DISTRICT HEATING SYSTEM REHABILITATION AND MODERNISATION GUIDE

FOREWORD

The aim of this guide is to support the decision-makers (management and owners of district heating (DH) Companies) both in changing the DH system's operation philosophy and choice of optimal solutions. The proper management of DH Company activity should lead to the improvement of economy and efficiency of heat supply to customers at a heat price that is competitive with other heating systems. The information included in this guide is not prepared as a handbook, but concentrates on the main issues to address when considering management matters.

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1 CO-OPERATION BETWEEN OWNERS OF MODERNISED DH SYSTEM ELEMENTS

The total efficiency of any DH system depends not only on a high efficiency heat source and well-insulated DH network, but also on effective control and rational heat use in the customers' installations.

It can happen that advantages of a very high efficiency DH source are lost, because of large heat losses in the DH network, bad heat distribution control in substations, and lack of control by the customers, etc.

In order to achieve the best results from a modernisation programme it is essential that there is co-operation between owners of the different elements of the DH system.

DH systems represent well-known technology and long time practice in Central and Eastern European (CEE) countries and several EU countries. Comparison of DH system performance indicators shows important differences between the CEE and the EU member countries.

The main reason for the differences lies in the philosophy of DH system operation – in the CEE countries the systems are still mainly generation-driven whereas in the EU countries they are generally demand-driven.

Local authorities and economic entities should prepare their own energy strategy with the aim to rehabilitate and modernise the DH system, which should be energy efficient and environmentally friendly. This policy needs to recognise the need to move from generation to demand-driven operation. This will involve a certain amount of adjustment to the network.

The new strategy should normally be enshrined in a mission statement that provides the foundation for strategic decisions, which move towards realising the vision.

CEE countries => 'generation driven' mode	**EU countries => 'demand driven' mode**
The heat source regulates the amount of heat delivered to the DH network and to the customer's installations	Automatic control of heat supply to the consumer's installations by devices located in substations according to the actual customers' needs
An imbalance between the heat generation and the actual customers' needs -> irrational heat utilisation -> customers compensate the imbalance by opening windows or wearing extra clothes	The heat supply has to adjust continually to the customers' actual needs

The main reasons for DH system modernisation in CEE Countries

- improved energy efficiency
- reduction of heat supply costs and customer payments
- reduction of emissions to the environment

2.1 Advantages of DH

One of the most effective ways to modernise DH systems involves developing Combined Heat and Power (CHP), which is the only way to simultaneously use a variety of fuels to produce heat and electricity with high efficiency and low emissions. DH system modernisation can also lead to efficient integration of combined generation of heating and cooling services based on CHP plant. More detailed advantages of DH systems are described in 'The Case for District Heating', one of the other DHCAN guides.

2.2 Long term planning for DH system modernisation

It is essential to take a long-term view when considering DH system modernisation, because high investment costs are required, resulting in a long pay back period. It is strongly recommended that financial decisions should be made not on the basis of payback, but using life cycle costing.

Long term heat supply planning should be based on an evaluation of local conditions and all possible solutions (available fuels, technologies and heat sources, and transmission and distribution networks). Existing and expected changes of heat demands must also be considered, as must the life cycle of equipment, and available financial resources.

One of the most important issues concerns fuel alternatives: this influences the investment and operational costs of heat generation which in turn affects heat supply costs and customer payments. Reliable fuel supply is one of the main conditions for rational operation of centralised heating system. A fuel supply monopoly can lead to interruption in the DH system operation if the fuel supply is cut off (eg blocked fuel transportation routes). Therefore, it is very important to have the facility to store fuel and also to establish reliable and competitive fuel alternatives.

It is worth analysing the economic profitability of a heat supply system designed for at least two different fuels (eg gas and oil, coal, wood); furthermore local fuel reserves could compensate for possible disturbances in fuel supply, and ensure heat supply reliability. This could include, for example, incineration plant. 'The Case for District Heating' outlines the generic fuel and waste heat sources to consider.

Important factors, which should be taken into account before making a final choice of a fuel options and choice of an optimal heat supply technology include the following:

- availability and reliability of fuel supply throughout operation
- permissible level of emissions and expected changes of environmental protection requirements
- investment and operational costs, and availability of capital.

Additionally, existing and forecasted heat demands and heat demand density influence choice of fuel and heat generation technology.

The long-term plan for DH system modernisation and development should set out the immediate priority tasks, which do not need investment costs, second priority tasks with low cost and subsequent tasks, which require substantial investment.

These factors have an important influence on the long-term financial stability of the district heating company. Heat supply planning should be based on long-term contracts between heat producers and distributors, as well as with customers.

2.3 Optimisation of the total costs of energy supply

Optimisation of the total costs of energy supply to the customers is connected with long-term Local Energy Planning. The main aims are as follows:

- optimal utilisation of different energy carriers (taking into account existing energy sources and available local fuels)
- optimisation of energy supply costs
- reduction of environmental pollution.

Local Energy Planning (including optimisation of total costs of energy supply to the customers) is not yet developed in CEE countries. In many cities buildings are connected to the power grid, gas network and DH network, operated by three different enterprises so that customers have to cover costs of electricity, gas and heat supply to their buildings. It is, however, possible to carry out energy supply optimisation, because particular energy needs can be covered using different energy carriers.

Optimisation of total costs of energy supply to the end users involves analysis of investment (capital) costs and running (operational) costs. This should principally examine whether it is more economically justifiable to:

- supply electricity, gas and heat from the DH network to all buildings (taking into account total payments for all kinds of energy supply)
- allow 'free' competition between different 'network' systems (eg individual gas boilers versus DH network)
- implement Local Energy Planning and optimising particular 'network' systems development together with a legislative framework for 'zoning' of the city into areas supplied from DH system and power grid, areas supplied from gas network and power grid and areas supplied from power grid only.

In small municipalities, where heat density is usually rather low, there are not many options for optimisation of the energy supply systems. In large municipalities, however, there are two main options for consideration: centralised and decentralised heat sources (including CHP).

Grid or network	Heating & Ventilating	Domestic warm water	Cooking	Lighting & domestic appliances
Power grid	+	+	+	+
Gas pipelines	+	+	+	
DH network	+	+		

Comparative advantages resulting from economy of scale of the 'centralised' solution -> usually one large plant is supplying the DH network (sometimes a few plants are supplying separate DH networks or a common DH network)
• Lower investment costs
• Higher efficiency flue gas cleaning and environmental benefits
• Less staff needed

Comparative advantages of the 'decentralised' solution -> a number of relatively small heating plants scattered to various parts of the municipality
• Lower cost of DH network investments (less transmission lines are needed)
• Progressive expansion of a heat supply system capacity according to needs and resources
• Individual heating plants are located near the local heat load

It is necessary to stress that the combination of local industrial and municipal heat load gives the opportunity to operate one larger plant instead of two smaller ones. The larger plant benefit results from the economy of scale both in investments and running costs. There are several DH systems in Poland, which are supplied from industrial heat sources. For instance in Plock an industrial CHP plant is producing heat for the operational and heating needs of the refinery as well as selling heat to the DH company, reporting to the municipality, which operates the DH network supplying residential and public buildings.

3 ECONOMIC ASPECTS OF DH SYSTEM MODERNISATION

The financial security of the DH Company is very important for making sure the modernisation programme is sustained. This involves taking forward the most appropriate measures, in a planned sequence, which is affordable.

Usually the main aims of 'generation driven' DH system rehabilitation in CEE countries are improvement of the total energy efficiency of heat supply and rationalisation of heat utilisation by consumers. Generally DH system modernisation results in:

- considerable decrease of fuel and electricity consumption in heat sources,
- reduction of heat losses in DH networks,
- improvement of heat control on the supply side,
- reduction of heat consumption following demand side management (DSM) measures for energy conservation in buildings.

It means that rehabilitation of a DH system leads to considerable energy savings giving lower heat supply costs and improved environmental protection (reduction of emissions). Simultaneously the transformation from generation-driven to demand-driven encourages customers to consume less, increasing the unit cost of heat supply (fixed costs are divided into a smaller amount of sold heat). Thus economic aspects are very important for planning the DH system modernisation.

The starting point for the DH system modernisation planning should be:

- To define the scope of modernisation together with an evaluation of expected costs and economic effects (decrease or increase of heat supply unit costs) for particular DH system elements,
- evaluation of available financial sources

If available financial sources are not sufficient to cover all costs of planned DH system modernisation the plan should be divided into affordable stages.

Thus the DH system rehabilitation should be considered in this way: its first stages should include measures which can be realised without or almost without investment costs (eg organisational changes, improvement of operation quality etc), but giving savings and resulting in reduction of heat supply unit costs. This means that some improvements can be made quite quickly. More expensive improvements can be carried out when resources allow. Both the DH company's own and outside financial sources can be used.

It is necessary to stress that the economic effects of DH system rehabilitation affect heat supply unit costs and DH Company pricing policy, as well as the competitiveness of DH systems with other systems of heat supply (eg decentralised gas or oil fired boilers).

3.1 Long-term economic/financial analysis

The economic analysis of DH system modernisation should be part of a long-term plan for DH system operation and development. The analysis should define a profitable scope of modernisation in particular stages as well as be a basis for negotiations with potential outside investors and banks about financing the modernisation programme.

The economic analysis needs to take into account very important issues, influencing profitability of centralised heat supply, like:

- present heat demands and expected changes on the local heat market (increase or decrease of industrial and commercial needs, development of residential quarters, expected reduction of heat demands owing to DSM in buildings), availability and future availability of local waste heat,
- expected changes of fuel and energy prices, and the cost of materials, changes of taxes,
- heat price level accepted by customers (competitive with other systems of heat supply) and expected real collection rate.

The economic analysis should be prepared according to requirements of financial institutions concerning justification of application for loan, grant etc

Initially an outline Scoping Study can be carried out containing a general description of the DH system and the planned stages of modernisation together with an evaluation of expected costs and financial return. DH modernisation programmes can be expensive and it is therefore recommended that the economic evaluation be carried out on the basis of life-cycle cost rather than relying on simple payback.

The more detailed description of the DH system modernisation plan and economic aspects of its realisation can be prepared as a 'Feasibility Study', which include an option appraisal and economic information required by commercial banks or financial institutions.

The economic analysis should be followed by the development of a business plan and/or financial model, which should include a detailed description of particular tasks or actions with a financial plan for its realisation during a defined period. More detailed suggestions concerning DH system development planning are described in the parallel 'Management Guide', another DHCAN guide.

3.2 Specific problems of heat and electricity cogeneration

CHP is one of the most effective and environmentally friendly technologies. Because heat and electricity are produced in the same energy process (unit), there is a problem of cost division between heat and electricity and subsequent calculation of prices. There are many different methodologies of price calculation for heat and electricity produced in cogeneration[1]. The additional complication is connected with peak demand boilers, used when heat demands are very high.

Another problem is the low electricity price, due to surplus power: this means the price of electricity from CHP is also low. The knock-on effect is that the price of heat produced in cogeneration with electricity is higher. That problem is connected with energy policy, and electricity price regulation during a

1 The problem is described in the "Management Guide" and "Institutional Guide" (other DHCAN guides) and in the World Bank publication on regulation of heat and electricity produced in CHP plants (by Carolyn Gochenour).

ECONOMIC ASPECTS OF DH SYSTEM MODERNISATION

transition period. At present this can be a serious obstacle for development of cogeneration, both in existing plants and new small and mini CHP with gas turbines and engines.

This issue is very important, because cogeneration offers an excellent way to integrate local energy supply with parallel generation of electricity. CHP plant can provide space heating and domestic hot water, as well as industrial needs for steam and hot water. It is also possible to combine heat generation with space cooling (DC – District Cooling) and achieve an increase of heat sales, resulting in reduction of heat supply unit costs. The main benefits of such systems are:

- fuel flexibility
- reduction of environment pollution (improved urban air quality)
- highly efficient utilisation of the primary energy.

The size and type of equipment installed in modernised or new CHP plants depends on the local circumstances like availability and prices of fuel and energy, amount of heat and electricity sold to the DH network and power grid etc, and should be optimised for each individual case. The important issue is CHP capacity optimisation and load division into basic load, covered by cogeneration units and peak load covered by peak boilers. The optimised level depends on the individual case and type of the plant as well as local circumstances, but some general principles should be taken into account, when modernisation of DH system and CHP plant is planned:

1 The heat output of a single solid fuel fired cogeneration unit (boiler & turbine), may range from 10 to 20% of the maximum heat load of the DH system. From the economic point of view the unit should be operated throughout the heating season and in summer time, when the heat is produced for domestic hot water needs only.

2 The thermal capacity of a single gas fired cogeneration unit (gas turbine or engine) can range from 15 to 40% of the maximum heat load of the DH system. The higher possible share of heat output results from the greater flexibility of gas fired units, which can be operated in the range of 20% (gas engines) or 40% (gas turbines) up to 100% of the nominal heat output. It means that the minimum summer load should not be lower than 20% (gas engines) or 40% (gas turbines) of the unit nominal heat output.

3 The total heat output capacity of all cogeneration units in a DH system can range from 45 to 60% of the maximum heat load of the DH system. It is very important to put into practice heat load optimisation and operation of heat sources according to the least cost principle. This is possible when individual CHP plants and peak boilers are connected to various nodes of a densely looped DH network.

In general, the use of accumulators is a good way to size and integrate CHP in an effective way.

3.3 Economic effects of DH system modernisation

The overall economics of modernising a DH system depend on the necessary expenses (investments costs etc) and resultant energy savings, improved heat supply reliability, and other advantages resulting in lower heat supply costs. The economic effect of reduced environmental pollution is more important from a national perspective, but when it is established emission trading may benefit DH companies.

The main economic benefit for the DH Company and its customers is lower heat supply costs by implementing the least cost principle in the following ways:

- flexible fuel use - ability to use various fuels and use the cheapest
- utilisation of various waste heat sources
- economic load division between heat sources supplying DH network
- elimination of redundant capacity in heat sources and DH network
- elimination of low efficiency heat sources
- development of heat and electricity cogeneration
- reduction of heat losses in DH network
- reduction of electricity consumption for water pumping and other needs
- economy of scale by producing heat in larger central plants.

End users derive a further economic benefit from implementation of improved control and metering – they will be able to control their heat consumption according to their individual need and be invoiced according to the heat meter readings. Apart from that the overall system will be more reliable due to continuous monitoring of heat generation and distribution.

A major concern for DH companies is how modernisation affects heat supply cost and the price consumer pay.

The best outcome is when modernisation results in a decrease of heat supply unit cost and the heat price can be reduced or kept at the previous level.

When the heat price is reduced the DH Company may either decrease consumers' payments, or alternatively maintain the same heat price and use the surplus for financing further tasks in the modernisation plan. Sometimes the heat price increases after modernisation, but if modernisation lowers heat consumption by customers, their payment can be kept at approximately the same level.

It is worth stressing that the effect on heat supply unit cost often depends on total investment costs and 'financial engineering' of the separate tasks within the modernisation plan.

Investments with long payback periods (eg replacement of DH network, which needs high investment and brings low economic effect) can run parallel with investments with short payback time (eg improvement of energy efficiency of heat sources or implementation of automatic control of heat supply in substations and heat sources). Sometimes it is possible to reduce the impact on heat supply unit cost by negotiating loan or leasing conditions, for example increasing planned payback time, lowering interest rate etc Through proper business planning ('financial engineering') it is possible to avoid rapid heat price growth and moderate any increase in heat price to a level acceptable to customers.

It is important to co-ordinate investment in heat sources, DH networks and substations. It can happen that substantial savings in one part of the system (eg at the heat source owing to improved energy efficiency) can be lost elsewhere (eg in a network with large heat losses and leakages).

There are a number of interactions between particular elements of DH system, which influence economic effects and total energy efficiency of the system. The most important links between heat sources, DH networks and substations, which should be taken into account when scope and coordination of DH system modernisation are considered, are as follows:

1 Primary hot water temperature (in supply line) is regulated according to weather conditions, but return temperature and water flow depend on the customer, who regulates heat consumption according to actual needs (and sometimes ability to pay for delivered heat).

2 The difference between supply and return temperature (water cooling in substations depends on customers) defines the necessary water flow needed for heat supply at the heat source as well as on size pipelines in the network.

3 The heat losses in a DH network depend on water temperature in the supply and return lines and pipe dimensions (diameter and length) as well as thermal insulation quality.

4 Supply and return water temperatures have a direct impact on the power to heat ratio in the cogeneration unit as well as economic and energy effectiveness of the CHP plant. Lowering of water temperature allows increased electricity generation in cogeneration unit and improves the total efficiency of the CHP plant.

5 The water flow, pressure drop in pipelines and pressure difference required in substations have a direct impact on electricity consumption for pumping needs at the heat source (by circulation pumps). Electricity consumption can be reduced by means of variable speed pumps, which regulate water flow according to actual hydraulic conditions in DH network.

In demand-driven DH systems, effective control at the substations (of space heating and domestic hot water supply) is vital to the overall DH system efficiency and operational cost. So co-operation between the DH Company and its customers is very important when automatic control of heat supply is planned.

3.4 Evaluation of DH system modernisation (investment) profitability

Evaluation of profitability should be based on monitoring of investment and operational costs, and analysis of economic effect before and after each measure is carried out. This should be related to the whole plan of DH system modernisation.

It is very important to organise a proper system of cost and income recording in the DH Company using an adequate computer program (to reduce labour costs). This will enable a permanent supervision of economic performance of the system to be carried out, focusing on the impact of modernisation. This also means the modernisation plan can be adapted as it progresses to improve the economic effect and profitability of particular tasks and the whole plan.

The modernisation plan usually results in energy savings, decrease of heat losses, reduction of electricity consumption as well as labour cost rationalisation and other advantages. It usually leads to decrease of heat supply unit cost. However, simultaneously modernisation on the demand side causes reduction of heat sales, resulting in a drop in income which exceeds the drop in production costs.

Evaluation of modernisation (investments) profitability should be based on a comparison of difference between income and heat supply costs before and after realisation of the separate tasks (investments).

Economic benefits of environmental improvements may be difficult to assess - environmental protection is beneficial to all but not specifically for the company. This may be simpler after implementation of emissions trade and ‘green certificates’ in CEE countries.

4 TECHNICAL ASPECTS OF DH SYSTEM MODERNISATION

The main aims of the technical restructuring of DH systems are:

- reduction of heat supply costs,
- increase of heat supply reliability,
- lower environmental pollution,
- reduction of excessive heat consumption by consumers.

DH system modernisation costs depend on the size of the DH system and the scope of investment, but its profitability depends not only on the effect of individual tasks but also on the overall interaction between the various elements. Usually it is not possible to realise whole DH system modernisation at the same time and gradual modernisation of its elements is necessary.

Parallel to the DH system modernisation should be implementation of modern maintenance tools. This should be accompanied by implementation of a Planned Preventive Maintenance policy, which means regular servicing of DH system elements and also includes early detection and fast repair of small damages before they have grown.

It should bring spare part and labour cost savings, but the main advantage would be less instances of large damage, which usually result in heat supply interruptions and decrease of heat sales, together with economic and social consequences for the DH Company and its customers.

Very useful maintenance tools could include: (a) maintenance vehicle (four wheel drive) equipped with power aggregate, pressurised air, leak detection device, welding equipment, pumping aggregate etc, (b) pipe connecting tool working on pipe under operational water pressure, (c) Personal Computer with a maintenance database.

Successful DH System Modernisation:Riga

An example of successful DH system rehabilitation is the city of Riga (Latvia). The DH company (Rigas Siltums) provides 76 % of the total heat demand of the city. Approximately 30 % of heat is generated in company's own heat sources, while 70 % is purchased from Latvenergo's CHP plants. The company operates DH networks, which distribute heat to residential and industrial customers, as well as to the public sector. The company also provides the service to residential buildings. The City of Riga is divided into four heat supply districts and each has an appropriate company organisational structure (heat sources, DH network and functional administrative units), which are accountable to the company's economically and financially centralised administration.

The DH system was operated before rehabilitation in generation-driven mode which means that heat supply was regulated in heat sources. Heat was distributed from the central plants through DH networks (primary and return pipes) to 180 group-substations, which were connected with a four-pipe system supplying many buildings through two pipes for space heating, and another two pipes for domestic hot water supply and re-circulation. The domestic hot water was heated in heat exchangers installed in group-substations, while the space heating was carried out without heat exchangers. Additionally the corrosion of steel made pipes was a big problem both in heating and domestic hot water installations. The oxygen content in tap water was intensifying corrosion of the domestic hot water pipes.

The main objective of the DH system rehabilitation was the transition from generation to demand-driven mode of heat supply. It was connected with elimination of all group-substations together with four-pipe supply to many buildings.

In five years, more than 3570 individual substations (heat exchangers with control units both for heating and domestic hot water purposes) and metering equipment have been installed in buildings supplied earlier from group-substations. Simultaneously a considerable amount of work was done on the renewing of contractual relations with building managers. All these measures resulted in 15 - 20 % reduction of annual heat use by the customers.

At the same time the DH networks were reconstructed. The scope of works included replacement of large-diameter mains and use of modern insulating materials, as well as the replacement of insulation on aboveground mains without pipe replacement. Modern preinsulated pipes replaced some sections of mains and distribution networks. Modern fittings and accessories have also been installed in DH networks like ball and half-turn valves and bellows-type expansion joints.

It resulted in significant reduction of expenses related to emergency repairs due to pipeline ruptures (over 2,5 times smaller amount of emergency repairs). Apart from this, losses associated with the temporary shutdown of the DH networks when connecting, new consumers have been reduced because they can be tapped in to the working pipelines under pressure. The greatest gain from replacement of the obsolete pipelines is the reduction of heat losses and the leakage of the heat carrier, as well as an increase in the safety (reliability) of heat supply.

These actions were performed simultaneously with the optimisation of the DH network size, including reduction of the DH network length and pipe diameters, according to the actual heat load. Most important tasks included construction of two connecting pipelines, joining DH networks supplied from four heat only boiler (HOB) plants with two different main pipelines supplied from the more efficient 'Imanta' plant.

Improvement of operational service quality and implementation of an innovative service culture accompanied the reconstruction of the DH system where the client is the focus. The company has started in particular to pay attention to its technical and highly developed technological foundation, without which it is almost impossible to provide a high quality service. Using modern technologies as a foundation, heat use recording has been transformed from an estimation method to an instrumental one.

In this way the DH company achieved a big reduction of DH network's operational costs. Despite inflation, the company has been able to ensure a sound operation and has not changed the tariffs for the last six years. This outstanding result was achieved thanks to good management of the company and carefully planned refurbishment of the Riga DH system.

4.1. Scope of DH system modernisation

The first step of DH system modernisation should be optimisation of the system size based on analysis of heat capacity and DH network size and shape (radial or ring). If the heat sources and DH networks are oversized the modernisation plan should be confined to those areas where investment seems to be profitable - taking into account expected changes of heat demand resulting from consumer activities.

The principal issue regarding the scope of modernisation is to define the optimal system size taking into account existing heat source capacity, network transmission capacity, together with current and expected heat demands. This should take account of include potential new connections (increase in heat demand) as well as modernisation of existing buildings and controls (decrease in heat demand) and upgrade of distribution pipes (decrease in heat demand).

Before preparing a modernisation plan it is advisable to evaluate the heat demand density in each area of a city in order to determine where district heating is likely to be economically effective. The plan should be prepared taking into account the following restrictions and priorities:

- priority should be given to low cost measures, such as training, especially where available finance is limited,
- investments with high Internal Rate of Return (IRR) should have high priority (eg improvement of boiler efficiency by implementation of combustion control with monitoring system).

The DH system modernisation plan and schedule of the larger investments should be in accordance with an agreed set of priorities for modernisation of all heat sources.

Main elements to consider when modernising heat sources are:

- development of CHP generation both in existing heat sources and as new small and mini size CHP plants,
- closing down of low efficiency HOB and connecting customers to a DH network (or replacing by modern high efficiency fully automated boilers, fired by gas/oil or renewables),
- reduction of harmful emissions by changing fuel type, modernising existing plants (eg by installing of flue gas cleaning),
- optimisation of combustion processes by means of automatic control of fuel and air supply to the combustion chamber together with automatic control of exhaust gas removal,
- implementation of automatic control of heat delivery to the DH network,
- implementation of heat supply measurement from heat sources,
- implementation of energy services approach.

Investment in water treatment equipment may be necessary to increase the quality of water circulating in the DH network. Higher quality of circulating water extends the lifetime of the DH equipment (especially the network), while poor quality water can cause problems in modern equipment, especially in automatic control devices.

Modern variable speed pumps (equipped with frequency controllers) must be installed in heat sources together with automatic control in substations, when water flow in DH network starts to vary.

Lower heat use by customers and implementation of a looped network may lead to the reduction of heat demand and some boiler capacity (especially peak and reserve) becoming obsolete.

In heat sources equipped with cogeneration units it can be useful to install heat accumulators, especially in cases when electricity price is differentiated for day, peak and night time. The heat accumulator is discharged at a peak time, when the value of generated electricity is higher than at night. At these times, electricity generation in CHP plant can be maximised. The decrease of co-generated heat does not matter because the DH network can receive heat from the accumulator, which is charged during the night when electricity generation can be decreased.

CHP plant can also be modernised by interconnection of the gas and steam cycles (combined cycle plants – cc-plants) to intensify electricity generation and increase total energy efficiency. In a combined 'steam-gas' CHP plant the flue gases from a gas turbine can be used in the recuperator (waste-heat boiler) to produce steam at high pressure and temperature, which flows to an ordinary steam turbine to generate additional electricity. There are also possibilities to install a new gas turbine for effective upgrade of an existing solid fuel fired CHP plant. It can be implemented in two major ways:

1 Exhaust gases from a gas turbine with high oxygen content (15 – 16 %) can be use as combustion air (oxygen content in ambient air amounts to 21%) in a combustion chamber of the steam boiler to fire pulverised coal at very high efficiency.

2 Heat recovered from the flue gases from the gas turbine can be used for preheating of water feeding a coal-fired steam boiler.

Modernising coal-fired CHP plant in these ways can be considered when it is necessary to upgrade existing plant. However, it is important that the increase of electricity generation in CHP plant is economically justifiable.

Gas turbines and combined cycle CHP plants perform better than traditional coal fired plants (eg power to heat ratio).

In principle, electric power is a more valuable product of cogeneration, because it is otherwise generated by other thermal power plants in a condensing process at lower efficiency.

In smaller DH systems installation of gas-fired CHP engines can be considered, replacing traditional coal-fired HOB plants, especially when new plant will produce electricity and heat for industrial and municipal needs. Usually the different peak time of industrial and municipal heat load makes it possible to reduce investment and operational costs in comparison with two separate heat sources (industrial and municipal). The DH systems producing electricity and heat for industrial and municipal needs exist in several towns. For instance in Pulawy a large CHP plan is supplying both a 'mother' fertiliser factory and the municipal DH network; in Swidnik the CHP plant is producing heat for a helicopter factory and the municipal DH network.

TECHNICAL ASPECTS OF DH SYSTEM MODERNISATION

Many similar schemes are operated in the Silesia region, where industrial CHP plants are supplying heat both to the municipal DH networks and different factories.

The advantages of the common industrial-municipal heat sources development will usually be:

- decrease of heat output capacity in comparison with two separate plants (lower peak load)
- higher energy efficiency in cogeneration process
- additional income owing to electricity generation
- labour costs decrease.

Sometimes an increase of heat sales is possible in summer time owing to the development of a new activity called ‘District Cooling’. The principle of District Cooling is based on utilisation of hot water, circulating in the DH network, to supply absorption chillers installed in buildings. The chillers produce cold ‘ice’ water, which is used for space cooling (inside air chilling). This solution can be more economic in comparison with traditional air coolers using electricity, because the cost of heat generation in CHP plant during summer time is very low. Usually in summer time heat demand is low and excess heat from cogeneration unit is directed to the atmosphere.

Use of waste heat from the CHP plant to produce cool air for buildings is energy efficient.

Modernisation of DH pipe networks is one of the most serious problems in CEE countries because of the long payback time. High investment cost is the main factor limiting network modernisation.

Replacement of small diameter pipelines is usually a more cost-effective option than replacing large transmission pipelines. The small pipes are more tractable for external corrosion, their lifetime is shorter, and their heat losses higher. A DH system modernisation plan should include systematic (year by year) replacement of the worst pipelines (usually the oldest corroded pipes with damaged thermal insulation). Simultaneously modern fittings and accessories (valves, compensators etc) should also replace obsolete ones.

The main elements of DH network modernisation are as follows:

- decrease of heat losses owing to better thermal insulation of pipelines (eg preinsulated pipes) and optimisation of water temperatures in DH networks
- increase of heat supply reliability following the development of ring-shaped DH networks, elimination of long radial ‘telescopic’ sections of pipelines as well as implementation of modern fittings and accessories
- reduced water losses in DH networks owing to implementation of modern fittings, compensators and other accessories (with better tightness) as well as implementation of modern pipeline construction with better anti-corrosion protection, and electronic leak detection
- decrease of investment and operational costs owing to optimisation of DH network size
- optimisation of water flows and pressures in particular sections of DH network (variable speed pumps in DH network pumping stations).

Partial upgrading of DH networks is suggested - depending on the technical condition of the existing pipelines (eg age of pipes, level of corrosion, thermal insulation technology), available finance, and profitability of particular investment tasks.

4.2. Environmental protection

When a DH system is modernised there is usually an environmental benefit because the overall energy efficiency improves and hence fuel consumption falls. Development of CHP plant has a particularly large environmental benefit.

The efficiency of CHP is usually about 40% higher than for separate generation of electric power at a condensing power plant and heat at HOB plant, when the same fuel is used. In condensing coal-fired power plants, even 60 - 70% of fuel consumption is lost to the environment through condensing and chimney losses (to a sea, river or lake waters and to the atmosphere). Development of CHP benefits the DH Company and the environment at the national and even international scale.

Environmental requirements for small, dispersed heat sources are not so strict as for larger plant; so large DH plants equipped with flue gas cleaning systems are more environmentally friendly than small HOBs.

Closing down small coal-fired HOBs (which are not equipped with flue gas cleaning technology) and instead connecting customers to the DH network brings substantial reduction of annual emissions.

There are also environmental benefits from supplying the DH network from renewable fuels (eg wood, straw, geothermal), or from utilising waste heat from industrial processes.

Sometimes modernisation of heat sources is necessary, because of environmental requirements (emission levels are too high). There are various ways to fulfil these requirements:

- investing in flue gas cleaning installations,
- use of a better grade of the same fuel (with lower content of ash, and sulphur),
- change of fuel type and usually replacing existing boilers.

Implementation of more advanced flue gas cleaning systems (eg electrostatic precipitators, desulphurisation plants, low-NOx burners) is usually very expensive and the economic benefit for the DH Company is rather low, so these measures should be carried out together with other tasks resulting in energy savings (operational costs reduction). In this way there is a better economic effectiveness from the DH Company point of view.

4.3 Technical aspects of Demand Side Management

The efficiency of heat use in customer buildings is often low because substations and receiving installations are old technology often in poor technical condition. There is a general lack of automatic control and metering. Simultaneously heat losses in buildings are relatively high - approximately twice as high as in Western countries.

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Customers' buildings are equipped with internal space heating and domestic hot water installations, which are connected to the DH network by substations. There are various types of substation, differing in their connections to and between central heating and domestic hot water installations and use (or not) of domestic hot water storage.

Depending on the age of the building there are also in use so called 'hydro elevators' (ejectors), mixing pumps, shell and tube heat exchangers, and even direct connections (in industrial buildings). The 'hydro-elevator' and mixing pump are mixing water supplied from a DH network with return water (from the heating installation) in a constant ratio. The mixed water is supplied to the internal heating installation in a building – this regulates the temperature level of the internal heating circuit in the buildings.

Traditionally, heat supply control in DH systems in CEE countries is 'qualitative'. This means constant water flow during the heating season and periodic changes of primary water temperature in the heat source depending on weather conditions. Water flow rate is less in summer time with constant water temperature at a lower level. The low water flow speed and time delays in the DH network, together with uneven customer heating needs means that this kind of heat supply control does not secure rational heat utilisation, and customers often receive either surplus or deficit in heating. To avoid customer complaints concerning under-heating, the water flow in many DH networks is raised above the calculated value and results in overheating of buildings and too high a return water temperature.

Modernisation of substations is one of the most important tasks involved with changing the DH system operation philosophy from generation to demand driven.

The modernisation of substations should be well co-ordinated both on demand and supply side. It should take into account the possible scope of investments connected with automatic and remote control of heat supply.

The DH system modernisation plan should include the elements described below. Main elements of substation modernisation include:

- implementation of modern techniques and equipment, including:
  - plate heat exchangers replacing obsolete equipment like 'hydroelevators' (injectors) as well as shell and tube exchangers, (ensuring proper water treatment is incorporated and water quality is monitored and controlled to the required quality)
  - prefabricated 'compact' substations equipped with plate heat exchangers, automatic control devices, variable speed pumps, closed expansion tanks, and new types of valve.
- updating of existing substations including implementation of automatic control of heat supply for heating according to weather conditions and automatic control of domestic hot water temperature
- implementation of heat meters together with a new tariff system.

Modernisation of substations, the key element of DH system rehabilitation, is difficult because in most networks it would not be possible to replace all substations during one summer – it usually takes several years. This means that both old and new substations have to be operated at the same time and supplied from the same network.

The problem is that old and new substations are not able to co-operate because they are working according to a different mode of DH system operation. The old substations, working at constant water flow in the DH network, will be disturbed by modern substations equipped with a 'weather controller' (an electronic device with a control valve). The electronic controller compares the actual outdoor temperature to the programmed value and to the measured temperature in the supply to the heating installation. The controller operates a control valve, which alters the flow of water taken from the DH network according to the heating need. Closing the control valves in modern substations (especially in spring and autumn) will cause excess heat (DH water flow) to the old substations and overheating of buildings. The customer's only choice is to open a window and ventilate the excess heat out. The opposite situation causes under-heating, which leads to the use of additional heat sources (probably electric heaters) to keep room temperature at the required level.

This problem means that the actual benefit of modernisation is less than expected. Further problems are associated with substation ownership and financing its modernisation. The DH company is not able to include into the modernisation plan those substations which are owned by customers. Thus co-operation with customers is necessary in modernisation of DH system elements.

To reduce or even avoid disturbances in DH system operation during the transition years pressure difference controllers (limiting valves) should be installed in 'old' substations or even in distribution network branches. Simultaneously variable speed pumps should be installed in heat sources and pumping stations in DH systems.

DH networks in the CEE countries include individual substations supplying one building and group substations supplying several buildings owned by one or more customers. The group substations are usually connected with receiving installations in buildings through four pipelines: (a) two pipelines distributing water circulating for space heating and (b) two pipes providing domestic hot water.

Transmission of warm water from group substations to buildings causes large heat losses due to poor thermal insulation of pipes. The suggested solution is to use existing space heating pipes as a two pipe network delivering heat for heating and domestic hot water needs, pipes circulating domestic hot water and installing in buildings heat exchangers for domestic hot water needs.

4.3.1. Thermal upgrade of buildings

The low efficiency of heat utilisation in CEE countries usually results from the poor technical condition of internal systems, high heat losses from buildings, and lack of room temperature control.

The building thermal envelope is often upgraded at the same time as modernisation of heating and domestic hot water installations. This usually leads to lower heat demand and resulting decrease of consumer payments. It is therefore essential that the reduced load is implemented or at least taken into account before district heating system modernisation takes place.

The problem of oversized DH systems exists in several CEE countries and should be solved, because customers should not cover costs connected with unused assets or equipment.

The upgrading can be divided into following two groups:

Low-cost building modernisation

- improvement of window sealing
- installation of 'heat reflector - insulation' between radiator and wall in rooms
- replacing or tightening old radiator valves
- implementation of thermostatic radiator valves, heat cost allocators & individual billing system for flat users

High-cost building modernisation

- replacement of old windows with high heat losses
- additional thermal insulation to walls and roofs
- better insulation of internal pipelines
- replacement of space heating and domestic hot water installations (pipelines, radiators).

4.3.2 Measurements and heat tariffs, individual billing system

DSM as a part of a DH system modernisation plan includes installation of heat meters and implementation of a new heat tariff system instead of a billing system based on floor area (/m2 of heated floor area). Implementation of measurements at a building level and new tariff system should be carefully prepared, to avoid mistakes resulting in a rapid increase of customer payments and financial losses for the DH Company.

Before implementation of a new tariff system based on measurement of heat supply to the buildings the heat transmission losses should be properly estimated (based on measurements in the DH network – eg water temperature drop depending on length of transmission line)

Heat losses were in the past defined according to theoretical calculations, but these were usually lower than the actual losses. This resulted in calculation of artificially high heat sales, because a part of the real transmission losses was treated as heat delivered to the customers' buildings. Introduction of heat supply metering will show that real heat sales are lower than the earlier estimates. If the billing system is converted from a floor area based to a heat metered based tariff without analysis of real heat sales, the calculated heat price will be too low and income from heat sales will not cover costs of heat supply. Therefore tariff conversion should be implemented only when sufficient reliable metered heat consumption data is available. The new tariff should be designed according to the real data.

The heat tariff should include two main components reflecting the cost structure of DH Company:

- ***A fixed charge calculated according to the heat output ordered by the customers. This charge should cover the cost of permanent staff and part of the maintenance cost and heat losses.***
- ***A variable charge calculated according to the amount of heat delivered to the building. This should cover the cost of fuel, water, electricity and heat purchase, together with the remaining part of the maintenance cost.***

The tariff should include a profit element to enable the DH company to operate and develop in the long run.

The two-part tariff should benefit both parties –> covering heat supply costs while protecting customer from paying too much. The tariff structure (share of fixed and variable charge) should motivate a customer to rationalise heat use. The share of fixed charge amount is for instance 20% in Sweden, and in Poland 30% of the total customer's payment for heat. If the fixed charge proportion is too high, the customer payment will not reflect changes of heat consumption.

In most CEE Countries the payment for space heating and domestic hot water is the single highest cost item for households. Thus flat users are interested in differentiation of payments according to actual consumption and room temperature in their flats.

Sometimes heat meters are installed in particular flats (or rooms) to record individual heat consumption, but the heat meters are quite expensive and their readings often do not represent actual consumption. This is due to meter reading errors and heat penetrating through walls to/from other flats inside the building.

A building supplied from a DH network should be equipped with one main heat meter installed in the connection to the DH network. Sometimes heat supplied to the building has to be divided into space heating and domestic hot water installations –> an additional heat meter has to be installed in the heat exchanger.

To divide heat supply cost between flat users in the building the metered heat amount should be allocated to the particular flats. The simplest way of cost allocation is division of total cost according to the floor area, but such a tariff does not give any incentive for energy saving by consumers.

In some countries an individual billing system is implemented for flat users, based on heat cost allocators installed at room radiators and water meters installed in taps. In these cases it is also necessary to take into account fair allocation of heating costs, because the apartments are not in equivalent positions. The 'corner' apartment having three cold external walls has significantly larger heat consumption and almost no possibilities for energy saving in comparison with an apartment in the middle of the building (surrounded by other apartments).

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Proper heat cost allocation should take into account not only different heat losses (heat consumption) in particular apartments depending on its location, but also heat exchange between apartments. Clearly, reduction of heat consumption in an apartment results in a lower bill for space heating. But reduction of heat consumption in an apartment in the middle of the building also means an increase of heat bill for the neighbours, because heat flows from the warmer apartments to the cooler ones. Therefore, special computer programs have to be used, to ensure fair allocation of heating costs and compensation for different apartment locations. Together with cost allocators, thermostatic valves should be installed in the radiators. The thermostatic valves control heat output from the radiators according to the apartment user's need.

4.4 Modernisation/rehabilitation process

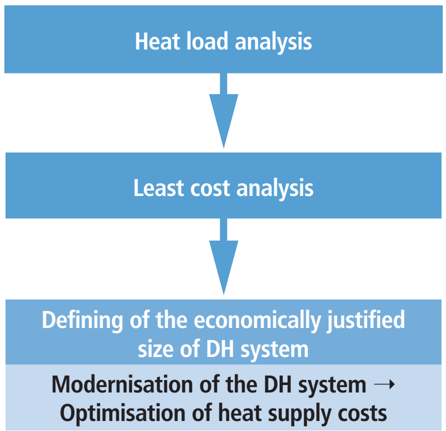
Recently in most transition economies the building owners have a choice of alternative heating methods and in several countries a relatively lower gas price is stimulating customers to disconnect from the DH network and install an individual gas boiler. Sometimes oil boilers and even electric heaters are replacing connection to the DH network.

Under free market conditions continuing to operate a DH system in the original generation mode is not a viable long-term option. The philosophy of 'status quo' could be justified if the customers had no choice and they were obliged to purchase heat from a DH system. That situation is rather rare and continuation of DH operation according to the former generation-driven mode will lead to decrease of heat sales for two reasons:

- rationalisation of heat use (DSM) by customers connected to the DH network,
- installation of alternative heating systems by owners of buildings disconnected from network.

Decreasing heat sales, and in consequence increase of heat price can lead to a 'spiral' of growing heat price, resulting in more and more disconnected customers, loss of efficient operation and ultimately the ruin of the DH system.

The process of DH system modernisation should include the following three initial phases:



Based on the results of this analysis it will be possible to evaluate the profitability of particular elements of DH system operation and to rationalise: modernisation of those which are viable, and closure of parts which are uneconomic in favour of decentralised solutions.

Heat Load Analysis is very important for DH system development planning and should be based on a municipality development plan (industrial, commercial, residential and public buildings) in areas where DH system operation is economic. The main aim of the Heat Load Analysis is to review the actual and predicted future heat load for a minimum 10 year period as a basic factor influencing on the schedule and extent of modernisation/ rehabilitation measures.

Heat Load Analysis includes demographic analysis together with a socio-economic study concerning the general economic situation of the city and its citizens, and their ability to pay for heat. The study should include analysis of probable local industrial development (or decay), as well as changes in commercial activity and households.

Local industry shall be reviewed taking into account local industrial development or collapse and likely new industrial development, and the effect on local employment and the DH system (heat supply from industrial heat sources or heat consumption for industrial needs).

The socio-economic study should include information concerning physical planning as well as the general character of the city and its main development trends, including migration balance (people coming/escaping into/from the town) and increase/decrease of the population.

The Heat Load Analysis should define the necessary heat output capacity covering customer heat demands, taking into account possibilities of economic load dispatch in a DH system.

The problem of heat supply reliability and reserve capacity in a DH system should be also considered. It will be connected with change of the DH system operation philosophy from 'generation-driven' to 'demand-driven' mode.

The load dispatch in DH systems of most CEE Countries usually supplies separate radial elements (or several different networks eg hot water and steam at different pressure). It means that heat can be supplied to a customer from one direction only (from a single heat source). There are typically a number of separate radial systems, each requiring their own reserve capacity (even existing physical loops in the DH network are closed with valves for operational purposes). The reserve heat output capacity is located at the heat source. Depending on the number of installed heat generators (boilers, cogeneration units) the reserve heat output capacity is usually 20 – 30 %, but sometimes even 100 % of the real heat load.

In many cases the reserve capacity is equivalent to the largest production unit in the system. Of course, the construction and maintenance costs of that reserve capacity are relatively high and increase the heat price.

Apart from that, the radial DH network is much more vulnerable to interruption in heat supply, with customers also cut off from the reserve capacity.

Transformation of a radial DH system into a looped one enables an Economic Load Dispatch to be implemented, because a number of different heat sources can be connected in parallel to a common (united) network.

The looped system improves the reliability and economy of a DH system, because heat can be supplied to the customers from different directions.

It allows a free load dispatch and is the most cost-effective, because the low-cost heat source covers the base load and the high-cost one works only at peak times (if at all).

On the other hand, the heat sources, which can be located in different places across the city and connected to one common (united) DH network, are able to support each other. Therefore, very little reserve capacity (less than 10% of the real heat load) is needed in a looped DH system.

Furthermore, in the event of pipeline fracture, heat can be transmitted to customers through another pipeline (from another direction) owing to different locations of heat sources. It minimises the effect of DH network damage on heat sales (a reduction caused by interruptions of heat supply to the buildings). Transformation of a radial DH system into a looped one enables heat supply costs to be optimised through Economic Load Dispatch, and heat supply reliability is maximised.

Transformation of a DH system from radial into a looped one also brings additional advantages, associated with decreased water flow. The water flow in radial DH networks is usually too high: the constant water flow together with poor water cooling causes large water flows, resulting in high electricity consumption for pumping and requiring large and expensive pipelines in DH networks.

In contrast, the water flow in a looped DH network is smaller, because the DH water-cooling is larger. This enables smaller pipes to be used resulting in lower investment and operation costs. Alternatively, the surplus capacity arising from keeping existing pipelines enables new buildings to be connected to the looped network without additional investment in pipelines.

The results of the Heat Load Analysis are crucial to successful DH system modernisation and designing, prioritising and quantifying the necessary tasks.

The **Least Costs Analysis** is connected with Local Energy Planning. It helps to identify the least cost solution for heat demands covering each part of the municipality and each type of customer.

The DH system optimisation should focus on densely populated and industrialised areas where a centralised system of heat supply seems to be least cost solution in the long run. Areas or customers for whom DH is probably not the most economic solution shall not be included during the DH system optimisation process and may be suggested for disconnection some time later.

To select areas where DH system development or further operation is uneconomic, a heat supply study for a town should be worked out. The study should analyse the least cost solution for various types of customers and different areas of the town. The most important factors, which should be defined in the heat supply study, include:

- density of heat load (in MW/km^2) in particular areas of the town (heat

density map), and expected changes in heat demands in those areas during the next 10 years (or more)
- existing heat sources (CHP and HOB) location, heat output capacity and generation, electric power and electricity generation (in cogeneration with heat), heat and electricity prices, technical condition of installed equipment (age and depreciation ratio, energy efficiency, maintenance costs, and expected modernisation costs)
- feasibility of new CHP plant construction or modernisation of existing ones, including implementation of cogeneration cycle in existing HOB plants; introduction of combined gas-steam cycle or eventually extending cogeneration to existing plants
- availability and cost of various fuels including their delivery to heating plant (including local fuel resources, renewables etc)
- availability and cost of waste heat delivery to the DH network from industrial plants, condensing power plants etc
- availability and cost of heat delivery to the DH network from waste incineration plants
- existing DH networks including technical condition (age and depreciation ratio, heat losses, water losses, maintenance costs, and expected modernisation costs)
- existing gas distribution network and its technical condition (age and depreciation ratio, maintenance costs, expected modernisation cost) as well as cost of gas delivery to particular areas of the town
- environmental requirements and priorities
- customers' economic situation (ability to pay for heat delivered from the DH network)
- possibility to co-operate with other municipalities in the development or modernisation of the DH system.

The heat supply study and Least Cost Analysis should support decision makers in the choice of least cost solutions of heat supply to different parts of the town, as well as in optimisation of DH system development and preparation of the modernisation plan.

The DH system modernisation plan should include economic and financial analyses. The Economic Analysis of the project considers results of a project at the national level. The Financial Analysis of the project considers results of a project at the DH Company level.

The **Economic Analysis** describes investment costs and advantages expected on a country level after realisation of the DH system modernisation plan. Therefore, the prices and costs should be calculated without taxes. Emission reductions bring economic effects mainly at the national (or even international) level. In that analysis the charges for emissions may be high, because of the social impact (human health, material corrosion etc).

The **Financial Analysis** enables the economic effectiveness of the modernisation plan to be assessed. The analysis defines costs necessary to realise the plan in whole or in part, the schedule of costs the DH Company should invest at a certain time and the benefit (savings) expected following implementation. Therefore the prices should include taxes,

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and emission charges should be calculated according to the actual level, defined by proper authorities.

The main idea of this analysis is to create cash flows for a minimum 10 year period and compare for two cases:

- 'first' for the DH Company's economic activity without implementing the analysed plan/project,
- 'second' for the DH Company's economic activity after implementing the analysed plan/project.

Comparison of the cash flows demonstrates the projected difference between the 'first' and 'second' options and enables a comparison to be made of increase or decrease of costs and sales. The comparisons should take into account the losses occurring in the DH system, for instance: investment losses (unused equipment costs), work losses (inefficient work costs), heat losses at source (combustion losses, emissions), heat transmission and distribution losses, electricity losses, and water losses. The table below illustrates a specimen cash flow for both financial and economic analyses.

It is very important for proper comparison of the cash flows that the dependency of heat sales on weather conditions is taken into account, as well as year-by-year changes in customer heat demands.

These changes have an important effect on heat supply variable costs and income resulting from heat sales. For proper cash flow comparison the same assumptions should be made for each case.

It is suggested to assume average degree-days over a 20 year period according to definitions used by Euroheat & Power. The resultant change in heat demand should of course be the same in both compared cash flows.

Costs	*Losses*	*Sales*
Investments	unused equipment	
Heat generation fixed costs: • heat • electricity (CHP only) • conditioned water Heat generation variable costs: • heat • electricity • conditioned water	fuel (combustion) losses heat losses electricity losses water losses emissions inefficient work	heat electricity (CHP only) conditioned water
Purchased heat Purchased water DH network operation fixed costs DH network operation variable costs	heat losses water losses inefficient work	heat conditioned water
Additional services costs: • manpower • materials, spare parts	inefficient work	additional services

Heat demands depend on heat losses from buildings (thermal insulation of the building envelope), the efficiency of internal installations in buildings and customer demands needs. The DH Company has no direct influence on heat demand except at the substations, which are connected to the DH network. The DH Company is able to control water flow from a heat distribution system to substations owned by the customer (building owner), and control heat supply to the substation owned by the DH Company.

Modernisation of substations can create some economic and financial difficulties. The substations are located in the customer's premises and are often owned by the customer (except group substations, which are usually owned by the DH Company). The heat meters and DH water flow-limiting devices (eg pressure difference controllers) are located between the substation and the heat transmission network. This means that energy savings achieved by substation modernisation will directly reduce DH Company heat sales and income.

There is a formal conflict of interest, because the result of the DH Company investment into substation modernisation is to simultaneously reduce heat sales. On the other hand, it is very difficult to encourage customers to invest in substation modernisation due to their poor economic situation and the complex decision-making processes.

Modernisation of substations, financed by the DH Company, has to be profitable both in economic and financial terms. Economic justification is usually quite easy but financial profitability can be achieved only if an additional agreement is agreed with the customer.

The additional agreement usually concerns substation leasing and an additional operation & maintenance fee (based on their real cost) paid by the customer to the DH Company. Another solution is possible through the tariff system, defining differentiated charges for customers supplied from their own substations modernised by DH Company, their own substations modernised themselves, and substations owned by the DH Company. To avoid a large number of tariff groups it is suggested to calculate average charges for each of these groups of customers.

Transformation of a generation-driven DH system into a demand-driven one is connected with modernisation of consumer substations and implementation of variable water flow in the DH network (by means of variable speed circulating pumps). The change of operation mode usually reduces the heat load and DH Company income but also reduces the variable costs of heat supply to the customers. The customer's reaction is usually very positive because their payments are usually reduced (so for the DH company arrears are likely to drop) and heat supply quality is improved. Implementation of the demand-driven mode means that customer payments depend on real heat supply to individual buildings, with heat supply matching actual consumption. It is obvious that satisfied customers are not interested in their building disconnecting from DH system and investing in another heating system. The demand-driven DH system is also attractive for new customers looking for an economic heat supply. Apart from that, the reduced heat load allows local HOB plants to be shut down, and connection of those buildings which were supplied from those plants to the DH network.

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Successful DH System Modernisation: Dzierzoniow, Poland

An example of a successful DH system rehabilitation is the city of Dzierzoniow in Poland: before rehabilitation customers were supplied from central HOB plant and DH network as well as 10 coal-fired HOB plants supplying separate building or group of buildings. The scope of works included:

- implementation in central HOB plant of variable speed circulating pumps and automatic control of heat supply to the DH network and automatic control of combustion processes in coal fired boilers with moving grid
- nine HOB plants shut down and those buildings connected to the DH network
- installation of modern 'compact' heat exchange substations in buildings connected to the DH network.

The financing scheme for this DH system rehabilitation was based on a commercial bank loan, which was guaranteed by the main equipment supplier (foreign company). Substantial energy savings and reduction of heat supply costs have been achieved, while the heat price has not changed. The difference between the constant heat price and reduced unit cost of heat supply allowed investment and financial costs without an increase of customer payments for heat.

Nevertheless it is necessary to stress, that most of the economic benefits of implementing a demand-driven DH system are given to the customers in terms described above. The DH Company gains relatively little economic benefit and is obliged to operate under extremely tight financial circumstances during the modernisation years, because the Company should be able to finance at least 30% of the total costs of the plan realisation. In the long-term, however, lost customers are likely to re-join and new customers attracted, to DH schemes which have been modernised and therefore offer a competitive energy service.

In demand-driven DH systems the payment discipline is usually higher, because the customers are able to control heat consumption and the related payment. Implementation of the demand-driven mode improves the DH Company economic situation by keeping 'old' customers connected and securing 'new' customers, as well as receiving regular customer payments.

However, changing the DH system operation mode into demand-driven usually improves cash-flow for the following reasons:

- reduction of heat supply costs resulting from optimisation of heat load in the DH system
- improvement of the collection rate resulting from higher payment discipline
- increase of customer payments resulting from dependency of charges on thermal comfort in particular flats and the possibility of additional heat sales during spring and autumn (when the outside temperature is lower)

- attraction of lost customers back to the network, and of new customers to join.

Modernisation of heat sources and DH networks, and especially development of heat and electricity cogeneration should bring additional benefits both for the DH Company and its customers, owing to more efficient heat supply.

The completion of the DH system modernisation plan should lead to improved heat supply reliability at reduced heat supply costs and lower environment pollution. The business should finally start to be profitable, satisfying customers and the DH Company. Based on experiences gained from realised modernisation plans, the following scope of a DH system modernisation plan can be suggested as follows; it is also suggested that this is integrated at the strategic overview level, with local DSM initiatives:

Modernisation of substations:

- equipping all substations in buildings with heat meters and devices controlling the pressure difference between supply and return pipelines connecting the substation to the DH network (eg 'limiting' valves)
- replacing 'hydroelevators' and 'mixing pumps' with heat exchangers (ensuring there is also adequate water treatment), to separate DH water (circulating in the DH network), internal space heating and domestic hot water circuits
- installing a 'weather controller' and domestic hot water temperature regulators in most or all substations
- eliminating domestic hot water circuits (heat exchangers) in group substations together with pipelines distributing this water to the buildings; utilisation of the existing external heating installation (pipelines connecting group substation with buildings) to deliver heat to the buildings both for space heating and domestic hot water; the buildings should be equipped with individual heat exchangers for domestic hot water provision.

Modernisation of DH networks:

- replacing those obsolete pipelines which are in the worst condition with modern pre-insulated pipes with much better thermal insulation (polyurethane foam) and anti-corrosive protection, together with fittings and other accessories (eg compensators); replacing the worst pipelines (some 5 – 20% of the total DH network length) is likely to be feasible and has a higher IRR than replacing all pipelines,
- construction of interconnections to reconfigure the DH system as a looped scheme (from a radial one) – this will improve reliability of heat supply and reduce required reserve capacity.

Modernisation of heat sources:

- eliminating a possibly large number of small, low-efficiency coal-fired HOBs and either connecting the customers to the DH network or replacing old boilers with much more efficient modern gas or oil boilers equipped with automatic controllers,
- improving automatic control of combustion processes in boilers,
- implementing automatic control of heat supply to the DH networks according to actual heat demand,
- improving the operation of the system by installing variable speed circulation pumps (frequency control) and adjusting supply temperature to actual needs,

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- improving DH water quality by modernising the water treatment process and improving make-up water quality, to reduce internal corrosion and sedimentation in pipelines, automatic control devices and substation heat meters.

In larger DH Companies, the Company's own staff can usually carry out the modernisation plan. Smaller DH Companies will not usually have all the necessary specialists among their permanent staff, so specialists may be temporarily employed or else the work may be contracted out to an appropriate consulting company. Simultaneously, the Company's permanent staff should receive training in financial management and economic analysis, marketing and public relations, environmental management, and heat tariff setting. Staff training should be accompanied by modern management methods, together with implementation of systems for quality assurance, preventive maintenance, and provision of information about use of modern technologies in other DH Companies. Experience from completed projects demonstrates the importance of this training for successful modernisation.

Some of the key benefits gained from carrying out DH system modernisation plans in five Polish cities (Warsaw, Krakow, Gdansk, Gdynia and Katowice) are described below. Modernisation was co-financed by World Bank loans.

1 Technical modernisation of DH systems raised the heat generation efficiency, reduced heat and water losses in DH networks, and partly transformed the system operation mode from generation-driven to demand-driven. Energy savings (22 % of used coal valued at US$ 60 million per year) were even more than planned in 1990 when the DH systems modernisation plans were prepared.

2 Consumers have benefited from a big (56%) drop in heat price (from 54,5 PLN/m^2 in 1991 to 24,0 PLN/m^2 in 1999, at 1999 prices) as well as a decrease in heat consumption. Installation of metering and automatic control of heat supply in substations has enabled customers to monitor and control their heat consumption. However, customers now pay VAT (22% in 1999) on the heat they buy.

3 The competitiveness of DH systems in comparison with gas heating has improved. Lower costs and higher quality of service mean customers no longer want to disconnect from the DH system and even those who disconnected earlier are starting to apply for re-connection to the DH networks.

4 The DH Companies' economic situation has improved, and they have started to generate their own investment funds. Despite the initial reduction of profit due to the fall in heat price and income, regaining customers and reducing arrears have meant the Companies were able to generate their own funds which even exceeded the minimum level of 30% required by the international financial institution (according to the World Bank loan conditions).

5 Environmental benefits: the elimination of small coal fired HOBs and higher DH system efficiency substantially reduced SO_2, NO_x, CO_2 and dust emissions. A substantial decrease of make-up water consumption in the modernised DH systems resulted in raw water savings, as well as energy savings, in water treatment stations. Owing to modernisation, the DH Company in Krakow was officially taken off from the list of heavy air polluters.

4.5 Co-ordination of heat supplier and consumer activity

The DH Company will need to co-ordinate its modernisation schedule with its consumers. This is particularly important for the change from generation-driven to demand-driven mode. When the buildings themselves are thermally upgraded, resulting in decreased heat demand, calculations of water flow, heat supply unit cost and heat price need to be reviewed. When automatic control of heat supply is implemented in substations, the resulting changes in water flow mean the circulating pumps must be adjusted to the changing flow.

Co-operation between supplier and consumers is very important when modernising a DH system. This applies not only for specific activities but also to inform them about, and secure their overall agreement to, the aims of modernisation. Co-ordination of the time schedule is very difficult because it depends on many factors (eg weather conditions if ‘open air works’ are necessary), which are sometimes difficult to define.

Co-ordination of heat supplier and consumer activity needs not only good relationships between both parties but it should also be formally set out in a heat supply contract. This document should define the rights and obligations of the heat supplier and consumer as well as describing the main procedures - including changes in ordered heat output capacity (heat demands), implementation of automatic control in substations, and changes in tariff system. The procedures should define the necessary period of notice informing a partner about planned actions, which can influence both technical and economic conditions of DH system operation. A ‘template heat supply contract’ can be useful for most ‘typical’ customers, while an individual heat supply contract should be negotiated for ‘untypical’ customers.

Separate modernisation of some elements of a DH system may not be cost-effective; in order to achieve overall profitability those investments should be combined with more profitable ones.

In some cases it could be reasonable to prepare a common investment programme for heat source owners, the DH Company and its customers. This requires a special arrangement of common financing as well as profit division between participating investors. It is recommended that these investors should come to an agreement about how to carry out the common programme of DH system modernisation. This should be based on plans prepared by each of the investors and should cover modernisation of the particular DH system elements owned by those investors.

5 FINANCIAL ASPECTS OF DH SYSTEM MODERNISATION

One of the most important financial aspects of DH system modernisation is connected with energy and pricing policy in CEE Countries. In many of these countries subsidies still exist in the energy sector and the price of different fuels and energy (including heat) do not fully reflect the real costs of generation and transportation. It is obvious that subsidies will distort the results of the Least Costs Analysis, which is one of the main tools supporting decision makers in their choice of least costs solutions of heat supply in different parts of the town, optimisation of DH system development and preparation of the DH system modernisation plan.

Elimination of subsidies is one of the most important actions from economic and socio-political points of view.

For instance subsidies in the Polish DH sector decreased gradually from 78% of the heating bill in 1991 to zero in 1998 (average figures for the country). It is suggested that while subsidies still exist a comparative calculation between different heat supply systems should be based on the price of different fuels, energy and heat from DH systems, using average values from EU countries.

Usually the DH Company has only limited available finance and has to be supported from outside financial sources. To borrow money from commercial banks or another financial institutions it is necessary to prepare an application for the planned investment together with a supporting feasibility study and business plan. The feasibility study is necessary regardless of the source of finance; this study should indicate the proposed priority of investments, expected benefits possible risks and proposed arrangements for implementation of the project. The international financing institutions always require another financial analysis of the entire DH system. In the case of DH systems operated by a municipality or DH Company, which is strongly linked with a municipality, a financial analysis of the municipality is usually required. These financial analyses are needed to evaluate the profitability of the DH system modernisation plan from the borrower's point of view.

Modernisation of DH systems in CEE Countries could be very economic and has substantial environmental benefits. However, the profitability of modernisation is usually less attractive than would be expected. This is due to regulated tariffs and protection for customers from high heat prices – this leads to a lower income for DH Companies and reduces the profitability of modernisation plans.

5.1 Available financial sources

The financial resources of the DH Company and the municipality are usually very restricted and external financing is usually necessary. There are various possibilities for external finance from both domestic and foreign sources.

Domestic external financing sources usually differ from country to country, but there are some common Third Party financing schemes. This is usually carried out by specialised companies like ESCOs (Energy Services Companies), as well as by equipment producers who offer so-called Performance Contracts with DH Companies.

The foreign (and sometimes domestic) external financing schemes, which can be taken into consideration, are briefly described below:

Sale of fixed assets – the foreign (or domestic) investor buys all the fixed assets of the DH Company (or CHP plant) and continues to operate existing equipment as its owner, being fully responsible for the modernisation and development of the DH system (CHP plant).

Strategic investor – the foreign (or domestic) investor buys a share of the DH Company as a strategic investor and minority shareholder. It usually assists DH system modernisation by bringing know-how to the DH Company and improving its financial resources.

Lessee – the foreign (or domestic) company leases the assets of the DH system for an agreed period of time. The Lessee Company pays an annual rent to the owner and undertakes investments to maintain and develop the leased assets. The Lessee Company can operate the leased assets only during the period of lease.

Borrowing – the international financial institutions, (eg World Bank, EBRD) are usually interested in co-financing (mainly as a loan) successful DH systems modernisation projects. Those institutions have some special requirements for lending, like for instance:

- the World Bank always requires a government guarantee for the loan, which is usually submitted by the Ministry of Finance
- the EBRD either requires the sovereign guarantee (by government or sometimes by the municipality) or foreign private partner guarantee.

Joint Implementation – several investments, which together reduce greenhouse gas emissions (especially CHP units) can be financed by means of a Joint Implementation scheme. The principle of this scheme is based on the international emissions trade. Emission reduction credits can be traded internationally, via a special fund, which buys the credits and sells them to another country in need of such credits. Credit trading can take place bilaterally between countries and also between companies in different countries. Nevertheless, Joint Implementation gives the possibility to reduce investment and operation costs because additional income is received from ‘emission reduction’ sales.

EU structural funds – these funds are in principle predestined for local authorities (municipalities) but in many cases municipalities own the DH Companies or DH assets. Thus EU structural funds can be used for financing DH system modernisation.

The DH companies should co-operate with local authorities in preparing applications, and justifying the proposed investment. It is necessary to arrange the finance scheme and prepare all the necessary documents. It will be necessary to employ people with the relevant knowledge and language skills or to involve specialist consulting companies, especially for the first stage of the activity.

The DH company and the municipality will need to implement long-term energy planning. Common training of personnel will be useful; training can beneficially be arranged for a group of DH companies and municipalities.

Finally it is necessary to say that the selection of finance scheme depends on the availability of financial sources, and also on the political targets and priorities of the current DH system owner.

5.2 Privatisation of DH Enterprises

The process of ownership and organisational transformation of the DH sector in CEE Countries is rather slow and is not yet finished. In several countries, communes have already taken over DH system assets and created their own organisational units. Usually the form of budget entities and Ltd companies (100 % owned by municipality) has been selected, but in some cases a joint stock companies has been established (also 100 % owned by municipalities).

Another possibility for the DH Company's transformation is injection of private money, with either national or foreign capital. There are different forms of privatisation, but usually foreign or domestic strategic investors purchase shares of the DH Companies. Sometimes a foreign or domestic investor purchases the whole DH Company assets. In Poland a few companies are listed at the stock exchange.

These issues are set out in the Ownership Guide, another of the DHCAN guides.

This guide was written by Witold Cherubin, Polish National Energy Conservation Agency (KAPE), with review carried out by the DHCAN project team (see page 2).