Europe. However, the used technologies are old and inefficient and maintenance is lacking due to bad economy. This results in high energy losses and severe pollution. It is therefore essential to extract the essence from Western experiences in order to offer the optimal support to the improvement of the energy situation in Eastern Europe.

Establishment of an OECD database with relevant information about all CHP and DH systems which (annually) could publish overviews and statistics of the kind published in DH Yearbook 1991 is considered to be a valuable tool in the dissemination of results and experiences. The database further could serve as a contact network between cities having familiar problems in respect of the development of the CHP/DH systems.

Another tool for development of CHP/DH systems has just been published by IEA. It is the DETECT programme. The DETECT programme is part of an information project carried out by the IEA's Executive Committee for DH and Cooling. The objective of the programme is to demonstrate the environmental and economic benefits of introducing district heating and cooling (DH&C) and CHP schemes.

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