Increasing the Efficiency of Heating Systems in Central and Eastern Europe and the Former Soviet Union

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PURPOSE

The Joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP) is a special global technical assistance program run as part of the World Bank's Energy, Mining and Telecommunications Department. ESMAP provides advice to governments on sustainable energy development. Established with the support of UNDP and bilateral official donors in 1983, it focuses on the role of energy in the development process with the objective of contributing to poverty alleviation, improving living conditions and preserving the environment in developing countries and transition economies. ESMAP centers its interventions on three priority areas: sector reform and restructuring; access to modern energy for the poorest; and promotion of sustainable energy practices.

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FURTHER INFORMATION

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ESMAP financed the present study to examine the following questions:

- Which factors determine the choice of the economically preferred heating option from a set of alternatives?
- Under which circumstances is DH, decentralized heating with natural gas, or another alternative the preferred option?
- How does the institutional environment have to change in order to foster cost-effective heat supply and demand?
- How can the preferred option be implemented when the countries in CEE/FSU are in a period of transition?

To answer these questions, case studies of the heat situation in six CEE/FSU cities were carried out in 1996: Dnipropetrovsk in Ukraine, Kaunas in Lithuania, Orenburg in Russia, Sofia in Bulgaria, Timisoara in Romania, and Wroclaw in Poland. In all six cities, DH is the dominant technology for the supply of heat.

The six case studies followed the same methodology, which emphasized the analysis of the scope for interfuel substitution between DH and alternatives such as building boilers and apartment boilers using natural gas. The issue of interfuel competition seemed to be inadequately addressed in many of the feasibility studies for DH systems that had been prepared previously. The methodology also emphasized the identification of the institutional and policy changes that are required to provide an enabling environment for cost-effective heat supply and demand.

This report summarizes the main findings from the case studies and describes the major issues encountered in the modernization of DH systems, the commercialization of companies in the heating sector, and requirements for policy changes. It provides examples of best practices in the reform efforts in CEE/FSU and of investments designed to make heating more efficient.

This report is intended to assist (1) World Bank staff, in preparing and implementing DH projects; (2) politicians and planners in CEE/FSU, in dealing with the restructuring of the heating sector; and (3) consultants, in preparing feasibility studies for investments in the heating sector.

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The report is based on the results of six case studies undertaken by the consulting teams of MVV/Sofregaz, Stork Comprimo, and Tebodin/ECN/ENECO. We are grateful to the authorities in the six cities in which the case studies were carried out, as well as to the respective national governments for the support they provided. The work relied on the financial support of the Dutch Ministry of Economic Affairs, the THERMIE program of the EU Commission, and Kreditanstalt für Wiederaufbau, as well as the advice of many heating experts in Eastern and Western Europe as well as in development institutions. Without this support and advice, this project could not have been undertaken.

Abbreviations and Acronyms

CEE	Central and Eastern Europe
CHP	combined heat and power
DH	district heating
DHW	domestic hot water
DSM	demand side measures
EBRD	European Bank for Reconstruction and Development (European Bank)
EU	European Union
FSU	Former Soviet Union
HCA	heat cost allocator
HFO	heavy fuel oil (mazut)
HHV	higher heating value
HOB	heat-only boiler
IBRD	International Bank for Reconstruction and Development (World Bank)
IFC	International Finance Corporation
IPP	independent power producer
LFO	light fuel oil (heating oil)
LP	low pressure
LRMC	long-run marginal cost
MP	medium pressure
NPV	net present value
O&M	operation and maintenance
PE	Polyethylene
PPI	private participation in infrastructure
SPM	solid particle matter
TRV	thermostatic radiator valve

Units of Measure

BTU	British thermal unit
Gcal	Gigacalorie (one million kilocalories)
GJ	Gigajoule (one thousand megajoules)
KJ	Kilojoule
kWh	Kilowatt-hour
MWh	Megawatt-hour
MWel	Megawatt electric
MWth	Megawatt thermal
TSC	Tons of standard coal
TJ	Terajoule

Energy Unit Conversion

1 BTU = 1.05506 kJ

1 Gcal = 1.16 MWh = 4.19 GJ = 1.75 steam tons/hour

1 GJ = 0.278 MWh = 0.239 Gcal = 0.42 steam tons/hour

1 MW = 0.86 Gcal = 3.6 GJ = 1.52 steam tons/hour

1 m^3 natural gas = 8.5 Mcal (at lower heating value) = 35.86 MJ = 9.88 kWh

1 TSC = 7 Gcal = 29.3 GJ = 8.15 MWh

Currency Equivalents

The following were equal to US$1 (period averages):

	Bulgaria (lev)	*Lithuania (litas)*	*Poland (zloty)*	*Romania (leu)*	*Russia (ruble)*	*Ukraine (hryvna)*
Average for 1996	178	4.0	2.70	3,084	5,067	1.83
Average for 1999	1.84	4.0	3.97	15,333	24.62	4.13

Executive Summary

Introduction

Heating is a vital energy service in the countries of Central and Eastern Europe (CEE) and the Former Soviet Union (FSU). In most of these countries, district heating (DH) is the major source of heat for the urban residential, public, and commercial sectors, as well as an important source for industrial heat use. In larger cities, DH can supply up to 90 percent of residential and commercial buildings with heat and domestic hot water.

Large, centralized DH systems became popular in the 1950s as a means to improve the global energy balance by using the waste heat recovered from power generation. Heat loads offered the opportunity to exploit the advantages of cogeneration of power and heat. The efficiency of a cogeneration plant can reach 90 percent or even more. Such combined heat and power generation (CHP) offers a substantial benefit compared with a typical power generation efficiency of about 35 percent at thermal condensing power plants and with separate production of heat at heat-only boilers.

In the CEE/FSU countries, the benefits of CHP have been realized at only a modest level compared to the available DH potential. Typically, only a minor part of the national power supply is based on CHP. Together with lack of maintenance and financing for technological upgrades, the DH systems and the connected buildings in CEE/FSU have become symbols of energy waste rather than energy efficiency. Customers cannot control heat consumption and react to overheating by opening windows, even in winter. The resulting high costs of the DH systems became apparent in the early 1990s, when primary energy prices in these countries increased towards world-market levels. Consequently, expenditures for heat have become major drags on household incomes and municipal budgets. In addition, in many cities, DH facilities together with other forms of individual heating are responsible for air pollution, severely affecting the health of urban residents.

The World Bank as well as other multilateral and bilateral development institutions provides an important source of funding for priority investments to modernize the heating sector in CEE/FSU. This report aims to put these investments within the overall context of sector restructuring. It is based on the ESMAP project *Improving the Efficiency of Heating Systems in CEE/FSU*, as well as on a wealth of experience with district heating in both Western Europe and in CEE/FSU.

ESMAP financed the present study to examine the following questions:

- Which factors determine the choice of the economically preferred heating option from a set of alternatives?
- Under which circumstances is DH, decentralized heating with natural gas, or another alternative the preferred option?
- How does the institutional environment have to change in order to foster cost-effective heat supply and demand?

- ☐ How can the preferred option be implemented when the countries in CEE/FSU are in a period of transition?

Because solutions to heating problems are highly local in nature and answers to the above questions will largely be based on the situation on the ground, it was decided to base the preparation of this report on a number of case studies of heat generation and delivery. These were carried out in 1996 in the following six CEE/FSU cities: Dnipropetrovsk in Ukraine, Kaunas in Lithuania, Orenburg in Russia, Sofia in Bulgaria, Timisoara in Romania, and Wroclaw in Poland. In all six cities, DH is the dominant technology for the supply of heat.

The six case studies followed the same methodology, which emphasized analysis of the scope for interfuel substitution between DH and alternatives such as individual building and apartment boilers using natural gas. The issue of interfuel competition seems to have been inadequately addressed in many of the feasibility studies prepared previously on DH systems. The impact of investing in energy efficiency measures in buildings and of explicit valuation of environmental externalities of heating systems was considered as well. The methodology also emphasized identification of the institutional and policy changes required to encourage more-cost-effective heat supply and demand. The case studies were based the assumption that heat supply options would deliver a uniform level of heat service, i.e., a temperature of 18°C in the entire dwelling, even though this may result in heat bills that are beyond the short- to mid-term ability to pay of many households, particularly in FSU countries.

Investment Requirements in the Heating Sector

The rehabilitation and modernization of DH infrastructure in CEE/FSU will be very expensive because the infrastructure is in such poor condition. The worst problems usually exist in the secondary distribution networks that connect central substations and buildings and that are usually owned by municipal heating companies. On the generation side of DH, investments are required to consolidate the many small, inefficient, heat-only boilers (HOBs) that supply heat to isolated networks at high cost and often have a negative environmental track record. An upgrading of existing CHP plants, including emission-abatement equipment, and the provision of additional CHP capacity are necessary measures if DH is to survive in competition with more decentralized systems.

In comparison to DH, investments in natural gas infrastructure are less costly. To accommodate increased demand—e.g., for heating—gas supply can often be increased by upgrading the existing low-pressure network to medium pressure. More costly is the provision of gas appliances such as building or apartment boilers.

A huge amount of investment is needed in the building sector, where many of the required measures are independent of the source of heat. It is very often possible to implement low-cost energy efficiency measures that reduce energy demand and, consequently, the need for investment in generation and transmission/distribution of heat.

A set of investment measures needs to be taken on both the supply side and the demand side (meters, automation, and controls). Together with consumption-based billing, these investments will serve to convert the traditional DH system, where the heat source in effect regulates the heat demand, to a flexible system that consumers can influence according to their preferences and financial means.

Competitiveness of District Heating

Depending on local and national circumstances, the least-cost heating option could be based on DH or it could be of a more decentralized nature, such as gas-fired building boilers. The competitive advantage of DH is its ability to produce heat at a lower cost than with individual boilers. Conversely, the cost of transporting heat to consumers is the source of the competitive disadvantage of DH. Thus, the extent of heat produced in cogeneration and the heat load density are crucial factors to consider when making investment decisions.

The case studies showed that, based on the economic cost of gas in each city and assuming a remuneration of US$0.04/kWh for electricity output of CHP plants, heat can be produced at an average economic cost of US$9/Gcal (CHP) and US$23/Gcal (building boilers). For DH to be competitive, the economic cost of heat distribution (including distribution losses) would need to be below US$14/Gcal on average. These averages hide wide local differences in "allowable" heat distribution costs; from about US$11 (Orenburg) to US$20 (Wroclaw). Thus, if the heating network needs substantial rehabilitation investment or if the heat load is rather low, low heat generation costs may not be sufficient to make DH competitive.

The case studies confirmed the general superiority of established DH systems in densely populated areas supplied by cogeneration facilities compared to investments in new building boilers. However, as the example of Orenburg shows, a high level of fuel savings must be obtained in cogeneration; otherwise, building boilers will have an advantage. If a CHP plant can achieve a good price for its outputs, especially for power, this will favor DH. In many countries of CEE/FSU, however, the existing power supply surplus leads to a low economic cost of power that tends to decrease the income from power sales, leaving more of the costs to be covered by heat.

- In **Orenburg**, the preferred heating option was building boilers; DH came in only third after gas-based apartment heaters. The determining factor was the low economic cost of natural gas in combination with the low long-run marginal cost of electricity. Orenburg is located on top of huge natural gas resources that, because of distance, have relatively high transport costs to the borders of gas-importing countries. This makes the netback value of natural gas a low US$45 per 1000 m^3 (export price minus cost of transport). Because the economic advantage of DH depends on the value of the fuel savings in CHP production compared to individual boiler consumption, the low value of these savings undermines its economic attractiveness. The long-run marginal cost of electricity is low because of existing surplus capacity in the Russian power system and because of the low economic value of natural gas use in electricity production. A surplus of cheap power leads to a low bulk tariff for power, so that heat has to cover most of the cost of CHP production. A further disadvantage of DH is the relatively high cost of the investment needed to replace the secondary distribution system with a system of building substations.
- In **Timisoara**, the essential factor that makes DH non-competitive is the absence of old CHP capacity and the high cost of new CHP capacity. To make DH on the basis of a new CHP

plant economically viable, a CHP plant would need to receive US$0.06/kWh, a price 50 percent higher than the cost of power production of modern, gas-fired combined-cycle plants. Building boilers would result in lower heating costs, even though the secondary gas distribution network would need substantial investment because it does not have the capacity and ability to meet a higher heat demand.

- In **Wroclaw**, several factors combine to make DH competitive. There is a relatively efficient and low-cost heat supply from cogeneration. This, combined with a DH network that is in relatively good shape—thus requiring less modernization investment—makes DH the economically preferred heat supply option. The same circumstances exist in **Sofia**, although both the negative and positive aspects are less pronounced here than in Wroclaw.
- In **Kaunas** as well as in **Dnipropetrovsk**, no heating option stands out as being clearly preferable to others, according to the case studies. In Kaunas, the option of DH network modernization with a modern, large-scale CHP plant results in a minimally lower per-unit heat cost than the next-best option, gas-fired building boilers. In Dnipropetrovsk, the unit heat costs are slightly lower for a modernized DH system supplied by a modern CHP plant than for the other options. Somewhat surprisingly, the economic heat costs in Dnipropetrovsk are the lowest for all six cities, even though the economic cost of gas—the main fuel—is in a mid range and only slightly lower than in Kaunas. The disadvantage of DH in Kaunas is that there is no demand for the electricity output of the CHP plant due to very cheap and abundant electricity supplied from the Ignalina nuclear power plant. Only a part of Dnipropetrovsk is supplied with heat from a CHP plant. Among the six cities the heat density in Kaunas is the highest after Sofia. The condition of the networks in Kaunas and Dnipropetrovsk seems similar, with losses of about 25 percent in the secondary four-pipe systems. Here, as in Orenburg, a more differentiated approach—looking in more detail at parts of the city with different characteristics—might have led to different heat supply options being chosen for different parts of the city.

Building boilers fueled by natural gas are the main competition to DH. Despite their obvious advantages in terms of flexibility for the end user, more-decentralized systems such as gas heaters or boilers in apartments are not a viable alternative when considering the need to switch heating systems in existing apartment buildings. The costs are very high and there would be a significant, negative environmental impact. Furthermore, the implementation of switching to individual heating would be very difficult because all households in a apartment building would have to make the decisions jointly and would have to bear the considerable investment expense themselves.

This conclusion presumes that households are able and willing to pay for the quality and quantity of heat typically delivered by a modern heating system. However, in some of the countries of the FSU, household incomes are on average too low, and will remain too low for many years to come, to allow households to pay for a heat service that would heat the entire dwelling to, say 20°C for the entire heating season. Here, low-cost alternatives that are financially and environmentally sustainable need to be identified and their implementation supported.

The Need for Policy Changes and Restructuring of Energy Companies

The high costs of heat delivery, both in absolute terms and relative to the quality of heat supply, can be reduced in the future by providing additional funds for system rehabilitation and upgrading of the DH supply systems or through investment in more decentralized solutions or customer installations. However, to ensure that maximum benefits are gained from these investments and that these benefits are sustainable over time, a number of other actions on the institutional and policy levels and on the company level are needed. Many countries, especially in CEE, have already taken substantial steps toward implementing the necessary measures.

An **efficient macroeconomic and sector framework** will enable sound competition and establish the rules for necessary tariff reforms.

Commercialization of companies in the heating sector is a *sine qua non* of a more cost-effective heat supply. In CEE/FSU this sector is lagging behind other energy sectors for obvious reasons of technical inefficiency, lack of suitable investors, and fear of political interference in business decisions. An interim solution is to "corporatize" and restructure the heating companies, divesting any functions that are not directly related to the core business or that could be provided by the private sector on a competitive basis, and imposing strict profit accountability and financial discipline (both short-term and long-term) on management and employees. A commercially oriented heating sector would be able to attract financing either in the form of commercial loans or through participation by the private sector.

Any efforts to restructure these countries' energy sectors must take into account **the interaction between the power sector and the heat sector**. The operation of CHP plants and the ownership of heat transmission facilities by power companies creates strong linkages between the DH and electricity sectors in many large cities. The integration of the power and heat sectors, which existed in CEE/FSU countries under central planning, broke down when dedicated CHP plants and heat distribution networks were divested to different owners. In the short term, nascent **competition** for the most profitable DH customers from gas distribution utilities and manufacturers of gas appliances may jeopardize viable DH systems, if the power sector continues to receive all the benefits of cogeneration. Two options exist to reconcile the interests of both sectors:

1. If the ownership of CHP plants is transferred to the municipal DH companies, regulation can be restricted to one aspect only—providing the CHP plants with non-discriminatory or preferential access for selling their power output to the national grid.
2. If the ownership of the CHP plants is left in the hands of the power companies, the regulators should define rules for establishing the prices of power and heat from the CHP plants to assure that both products of the CHP plant—power as well as heat—can be competitive in their respective markets.

Social equity considerations tend to favor **a sharing of the joint production benefits** between the electricity consumers (all citizens) and the heat consumers (the minority). Energy/environmental policy considerations tend to allocate most of the cost-saving benefits to DH in order to promote the application of energy-efficient cogeneration.

Experience from Western European countries shows that special **regulation** for the DH sector is not required. While DH transmission and distribution has the characteristics of a natural monopoly, competing suppliers of alternative heating fuels and systems do not depend on access to the DH distribution system. In several CEE/FSU countries, such competition in the heat market is starting to be effective. Industrial customers increasingly disconnect from DH and install their own heating sources. It will only be a matter of time before other consumer groups will also disconnect. Currently and within a transition period, financial barriers and lack of access to alternative heating systems will prevent residential customers from switching, thus preventing market forces from achieving the rationalization of non-competitive systems of heat supply without undue costs. This will require effective regulation, especially in the area of retail pricing at a time when alternative heating systems are not yet available or are prevented from competing effectively by outdated regulations.

In the meantime, **heat planning** is a tool for promoting efficiency in allocating scarce resources by providing a reference framework for investment decisions in local heat markets. The DH companies need to know which sections of the DH network are not economically viable in order to avoid making long-term investments in these sections. The natural gas distribution companies need to know in which sections of the service area they should start to upgrade their gas grids in order to satisfy the demand from gas-fired building boilers. A heat plan elaborated jointly by all actors in the local heating sector would speed up decisionmaking by the energy supply companies and by customers. Therefore, although public planning of economic activities has gone out of fashion in CEE/FSU, the need for the preparation of integrated heat master plans is recognized. Heat planning could thus provide a mechanism that would make potential investors in new generation capacity aware of existing heat loads. This would in turn provide a basis for CHP capacity that could reduce fuel costs and fuel imports as well as CO_2 emissions. By incorporating a sound analysis of existing and future heat demand and of the complete DH system, heat planning would also improve the optimization of the entire system, including the demand side.

Compared to most other heating systems, DH tends to improve the **fuel security** of a country because most large heat generation units have a dual-fuel capacity. This fuel flexibility is particularly important in countries that depend largely on fuel imports. This advantage of DH over, say, gas-based systems is not captured in the economic analysis. However, it can be incorporated into the political framework for the energy sector by, for example, establishing differential taxes and mandatory guidelines for developing energy systems that improve fuel security.

Substantial barriers prevent the realization of the **enormous energy efficiency potential on the demand side** of heating, especially in buildings connected to DH. Two of the most important measures to support vis-à-vis these barriers are (1) forming and educating homeowner associations that must decide on investments in common spaces and (2) giving those associations and individual households access to financing.

Effective heat planning, as well as decisions about cost-effective investments on the supply and demand sides, must be based on **prices** that give the right signals and level the playing field for the actors in the heat markets. There is a consensus on the key principles of energy tariff policy as follows:

- The tariff for each consumer group should reflect the full cost of supply,
- Cross-subsidies between major categories of consumers should be avoided, and
- Billing should be based on metered consumption.

Pricing reform, together with modernization investments in DH and the introduction of metering and controls at the end-user level, will convert the previously inflexible DH systems into ones that consumers can influence according to their preferences and financial means.

Transitional Requirements

A restructured, modernized, efficient system of heat supply and demand cannot be achieved overnight. A number of economic, financial, and institutional obstacles delay the rationalization of heat supply in CEE/FSU. These are as follows:

- High costs of production and a limited ability to pay on the part of DH consumers are compounded by a combination of below-cost tariffs and arrears in consumer payments.
- Feasibility studies show a substantial scope for cost-reducing investments that could narrow the gap between the level of a full-cost tariff and the average consumer's ability to pay. But the implementation of the investments is often blocked by a lack of finance and an inadequate macro-economic and sector framework.
- Very profitable investments could be made on the demand side that would further reduce the heating bills of households. But these are delayed by pending issues of apartment ownership, responsibility for undertaking necessary investments in buildings, and identification of institutional mechanisms to initiate such investments.

The starting point for achieving greater efficiency in heat supply is to sever the close ties existing between the municipal DH companies and municipal politics. The first step in making DH a commercial activity is to establish accounts for the DH company separate from the accounts of the municipality. DH companies need to be restructured by divesting any functions that are not directly related to the core business or that could be provided by the private sector on a competitive basis. Commercialization might be easier to achieve if the DH company is set up as a joint stock company with a commercial identity and accounts. However, the ease of conversion depends on the national privatization laws and their local implementation. In any case, a commercially oriented management needs to take strict measures to address arrears in the heating sector, in terms of both accounts receivable and accounts payable.

For the subsequent steps, there are no simple solutions. But a number of measures can improve the situation.

It will be necessary to find an equilibrium in the transition period between, on the one hand, full cost recovery tariffs (which allow a modest level of self-financing of rehabilitation investment), and, on the other hand, affordability problems aggravated by sharply increasing tariffs. Reducing the tax burdens of the new DH companies, through such measures as accelerated depreciation and bad debt write-offs, should help to achieve this.

Existing discrimination against heat generation at CHP plants in the form of tariff rules that pass the full combined cost advantage on to the electricity tariff should be replaced by a more equitable treatment of heat and electricity. The guiding principles should be that both heat and power need to be competitive in their respective markets and that cogeneration benefits should be allocated equitably. Thus, investigations should be made for each CHP plant as to whether most of the combined cost advantage could be passed on to the heating sector for a period of several years to facilitate financing of the required large modernization investments.

In most CEE/FSU countries, the switch from energy price subsidies to social subsidies is under way. Where socially justified—i.e., for low-income families—subsidies should compensate for housing-related cost escalations. Payments to households for heating bills and the accompanying subsidy payments by municipalities should be made directly to the DH company to avoid diversion by intermediaries such as housing cooperatives.

The heating bills of households and other DH customers could be lowered considerably if the buildings themselves were more energy-efficient and consumers had an incentive to use less heat. Some demand side measures are very effective with high rates of return, but are rarely implemented due to the institutional and financial barriers. As long as tenants and building owners lack the means and organizational structure to invest in demand side measures, the DH company will be the second-best choice for implementing such basic measures, which will ensure that the quality of supply within the building is improved. This would then allow the DH company to significantly reduce investment in the system because of reduced capacity demand. The costs could be recuperated by charging the consumer a monthly fee over a period of several years. The overall heating bill would not increase due to savings. If the installations become the property of the consumers only after the DH company has recuperated the cost, the DH company could depreciate the cost of investment.

Conclusion

District heating is not a dinosaur that will disappear soon. On the contrary: modernized DH systems that are managed in a business-like fashion can provide competitively-priced heat to consumers who will be able to regulate, control, and pay for them according to their consumption. This presumes, however, that DH companies take a hard look at existing systems and modernize only those parts where DH is clearly the more economic heat-supply technology.

Multilateral organizations such as the World Bank should therefore support the rehabilitation of DH systems and the restructuring of DH companies when DH is competitive, and should support conversion to more decentralized heating systems when this is the more cost-effective solution. This is the recommended strategy in countries where incomes are high enough that the majority of consumers can pay in full for the resulting quantity and quality of service. In low-income transition countries, however, most consumers will not have the means to pay for DH or heat services of similar quantity and quality in the foreseeable future. Here, the role of the World Bank is to help governments and local organizations identify and implement technical and institutional solutions that will result in a heat infrastructure that is financially, socially, and environmentally sustainable.

1

Introduction

1.1 The Problem

Heating is a vital energy service in the countries of Central and Eastern Europe (CEE) and the Former Soviet Union (FSU). In most of these countries, district heating (DH) is the major source of heat for the urban residential, public, and commercial sectors, as well as an important source for industrial heat use. In larger cities, DH can supply up to 90 percent of residential and commercial buildings with heat and hot water, especially in densely populated areas.

Large, centralized DH systems (see Box 1-1) became popular in the 1950s in CEE/FSU as a means of improving the global energy balance by using the waste heat recovered from power generation. This linked the development of DH systems and the use of cogeneration from the very beginning .[1] At the outset, existing power plants were retrofitted to supply heat to the new (sub-) urban settlements. Heat was often transported over large distances. Later, new cogeneration plants were designed to meet growing electricity and heat demand. Typically, development started with the construction of boilers (steam and/or hot water). Turbines were installed later, once the planned buildings were constructed and the total heat demand was achieved. [2]

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[1] In Western Europe, the development of DH and use of cogeneration have been linked since the first "oil shock" in the early 1990s.

[2] In many cases, cogeneration facilities were never installed due to the lack of finance. One example is Timisoara in Romania, one of the case studies.

Box 1-1. What is District Heating?

Usually, the term describes a system supplying heat produced centrally in one or several locations to a non-restricted number of customers. It is distributed on a commercial basis by means of a distribution network using hot water or steam as a medium. Often, the heat is also used for DHW and industrial purposes, such as process heat. Although most people understand DH to be large centralized urban heating systems, many national statistics also include very small heating systems. Furthermore, systems that supply only steam for industrial purposes are usually also called DH systems. In fact, the term *DH system* is usually linked with the activities of the respective DH company. Such a company usually operates larger centralized DH networks, smaller isolated "block" heating systems (supplying only a small number of buildings), and even individual boilers in single buildings.

Demand for space heating, domestic hot water (DHW), and process heat thus offered the opportunity to exploit the advantages of cogeneration of power and heat. The efficiency of a cogeneration plant can reach 90 percent or even more.[3] Such combined heat and power (CHP) generation offers a substantial benefit compared with a typical power generation efficiency of 35–40 percent at thermal condensing power plants and with separate production of heat by heat-only boilers (see Figure C-1 in Annex C).

In the CEE/FSU countries, the benefits of CHP have been realized only at a modest level compared to the available DH potential. Typically, only a minor part of the national power supply is based on CHP, e.g., about 10 percent in Poland.[4] Together with a lack of maintenance and financing for technological upgrades, especially of DH networks, the DH systems and the connected buildings in CEE/FSU have become symbols of energy waste rather than energy efficiency. Customers typically lack individual control within apartments, etc., and react to overheating by opening windows, even in winter. The resulting high costs of the DH systems became apparent in the early 1990s, when primary energy prices in these countries increased towards world-market levels. Consequently, expenditures for heat have become major burdens on household incomes and municipal budgets. In many cities, DH facilities together with other forms of individual heating are also responsible for substantial air pollution, severely affecting the health of urban residents.

In some countries, competition for DH systems is slowly beginning to emerge, with gas utilities or manufacturers of gas appliances offering large DH consumers lower heat costs through switching to individual, gas-fired boilers. This development leads to questions about the future of the heating sector in CEE/FSU and about the conditions under which DH would be a competitive heating system that would merit investment in modernization.

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[3] See Table 3-2 for the definition of efficiency and different cogeneration technologies.

[4] By contrast, in Finland 30 percent of all electricity is generated by CHP plants. This results in primary fuel savings of 22 percent.

1.2 World Bank Activities in the Heating Sector

After an initial period of funding energy sector assessments and other studies on energy sector issues in CEE/FSU and advising on energy sector reform, international financing agencies such as the World Bank and the European Bank for Reconstruction and Development (EBRD) are increasingly financing investment in rehabilitation of energy sector installations. Given the importance of heating in aggregate energy consumption and the vast problems of the CEE/FSU heating sector, the World Bank started getting involved in lending operations in 1991 with its biggest loan in this sector so far—the Polish Heat Supply Restructuring Project (Gdansk, Gdynia, Krakow, and Warsaw). Projects with major heat components followed in Bosnia-Herzegovina, Bulgaria, China (Beijing), Estonia, the Kyrgyz Republic, Latvia (Jelgava), Poland (Katowice), Slovenia, and Ukraine (Kiev). Heat projects are under preparation in Latvia (Riga), Ukraine (Sevastopol), and in several cities in Russia. In addition, projects that aim to improve the efficiency of heat consumption in residential and public sector buildings are under way in Lithuania and Russia and are under preparation in Ukraine. For a brief summary of these projects, see Table A-1 in Annex A.

The World Bank heat supply and demand projects currently being implemented comprise a total of about US$1,100 million in loans,[5] and projects with total loans of US$ 800 million are under preparation. For most of the projects under implementation, it is too early to quantify the benefits. However, the projects in Latvia and Poland are advanced enough to provide evidence of substantially improved technical and commercial efficiency (see Boxes A-1a and A-1b in Annex A).

Projects under implementation that involve investment in heat supply all deal with the rehabilitation and modernization of DH systems. The project currently under preparation in Sevastopol is the first and only project in which investment in a more decentralized heating system is proposed.[6] In the early projects, the alternatives to DH—decentralized heating systems—were not evaluated during the project preparation phase. In the second generation of projects, the project components underwent a least-cost analysis. The Kiev DH improvement project is a case in point (see section 4.1.3 in Chapter 4).

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[5] According to *Profile of Energy Sector Activities of the World Bank in ECA* (April 1998), the Bank is implementing 45 projects in the energy sector in Eastern Europe and Central Asia (ECA), with a total of US$4.9 billion in lending. Seven of these are in the district heating/energy efficiency subsector, totaling US$439 million. A more complete account appears in Table A-1 in Annex A.

[6] In Sevastopol on the Crimean Peninsula, the initial proposal was to rehabilitate the existing DH system. But when the financial analysis showed that even a modernized DH system would not be financially viable for the foreseeable future, the borrower and the Bank decided to prepare the project on the basis of the alternative: replacement of the DH system with gas-fired boilers in the basement or on the roof of each building. The key factors in the non-viability of DH in Sevastopol are the short heating period and the relatively mild climate on the Black Sea. The heat load density is only 0.86 Gcal per hour per km of DH network and the peak load duration is only 1500 hours per year (compared to 2000–4000 hours in most parts of CEE/FSU).

1.3 Purpose of this Report

The World Bank and other multilateral and bilateral development institutions are important sources of funding for high-priority investments to modernize the heating sector in CEE/FSU. This report aims to put these investments in the overall context of sector restructuring. It is based on the ESMAP project *Improving the Efficiency of Heating Systems in CEE/FSU*, as well as on a wealth of experience with DH in both Western Europe and CEE/FSU.

ESMAP financed the present study to examine the following questions:

- Which factors determine the choice of the economically preferred heating option from a set of alternatives?
- Under which circumstances is DH, decentralized heating with natural gas, or another alternative the preferred option?
- How does the institutional environment have to change in order to foster cost-effective heat supply and demand?
- How can the preferred option be implemented when the countries in CEE/FSU are in a period of transition?

To answer these questions, case studies of heat generation and delivery were carried out in 1996 in six CEE/FSU cities: Dnipropetrovsk in Ukraine, Kaunas in Lithuania, Orenburg in Russia, Sofia in Bulgaria, Timisoara in Romania, and Wroclaw in Poland. In all six cities, DH is the dominant technology for the supply of heat (see Table 2-1).

The six case studies followed the same methodology, which emphasized the analysis of the scope for interfuel substitution between DH and alternatives such as building and apartment boilers using natural gas. The issue of interfuel competition seems to have been inadequately addressed in many of the feasibility studies on prepared previously DH systems. The methodology also emphasized identification of the institutional and policy changes required to provide an enabling environment for more cost-effective heat supply and demand.

This report summarizes the main findings from the case studies and provides details on the major issues encountered in the modernization of DH systems, the commercialization of companies in the heating sector, and requirements for policy changes. It provides examples of best practices in the reform efforts in CEE/FSU and of investments designed to make heating more efficient. Prospective audiences are staff in multi- and bilateral agencies dealing with DH, as well as politicians, planners and heating practitioners in CEE/FSU, and consultants involved in preparing feasibility studies for investments in the heating sector.

1.4 Issues and Opportunities to Improve Efficiency in the Heating Sector: A Guide to this Report

The Bank has been involved in a number of initiatives relating to municipal heating systems in CEE/FSU. This work has revealed that the following generic problems tend to prevail in most municipal heating systems:

- High costs of heat delivery, both in absolute terms and relative to the quality of heat supply;
- Inefficient use of heat at the household level;
- Non-payments of bills and customer arrears;
- Inadequate tariffs to support either operating costs or investments in system maintenance and rehabilitation; and
- Environmental problems, which affect large populations in cities where DH plants burn low-quality fuels and are located in densely populated areas.

A variety of initiatives is needed to address the above issues. One aspect of the solution is to supply additional funds for system rehabilitation and upgrading of the DH supply systems or for investment in more decentralized solutions or end-user installations. The kind of heating system that will, in principle, be the most cost-effective depends largely on local factors such as heat load density,[7] but also on the extent to which cheap heat sources (such as cogeneration or local fuels) can be made available, which often depends on national energy policies. However, in order to ensure that maximum benefits are gained from these investments and that their benefits are sustainable over time, a number of other actions on the institutional and policy levels and on the company level are needed. An efficient macro-economic and sector framework will enable sound competition and establish the rules for necessary tariff reforms. Companies active in the heating sector need to act like commercial entities. A first step in this direction is the restructuring and "corporatization" of the mostly municipal heating companies. This would include the reduction of arrears in terms of both accounts receivable and accounts payable, and should be complemented by an effective social safety net targeted at low-income consumers. Eventually, private sector participation in the ownership and operations of municipal heating companies will further improve the technical and commercial efficiency of the heating sector. Many countries, especially in CEE, have already taken substantial steps towards implementing these and other measures.

Table 1-1 summarizes the issues and problems in the heating sector and the measures necessary to address them and to make heating more efficient. It emphasizes the required actions, at the macro-policy level and at the company level, necessary to achieve a restructured, modernized, efficient system of heat supply and demand. These are discussed in more detail in Chapter 5. The actions required on the technical and investment level are taken up in Chapters 3 and 4. Chapter 3 provides an overview of the technical measures to be implemented in DH and natural gas distribution systems and in buildings, respectively, to make heat supply and demand more efficient. Chapter 4 summarizes the results of the case studies, isolating the factors determining whether DH or a more decentralized heat supply is the preferred solution. Also considered are the

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[7] The concept of "heat density " is straightforward. It compares the heat demand (either in terms of heat load or of energy) to the size of the service area or the length of the pipe network. A high heat density indicates a compact distribution system with relatively low distribution costs. For a description of the advantages and problems in using heat density as an indicator for the competitiveness of heating systems, see Annex F.

impact of investing in energy efficiency measures in buildings and of the explicit valuation of environmental externalities of heating systems.

After this introduction, Chapter 2 briefly explains—mostly for readers unfamiliar with heating sector issues—the inherited structure of heat supply and demand in CEE/FSU and the shift toward a new paradigm for heat supply and demand in these countries. Finally, Chapter 6 provides the conclusions for recommended heating sector policies and projects. The annexes contain more-detailed information on a number of subjects.

Table 1-1. Issues and Required Actions in the Heating Sector in CEE/FSU

	Efficient Macro and Sector Framework	*Streamlining Companies in the Heating Sector*	*Technology and Investment Choices*
High cost of heat	CHP cost allocation Heat planning Appropriate safety, licensing, and efficiency standards	Commercialization: strict profit accountability and financial discipline; use of a Management Information System and of performance indicators Rationalization/divestment Leasing and operating agreements Heat planning	Modernize DH networks Low-cost heat sources Switch to decentralized heat supply where heat load is low and heat generation costs are high Optimize the use of CHP (dispatching of heat sources)
Inefficient use of heat by consumers	Change in standards Consumption-based pricing Incentives: tariff reform Financing/TA	Tariff structure/level Financing	Demand-side investments
Non-payments/ arrears	Social safety net for low-income population Disconnection of non-paying customers	Commercialization Marketing Settlements of forward and backward arrears	Prepayment Decentralized heat supply
Inadequate tariffs	Tariffs based on full cost recovery Adequate depreciation charges	Fixed/variable two-part tariffs based on metered consumption	
Environmental problems	Environmental standards Effective enforcement of existing standards		Fuel switching Change in technology Integration of DH islands

2

Restructuring the Heating Sector in CEE/FSU: An Overview

2.1 The Inherited Structure of Heat Supply and Demand

The residential sector is typically the biggest consumer of heat in a country's economy.[8] In recent years in CEE/FSU, this share has increased due to the collapse of industry. In the Baltics, for instance, residential use accounted for almost 30 percent of final energy use per capita in 1992, compared to just above 20 percent only two years earlier. Heat accounts for about 80 percent of residential energy consumption in CEE/FSU countries, as well as in Western Europe. This similarity however hides differences in underlying factors such as smaller living areas and higher heat requirements due to less insulation, for example, than in Western Europe.

Local circumstances largely determine which measures are necessary to improve heat supply and demand. But the technological characteristics of the existing heat supply systems in CEE/FSU are fairly similar[9] and, compared to the situation in Western Europe, the heating sector in CEE/FSU countries distinguishes itself as follows:

The market share of DH in urban heat supply is very high. In most CEE/FSU countries, DH systems are the heating systems with the highest market share. This is in stark contrast to Western Europe, where DH has a dominant position only in the Nordic countries (see Table 2-1). In CEE/FSU, autonomous heating boilers serving single buildings account for most of the remaining heat consumption. Boilers in individual apartments are rare, and the use of coal stoves, especially in historic city centers and in rural areas, is starting to decline.

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[8] The one exception seems to be Russia, where industry used to have a share of about 40 percent of total heat consumption.

[9] One import exception concerns the use of the so-called four-pipe system for heat distribution. It seems to be more prevalent in DH systems in FSU. See section 3.1 and Annex D.

Table 2-1. Characteristics of Case Study Countries and Cities: Market Share of DH in CEE/FSU and Western Europe

	Average Annual Household Income, US$	*Share of DH*		*Inhabitants (million)*		
	(1996)	National	Case Study Cities	Country	City	*Degree-days* [c]
Bulgaria	1481	25% of dwellings	Sofia: 85% of apartments 65% of inhabitants	8.3	1.2	3000 in Sofia
Lithuania	2705	50%	Kaunas: 85%	3.7	0.41	3750 in Kaunas
Poland	4950 [a]	34% of housing 53% (of WBS)[b] 76% in towns	Wroclaw: 68% of dwellings	38.6	0.64	3450–4000 3044 in Wroclaw
Romania	2200	31% of homes 58% in towns	Timisoara: 90% of flats	22.5	0.34	2900–5150
Russia	2760 [a]	80%	Orenburg: 87% of dwellings	147.3	0.55	5071 in Orenburg
Ukraine	2000 [a]	65%	Dnipropetrovsk: 65% of dwellings	50.4	1.15	3430 in Dnipropetrovsk
Denmark	Not avail.	49% (of WBS)	Not appl.	5.2	Not appl.	Not avail.
Finland	Not avail.	46% (of WBS)	Not appl.	5.1	Not appl.	4300–6500
Sweden	Not avail.	36% (of WBS)	Not appl.	8.9	Not appl.	Not avail.

[a] Annual average household expenditure; in Russia median expenditure. See section 5.2.5.

[b] WBS whole building sector.

[c] Degree-days = (the target inside temperature minus the average outside temperature during the heating season), multiplied by the number of days in the heating season.

Source: *Euroheat & Power Yearbook 1997*; figures on Lithuania, Russia and Ukraine are from World Bank sources.

The dominant market share of DH in urban heat supply is linked to the high proportion of residential property consisting of multi-story buildings and to the high number of degree-days[10] in most CEE/FSU countries. These factors lead to a high heat load per kilometer of DH network, a demand situation that favors the economic feasibility of DH.[11]

However, there is concern that many DH systems could be overextended from an economic point of view and that competition from natural gas will eventually lead to a loss of customers. Once this happens, whole sections of DH systems risk becoming non-viable. Recent modernization

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[10] Degree-days = (the target inside temperature minus the average outside temperature during the heating season), multiplied by the number of days in the heating season.

[11] A high heat load is one of the two decisive determinants for the economics of district heating. The other is reliance on CHP for heat production; see Chapters 3 and 4.

investments would then turn into stranded costs. The ability of DH to compete in a free market should therefore be investigated for critical sections of a city before investments are made in modernization.

Heating has been perceived as a basic public good. DH systems in CEE/FSU were designed to be robust and reliable in the sense that the systems deliver heat to the end-user under all circumstances. In the communist period, heat was considered an elementary need (and as such it still is) that has to be provided in abundance for little or no cost. Since energy prices were very low, energy efficiency was not an issue in the design of DH systems. Instead, the focus was on simplicity, robustness, reliability, and safety.

The resulting designs were based on constant water flows through all parts of the networks. At the building level, ejector-driven circulation systems (hydro-elevators) were applied, so there was no need for additional pumps. Because heat was provided in abundance, according to the design concepts the end-user needed no control devices, not even radiator valves, to influence the supply of heat. In this manner, the flow of heat at the building level was kept constant and the need for control systems in the networks was eliminated. The only system control is the supply temperature at the heat production facilities, which is determined in relation to the outdoor temperature. The result is a simple system that can be controlled and maintained easily from the heat production plant by keeping the supply pressure and temperature at the required levels.

Consequently, the systems provided neither incentives nor the technical means for consumers to regulate consumption of heat and hot water. The reverse side of the coin is that the constant flow supply system is not geared technologically to cope with fluctuating consumer demand in an efficient manner. Once consumers install heat regulating devices on their premises, the system switches to variable flow at the consumer level and the supply side has to be adjusted accordingly.

A low quality of year-round service is another indirect aspect of constant flow operation.[12] In DH systems in Western Europe, space heating and DHW is supplied year-round to consumers. In CEE/FSU, DH systems supply space heating only during the "heating season."[13] Outside the heating season some DH companies continue to supply consumers with DHW; others supply none, or only supply DHW during part of the off-season. In general, all necessary repairs can be undertaken only during the summer because the entire network must be shut off and drained. This level of service was possible as long as consumers had no alternatives. Now, however, natural gas companies have started to offer year-round space heating whenever the consumer wants it. If the DH companies do not want to lose too many customers, they will have to be able to match this level of service.

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[12] In the summer period the water flow is reduced to cover only the need for DHW.

[13] See section 3.1.3.

These factors must be taken into account in the restructuring and modernization of the CEE/FSU heating sector, which is required if CEE/FSU is to effect a successful transition to a market economy. The need for restructuring is driven by the low overall factor productivity of the inherited systems of heat supply, caused by the following factors:

- Central planning of heat supply focused on the provision of heat supply regardless of its relative economic cost of supply.
- Low-cost energy supplies from Russia for a long time sheltered countries in CEE/FSU from making the type of adjustments Western economies did in the face of much higher international energy prices.
- This led to postponement of the introduction of modern, energy-efficient technologies in demand and supply. Present heat demand per square meter of building space is approximately 40–100 percent higher than in Western Europe; and energy losses in DH transmission and distribution amount to 15–35 percent, as opposed to less than 10 percent in Western Europe (see Chapter 3). The large energy losses have resulted in the considerable oversizing of existing DH generation facilities and networks.
- Prior to the early 1990s, virtually no metering of the consumption of heat, of DHW, and of natural gas for cooking existed for the majority of customers. The supply of heat was metered at the heat production facilities, at the industrial consumers, and, in some cases, at the distribution substations. DH companies had little quantitative data about system losses; these were assessed by theoretical calculations, formulated as standards. Inappropriate surrogates were selected to measure consumption. Residential customers were billed for space heating according to the size of their dwellings (such as area or volume), and for DHW consumption and for the consumption of natural gas for cooking according to the number of persons living in the dwelling.
- Control and regulation of heat supply (and thus, of consumption levels) in the constant flow DH systems has been done centrally at the heat production plants and at the central substations according to outside temperature levels.
- Residential consumers had, if at all, only very limited technical capabilities to regulate the heat supply individually at their radiators or at the level of their individual buildings. There was no possibility for behavior-related energy savings.

The introduction of market pricing for the factors of production made visible the high actual cost of heat supply of these systems. The shift in relative prices between internationally traded commodities (such as fuels) and non-traded domestic goods (including a "good" such as labor) was swifter in the heating sector than in most others. The shift was particularly severe in the fuel-importing countries. Prices for coal, oil, and gas increased to international levels almost overnight, whereas wages, salaries, and pensions lagged behind. This gave rise to severe affordability problems. Households were increasingly unable (or unwilling) to pay the full economic and financial cost of heat supply. In 1996, in such countries as Estonia, Lithuania, Russia, and Ukraine, the full cost of heat and hot water supply for a typical apartment would represent about 20–40 percent of the average income of an average household (see section 5.2.5). This compares to no more than an 8 percent share of average household expenditures for telecommunications, water, and domestic energy in EU countries.

Excess capacity in heat and power supply is another new phenomenon, caused by the decline in industrial production and the implementation of energy-saving measures.

The macroeconomic costs of these inefficiencies are considerable. In Lithuania, for example, the total energy system cost as a percentage of GDP is in the range of 12–17 percent per year, and heating represents an important share of it. The largest proportion of the cost is the cost of fuels and all of it, with the exception of a small fraction of domestic oil production and renewables, is imported. The foreign cost share amounts to 80–90 percent of the total system cost. In many fuel-importing countries such as Lithuania or Ukraine, the demand for foreign exchange necessary to pay for those imports can at times not be met.

2.2. The Future of Heat Markets in CEE/FSU

A prudent assessment of the heat market and the potential share for DH is a task of utmost importance for the economic viability of DH systems. Being a highly capital-intensive system, under- or overestimation of future demand will seriously affect the cost of heating. In the past, demand forecasts were typically prepared by engineers. This was based on the assumption that heat demand was merely a technical issue dealing with physical properties of construction materials, types of usage, outside temperatures, etc. This approach was justified to a certain extent as long as consumers did not have the opportunity to control their consumption and to select their heating systems.

As soon as customers have the ability to influence their consumption levels or have a choice of heating systems, heat consumption will become increasingly dependent on price, family income, prices of alternative heating systems, quality of service, etc. The technical approach to heat demand forecasting therefore needs to be recast in a market-oriented framework. Heat demand will then also be dependent on among other factors, the price of heat, which in turn will be affected by the investment in energy supply and demand systems.

Alternatives to DH are only slowly entering the market, providing only spotty experience about consumer reactions to the changes in the price and quality of heating systems. However, in every CEE/FSU country there is ample experience regarding the effect of consumer reactions to higher prices on utility revenues. Simply stated, the higher the share of heating costs in family income, the lower the share of consumers who pay on time or at all. In addition, as soon as cost-effective alternative heating systems are available, industrial customers, who are usually paying very high tariffs, start to switch from DH mostly to gas-fired systems.

It is obvious that size and structure of demand for DH are no longer pre-determined by non-market forces. However, because serious market analysis is difficult to perform when market forces are very slow in materializing, systematic analysis of this market in CEE/FSU is therefore still lacking. In the present case studies, the problem was solved partially by (1) analyzing the costs and prices of (potentially) competitive heating systems and (2) assessing the affordability of heating services to consumers.

Both approaches determine an upper price limit for DH, and if the DH systems would not be upgraded, customers would indeed have to switch to systems that better match their demands in terms of quality and quantity. But modernized DH systems with some investments on the demand side will match the flexibility of more decentralized systems in most aspects; consumers will be able to choose temperature levels and quantity according to their comfort preferences and incomes. For DH companies, this means that they need to take these reactions into account, as both a threat (lower sales and revenues) and an opportunity (retaining more satisfied customers).

As long as the relevant information and analyses are unavailable, the scenario approach is recommended as a surrogate for an appropriate market analysis. The scenarios should reflect various assumptions about consumer behavior. However, future DH studies should assess the heat market more carefully using the proven tools of market analysis. These tools are explained in more detail in Annex B.

2.3 Integration of Supply Side and Demand Side Options

Technically and economically, a DH system is highly complex, comprising various functions: generation, transmission/distribution, and consumption. Many studies, including the case studies, have demonstrated that an integrated optimization of the whole system will achieve better results than the isolated optimization of individual components. However, the present institutional framework makes integrated approaches difficult. DH companies have the responsibility and liability for generation and transmission/distribution: or there is a generation company in charge of generation (usually including transmission) and a distribution company is in charge of distribution. On the demand side, municipalities, housing maintenance organizations, housing cooperatives, homeowners associations, and individual consumers are in charge of buildings and apartments.

This distribution of responsibilities has led to a neglect of the demand side. Not being responsible for the demand side, DH companies are focussing on rehabilitating the supply side system up to their ownership boundary (which usually includes the substations). Their access to funds for investment is improving, especially in CEE countries. In contrast, the participants on the demand side are dispersed. A large number of customers (e.g., housing associations) and an even larger number of consumers (e.g., tenants) are involved. Most of them do not have the money required for investments, nor are they creditworthy. Consequently, system rehabilitation will be lopsided, with large investments in the supply side leading to oversized supply facilities, because the energy savings potential on the demand side will only be exploited much more gradually.

All the case studies have included demand side measures in their analysis; mostly, they proved to be viable, with high rates of return. Unfortunately, a high rate of return is no guarantee for the implemen-tation of such a measure due to institutional and financial barriers. Identifying viable energy efficiency investments on the demand side is only a first step. Implementing them is the most difficult task and will require new, innovative approaches. Future studies and projects need to consider this issue explicitly.

2.4 A New Paradigm for Heat Supply and Demand

The inefficient supply and consumption of heat in CEE/FSU can be improved through specific energy-saving investments in existing systems. However, the limits to energy efficiency within the current framework of supply and demand would soon be reached. In order to progress further and reach international best-practice standards of technical efficiency in the coverage of heat demand, it is necessary to restructure the heating sector through a parallel process of interrelated changes in the technologies and in the organization structures for the supply and the demand of heat.

The heating sector in all CEE/FSU countries has started the process of change towards a system based on economic incentives. The reforms of the heating sector that are initiated at the macro-level (overall ownership-industry-regulatory structure, pricing policy, subsidy schemes) are followed up by a series of initiatives at the micro-level (company structure, corporate governance, accounting, planning, financing, investment appraisal, billing).

This report outlines how changes in technology and in institutional setup can reinforce each other. The introduction of heat metering and of billing according to metered consumption (institutional change), for example, has a limited impact on consumer behavior as long as the technology does not allow consumers to regulate the supply of heat to their premises.

The paradigm shift in the provision of heat supply is summarized in Table 2-2. The achievement of overall efficiency in heat supply is broken down into the six sub-components of investment efficiency, operational efficiency, financial efficiency, pricing efficiency, regulatory efficiency, and environmental efficiency. The table shows how the efficiency targets (plus social equity) are achieved in a centrally regulated and in a market-based system. In general, the table highlights the limited use of incentives and of competitive pressures in the centrally regulated system. The most striking differences concern the promotion of financial and pricing efficiency, which hardly were matters of attention under the centrally regulated system.

Table 2-2. Efficiency of Heat Supply: Paradigm Shifts

Objective / Means	*Centrally Planned and Regulated System*	*Restructured, Commercialized Efficient System*
1. Investment Efficiency a) Planning of investments b) Choice of technology c) Implementation of investment projects	a) Central planning by vertically integrated state companies avoids duplication of resources and gives access to specialized expertise b) Choice concerning service and equipment provider limited to local/regional suppliers, promotes close cooperative links between users and producers of technology c) Experienced company staff organizes and implements investments	a) Government policy provides general planning framework. Municipalities may initiate heat planning as part of their physical planning; company investments in supply based on a market analysis b) Worldwide access to suppliers provides broad range of technology choice and competitive pressure on suppliers c) Equipment suppliers and contractors are selected by bidding process often with help of outside consultants
2. Financial Efficiency a) Level of self-financing b) Outside sources of finance c) Credit conditions	a) Low level of self-financing b) Allocation of investment finance from public/government budgets c) No interest rate payments nor repayment of principal; no dividend payments to government	a) Self-financing preferably at least 30% b) Debt financing from investment banks and bond issues c) Payment of interest (and repayment of principal) make cost of capital an important factor for ability to compete
3. Operational Efficiency a) Choice of fuel b) Level of outsourcing c) Incentives d) Quality of service	a) Fuel choice determined by physical access to fuels and/or government decision b) Almost all services are performed by company staff; use of hired man-hours much smaller than own staff hours; direct control over the production of the whole chain of services; performance ensured through staff training and control c) Rewards in case of plan fulfillment and norm fulfillment d) No direct policies for consumer satisfaction; but consumer complaints lead to corrective action	a) Fuel choice according to least cost; environmental and security of supply considerations eliminate some options and promote others b) Small number of company staff, large recourse to outside suppliers and contractors for services gives most employment generation to outside resources. Performance ensured through detailed contracts. c) Cost-based accounting allows development of incentive packages based on the financial indicators d) Consumer satisfaction standards are part of company policy and are quantified.
4. Pricing Efficiency a) Level of cost coverage b) Basis for payment	a) Neither input nor output prices are market related b) Lump sum-based billing according to floor area and number of persons, etc.	a) Full cost pricing, often including environmental taxation b) Payment according to metered consumption
5. Regulatory Efficiency a) Range of instruments b) Use of standards c) Consumer influence	a) Direct orders; no economic regulation, as companies are state-owned monopolies; little use of market instruments b) Detailed technical performance standards c) No institutionalized involvement of consumers in performance monitoring	a) Mix of direct orders and market instruments such as taxes and subsidies; definition of framework conditions in detailed concessions and licenses b) Sometimes economic regulation—by specialized institutions—of tariffs, investment policies, and consumer service standards of natural monopolies c) Sometimes involvement of municipalities in regulation and monitoring used as a proxy for consumer representation
6. Environmental Efficiency a) Energy efficiency b) End-of-pipe and cleaner technology solutions c) Choice of fuel	a) Little emphasis on optimization of fuel use due to low cost of fuel b) Since 1980s, increasing emphasis on improved air quality led to some investments in combustion control and in end-of-pipe pollution control c) See 3a)	a) High cost of fuel reinforced by environmental (and pure fiscal) taxation promotes attention to and investments in energy efficiency b) Green political movements and local population involvement in public hearings prior to the issuing of investment permits promotes environmental solutions c) Promotion of cleaner fuels through differential taxation
7. Social equity	Low tariffs for housing services including heating provide equality in the satisfaction of basic needs	Subsidy schemes targeted at low income households reduce real income gaps between rich and poor

3

Technical Requirements and Investment Strategies for a More Efficient Heating Sector: District Heating, Decentralized Heating Options and Buildings

This chapter lays out the options for investments designed to make heating more efficient. These investments can be directed at (1) rehabilitation and modernization of the district heating (DH) systems that already exist in most cities in CEE/FSU; (2) the upgrading of natural gas distribution systems and installation of more decentralized heat generation facilities, which would replace DH partially or completely; and/or (3) improvement of consumer installations and the energy-efficient rehabilitation of buildings.

Each of these options will be illustrated in this chapter with examples from the case studies. Once the investment options and their costs are laid out, it will be easier to determine which option is best under different sets of circumstances. This will be shown in Chapter 4.

3.1 District Heating Systems

3.1.1 Determining the Optimum Size of District Heating Systems

The size of a DH system in centrally planned economies was determined by planning authorities and based on general technical and economic guidelines. In combination with cogeneration, DH offered a cost-effective technology meeting both the heat demand of growing urban populations and the rapidly increasing industrial demand for electricity. With planning authorities determining the type of heating system, and with heat deemed a public service to be supplied cheaply or even free of charge, there was no need to consider the economic costs of resources or consumer preferences.

In recent years, the situation has dramatically changed, with consumers developing their own mechanisms to react to sharply increased energy prices and to the inconveniences of the existing DH systems. These mechanisms include the following:

- A large share of consumers, often up to 20–30 percent, pay their heating bills late or never pay them at all.
- Increasingly, industrial customers are installing their own decentralized hot water and steam generation facilities.
- Even residential consumers in multi-family buildings are disconnecting from DH (e.g., up to 30 percent in Bulgaria or in Romania), switching to cheaper electricity or gas for heating purposes.
- Natural gas distribution companies are increasingly installing and retrofitting gas distribution networks, thus offering customers an alternative heating system with higher quality and often lower cost.

Under these new circumstances, any rehabilitation and modernization scheme should prudently investigate the optimum size of the existing DH systems by asking the following questions:

- Is the rehabilitation of each of the existing service areas and its sections economically viable? Often, there are sections and/or pipeline segments that should not be rehabilitated due to excessively high costs.
- Could it be more cost-effective to replace DH networks in any particular area or section with alternative heating systems?
- Should an existing insular network be connected to the centralized, interconnected system?
- Could new customers sited along the existing pipelines be connected economically?
- Should additional pipelines connect new customers sited beyond the existing service area?
- Should an existing steam network supplying mostly industrial customers be replaced with decentralized systems?

In most DH systems, industrial demand for heat and steam has fallen significantly. For example, in Bulgaria, sales to industrial customers fell by some 40 percent within three years (1993–95). It is particularly difficult for DH companies to accept that the substantial drop in the industrial demand for steam (typically 50–70 percent) is likely to be permanent. Although industrial production is picking up, there will be a shift in future from heavy to light industries; the surviving industries will install more energy-efficient equipment; and some plants are likely to install their own steam boilers and disconnect from the centralized steam supply system.

In the future, additional decreases in heat demand can be expected that will be triggered by

- a decline in the specific demand for heat in the residential and commercial sectors;
- an increase in the diversity factor of peak consumer demand (resulting in lower coincidence factors); and
- a reduction in heat losses in the transport and distribution of heat.

Obviously, DH companies in CEE/FSU have already been seriously affected by market forces, although the management of DH companies typically is slow to react in a market-oriented way. In determining the optimum size of a DH system and a modernization program, a market analysis needs to replace the previous, technically determined concept of demand forecasting. Such a market analysis for heating services should consider the following:

- Consumer reactions to prices and price changes,
- Macroeconomic factors (such as income development),
- Relative energy prices,
- Competing alternative heating systems, and
- Customer reactions to product and service quality.

Based on a market analysis, heat demand will no longer be a static quantity, but instead a dynamic one affected by internal factors (i.e., factors stemming from the DH system itself, such as production cost, price structure, and technologies), as well as by external (e.g., macroeconomic) factors. Annex B provides an introduction to determining heat demand on the basis of a market analysis.

Taking into account the new, emerging market forces in CEE/FSU, restructuring a DH system must go beyond just rehabilitating and modernizing the existing system. Restructuring has to be based on the proper determination of the optimum size of the system taking into account the risks and opportunities of an increasingly competitive heat market. Even if rigid regulation would shelter DH from competition, customers will have a range of possibilities to influence their heat consumption; for instance, by regulating heat and by installing insulation and other weatherization measures. In section 5.2.4, heat planning is discussed as a tool that municipalities can use to provide a framework on which heat supply companies can base their investment decisions.

3.1.2 Rehabilitating and Modernizing District Heating Systems

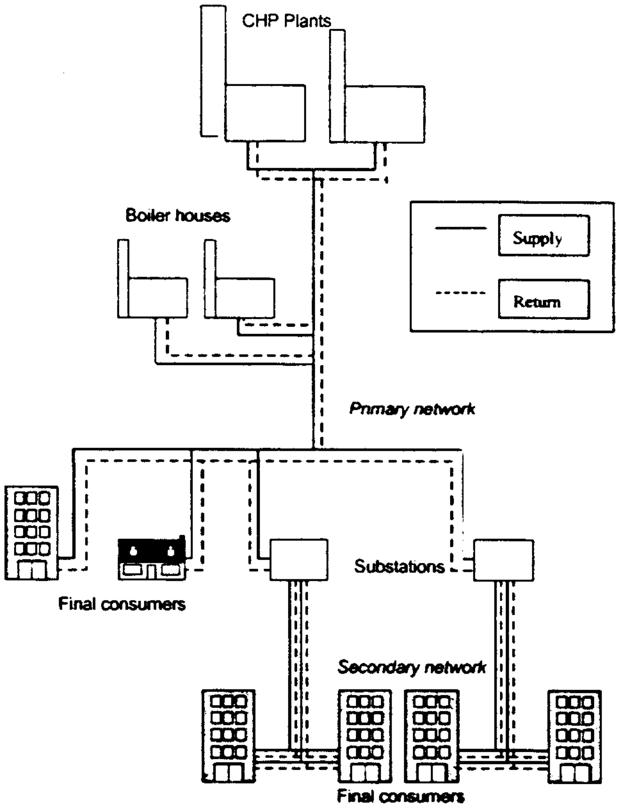
The remainder of section 3.1 introduces the various functions of a DH system (heat generation, heat transmission, and distribution networks) and discusses which investment options exist to improve the efficiency of the DH system. The exact composition of an optimal investment package will depend on the nature of the problems of the DH system in question.

The rehabilitation and modernization of the facilities in the various functions of a DH system (generation, transmission/distribution, and customer installations) are discussed separately. This is *not* a recommendation for dealing with the rehabilitation of the various functions in an isolated manner when designing a modernization program. On the contrary: modernization requires a system-based approach that aims at optimizing the interaction of the various system components.

3.1.3 Typical Large-City District Heating Systems and Connected Buildings: A Description

The DH system (Figure 3-1) in a larger city in CEE/FSU typically consists of one or more large networks receiving their heat supply from a number of heat production plants. In addition, several isolated (mini-) networks are being operated, each configured around a heat production plant. Large networks may be operated as hydraulically interconnected networks (the usual case in Western European systems) or as networks that are hydraulically separated (the usual case in CEE/FSU). In this mode, a network that is physically interconnected is divided by valves into separated sections.[14]

Figure 3-1. Schematic View of Typical District Heating System in CEE/FSU



Source: World Bank.

3.1.3.1 Generation of Heat

The heat production plants are composed of heat-only boiler (HOB) plants and, in larger DH systems, of combined heat and power (CHP) plants. The CHP plant usually has steam boilers for the cogeneration of heat and electricity aimed at providing the base load and HOBs for peak load

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[14] In some cases (e.g., in Warsaw), the system is operated as separate systems in the heating period; beyond the heating period, it is operated as an interconnected system.

generation of heat. Ideally, the CHP should deliver the heat for the base load, as heat can be produced more efficiently and therefore more cheaply in cogeneration plants than in HOBs.[15]

In CEE/FSU systems, the generation facilities (such as plants with cogeneration units and peak boilers, or HOB plants) are usually combined at one site or, in larger systems, at several sites. Many heat generation plants have originally been designed as CHP plants with a cogeneration unit for the base load and HOB for the peak load. Due to financial problems, many sites have never been equipped with the much more capital-intensive cogeneration unit, but only with steam boilers (for the later supply of cogeneration units or for industrial demand) and/or hot water boilers.

Heat is usually extracted from the cogeneration facilities at a high temperature, often at 180°C, although the maximum required temperature for the distribution system is usually 130–135°C. High extraction temperatures are the reason for low energy efficiency, as the potential of the steam for power generation is not used at the maximum level. Theoretically, the extraction temperature could be as low as 100°C or even lower, as the peak boilers could heat the hot water up to the required level of 130–135°C.

The range of fuels consists of natural gas, town gas, heavy fuel oil (mazut), coal, lignite, or, in some rare cases, biomass. In exceptional cases, light heating oil may also be used. Waste incineration plants are not yet used in CEE/FSU.[16] The share of gas utilization is rather high and increasing because gas is clean and easy to use. Especially in the smaller boiler houses, this fuel is preferred. In several countries, larger heat production plants are obliged by law to be dually fuelled by a combination of gas and heavy fuel oil or other combinations, in order to reduce the city's and the country's dependence on one type of fuel. In the case studies, natural gas is the main fuel in the heat generation plants in all cities, with the exception of Wroclaw and Timisoara, where coal and lignite, respectively, dominate.

3.1.3.2 Transport and Distribution Systems

The heat transport system of a large DH network consists of transmission, primary distribution, and secondary distribution. A typical network for DH consists of paired supply and return pipes for the circulation of hot water, either in concrete channels or above ground. The transmission system is composed of the main pipeline from the central CHP/HOB plant. Usually, the

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[15] Sometimes financial costs have caused the opposite. Old HOBs that are totally written off may have lower generation costs than CHPs which have high depreciation charges. In this way, HOBs are sometimes used in base load, even if their efficiency is low and emissions are high. This has been the situation for some years in one of the service areas in Warsaw.

[16] Incineration plants for base load heat supply exist in Western Europe, with the highest share in France (24 percent). They are not likely to be set up in the near future in CEE/FSU, because of their high investment costs. But in the longer term, CHP incineration is expected to replace landfills.

transmission line is branched step by step into the primary distribution system. Determination of where the transmission line ends and the distribution system starts is then arbitrary.

The primary distribution system is made up of the feeder pipelines from the transmission line to the (central or block) substations. Together, the transmission and primary distribution system make up the primary network. The pipelines from the central substations supplying a number of buildings make up the secondary distribution system. In systems with direct transport of heat to the buildings, the distinction between primary and secondary distribution is arbitrary.

Domestic hot water (DHW) is usually prepared in the substation and, accordingly, the secondary network is a three- or four-pipe system (see Figure 3-1). The technical concept of the substations is different in different countries. In Romania, where they supply a larger number of buildings, the loop length of the secondary system is quite large (sometimes larger than that of the primary system). In Bulgaria, most substations have been installed in the individual buildings, such as in Western European systems, but without the sophisticated control and regulation devices. (See also Table 3-3.)

Corrosion is a major problem of DH networks, resulting in large water losses and reduced technical service lifetime. In systems with high water losses, make-up water has to be added constantly; the total volume has to be refilled, sometimes more than 100 times a year. In Western Europe, the state of-the-art requires—in Finland, for example—not more than one or two refillings per year. Besides aggressive underground water penetrating into the concrete channels, bad quality of the make-up water is the main reason for corrosion of pipes. Frequently, the capacity of water treatment plants that are usually located on the premises of the heat generation facilities is insufficient to cope with these huge water losses.

Both in Western European and CEE/FSU countries, hot water is the predominant medium for heat transmission and distribution; steam is usually only used for the supply of industrial customers. Even if steam is produced for the supply of non-industrial customers, it is converted to hot water, thus causing considerable energy losses.

3.1.3.3 Network Operation and Regulation

The dominant mode of operation in CEE/FSU DH systems has been the constant flow regime; in Western European systems, it is variable flow (see section 3.1.6). Basically, constant flow means that heat supply and heat demand are being adjusted by varying the flow temperature (typically in the range of 70–130°C). In addition, a limited mass flow regulation is possible by switching individual pumps on or off. Pumps are usually not equipped with variable speed controls. Low investment costs are the advantage of this pumping technology, while high electricity costs are the disadvantage, because of the permanently high level of water flow.

Pumps installed in the generation plants circulate the heating water in the primary network, while the (block) substations pump it into the secondary network. Booster stations may be located at various points in the network to offset pressure losses.

Another operational difference is that space heating in cities in CEE/FSU systems is usually provided only during the "heating season." It starts when average daily temperatures have dropped to a certain threshold level (8–10°C) for about five days in a row and ends when the average temperature has been above the threshold level for about five consecutive days. In most regions, this results in space heating being provided from about October to April. During the summer, only DHW is provided, with the exception of a 2–8 week period when the system may be shut down completely for maintenance work. In Western European systems both space heating and DHW are available year-round. Technically, it would be no problem to supply hot water as well for space heating purposes outside the official heating period in CEE/FSU. DH companies in Western Europe try to achieve a high summer load, as this improves the exploitation of the cogeneration units, resulting in larger electricity sales.

3.1.3.4 Heat Transfer and Customer Installations

Heat transfer in the substations can be "direct" or "indirect." "Indirect" means that heat is transferred by heat exchangers from the primary to the secondary network; the systems are then hydraulically separated. Both direct and indirect systems exist in CEE/FSU, even in the same network. In Western European countries, the indirect system prevails (see Annex D). Only in smaller systems is direct heat transfer applied.

Indirect heat transfer aims at changing the operational parameters; i.e., temperature and pressure. While the primary network is usually operated at a higher temperature level (such as 130/65°C)[17], secondary networks are operated on the same, lower temperature level as the internal building systems (such as 95/75°C).

Although it creates additional costs, indirect heat transfer offers some substantial advantages:

- By separating the networks from customers' installations, harmful impacts caused by soiling, illegal tapping of (make-up) water, infusion of water bad quality water, etc., can be avoided. The expensive primary network can thus be better protected against corrosion.
- Indirect heat transfer enables a more efficient network regulation.

As shown in Figure 3-1, various concepts exist for placement of the heat transfer station:

- Heat transfer can occur within a building in small substations. In this case, the substation feeds directly into the internal building distribution system.
- Heat transfer can occur in a separate structure, which in turn supplies a number of buildings. Accordingly, the heat is fed by a secondary network directly into the internal building distribution system; there is no further heat transfer for space heating. DHW preparation can be done centrally in the transfer station, thus requiring a three- or four-pipe system. Or, it can be decentralized in the individual buildings thus requiring a heat exchanger in each building.

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[17] The first number stands for the supply temperature, the latter for the return temperature.

- Transfer can occur in a separate structure, but supplying a substantially large number of buildings. The loop length of the secondary system may in this instance exceed that of the primary system. Correspondingly, heat losses in four-pipe systems are extremely large.

The larger the heat transfer station and the longer the length of the secondary network, the smaller are the advantages of the indirect system that can be exploited.

It seems that most DH systems in CEE/FSU have a point of indirect heat transfer somewhere in the networks.[18] Only a few deliver heat directly from the generation plants to the internal building distribution systems. The dominant option for indirect heat transfer has been a more centralized one; that is, supplying a larger, varying number of buildings instead of individual buildings. The use of heat distribution technology in the six cities is shown in Table 3-3. In Western Europe, indirect heat transfer with individual (building) substations is the dominant system. Furthermore, there seems to be a growing interest in small substations for individual apartments.

3.1.3.5 Buildings and Customer Installations[19]

Cities in CEE/FSU were designed with a central heat and hot water supply in mind. Most urban dwellers live in large multi-family apartment buildings, which vary in height from three to more than 20 stories. Throughout the 1950s and 1960s, most multi-family buildings constructed were no more than five stories high. Later, in the 1970s and 1980s, more nine-story and 16-story buildings were constructed, often in residential neighborhoods on the very outskirts of cities or in open country completely outside of cities. This pattern of development has sometimes led to larger population densities further away from city centers than in the centers themselves.[20, 21]

Low thermal requirements in construction standards, a historical lack of attention to quality in construction materials and practices, and a poor record of operation and maintenance have led to high thermal losses in residential buildings. The most recent Soviet norms (1984–87) permitted heat transmission values more than twice those of Germany and Great Britain, and about five times those of Sweden for the same period. Actual heat losses in residential buildings are estimated to be 25–40 percent higher than design values. Deficiencies found most frequently are

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[18] Annex D provides a short overview of the distribution systems that are used.

[19] This section is based on a study by Eric Martinot, "Investments to Improve the Energy Efficiency of Existing Residential Buildings in Countries of the Former Soviet Union," *Studies of Economies in Transition 24* (Washington, DC: The World Bank, 1997), pp. 7-9.

[20] Alain Bertaud and Bertrand Renaud, "Socialist Cities without Land Markets," *Journal of Urban Economics*, Vol. 41 (1997), pp.137-151, provide an analysis of inefficiencies related with this development structure.

[21] However, in the centers of the cities itself, the building density (and therefore the need for heat) can be extremely high (such as in Budapest), but as the buildings are quite old, they are equipped with individual heating systems. A later retrofit would have entailed high construction costs.

leaky windows and doors, uneven heat supply within buildings, and missing or insufficient basement and roof insulation. Although building designs and methods are very similar throughout CEE/FSU, seemingly identical buildings display enormous differences in actual construction and thermal properties; for instance, up to 40 percent in the Russian city of Ryazan.

Most space heat for multi-family buildings built in the last four decades is supplied from DH systems. Commonly, arrangements of heating pipes supplying radiators within buildings are vertically arranged one- or two-pipe systems (see Figures D-1 and D-2 in Annex D). In the one-pipe system, the hot water flowing through one radiator continues through several more before returning to the source. In contrast, in Western Europe (at least in newer buildings), pipes are arranged horizontally, so that each radiator and DHW source in an apartment is supplied in one single loop; two-pipe systems are standard.

In CEE/FSU, virtually no heat or hot water metering existed before 1990 in residential or commercial and public sector buildings such as schools and hospitals. According to the original designs, consumers did not have the technical capacity to regulate the heat supply individually at their radiators; nor has it been possible usually at the level of an individual building. The regulation of heat supply (and thus of consumption levels) in the constant flow DH systems has been performed centrally at the heat production plants and at the substations according to outside temperature levels. Even if valves were installed at the radiators and were functioning, their proper operation and use would not affect the heating bill, as billing is based on lump-sum tariffs (see section 5.2.5).

3.1.3.6 Conclusions

In its existing form, DH in CEE/FSU is an inefficient energy system in which investments in all parts of the system are needed. These investments, which are dependent on each other to improve the overall efficiency of heating, are first of all required for the following:

- Optimizing heat generation,
- Reducing heat and water losses in the networks,
- Improving the efficiency of system regulation,
- Reducing heat losses on the demand side by improving consumer installations, and
- Expanding the system by integrating isolated networks where it is economic to do so.

3.1.4 Investments to Optimize Heat Generation Capacity

Heat generation in CEE/FSU is characterized by four major sets of problems:

- Heat production capacity is often in oversupply, causing low boiler efficiencies and high fixed costs (for unused capacities);
- Boilers are old and often inadequately maintained, causing high fuel consumption;
- The share of CHP is rather low, resulting in high heat production costs; and
- DH plants can be a source of major environmental problems, especially if they consume lignite, coal, or heavy fuel oil.

On the basis of a realistic heat demand forecast (see Annex B), investments on the generation side need to address the above problems.

3.1.4.1 Improving Efficiency and Performance of HOBs

Provided that the existing boiler capacity is needed, its efficiency needs to be improved beyond the current 60–80 percent common among of older boilers. With automation, controls, replacement of burners, and cleaning of boiler surfaces, efficiency can be increased to up to 85 percent. Sometimes the only alternative may be a new boiler, which can reach efficiencies of 90 percent (or even more with condensing boilers). Condensing boilers will be especially cost-effective in low-temperature DH systems operating at 90–95°C at maximum (e.g., in insular networks).[22]

Modern gas-fired boilers increasingly replace coal- and heavy oil-fired boilers, mostly for environmental reasons, to reduce locally harmful emissions. Although this is a positive step, any rehabilitation scheme should carefully investigate whether a DH system with a centralized HOB could not be better replaced by a more decentralized system (also using natural gas). This option should be taken into account, especially when a comprehensive rehabilitation program for the network would be required.

The use of local renewable fuels in HOBs may be a viable strategy to reduce heat generation costs as the experience in Estonia shows. Forestry or agricultural waste products or peat are available in many countries. In Estonia, for example, peat or wood chips can be the least-cost fuel.

3.1.4.2 Improving Efficiency and Performance of Cogeneration

Cogeneration has always been the most important justification for establishing large centralized DH systems, which offered a market for the heat that otherwise would have to be disposed of as a useless byproduct of power generation. When compared with the separate generation of heat and electricity, cogeneration is the more efficient way to produce heat and power (see Table 3-2 and Annex C). However, how this technical advantage translates to an economic advantage in the form of lower heat or power costs depends on non-technical factors.

This report takes the position that the maximum use of the economic potential for cogenerated heat is the key to reducing heat costs in DH systems in CEE/FSU. This requires heat benefiting more from the advantages of joint production than it currently does. This is discussed in more detail in section 5.2.6 and in Annex C. The discussion in this and the following chapter uses the following approach: Direct costs that are clearly caused by one of the two products will be directly assigned to that product. In a second step, the revenues from electricity sales are subtracted from the remaining costs and heat will be charged with the residual costs (plus the

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[22] Low-temperature DH systems are generally used in Denmark. See footnote 26.

directly assigned costs). If the electricity tariff that can be obtained is around US$0.04/kWh or above,[23] this results in heat being allocated most of the benefits of cogeneration.

As a rule of thumb, it can then be assumed that the economically optimal balance between CHP-generated and HOB-generated heat is a 90 percent/10 percent (or 80 percent/20 percent) split of annual heat generation. To reach this share of generation, the heat production capacity of the CHP plant (in cogeneration mode, not counting installed HOB boilers) will be around 30–50 percent of the annual peak demand for heat generating capacity. HOB capacity should amount to 85–65 percent (including stand-by and reserve capacity of 15 percent) of annual peak demand to provide sufficient security of supply. If the electricity prices that can be obtained are lower, which is the case when there is a substantial overcapacity in the power sector, the optimum share of cogeneration will be lower and heat production costs will be higher.

Only in very few of the large cities in CEE/FSU is the CHP share close to the economic optimum suggested above. The situation for CHP in the six case studies is shown in Table 3-1. Wroclaw comes closest to the optimal balance; the heat generation capacity in cogeneration mode is about 60 percent of installed heat (and industrial steam) generation capacity, but the actual share of heat produced in cogeneration is smaller. The CHP shares in total installed capacity in Orenburg, Sofia and Dnipropetrovsk look fairly high, but especially in Orenburg and in Dnipropetrovsk the actual heat production share of CHPs is considerably lower. Entire parts of these two cities are supplied by HOBs. Timisoara has no CHP production at all. The large HOB plant was originally designed for CHP operation, but the generators were never added. In Kaunas, the installed electricity generating capacity of CHP plants is hardly used because of lack of demand for the output. The CHP plant produces in HOB mode, but does so less efficiently than a dedicated HOB.

The overall efficiency of many CHP plants in the maximum heat extraction mode of operation is often rather low, around 70–75 percent.[24] In Western European CHP plants, the efficiency is typically 80–90 percent. Many of the existing CHP plants in CEE/FSU use backpressure turbines producing electricity and heat in more or less fixed proportions.[25] CHP plants in Western Europe use both backpressure turbines and condensing extraction with flexible proportions of heat and electricity, which add to the efficiency of the DH systems. In addition, gas turbines and combined cycle plants are increasingly used in Western Europe due to the increased efficiency, especially of power production, and lower specific investment costs. For a comparison of typical modern cogeneration technologies, see Table 3-2. The efficiency of heat generation in

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[23] This will be the case if the national power market has an appropriate balance between the demand for and the supply of electricity generating capacity, resulting in long-run marginal cost of this magnitude.

[24] Defined as $((MW_{el}+MW_{th})/MW$ fuel input). The overall efficiency of a CHP plant is an ambiguous indicator. Some plants operate cogeneration units and pure power units; accordingly, the overall efficiency will be lower. For a more detailed discussion of cogeneration efficiency, see Annex C.

[25] Some flexibility can be obtained by installing an extra cooler and pressure reduction valves.

cogeneration can be further increased by using heat storage tanks in combination with low-temperature operation of the DH system, resulting in increasing and more-flexible power generation and lower costs of heat.[26]

Table 3-1. Use of CHP in Heat Production

	Technical Characteristics					
City	*Installed electricity capacity, MW$_{th}$*	*Heat capacity in cogeneration mode, MW$_{th}$*	*Total Installed thermal capacity, MW$_{th}$*	*Fuel*	*Peak Heat Demand, MW$_{th}$* [b]	*Share of Cogenerated Heat (in % of capacity)*
Dnipropetrovsk[a]	600	600 (400 used)	2600 (nominal), of which 2000 in HOBs	Coal Natural gas	1372	30
Kaunas DHNE	170 12	594	1400	Gas, HFO	N/A	2-5 [d]
Orenburg	445	745	1605+	Gas	N/A	46
Sofia	311	933	4096	Gas, HFO, LFO	2895[c]	23
Timisoara	0	0	1025 or 901	Lignite/ gas	909 connected, 628 supplied	0
Wroclaw	369	1459	2311	Coal	N/A	63

N/A: not available.

HFO: heavy fuel oil. LFO: light fuel oil.

a. The data refer only to the main DH systems on the right and on the left bank. Only the left bank DH system is supplied by heat from the cogeneration plant. A second CHP plant (87 MWel, 730 MWth) supplies heat to a machine factory and to a separate DH system.

b. Including the industrial demand for steam.

c. Peak heat load in generation plants 1995.

d. Share of cogenerated heat in annual production.

Source: ESMAP case studies.

In small DH systems, cogeneration is generally not yet a cost-effective way of reducing heat generation cost, as long as electricity sales prices remain low. Although small-scale CHP plants in the 25–50 MW range have penetrated the heat market in small to medium-sized Danish cities since the late 1980s, their costs of production have been higher than those of the larger systems. Their penetration was facilitated for environmental reasons by direct and indirect state subsidies. In Finland, though, some small CHP units (2–5 MW) that provide heat to 2,000–5,000 consumers are considered economic.

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[26] Low-temperature operation of DH systems is common in Denmark. In some cases temperatures are as low as 70-80°C most of the year. For a description of the advantages of low-temperature operation, see Danish Board of District Heating, *News from DBDH*, No. 1/1999, pp. 3-9.

Table 3-2. Characteristics of Cogeneration Technologies

Technology	*Typical Total Plant Efficiency[a] (%)*	*Typical Electricity Efficiency (%)*	*Typical Heat Efficiency (%)*	*Typical Size (MW_{el} + MW_{th})*	*Typical Investment Costs (US$/kW)*
Coal-fired Condensing-Extraction CHP	90	42	48	500	1400
Coal-fired Backpressure CHP	90	38	52	100	1600
Smaller Gas-turbine CHP	90	28	62	20	1200
Larger Gas-turbine CHP	90	35	55	150	750
Combined Cycle Gas/Steam Turbine CHP (CCGT)	94	48	46	200	950
Gas-Diesel Engine CHP	85	45	40	2	1200

a. Defined as $((MW_{el}+MW_{th})/MW$ fuel input).

Source: World Bank staff.

In some cases, the interconnection of separated sections of a DH system can result in a higher share of cogeneration. This will happen, if different types of heat generation facilities supply the previously separate service areas. In Warsaw, for instance, some service areas are supplied by CHP plants and others are supplied by HOB plants. The available CHP capacity would be sufficient to supply the base load of the whole system.

3.1.4.3 Investments to Reduce Harmful Emissions from Heat Generation Plants

The most important environmental issue in the DH sector relates to air pollution caused by the use of coal and heavy fuel oil (HFO or mazut), both of which tend to have a high sulfur content. (For a more detailed analysis of environmental issues, see section 4.3 in Chapter 4.) Often, the continued use of these fuels is not compatible with local norms and standards for air quality. The DH company would have to invest in desulfurization equipment or switch to natural gas. When the economic life of the CHP/HOB plant is less than 10–12 years, it does not pay to install desulfurization equipment. When it comes to investment in a new CHP plant, the choice is between a combined-cycle gas turbine (CCGT) and a new modern coal-fired CHP plant with efficient desulfurization equipment. In Wroclaw, the former option turned out to be the most cost-effective (see Chapter 4). Here, as in many other cities in Poland, the use of coal in building boilers or in HOBs that supply small isolated networks is systematically reduced either by using natural gas or by connecting the isolated networks to the interconnected DH system.

3.1.5 Investments to Reduce Technical Losses in Transmission and Distribution[27]

3.5.5.1 Pipeline Technologies

Steel pipelines insulated with mineral wool or with concrete foam have been the dominant technology used in the DH networks in CEE/FSU countries. The pipelines are usually laid underground in concrete ducts that protect the pipelines against outside pressure and permit

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[27] For a recapitulation of the common technical configurations in DH systems in CEE/FSU, as well as temperature and pressure regimes and modes of operation, see Annex D.

water to be drained away.[28] In some sections of the pipeline system, especially in the transmission system, the pipelines are located above ground.

Pre-insulated pipes placed directly in the ground have become the dominant technology in Western Europe, and they have started to be used in DH systems in CEE/FSU since the late 1980s. They consist of an inner pipe of steel, an insulation of polyurethane, and an outer casing of high-density polyethylene that eliminates the need for a concrete duct. But as long as pre-insulated pipe technology is more expensive as steel pipe technology, the latter will continue to be installed as well. This will change when market prices covering real costs are paid for concrete, steel, mineral wool, and labor.

3.1.5.2 Heat and Water Losses

The overall quality of a distribution system can be assessed by determining the heat and water losses and the frequency of damages.[29] At the outset of a modernization and rehabilitation program, most DH systems in CEE/FSU are characterized by high water and energy losses compared to the systems in Western European cities. In Table 3-3, the water and heat losses in the six case study cities are compared with Western European standards. The heat losses represent rough estimates because in most DH systems, only a few heat meters exist. Most heat generation facilities meter (with greater or lesser accuracy) the heat supplied to the distribution system. Increasingly, the central substations are being retrofitted, but due to a lack of heat meters in buildings, losses in the secondary networks cannot be measured. New modern substations, which are usually installed in the individual buildings, are generally equipped with a heat meter.

Table 3-3 demonstrates the high losses in the CEE/FSU DH systems compared to systems in Western Europe. It also shows that the inefficiencies are found in the secondary rather than in the primary distribution systems. There are several reasons for this. Heat losses depend on the water flow, on the temperatures of the hot water (inlet and return), ambient temperature, surface area the of pipes, length of the pipes, and the physical properties of the materials used. Sometimes one factor offsets the effects of the others; sometimes it will reinforce them. Underground or wastewater penetrating the concrete channels adversely affects the properties of insulation material, resulting in high heat losses. A small network length can mitigate losses; a large network would increase the effect of the heat losses. Lower average hot water temperatures in secondary networks will result in relatively small losses, while the higher temperatures in primary networks result in relatively larger losses. However, the lower losses in the secondary networks may be offset by the impact of another factor, such as the larger mass flow.

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[28] In addition, ventilation needs to be in place to prevent moisture build-up.

[29] The frequency of damages can only give a rough picture of the state of the system. There exists no standardized definition of the term "damage." Without classifying the damage, it is also unclear whether it represents larger breakdowns or less significant events. However, assuming that a specific DH company will record damages according to one unique approach, the development of damages over a period of a few years will provide useful information about the state of the system.

The high level of water losses for most of the DH systems in the case studies indicates the bad technical state of the networks, which are prone to corrosion. The water losses are also a major contributor to the high heat losses. The state of the secondary distribution system is often one major reason for the high level of heat and water losses in the CEE/FSU DH systems. Heat losses of up to 25 percent are frequently found in secondary distribution for the following reasons:

Table 3-3. Comparison of Water and Estimated Heat Losses in Transmission and Distribution: Case Study Cities and Western Europe

City	*Water losses (refilling of total volume, times per year)*	*Heat losses (percent of heat input to network)*	*Type of secondary distribution system*	*Length of network, primary/ secondary, km*
Dnipropetrovsk	Primary: 40 Secondary: N/A	Primary: N/A Secondary: 25%	4-pipes direct	89 / 296
Kaunas	Primary: 40 Secondary: N/A	Primary: 14% Secondary: 24%	4-pipesdirect	268 / 102
Orenburg	Primary: 40 Secondary: N/A	Primary: 9%[a] Secondary: 25%	4-pipes (100%) direct (70%)	103 / 310
Sofia	Primary: 40 Total: 26	Total: 20%	2-pipes building substations	827 / 0
Timisoara	Primary: 29 Second: 155	Primary: 9% Second: 18% Total: 24%	4-pipes indirect	88 / 302
Wroclaw	Primary: 40	Total: 11%	2-pipes building substations (60%)	49 / 360
Western European System	Total: maximum 1–5 times	Primary: 5–10% Secondary: 0%	building substations	N/A

N/A: not applicable.

a. Transmission system only; secondary includes primary distribution.

Source: ESMAP case studies.

- Block substations that use heat exchangers to separate the secondary distribution system for space heating from the primary distribution system often have problems with their production of make-up water, a fact that substantially reduces the average lifetime of secondary pipes, compared to primary pipes. Another reason for accelerated corrosion is that the water flow in the secondary distribution system for space heating stops outside the heating season. The efficiency of the heat transfer is often reduced by the high level of fouling of the heat exchangers caused by mineral deposits.

- The four-pipe systems are particularly inefficient. Table 3-3 shows a clear correlation between a high level of losses in the transport of heat and the use of four-pipe systems. DHW circulates continuously in the system, thus causing large heat losses[30] that are

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[30] For this reason, in Romania DH enterprises supply DHW only for a few hours per day.

magnified by high water losses caused by the rapid corrosion of DHW pipes.[31] The technical lifetime of DHW pipes is normally 10 years, but may be as low as two or three years, depending on the quality of the pipe material. In some cities in FSU, where funding even for maintenance is extremely limited, the DHW return pipes are sometimes not being replaced, and the water not being returned. This kind of "open" system would further increase water and heat losses. DHW consumption per consumer in DH systems in CEE/FSU can be as high as six times the average level in Western European DH systems. Only a small part of this is due to over-consumption due to lack of metering; the majority is due to losses in the distribution system.

- Water losses also occur when the space heating network is open in the sense that water expansion is compensated with an open pool located on the upper floor of the building where the overflow is conducted to drainage (open expansion), rather than with an expansion tank where membrane and/or pressurized gas take care of water expansion (closed expansion). The former system is prevalent in CEE/FSU, the latter in Western Europe.

3.1.5.3 Non-technical Heat and Water Losses

Besides the deteriorated state of their distribution networks, the traditional CEE/FSU DH systems are prone to other, though less severe types of water and heat losses. Commercial losses are caused by diverting of hot water for non-heating purposes on the premises of the consumer. Tapping from radiators occurs in "direct" DH systems where the internal building heat distribution is not separated from the DH distribution.[32] As long as the inflow-outflow of DH water is not metered at the entrance of the building, the tapping is counted as system losses. Another type of loss is caused by the lack of mechanisms for the regulation of heat supply on the consumer premises. Consumers can get rid of excess heat only by opening the windows.

Since non-technical losses occur mostly in the internal building systems, it is extremely difficult it assess the amount of non-technical losses in systems with direct heat transfer systems.

3.1.5.4 Investment in Network Rehabilitation and Replacement

The major share of the "extra losses" (compared to Western European systems) is caused by specific weak points in the DH systems. Targeting an investment program to eliminate these weaknesses leads to a substantial reduction in losses at a fraction of the cost of total system replacement. The most important sources of these inefficiencies are identified in the next sections.

The most important categories of loss reduction investments in the DH networks in CEE/FSU are as follows:

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[31] Make-up water cannot be used because the DHW is for consumption and use of copper pipes instead of iron or steel pipes is too expensive.

[32] These systems are sometimes referred to as *open systems*.

- Tightening the network by installing valves;
- Improving the capacity for producing make-up water in systems in which existing capacity cannot cope with the demand caused by water losses; this investment reduces pipe corrosion;
- Installing new compensators in systems that use "telescopic compensators" that are prone to leakage, provided that the pipeline segments will not be replaced by pre-insulated pipes;
- In areas with high ground water levels, either replacing pipes or sealing channels and pipes against water penetration.

High losses in a DH network lead to the question as to whether it makes economic sense to replace all or parts of the network with modern, pre-insulated pipes. Due to the high cost, replacement of the entire existing system with a modern network is neither economic nor financially feasible. The cost of a pre-insulated pipe depends on its diameter. The average for the sizes of pipes found in a typical DH system is around US$250,000 per kilometer of double pipe installed in the ground. The split between the cost of the pipes and the cost of installation is approximately 70 percent/30 percent for the larger transmission lines and 80 percent/20 percent for the smaller distribution pipes.

As long as heat losses are due only to insufficient insulation (convection and radiation losses), replacement of old pipes will not be viable. The net present value (NPV) of accumulated energy savings is usually too small to compensate for the large investment costs. However, if heat losses are in a large part due to water losses, replacement usually becomes an urgent and viable rehabilitation measure. Since water losses are usually caused by bad make-up water quality and are correspondingly linked with larger corrosion problems, the whole system can be affected and the service lifetime of the system (or the respective section) can be shortened. In Warsaw, water losses used to be some 2,000 tons per hour (t/h) in the 1980s. A mix of pipeline replacement and refitting and replacement of compensators resulted in a reduction from 1,400 t/h to 450 t/h between 1992 and 1998 with an extremely short payback time for the investment.

The issue of whether sections of the network merit replacement relates to the state of the pipes, to the differences in the technology of old and new pipes, and to the physical environment in which the pipes are installed. Due to the varying problems with corrosion, the age of a pipe is only a rough indicator of its state.[33] On average, older heat distribution pipelines have larger heat and water losses (leakage) than new pipelines. Losses increase over time because of (1) internal corrosion caused by insufficient water treatment systems, (2) lost insulation properties caused by the penetration of water into the concrete channel, and (3) external corrosion caused by the aggressive water penetrating into the channels. Both internal and external corrosion considerably reduce the technical service lifetime. Although older pipes have a larger wall thickness, corrosion can reduce the technical lifetime to 10 or even fewer years. Where high groundwater

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[33] In Kaunas, 10 percent of the pipes were more than 35 years old. However, the 20 percent of the pipes that were 20-25 years old were generally in a worse condition, because the quality of pipe manufacturing had declined during the period when the pipes were installed.

levels are prevalent, such corrosion is particularly pronounced. In addition, the advance of technology provides modern pipes with better insulation properties.

Older pipes have higher maintenance costs than modern pipes due to wear and tear and due to the inherently lower maintenance costs associated with modern pipeline technologies. In networks in concrete ducts, localizing and repairing leakages is difficult and expensive. Pre-insulated pipes can be pre-installed with sensors that detect and report leakages. In CEE/FSU, preventive maintenance is rarely performed and repairs are undertaken only in cases of major breakdowns. In these instances, not only the directly affected pipeline, but also a larger section of the connected pipelines are usually replaced or rehabilitated.

The repairs provide the "automatic" part of network renovation—the damage replacement.[34] The replacement of a damaged pipe by a new pipe is often a necessity when a pipe has reached the end of its technical lifetime. The lifetime of steel pipelines in the transmission and primary distribution systems is 25–35 years unless problems with make-up water quality and aggressive underground water accelerate the corrosion of the pipes. The technical lifetime of modern pre-insulated pipes is 40–50 years, provided quality of the water is adequate.[35] Such replacement is a cost of operation and maintenance (O&M) rather than a cost of investment, but it provides a "free" investment benefit in terms of lower energy and maintenance costs during the lifetime of the new pipes.

A key question in network rehabilitation is, When is it justified to invest in the replacement of a pipeline section that has not reached the end of its technical lifetime? The frequency of damages and repairs per kilometer of pipeline during a year in a section of a DH network is a rough indication of the condition of the pipes in that specific section and permits the identification of sections where preventive pipeline renovation may be economically justified. In German DH systems, the average is 0.2 damage incidents per kilometer; in Odense/Denmark 0.5; in Sofia, between 0.7 and 2.1; in Warsaw, damages/km were reduced from about 2 to 0.6. A network section reaches the end of its economic lifetime in the year when the NPV of the "excess operating costs"[36] during the remaining years of its technical lifetime is higher than the NPV of the levelized cost of investment in new pipes during the same period. The economic evaluation of investments in accelerated pipeline renovation comprises two calculations:

- ☐ The analysis of costs and benefits during the remaining technical lifetime of the *existing* pipeline defines whether and when the end of its economic lifetime has been reached.

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[34] Some such damages occur during the heating season and lead to disturbances in the supply of heat. Others occur in connection with pressure tests, which are undertaken once or twice per year outside the heating season. The pipes that break are repaired.

[35] In parallel with the laying of pre-insulated or other new pipes, the water quality must be improved in order to avoid corrosion of the new pipes.

[36] Heat and water losses, repairs, and extra electricity for pumping water.

- The cost/benefit analysis for the lifetime of the *new* pipeline establishes the total rate of return of the investment in a new pipeline. The benefits include the forgone damage replacement in a later year plus the reduced O&M costs (lower water and energy losses, electricity savings, lower annual maintenance) during the lifetime of the pipeline.

Normally, the analysis of network rehabilitation results in the definition of a relatively modest program of investments in pipe replacement in the transmission and primary distribution system. In the Bank's Polish heat supply projects, for example, between about 10 percent and 25 percent of the pipes were replaced during a 4–5 year period. On the other hand, the secondary distribution system—the four-pipe systems in particular—is usually eliminated.

In assessing the problem of replacement, the following should be taken also into account:

- The network consists of more components than just pipes. Compensators are a frequent source of heat and water losses. Replacing the worst of them can reduce losses considerably, as demonstrated in the Bank's DH project in Warsaw. Other sources of losses are valves and heat exchangers.
- If the pipeline is in reasonably good shape and the damage can be localized, refitting may be a cost-effective alternative to pipe replacement. Frequently, the bad condition of the concrete channels is the reason for heat and water losses. Groundwater and sewage water penetrating the channels wets the insulation material and starts the destructive corrosion process. Obviously, just replacing the insulation will not solve the problem. One possibility is to seal the whole channel, thus preventing the penetration of water and stopping the external corrosion process. A mixture of bitumen and granulated cork ("LEBIT") has been used for the sealing of channels with good results, for example, in several DH systems in the former German Democratic Republic, but also in Wroclaw.

The problems caused by secondary distribution systems are discussed in detail above. It is usually recommended to eliminate central substations and extend the primary distribution system to the buildings where individual substations would be installed. This is state-of-the-art, both in Western European DH systems, as well as in most larger modernization programs for DH systems in CEE/FSU. A careful analysis, as to whether secondary networks should actually be eliminated and centralized substations should be replaced by individual substations, should nevertheless be performed. Rehabilitating larger substations and eliminating the four-pipe system may be a cost-effective option (see below), due to economies of scale. Secondary networks can in principle be operated as efficiently as small DH systems in Western Europe. However, one can assume that over time, most buildings would be equipped with individual substations.

3.1.5.6 The State of the Pipelines in the Case Studies

The circumstances of the pipelines in the DH systems investigated for the six case studies depend partly on the quality of the make-up water. It was satisfactory in Kaunas, Sofia, and Wroclaw and in the transmission and primary system in Orenburg. The condition of the networks was as follows:

- In Kaunas, the ongoing program for annual damage replacement of pipes (primary plus secondary) amounted to 6–10 kilometer per year, equal to 2.5 percent of the installed network. The consultants recommended an increase to about 17 kilometer per year during the first five years. This would equal an annual replacement of 4 percent of the installed network. Part of the accelerated pipeline replacement program was for sections located in areas with high underground water levels.
- In Sofia, pipes insulated with concrete foam had been severely damaged by corrosion. These pipes had been in operation for over 30 years and made up 23 percent of the total pipeline work. The consultants recommended replacing these with pre-insulated pipes.
- In Orenburg, the transmission system was in reasonably good order and investment could be limited to normal damage replacement. Water losses in the primary system were due mainly to leakages at compensators, and an investment program was proposed to handle the problem. Water treatment capacity problems led to the use of untreated water in the secondary system, with resulting leakages and the need for pipe replacement every 2–3 years.
- The DH company in Wroclaw is already investing in a moderate program of network modernization, including pre-insulated pipes.
- The secondary networks in Timisoara are in very poor condition. Water is entering the concrete channels, leading to corrosion and large water and heat losses. The feeding water is not treated and thus causes internal corrosion. The consultants proposed to replace the four-pipe system by a two-pipe system, abolishing the central substations and supplying buildings with individual substations.
- In Dnipropetrovsk, the average lifetime of pipes in the secondary system is about 10 years. The capacity of water treatment plants is insufficient for the required amount of make-up water. In many parts of the system, pipes therefore have to be replaced every 3–5 years. In total, about one quarter of the secondary network would need to be replaced immediately. The consultants proposed to use pre-insulated pipes, whereas the DH company would prefer to use enamel-coated pipes.

3.1.5.7 Interconnection of Networks

As part of a DH modernization program, a strategy for the rationalization of DH networks is usually developed. Such a strategy should take into consideration the answers to the following questions:

- Are any of the small, isolated DH systems located close enough to the main network or the transmission pipeline to be connected to the grid, thus reducing local environmental problems or exploiting the advantages of cogeneration to a higher degree?
- Should an interconnected system operated in an "island mode" be transformed into a system that is operated in an integrated mode with merit-order operation of the heat generation plants?

Connecting isolated systems to the interconnected network has two advantages: it can save energy and costs, and it can reduce local environmental problems. Energy will be saved if plants with higher efficiencies (such as CHP plants) can replace the heat generation of the local HOBs.

Similarly, harmful emissions can be reduced if the heat production can be concentrated in the environmentally more efficient plants. Costs can be saved due to merit-order dispatch. The capacity in an interconnected system can normally accommodate a higher level of demand. The pipeline systems in many cities in CEE/FSU are over-dimensioned,[37] and the fall in industrial steam demand has liberated some heat production capacity. Some of the isolated systems are located too far away from the interconnected network to justify a connection, often 7–10 kilometers. Other systems that are located closer to the grid, however, may be candidates. In Wroclaw, for example, there is scope for expansion of the integrated grid. Connecting small networks currently supplied by coal-fired HOBs to the interconnected network would result in a considerable decrease in the economic cost of heat supply to a dwelling.

The issue of "island" versus "integrated" modes of operation was not addressed in detail in the six case studies. A detailed hydraulic analysis is required to draw any conclusions on the subject. Briefly, the situation was as follows:

- In Kaunas, the network is divided into two sections: a large section supplied by the CHP plant and a smaller section supplied by HOB plants. A reason for the island mode of operation is the difference in elevation between the areas of the town. Changing to integrated operation would require investments in stronger pumps at the CHP plant, plus reinforcement of the pipes in some sections of the network.
- In Sofia, the network is operated as four separate service areas. The possibility of integrated operation is restricted by insufficient transmission capacities between the networks.
- In Wroclaw, the network is currently divided into two sections. An interconnection is planned.

The decision about an interconnection needs to be based on a economic analysis. Investing in the interconnection of formerly separated networks only makes sense if it is (or will soon be) supplied by a CHP plant. In the past, viable cogeneration could only be realized in large units, which were usually fired by coal or HFO. Natural gas or light fuel oil (LFO) were for many reasons not available for power and heat generation. With the increasing supply of natural gas and the deregulation of energy markets, decentralized technologies based on natural gas are now being developed and are becoming competitive. Today, small gas turbines or combined cycle CHP plants can produce heat and electricity at costs comparable with or even lower than those of the big CHP plants.

New technologies have made the justification for large, centralized DH networks obsolete or at least questionable. There is no reason to expand centralized systems quasi-automatically by

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[37] The pipelines are dimensioned for the accumulated calculated peak heat demand according to the technical norms of the buildings connected to the system. Because the norms are usually calculated to be "on the safe side," the system is typically over-dimensioned. Furthermore, decreasing load requirements of the residential sector and especially of the industrial sector result in further over-dimensioning.

adding isolated networks or interconnecting large separated networks. Large interconnected systems are viable, if they are supplied by existing large CHP plants or by large new ones that are more competitive with respect to electricity generation. Otherwise, it is recommended to investigate at least the following possibilities in addition to interconnection: (1) installing smaller CHP units in small isolated networks or (2) installing smaller HOBs when a clean fuel such as natural gas, or a renewable-energy source, is available.

3.1.5.8 Downsizing of Pipeline Diameters and Other District Heating Components

As already mentioned, in many DH systems in CEE/FSU, parts of or the entire network are over-dimensioned, leading to excess heat losses and maintenance costs. In Sofia, for instance, the transmission main could supply approximately 10,000 MW at a hypothetical temperature differential of 80 K; in recent years, the actual output to the network was less than 3,000 MW. Pipes with inside diameters of 100 millimeters were installed for building substations with capacities of 250 kW; a diameter of 40 millimeters would have been sufficient. The installed capacity of pumping stations also seems to be over-dimensioned.

Over-dimensioning can be explained by overestimation of demand (due to the use of a demand forecasting methodology that considers only technical factors[38]) as well as by the more recent decrease in overall demand resulting from the economic crisis. (The latter mainly affects industrial demand for heat and for steam.) In many cities, plans for new building construction were never realized, but DH infrastructure had already been designed with this additional demand in mind.

The DH rehabilitation program will add to the problem of over-dimensioning by increasing the energy efficiency of substations, pipes, and other components, and thus reducing both energy and capacity demand. External factors such as the energy-efficient retrofit of buildings will also result in reduced energy and capacity demand.

When a secondary four-pipe distribution system is replaced by a two-pipe system with building substations for the production of space heating and DHW, it can often make sense to invest in a replacement or retrofitting of the existing secondary space heating pipes. The four-pipe systems were designed for flow/return temperatures of 95°C/75°C. A new primary network would be designed for 130°C/65°C, which allows reduction in the size of the pipes. The cost savings are considerable. In Timisoara, the cost for a new 328-kilometer secondary four-pipe network would amount to US$97 million; a two-pipe network with the same temperature differential as the existing primary network would cost US$65 million.

Although this example illustrates that the original DH system designs caused unnecessary costs, it does not necessarily call for a replacement. If the space heating pipes are in an acceptable state and the capacity is sufficient, the investment can be postponed, thus mitigating the financing problem.

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[38] See Annex B.

The pipeline size problems of these systems call for a strategy to determine how the network dimensions can be reduced over time.[39] The fact that probably one-half of the annual pipeline replacement occurs as damage replacement is a complicating factor. If a pipe of similar size replaces an oversized damaged pipe, the particular pipeline section will never be reduced in size in effect, and the cost of replacement will be larger than necessary. To illustrate the latter point, the average inside diameter of the pipes in the six cities is around 250 millimeters. If it were assumed that an average of 200 millimeters represents an adequate diameter, the cost of investment would be roughly 15–20 percent lower.

In the still-dominant constant flow systems, the reduction of pipeline diameters should be implemented starting at the consumer premises and working backwards. In a variable flow system, a stepwise reduction of pipeline diameters in connection with damage replacement is possible in principle. In both systems, a thorough modeling of the hydraulics is required.

In the same manner, other components of the system can be downsized, including heat generation facilities. It is obvious that this requires an integrated approach covering the entire system. The adequate size of the generation facilities can only be determined if the energy and capacity savings in the transmission and distribution system and on the demand side can be estimated satisfactorily.

3.1.6 The Economics of Investments in More Efficient System Regulation

3.1.6.1 Traditional Network Regulation in CEE/FSU

In the past, DH network regulation in CEE/FSU has been a simple affair. This simplicity, coupled with a considerable robustness, has its price in the form of low energy efficiency. The simple system is not suited to responding to all influences that determine actual heat demand because it is usually operated solely according to the outside temperature. Outside temperature is an important, but not the sole, factor determining heat demand. There are other climatic (e.g., wind and solar radiation) and technical factors (e.g., industrial process requirements), as well as end-user influences (e.g., consumer behavior and number of people in the heated rooms). The operator of such a system can only insufficiently react to such fluctuations in the heat demand. Inappropriate and insufficient regulation thus results in considerable energy losses.

Automation aimed at regulating the system by taking these various factors into account opens up a large scope for energy savings in the system's various sections, especially in generation facilities, pump stations, substations, and radiators. It also enables the use of various heat sources that could be dispatched according to merit order. Successful automation requires an integrated approach involving the whole system to realize the largest benefits. Automation results in a new, more efficient network operation, compared with the constant flow regime, the

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[39] How to tackle the issue of downsizing in practice was not part of the terms of reference for the case studies.

dominant mode in CEE/FSU. The technical framework for switching can be described as follows (see Annex D for more details):

- *Constant flow and variable temperature.* The water flow is more or less kept constant while the supply temperature varies according to outdoor temperature to match the system output with heating demand. This mode does not require sophisticated flow regulation equipment. Supply temperatures are usually regulated manually at the heat plants according to outdoor temperatures at the heat sources. Water flow can change during the heating season, but this is normally a consequence of the typical summer/winter arrangement of system configuration.
- *Variable flow and variable temperature* is the alternative to the constant flow regime. The water temperature and flow vary according to outdoor temperature to match the system output with heating demand.

In DH systems, both regimes have been applied, but rarely in the pure forms described above. In Warsaw, for example, the constant flow scheme has been applied, but usually in combination with some regulation by switching individual pumps on or off (cascade configuration).

3.1.6.2 Substations and Consumer Installations

Substations and consumer installations are an essential part of the automation measures. Substations are sometimes in the ownership of the DH company, and sometimes of the building owner. The internal distribution systems for space heating and DHW are the property of the building owner.

Substations are either equipped with heat exchangers providing a hydraulic separation of the internal circulating water from the secondary distribution system, or they can be mere "transmitters," or "mixers," of incoming and outgoing water—the so-called hydro-elevators. The existing substations have heat losses of up to 4 percent due to inefficiencies in the heat transfer technology and insufficient insulation. Neither the substations nor the hydro-elevators have customarily had automation to regulate the intake of heat according to outside temperature or according to individual temperature preferences of the end-users. As previously noted, until recently, it was also unusual to have metering devices installed at residential and commercial buildings.

Investigations in Poland have shown that heat losses in the internal distribution system can be as high as 50 percent.[40] Lack of individual heat regulation at radiators is a further source of energy losses, as the opening of windows is typically the means to get rid of excess heat. Even in systems with two pipes—the dominant technology in Sofia, Timisoara, and Wroclaw—radiator valves were mostly not installed or were non-functional.

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[40] In Lithuania, a study showed that the "useful energy efficiency" of DHW production (energy content of tapped DHW/ energy content of fuel input) was as low as 14 percent; thus, 86 percent of consumed primary energy was lost in the DH system and in the internal distribution system.

Because the inefficiency of the secondary distribution system is clearly recognized, the elimination of four-pipe systems is a standard component of rehabilitation programs. The following possible investment measures aim at reducing technical and non-technical losses:

- One solution for DHW is to install gas-fired "heat through boilers" in each apartment. This reduces the huge technical losses, the over-consumption due to lack of metering, and the problem of consumer arrears because the gas supply can easily be cut off.[41]
- Another solution is to replace the entire secondary distribution system by building substations for space heating and DHW preparation (see Figure D-2 in Annex D). This reduces technical losses and eliminates non-technical losses associated with the illegal tapping of water for space heating. In the World Bank project in Jelgava, Latvia, investments in automated individual substations reduced the energy consumption of buildings by up to 40 percent (see Box A-2 in Annex A).
- A third solution is the rehabilitation of the centralized substations, including elimination of the four-pipe systems. This requires the installation of individual DHW preparation devices in each building (see first of these points, above).

Another set of investment approaches aims at providing the technical means and the incentives for individual regulation of heat consumption (see also section 3.3):

- Building substations are equipped with automatic heat regulating devices for night and—for commercial buildings—weekend temperature reduction.
- Investments in heat regulating valves (possibly thermostats) at radiators are usually a cost-effective solution in two-string systems, provided that households are billed according to their individual consumption. In buildings with internal one-string distribution systems, a bypass can be installed at each radiator; this permits installing heat-regulating valves (possibly thermostats) at radiators. However, this requires careful planning of the bypass installation and the thermostatic valve configuration.
- Meters are installed in the buildings. Two devices exist for metering at the building level: heat meters and water flow meters. Heat meters are more precise in terms of measuring and billing according to the true consumption of heat, but are also more expensive. Water flow meters are cheaper and may motivate consumers to install large radiators that cool the heating water to a low return temperature.[42]
- At the apartment level, the options are precise but expensive heat meters or cheap evaporation meters that can be used to allocate the measured heat consumption of the

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[41] The provision of DHW does, however, considerably increase the viability of CHP plants by increasing the summer load and, correspondingly, the load-duration hours of the cogeneration facilities.

[42] Low return temperatures are usually desired; however, if customers have different temperature differentials, the flow is no longer a surrogate for heat quantity.

building among the households.[43] Water flow meters can be used to meter DHW consumption.

The investments in loss reduction and in individual heat regulation typically have economic and financial rates of return of more than 20 percent. Using the example of Sofia, Table 4-8 (see Chapter 4) shows the substantial reduction in losses that is expected to result from these investments. They have an immediate, direct impact on energy consumption, accounting for up to 50 percent of savings in the short term. In addition, investments in heat regulation have an indirect impact by providing incentives for improving the energy efficiency of the building envelope and for changing the mode of operation in the DH system from constant to variable flow.

In new construction areas supplied by DH, the range of technological choices for the decentralized regulation of heat is larger. In many CEE/FSU countries, national regulations for new building construction require the installation of heat meters and thermostatic valves.[44] Recently developed technology distributes the hot water directly to each apartment where decentralized heating and preparation of DHW takes place. However, the economics still need to be proven.

3.1.7 Rationalization of Steam Supply

3.1.7.1 Current Steam Supply Systems in CEE/FSU

In the larger cities in CEE/FSU, most of the CHP plants and some medium-to-large sized boiler houses have a system of steam supply to industry attached. The length of the steam supply pipelines can vary from a few hundred meters to several kilometers. Heat and steam sales to industries typically used to account for up to 25 percent of total sales of large DH companies. In some countries, some DH systems' primary aim was the supply of industrial customers (e.g., in Bulgaria and the former German Democratic Republic).

The operation of centralized steam systems is demanding, as the quality of steam for industrial processes needs to be constant. When the consumer receives steam in a condition that he cannot use, he returns the steam as condensate to the system, thus wasting energy. Other losses are caused by condensation formation inside the pipes due to temperature losses. This condensate,

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[43] See Table 5-2 in Chapter 5. It should be stressed that even an accurate meter installed in the pipes or radiators does not meter the entire heat supply. Heat transmission within the building transports heat from warmer rooms or flats to colder ones. Technically this is difficult to measure and would in any case be too costly.

[44] In the Czech Republic, such a proposal met political opposition. The opponents claimed that it was against the principle of free consumer choice. That is a misunderstanding. Any regulation implies restrictions on the free choice of consumers and producers. The issue is whether the cost of a given regulation is justified or not by the economic benefits; in this particular case, whether or not thermostatic valves reduce the lifetime cost of heat supply!

which is high quality, de-mineralized water, is removed at various points in the pipeline system. All industries have return systems for the condensate water from the steam they have received. The quantity of outgoing condensate is measured and industries are paid for returned condensate. But typically, no more than 30–40 percent of the make-up water transported in the form of steam is returned as condensate. It is expensive for the industrial steam consumers to reach the required quality for condensate water. Therefore, it is cheaper to use the condensate water in the industrial process or for space heating. The technical losses and non-technical losses (such as measurement errors) in steam supply systems may be as high as 30–40 percent.

For DH companies, the production and supply of steam to industries used to be a liability rather than a commercial business. If centralized steam supply is cheaper than decentralized production, and if DH companies can agree with their industrial customers on cost-covering tariffs, industrial steam supply can be a profitable undertaking.

3.1.7.2 The Future of Steam Networks

Assessing the viability of steam networks is difficult because heat, steam, and—in CHP plants—electricity are produced jointly. Usually, the costs of steam supply are considerably higher than the costs of hot water supply. In the case studies, the economic feasibility of the steam supply systems in the six cities was not investigated. However, it is known from other studies (e.g., a feasibility study for a proposed EBRD project in Kaunas) and experiences in Western Europe that the closure of the centralized steam supply systems and conversion to steam production on the industrial premises is the cheaper solution, unless the industrial plants are located in the immediate neighborhood of a CHP/HOB plant.

If DH companies are obliged by contracts or by law to deliver steam to industries and this activity is not cost-covering, they could offer to establish a decentralized steam supply facility, if possible, at the site of the customer (see also section 6.3.2).

3.2 Modernization and Expansion of Natural Gas Systems

Natural gas distribution systems exist in many cities in CEE/FSU to supply gas mostly for cooking purposes. One notable exception is cities in Bulgaria, where gas distribution systems were never introduced. In some cities, gas networks might have sufficient capacity, with some investments for upgrading, to accommodate demand for heating. In other cases, capacity may be too low and the state of the network too bad, thus requiring an entire rebuilding of the gas network. This section looks at both options and the required investments, as well as investments in heat/hot water generation equipment.

3.2.1 The Need to Modernize Gas Distribution Systems

From a general standpoint, typical gas uses in the residential and commercial sectors are space heating, water heating, and cooking. In CEE/FSU, the use of gas in the residential and commercial markets is currently limited to cooking in most countries. Furthermore, for safety reasons, the use of gas for cooking purposes is usually limited to buildings with fewer than 12 floors. The use of gas only for cooking dates back to when gas was produced from coal in gasworks, where gas production was seriously constrained by plant production and storage capacity. Gas was then used where its usage value was higher, i.e., in cooking, where it had virtually no competition, particularly in urban areas. The development of natural gas made such a distribution policy obsolete, because large quantities of gas had become available for water heating and space heating, not to mention industrial uses.

When it was designed, the current gas network architecture in CEE/FSU was well suited for the technology then available and for gas (cooking) needs. Steel was the leading material and, because gas was meant to be used mainly for cooking, the capacity of the low-pressure (LP) networks was sufficient; higher capacity, medium-pressure (MP) networks were deemed unnecessary.

Gas distribution companies and manufacturers of gas appliances are now very interested in expanding the market for gas into space heating and hot water preparation. This appears to be an attractive market because (1) in a standard household, gas consumption for cooking is generally 8 to 10 times less than it is for space heating and water heating together; (2) the construction cost of a gas network is high and does not vary significantly with its capacity; and (3) operating cost is virtually independent of consumption.

With an expanding market, the gas industry needs to introduce modern design and operation technologies that will enable it to enhance overall gas distribution safety, decrease the cost of both the construction and operation of gas networks, and increase the capacity. Fulfilling these objectives implies that MP substitutes for LP, which should be progressively abandoned, and that polyethylene (PE) substitutes for steel through the tubing of old LP pipes, as well as network extensions.

3.2.1.1 Design and Operating Techniques

For the time being, design and specifications of gas distribution networks in CEE/FSU do not match today's technical requirements. Modern gas distribution networks in Western European countries are mostly based on high and medium pressure (the latter generally 4 bar - 60 psi). LP technique has become obsolete for the following reasons:

- MP networks are less expensive because smaller pipes are required, which in turn require less expensive construction works; and because, for these smaller pipes, PE is competitive. For small diameters (6 inches and below), PE is cheaper than steel, and PE pipes do not need to be protected against corrosion.
- MP networks have a much higher capacity that enables gas supply to meet the likely increase in gas demand over time, as well as for seasonal swings.
- MP generates lower operating costs because with only two pressure levels instead of three, a smaller range of spare parts and maintenance and repair equipment needs to be kept in stock.

The development of PE techniques in CEE/FSU is limited by the larger size of the pipes required by LP, for which PE pipes are not competitive (most LP pipes have a diameter of 6–8 inches), and by the current shortage of raw material. The best use of PE pipes is under a MP scheme, but gas utilities in CEE/FSU have not yet gone beyond the pilot phase. Another constraint lies in most current regulations, which often prohibit the use of MP within 4 meters of a building; this prevents the MP network—including service lines—from being laid under most sidewalks and reaching the building wall where the building regulator should be installed. Such regulations, once established for safety reasons, have proved unwarranted in any country in which MP is in use.

The gas industries need to establish updated technical codes and standards that allow the use of materials and construction and operating techniques that have been developed in industrialized countries for over a decade. Implementing or expanding distribution networks may provide an opportunity to start developing gas distribution manufacturing industries. However, finding export markets requires that locally made products comply with standards widely accepted in other countries, such as the European standards currently being developed. Though the opportunities will be limited initially by the size of the local markets, it is likely that units like extruders for the production of polyethylene pipes, as well as supply lines for domestic appliances, can be easily implemented to accompany the evolution of the gas industries.

3.2.1.2 Pipeline Corrosion and Network Rehabilitation

In CEE/FSU, steel pipe corrosion is the cause of breakdowns that affect the gas distribution networks, threatening the life of people and gas workers and disrupting supply to consumers. Corrosion is generally caused by stray electric currents that pierce the pipe coating and remove particles of metal in a process that takes place over several years. Gas distribution networks suffer from both a lack of comprehensive pipe protection and the poor efficiency of locally made protection devices, where installed. Network rehabilitation should be done through the following two sets of measures:

- ☐ Replacement of faulty steel pipe sections with PE pipes, either by tubing or by PE-for-steel substitution; and
- ☐ Replacement of current protection devices with efficient devices, either imported or locally produced.

3.2.1.3 Gas Use Efficiency

The sources of inefficient gas use can be divided into two main groups: (1) technical losses caused by leaking pipes, inefficient gas appliances, lack of heat regulation, and outmoded and inefficient heating techniques; and (2) non-technical losses caused mainly by lack of metering equipment and inappropriate tariff policies that cause gas users to waste gas. In most cases, these sources are closely inter-related, which makes it necessary to promote a comprehensive approach to the problem. For instance, inefficient gas appliances are a consequence of, *inter alia*, inadequate tariff policies that do not provide incentives for efficient use of energy, and the common use of gas cookers for space heating, where DH is insufficient or is not provided. These, in turn, are the results of both inappropriate tariff levels and structure as well as ineffective DH systems.

Metering residential consumers who use gas only for cooking will contribute to decreased individual consumption. However, overall results should remain limited due to the low share of the residential sector in total consumption and the high share of non-energy-intensive (cooking only) gas consumers within the CEE/FSU residential sector.

More efficient use of gas will be achieved by combining energy efficiency measures (see Table 3-4) and a new tariff policy that reflects the real cost of supplying gas to consumers. On a case-by-case basis, it is possible that substituting gas for DH in an apartment building or group of apartment buildings would be the most efficient measure to increase gas efficiency, measured in volumes of energy saved, in the residential sector. This would bring gas directly inside to residential and commercial buildings, thus eliminating water and heat losses in DH networks. (See the analysis in Chapter 4.)

Table 3-4. Improving Gas Efficiency and Safety: Comparative Merits of Technical Alternatives

Technical Options	*Enhancing Gas Operation Safety*	*Improving Gas Efficiency*
Network rehabilitation	****	*
Metering residential consumers	**	**
Demand side management (residential)	*	**
Energy efficiency measures in industry and CHP	**	****
Energy loss reduction in DH networks	N/A	**
Replacing DH by building gas boilers	N/A	***

N/A: not applicable.
Source: World Bank staff.

The reduction of network losses is clearly the responsibility of gas utilities. The improvement of the efficiency of gas appliances, however, whether industrial or domestic, involves equipment manufacturers making products that reflect the needs of end users. Such improvement is obviously linked to the tariff policy and to the incentives given to end users to use energy-efficiently. Although the economic policies prevailing until recently in CEE/FSU did not provide incentives for suppliers to produce energy-efficient equipment, nor for end-users to use them, there are strong chances that the current economic reform policies will quickly create the need for such changes. Experience in market-oriented industrialized countries, particularly after the two oil price shocks, shows that gas utilities can play a leading role in the reduction of energy waste, and that an active energy efficiency policy can be profitable to all three main economic actors: gas utilities, end-users, and equipment manufacturers. To provide the incentives to increase the efficient use of energy, gas prices should reflect their true economic costs. This would also invoke a supply response in which appliance and equipment manufacturers would produce goods that would meet domestic needs and possibly also have export potential.

3.2.2 Technical Options for Gas Use in the Residential Sector

The use of gas in the residential and commercial sectors for space heating, water heating, and cooking can be based on various technical options. While all these options can be implemented in residential and commercial buildings from a technical standpoint, their construction and operating costs vary significantly. The urban and architectural patterns of the area to be supplied may in some cases dictate a particular option. However, selecting an option will mostly depend on its cost-effectiveness in relation to the quality of service and the level of comfort sought, and also the capacity for the household to control its gas consumption and afford the related fuel bill. The three major options are briefly described below and are summarized in Table 3-5.

Table 3-5. Main Characteristics of Decentralized Gas Heating Options

	Option A *Building-boiler*	*Option B* *Individual Gas Heaters*	*Option C* *Individual Gas Boilers*
Gas Uses	Space Heating; Water Heating	Space Heating; Water Heating; Cooking	Space Heating; Water Heating; Cooking
Individual meter	No	Yes	Yes
Gas appliances	Apartment building boiler supplies hot water to building's hot water piping [Cooking range if gas for cooking is already in use]	Independent room gas-heaters; Water-heater(s); Cooking range	Individual boiler supplies hot water to radiators and taps; Cooking range
Suitability	Buildings pre-equipped with hot water piping. Buildings supplied with district heat.	All types of buildings. Best where either individual electric or fossil-fuels-fired stoves are used.	Single-family houses
Pros and Cons	The cheapest option. Integrity of secondary hot water system needs to be assessed. Does not allow for individual billing.	Higher investment cost than A. Allows for individual billing.	More comfort. In apartment buildings not recommended because of high costs, unless internal piping has to be renewed. Allows for individual billing.

Source: World Bank staff.

Option A (per Table 3-5) consists of the installation of a dedicated gas boiler—called a *building boiler*—for each apartment building, or a group of clustered apartment buildings. This option is clearly cheaper where buildings are already pre-equipped with hot water piping, whether water piping is actually connected to DH or not. It fits, too, with larger commercial establishments such as hospitals, hotels, office buildings, etc. The boiler generates hot water for both space heating and DHW. It can be installed in the basement of an apartment building,[45] provided that the space for such equipment already exists (on the rooftop or in a dedicated boiler house) and meets safety regulations. The major drawback of the option is that, similar to DH, it does not allow for individual billing of end users. Gas is metered at the boiler inlet and charged to the building owner; the gas bill is then distributed among all apartments (including non-residential, if any) following a procedure established amongst them; generally on the basis of the floor area or the volume of the individual dwellings.

Option B is a fully decentralized system in which gas is used for the three main uses, space heating, water heating, and cooking. Inside buildings, piping supplies gas to each appliance through a service line and riser(s). In each dwelling, space heating is provided by individual gas heaters located in the main rooms (living room and bedrooms), while hot water is generated by a gas water heater. A gas cooking range or hot plates can supplement the household equipment because the marginal cost to supply these dedicated appliances is moderate, if they are not in

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[45] Installing these gas boilers in existing building substations, thus replacing the DH heat transfer facilities, seems economically interesting.

place already. Since the buildings are not pre-equipped with flue gas ducts (chimneys), flue gas must be driven out of the dwellings through short, horizontal pipes set in the outside wall. Capital expenditures for this decentralized option are higher than for the building boilers in Option A. However, it gives the household full control over the use of gas and the gas bill. In addition, the global efficiency of this system is slightly better than in Option A because no heat is lost in the water piping of the building.

The most expensive alternative, Option C would consist of installing in each dwelling an individual gas boiler that supplies hot water to the radiators. Although this option would suit individual houses where specific consumption is higher, it is usually not economic in apartment buildings, in particular, because the design of the internal water piping (vertical risers) prevents radiators from being connected within the same apartment at a reasonable cost. When the internal building piping has to be renewed, installation of horizontal piping should be considered.

3.2.3 The Costs of Expanding the Use of Natural Gas

3.2.3.1 Construction and Upgrading of Gas Distribution

The main parameter determining the cost of gas network construction or upgrading is the density of dwellings in a given area, as an indicator for demand. The typical gas distribution network consists of two main components: (1) the street pipeline network and (2) the service line from the street network to the dwelling (including riser and meter under Option B). Costs are extremely sensitive to urban density, both horizontal (built-up area at ground level over the surface of a given district) and vertical (overall built-up area over built-up area at ground level); urban density may vary significantly within a given city, even within a district. The figures in the following discussion are thus intended to give a tentative average cost estimate of gas distribution. This would need to be refined for a feasibility study.

According to the six case studies, the current operating conditions of the existing gas networks are generally considered unsuitable for the extension of gas operations to space heating. The main factor is the technical condition of the networks. Lack of cathodic protection in all or part of the systems, most of which are made of welded steel pipes, leads to pipe corrosion. In older networks—for instance in Wroclaw—25 percent of the network is still made of cast iron pipes designed for humid town gas. Where dryer natural gas has caused the joints to dry up, extensive gas leakage results. Another important issue is the constrained capacity of the networks that have been designed to operate at LP (20 mbar). Increasing operating pressure to MP would significantly increase network capacity and the ability to supply gas for space heating. However, this would decrease in the same proportion the safety conditions of the networks that are known to be leaky.

To increase the capacity of a network while increasing safety, technical solutions exist such as relining existing steel pipes with new, smaller PE pipes. As a rule of thumb, 63-millimeter (2-inch) PE pipes can be inserted into 100 millimeters steel or cast iron pipes, provided they are reasonably clean and straight. Cost savings are in the range of 20 to 30 percent, as compared to a new network. However, it implies that the technical data of the existing network (routing, location of service lines, diameters, special points) are available, which may not be the case. In Timisoara, for example, the small size of the existing 2-bar sub-network (75 percent of which is smaller than 4 inches), as well as the unavailability of the as-built drawings prevent relining from being considered on a large scale.

Wherever a new network would have to be built, case studies show that, in a typical city where buildings are equipped with building boilers (Option A from Table 3-5), the expected cost for the street network is US$160–180 per dwelling, and about US$370 for a detached house, for which the length of network per consumer is higher. The cost of the service line on a per-dwelling basis ranges from US$130 to US$160 (Option A); it reaches US$180 (Option B, apartment) to US$280 (Option C, house), including a meter and regulator. On average, the cost of the underground network is an estimated US$300–330 per household. In a medium-sized city such as Timisoara, the economic cost of a new network designed to supply building boilers, based on Western European standards, is estimated at US$46 million.

Where overall technical conditions are better, satisfactory safety and operating conditions may be achieved through a more modest scheme. In Wroclaw, where the two major issues are the condition of the cast iron pipes and a capacity constraint in the south of the city, it is estimated that the network could be upgraded through the complete replacement of the leaky sub-network, the construction of a new city gate station in the south associated with the extension of the MP ring, and the replacement of a limited portion of the steel network. Overall cost is estimated at US$14 million; i.e., about US$100 per household.

3.2.3.2 Appliances

Appliances represent by far the largest share of the prospective investment. Based on conventional, sturdy equipment easy to install and operate, rather than expensive, sophisticated equipment such as condensation boilers, the cost of the building boilers represent about 70 percent of the total cost of the system investment. The ratio is even higher for decentralized appliances. Since Western European equipment has been considered, only limited differences caused by transportation costs and price variations among suppliers are to be found.[46] In Option A, the cost of a building boiler on a per-dwelling basis, without civil works, is estimated at US$700–750 for a medium-sized building (25 to 50 dwellings). Where a dedicated boiler-house and an associated underground hot water piping system have to be installed, an additional US$50–100 must be considered, depending on local conditions. In Option B, the cost of the individual gas heaters, plus a water heater and a cooking range, would be about US$1,000 for a typical apartment and US$1,200 for a house.

According to Table 3-6, for Option A, total investment cost (network and appliances) amounts to about US$1,100 for an apartment in a typical medium-sized apartment building (40 dwellings) in

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[46] Within the ESMAP project, a market survey of appliances for decentralized heat and water supply was conducted in Lithuania and Poland in 1995. At that time, virtually all European brands were available in Warsaw, whereas the selection in Vilnius was more limited. See *Biomass Technology Group (BTG): Small-Scale Heating Systems in Lithuania* (Consultant Report, Washington, D.C., ESMAP, May 1995.). Gas appliance costs could be somewhat lower for locally manufactured equipment or for equipment procured through large-scale contracts.

which heat is supplied by a building boiler connected to an existing hot water system. For Option B, the cost is estimated at US$1,400 for an apartment, and US$1,850 for a double-family house. Cost estimates for Timisoara and Sofia confirm that building boilers are cheaper than apartment gas heaters and much cheaper than apartment boilers. In addition to being more expensive, these very decentralized solutions would be more difficult to implement in existing apartment buildings because this would require that all households agree to invest substantial amounts of money.

Table 3-6. Summary of Typical Investment Costs for Increased Residential Gas Use, per dwelling (US$)

Component	*Option A (apartment)*	*Option B (apartment)*	*Option B (house)*
Network	160 to 180	180	370
Service line	130 to 160	110	210
Meter (including installation)	Included in service line	60	70
Boiler-house	50 to 100	N/A	N/A
Gas appliances (including installation)	700 to 750	1050	1,200
Total Cost	1,100 to 1,200	1,400	1,850

Source: World Bank staff.

3.3 Options for Energy Savings in Buildings[47]

DH systems deliver hot water for space heating and DHW to buildings. The majority of them are large apartment buildings, followed by schools, hospitals, office buildings, and industrial buildings. Essentially all buildings in CEE/FSU suffer from the same problems: they are poorly insulated and poorly maintained, and individual heat controls and meters do not exist. These features lead to a specific heat consumption that is much higher than in Western Europe under similar climatic conditions. The following section discusses which measures are available to make buildings more energy-efficient. While they are essentially the same for the various types of buildings, the profitability of measures will vary with the use of buildings. For example, schools are not used at night and on weekends and therefore controls with night setbacks would be highly efficient in reducing heat consumption.

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[47] This section, section 5.2.7, and Annex E are based largely on Martinot, Eric (1997), "Investments to Improve the Energy Efficiency of Existing Residential Buildings in Countries of the Former Soviet Union," *Studies of Economies in Transition 24* (Washington, D.C.: The World Bank). He analyzes the experience gathered during the preparation of several Bank lending projects in FSU countries from 1994-1996. He covers both the broader housing sector transitions taking place in these countries and the specific technical, economic, social, and institutional aspects of energy efficiency improvements.

3.3.1 Energy Efficiency Measures

Many technical studies of energy efficiency in buildings in CEE/FSU have been conducted in the past few years, and there is a large and growing body of experience from retrofit demonstration projects (Martinot 1997, p. 25). These studies and experiences demonstrate that packages of energy efficiency measures in buildings offer technical opportunities to reduce the energy consumption of a residential building by as much as 25–30 percent and even up to 50 percent, at attractive economic and financial rates of return.

Technical measures can be grouped into three categories: (1) passive-technology measures, such as insulation, ventilation improvements, improved balancing, and low-flow shower heads that reduce the energy required to produce given levels of comfort and service; (2) behavior-related measures, such as valves and controllers, which allow occupants to regulate and control their energy consumption to desired levels of comfort and service; and (3) meters, which alter the way heat payments are calculated and create incentives for energy efficiency investments and energy consumption reductions. In general, passive technology measures are independent of household behavior and social institutions because they require no active intervention to reduce energy consumption, while behavior-related measures depend on household behavior and institutional conditions. The effects of meters depend on the existence of institutions and administrative systems for consumption-based metering and billing and on tariff policies and other institutional factors (see section 5.2.5).

Table 3-7. Typical Energy Efficiency Measures in Buildings

Passive technology measures			*Investments in Metering and in Regulation of Heat Demand*
Tier I	*Tier II*	*Tier III*	
• Improve windows • Replace or install heat pipe insulation in the basements • Install attic floor insulation • Renovate or replace building substations • Renovate or replace building entry doors, including door closer • Improve staircase windows • Renovate or replace apartment doors to staircases • Improve passive ventilation systems • Install low-flow showerheads and faucets	• Add additional roof insulation • Install heat riser balancing valves and controls • Improve hot water temperature control and availability • Renovate selected windows or add a third windowpane • Install slot-ventilators in window • Tighten outside joints between exterior wall panels	• Install exterior or interior wall insulation • Install active ventilation systems • Replace radiators • Replace one-pipe system with two-pipe systems • Replace windows • Install apartment-level hot water meters	• Install building-level heat meters • Install building-level heat controls • Install radiator thermostatic valves • Install apartment-level heat meters

Source: Martinot 1997.

Within the passive technology category, basic technical measures can be grouped into three tiers, representing different levels of economic viability under full economic cost (unsubsidized) heat prices in CEE/FSU countries. These are as follows:

Tier I: Basic measures that have short-to-medium payback times (often less than five years) and are typical of basic retrofit packages.

Tier II: Measures that present higher or more variable or uncertain (but potentially short) payback times, and whose use depends more on building characteristics and the overall retrofit package design.

Tier III: Measures that are generally not cost-effective by themselves, but that may be included in building retrofit packages whose goal is to provide a high degree of energy consumption reduction and/or in conjunction with more extensive building modernization or renovation.

Table 3-7 summarizes typical measures in each of the three tiers. Annex E explains them in more detail.

For some types of building renovations, there is also the issue of opportunity and sequence. Some measures can only be undertaken in conjunction with major renovation work (if walls are opened, for example, to repair moisture damage). So in evaluating economic possibilities, it must be known which measures can only be undertaken profitably when other measures are also undertaken (whether or not related to energy), or which measures are dependent on others occurring first.

Although many of the above retrofit strategies are straightforward (i.e., windows, insulation, and heating equipment renovation), heat metering and controls in buildings are of special importance, pose special problems, and deserve greater attention. Measures for metering and regulation of heat demand include both (1) building-level heat meters, valves, and automatic control systems for controlling the heat entering the building and (2) apartment-level heat meters and thermostatic radiator valves for controlling the heat in individual apartments. Building-level meters for measuring total building consumption are an essential part of any retrofit strategy. The question of metering at the apartment level, however, is more complex. Based on experience in the Nordic countries, there is little doubt that households in collectively metered buildings (i.e., with building-level meters but not apartment-level meters) consume more heat per square meter than households in buildings with apartment-level meters. Occupants tend to be more responsive when they can see (and have to pay for) their individual consumption. Controls are equally important. If the occupants of each unit are to be responsible for their own consumption, they must have control over the amount of heat they actually use. In Western Europe, dwelling occupants throttle back heat by using a variety of systems, including thermostatic valves on each radiator, outdoor temperature sensors controlling the flow of heat to the building (or combustion in the boiler), or shunts that permit closing of any room or radiator. In CEE/FSU, these measures are slowly being introduced (see section 5.2.5).

3.3.2 Integrated Combinations of Retrofit Measures

Although it is possible to analyze the energy efficiency potential of individual measures or technologies, most building renovations will include combinations of measures, and the net effect is achieved through the interaction of the individual effects, both positively and negatively. Actual savings from such measures depend on how they are combined. Integrated analysis of packages of measures is therefore preferable. For example, large apartment buildings have complex heating systems. Changes in heat losses through outside surfaces affect the basic heat load of the heating system and air infiltration as well. Thus, improving the thermal resistance of exterior building surfaces should not be done without making appropriate renovations and/or adjustments to heating controls. Otherwise, a mismatch between supply and demand will occur, and the over-dimensioned system will simply provide too much heat. Similarly, applying insulation without weather-stripping and careful caulking of cracks, as well as improving the windows ignores the obvious problems of air infiltration—especially important in the tallest buildings. If significant temperature differences build up between warmer lower floors and colder upper floors, convection currents of air rise in the staircases and elevator shafts (the so-called chimney effect), and draw in outdoor air through the windows of lower-floor apartments, cooling the building and wasting heat.

Although there may be good information on the cost-effectiveness of individual measures taken in isolation, estimating a measure's economic performance in combination with other retrofits is more complex. The optimal mix of retrofits varies from one building to another depending on a number of different factors, including building characteristics, climate, and utility cost structure. To some degree, space-heating measures are substitutes for hot water and household appliance measures: households periodically use the gas range and/or fill the bathtub with hot water to generate extra heat. In addition, lighting fixtures and the motors of household appliances generate waste heat that may contribute to total heating energy, particularly in small spaces. Some retrofits are substitutes for each other; for example, installation of exterior insulation may make radiator reflectors much less cost-effective.

Generalizing from the existing studies and demonstration projects, the following conclusions are possible: A basic package of measures, including heat meters, weather stripping of windows, heat balancing, and building-level heat controls, costs about US$300–900 per apartment and could be conservatively expected to save 10–20 percent of heat consumption.[48] The next-level package includes in addition measures for roof or attic insulation and additional piping insulation, and perhaps extra windowpanes on the top floor. This costs about US$700–1300 per apartment and could be expected to save 15–30 percent of heat consumption. A more comprehensive renovation could cost US$1500–3000 or more per apartment and could save 40–50 percent of heat consumption. Integrated combinations of these measures can be designed to offer financial payback periods[49] of five years or less (assuming a heat price of US$20/Gcal), although there is some variation depending on building type and climate zone. Some potential measures, such as exterior wall insulation, have significantly longer payback periods by themselves and thus extend the payback periods of combinations that include them.

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[48] A package similar to this one has been used in four of the case studies to analyze the impact of demand side energy efficiency measures on the competitiveness of heating systems; see Table E-1 in Annex E.

[49] The term "payback period" refers to simple payback time calculated as total investment cost divided by annual *financial* savings.

Package costs may also vary substantially between different countries because of variations in wage and material costs. Payback times can sometimes be high for low-cost, high-savings packages because of the composition of packages and building size. For example, a large building with roof renovation may have low per-apartment costs, but the roof renovation may add substantially to total costs without providing much energy savings, thus driving up payback times. Energy savings associated with the investments also vary depending on building characteristics, as well as on "before and after" room temperatures, methods of heat consumption measurement and tariff calculation, household behavior, and analytical assumptions. In addition, energy savings can vary substantially because of significant diversity among apartment buildings and DH systems.

The above generalizations about technical measures, energy savings, and financial returns are just that—they provide an aggregate picture based upon knowledge of the overall characteristics of the building stock, DH systems, climate, technologies, costs, and existing energy prices. Despite the standardized nature of building design and provision of centralized DH systems, conditions vary greatly from one building to another, even between buildings of identical types. It is more difficult to predict the savings from a retrofit package in a single building, even with sophisticated building heating models, than to predict savings in a large number of buildings. For the larger number of buildings, the actual results on average will more closely agree with what the models predict. Thus, implementation of actual investments on a building level requires careful investigation of individual buildings or groups of buildings.

In general, the DH and building energy efficiency problems lend themselves well to concepts of least-cost, integrated resource planning concepts when looked at from a system viewpoint. Housing rehabilitation, DH system rehabilitation, new autonomous (building-level) sources of heat, and new DH system additions can all be considered in the context of least-cost solutions to deliver necessary energy services. Together, these investments will ultimately result in providing lower-cost, higher-quality heat to consumers.

Economically, these energy efficiency measures are viable as long the incremental (or marginal) cost of the last measure is lower than or equal to the incremental cost of the DH supply. Ideally, the task can best be done in a planning process that integrates supply and demand sides, such as Least-Cost Planning and Integrated Resource Planning.

4

Identification of Least-Cost Heating Options: Results of the Six Case Studies

4.1 Factors Affecting the Cost Advantage of District Heating

4.1.1 Sources of Competitive Advantage and Disadvantage of District Heating: An Overview

The ability to produce heat at a lower cost than individual boilers is the source of the competitive advantage of DH.[50] The cost advantage is due to the following, in order of analysis in this section:

- ❑ Economies of scale in fuel purchases,
- ❑ The ability to use cheap and low-grade fuels in large generation facilities in an environmentally compatible manner,
- ❑ The ability to use large CHP[51] and benefit from the fuel savings of cogeneration,
- ❑ The lower unit investment cost of and energy efficiency gains from larger boilers,[52]

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[50] It is also the source of the environmental advantage; see section 4.3.

[51] The development of decentralized cogeneration technologies (e.g., small gas turbines) and the deregulation of energy markets has started to reduce the need for large DH systems as off-takers of heat from large CHP plants. Currently, these new technologies are competitive only in niche markets, but they will be able to realize many of the same benefits as large cogeneration units in smaller, less centralized systems. In addition, they will reduce or even remove the competitive disadvantages due to heat transport costs by reducing the need for large networks.

[52] However, highly efficient small boilers (even for one-family houses) for natural gas and LFO are now supplied by boiler manufacturers.

- Merit order operation of heat sources, and
- Systematic maintenance.

A high share of heat produced simultaneously with electricity in the CHP process is the most important success factor for DH. The economic impact of CHP production on heat costs is analyzed in section 4.1.2.

The cost of transporting heat from the boiler plant to the consumer is the source of the competitive disadvantage of DH. The cost of transport comprises two components:

- The levelized cost of the investment in the transmission and distribution system; and
- The cost of O&M. The energy and water losses in DH systems contribute to high O&M costs, as well as costs of pumping electricity and pipeline maintenance.

The density of heat demand per kilometer of trace pipeline or per square kilometer of area served by DH is an important indicator for the cost of distribution. For a critical assessment, see Annex F.

4.1.2 Factors Affecting the Cost of Heat Production

4.1.2.1 Cost of Fuel

The ability to purchase and use fuels at a lower cost than competing decentralized sources of production is a factor in favor of large DH systems. In the past, the use of relatively cheap coal and high-sulfur HFO provided the economic basis for a number of DH projects. Large-scale HOB and CHP plants also enjoy a price advantage when they purchase natural gas.[53]

The following analysis of the role of fuel costs in the cost of heat production of various heat supply technologies is based on the economic costs of fuels; that is, costs that do not take into account subsidies or taxes. In the six cities where the case studies were carried out, heat production is based on natural gas or coal; mazut is used only to a small extent. The following analysis is based on the costs of natural gas when using various generation technologies. Gas would be the fuel of choice in more decentralized technologies for its environmental qualities and ease of handling. Where the economic cost of coal is lower than the economic cost of natural gas, the former may be the fuel of choice in large plants where the abatement costs are relatively lower.

The calculated economic cost of natural gas supply per category of consumer in the six case studies is shown in Table 4-1. The economic cost of natural gas supply to CHP plants is about 70–85 percent of the cost of supplying gas to a building boiler. Because the cost of gas

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[53] The advantage will be reduced if several plants at several sites have to be supplied.

distribution is much lower than the cost of heat distribution,[54] the cost advantage in the price of natural gas is obviously not sufficient to justify investments in a DH system.

Table 4-1. Cost of Fuel Delivered to District Heating Plants and Building Boilers

City	Economic Cost of natural gas at city gate, ($/1000m³)[a]	Central CHP/HOB plant		Local HOB plant	Building boiler	Difference-CHP and building boiler (gas) ($/MWh)
		Natural gas	Coal, HFO	Natural gas	Natural gas	
Dnipropetrovsk	83.3	$8.2/MWh	$5.9/MWh	$9.8/MWh b)	$9.8/MWh b)	1.6
		$9.6/Gcal	$6.9/Gcal	$11.4/Gcal	$11.4/Gcal	
Kaunas	85.5	$9.7/MWh	$6.0/MWh	$11.6/MWh b)	$11.6/MWh b)	1.9
		$11.4/Gcal	$7.0/Gcal	$13.6 / Gcal	$13.6/Gcal	
Orenburg	45	$5.9/MWh	N/A	$8.2/MWh c)	$8.2/Mwh c)	3.9
		$5.1 / Gcal		$7.0 / Gcal	$7.0 / Gcal	
Sofia	114.8	$11.6/MWh	N/A	$13.3/MWh	$14.4/MWH	2.8
		$13.5/Gcal		$15.5/Gcal	$16.8/Gcal	
Timisoara	114.8	$11.8/MWh	$7.3/MWh	$12.6/MWh	$14.0/MWh	2.2
		$13.7/Gcal	$8.8/Gcal	$14.7/Gcal	$16.3/Gcal	
Wroclaw	117.6	$11.6/MWh	$6.5/MWh	$15.7/MWh	$18.9/MWh	3.2
		$13.5 / Gcal	$7.6 Gcal	$18.3/Gcal	$22.0/Gcal	
Average	N/A	$9.8/MWh	$6.4/MWh	$11.9/MWh	$12.8/MWh	2.6
		$11.4/Gcal	$7.4/Gcal	$13.8/Gcal	$14.8/Gcal	3.0

N/A not applicable.

a. Economic cost of fuel as calculated for the six case studies; see Annex F, Tables F-1 and F-2.

b. Rough calculations that added 20 percent to the cost of natural gas at the CHP plant.

c. For Orenburg, economic cost of gas is approximately equal for HOB and building boilers.

Source: ESMAP case studies.

Alternative "lower-grade" fuels have a cost advantage in some cities. In Kaunas the cost of HFO is 62 percent of the cost of natural gas; and in Timisoara and Wroclaw the cost of coal is, respectively, 62 percent and 56 percent of the economic cost of natural gas at the CHP/HOB plants. Compared to the cost of natural gas for building boilers, the cost is even lower: 52 percent, 52 percent, and 34 percent for these three cities, respectively. Some of the cost advantage of the low fuel cost is eroded by higher costs of investments (including environmental) and of operation. In Kaunas, it is questionable whether the continued use of mazut (with a 3.5 percent sulfur content) is compatible with national requirements for local ambient air quality standards. Yet, it is obvious from these figures that the ability to use cheap, "dirty" fuels in an environmentally compatible manner (see section 4.3) is a factor that favors the use of DH.

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[54] The cost of investment in the gas network and the level of energy losses are both a fraction of the cost of a distribution system for DH.

The use of biomass fuels such as wood chips, peat, and straw, which is an option in some regions of CEE/FSU, was not analyzed in the case studies. Experiences from Estonia confirm that using wood chips rather than HFO or natural gas can reduce fuel costs while at the same time enhancing fuel security.

4.1.2.2 Non-fuel Cost of Boiler Operation

Economies of scale are also found in the non-fuel costs of boiler operation. The unit costs of investment in a boiler ($/kW) and the unit cost of O&M ($/Gcal) decrease with the increasing size of the boiler. Due to the diversity of consumer peak demand, a DH system (especially when operating in a variable flow regime) requires less installed boiler capacity than a system of heat supply based on building boilers.[55] Together, these three factors reduce the non-fuel cost of heat production in a DH system to roughly 40 percent of the cost of a building boiler (see Table 4-2.)

The non-fuel costs of CHPs shown in Table 4-2 implicitly assume that additional costs for the CHP/HOB plant are equivalent to those of the heat extraction equipment. This is generally correct for gas turbines, but not for combined cycle plants. In contrast, if power production is based on a steam turbine, the higher outlet temperature reduces power capacity. These costs of reduced power generation capacity have to be covered by DH. Therefore, these figures should be considered an approximation.

Table 4-2. Non-fuel Costs of Boiler Operation: District Heating Plants Versus Building Boilers

	Centralized CHP or HOB	*Local block boiler*	*200-kW boiler*
Cost of investment (US$/MW)	50,000	50,000	100,000
Coincidence factor of peak demand	0.8	0.9	1
Lifetime in years	30	25	20
Annual full load operating hours	2200	2200	2200
Annual cost of O&M as % of investment	2%	2.5%	3%
Cost of operation (US$/MWh heat)	2.4	3.9	6.7

Source Based with slight modifications on *Ukraine: Kiev District Heating Improvement Project*, Staff Appraisal Report (Washington, DC: World Bank, April 1998).

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[55] In some FSU countries, a reserve capacity of 100 percent is required for building boilers. Based on the reliability of modern gas boilers, a reserve capacity of 10–15 percent is usually considered sufficient. More precisely, the required reserve capacity depends on the number of heat generation units. The larger the number of units, the lower the impact of a failure on the whole system.

4.1.2.3 Cost of Heat Production

As mentioned earlier, because of the joint production process and the use of waste heat, heat and power can be produced at higher efficiencies and comparatively lower costs in cogeneration than in separate processes. However, DH enjoys a price advantage when using CHP rather than HOBs only if at least some of the efficiency benefits are allocated to heat. The cost advantage of CHP production depends largely on the level of the electricity tariff, which varies according to the situation of the national power markets.

The economic problem when determining the individual costs of both products—that is, heat and power—is that the production process is a coupled (or joint) process that produces both products simultaneously. Some of the costs can clearly be assigned to the respective products, such as heat transfer to the primary network. Others are consumed jointly, such as fuel.[56] Basically, any method to allocate these common costs is arbitrary. Once the decision about the method has been taken and the cost allocation formula has been determined, the costs of both products can easily be determined. Annex C introduces the methodologies for calculating the impact of cogeneration on the cost of heat production.

The guiding principle in Western Europe is that the economic/financial cost of heat supply in CHP is the difference between the total cost of CHP and the economic/financial value of the sales of electricity from the plant. However, if there is no corresponding regulation, deviations from this principle are normal and prices are negotiated. When there is power scarcity, the price of power in the national market will be favorable, resulting in high revenues from power, and resulting in a low cost left to bear for heat. The reverse is true in times of over-supply of power.

Both the actual and optimal share of heat supply from CHP plants in total depends, therefore, on the power situation in each country. Table 4-3 gives an overview for the case study countries. It also presents estimates of the long-run marginal cost of electricity in each country. In countries with higher economic costs of electricity production, the share of CHP tends to be higher.[57]

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[56] Other installations are also used jointly, such as steam boilers. However, the usual medium for DH is hot water, and hot water production does not require steam boilers. The question arises whether those costs should be attributed to DH.

[57] In comparison, the share of CHP-produced heat in Finland and Denmark is more than 70 percent. During the past 15 years, all large power plants have been constructed as CHP plants from the start. The development of small (10–50 MW) decentralized CHP plants was initially supported by economic incentives; it has now become commercially viable.

Table 4-3. Electricity Production Cost and CHP Situation within Power Sector, by Country

Country	*Long-run marginal cost of electricity (LRMC), US$/kWh*	*Power generation and CHP share*
Bulgaria	0.0335 (generation)	45 percent of electricity production from Kozloduy nuclear plant
Lithuania	0.028 (export price)	More than 90 percent of district heat in Kaunas and in Vilnius is produced by HOBs. The installed electricity generating capacity of the CHP plants is rather low compared with the demand for heat generating capacity. In addition, it is little used because the production capacity of the Ignalina nuclear power plant is sufficient to cover the national demand for electricity, as well as exports to Latvia and Kaliningrad. The electricity production capacity of the CHP plants serves as standby when one of the nuclear reactors is taken out of operation for inspection or maintenance.
Poland	0.045	20–30 percent of district heat and 10 percent of electricity are produced in cogeneration. Many thermal power plants are located near the coalfields—too far from the urban centers to be useful for DH.
Romania	0.042	Total installed power generating capacity is about 22,000 MW; 38 percent of total installed thermal capacity of 14,829 is in cogeneration. Current peak demand of about 9,000 MW can hardly be met due to plant design and construction deficiencies, use of low quality fuels and inadequate O&M practices.
Russia	0.025	About one-half of district heat is produced by cogeneration plants and one-half by HOBs. Cogenerated heat is about 26% of total heat production; cogenerated electricity about 30% of total thermal power production under RAO EES Rossii. Due to considerable surplus capacity, however, the long-run-marginal cost of electricity is too low to justify investments in new, modern CHP capacity.
Ukraine	0.035	In Ukraine, heat-only boilers produce more than two-thirds of heat. The justification for new CHP capacity depends on the fate of the nuclear power plant at Chernobyl.

Source: World Bank staff.

For the analysis in this chapter, it is assumed that the electricity tariff (or more precisely, the long-run-marginal cost of electricity production) is high enough to transfer "all" of the CHP cost advantage to DH. This requires a tariff of around US$0.04/kWh (for the case study results, see section 4.2). In the calculations inherent in the following tables and discussions, it is assumed that the cost of investment in heat extraction per MWh is the same as the cost of investment in boilers used in large HOB plants. Under these simplified assumptions, the cost impact is shown in Table 4-4. Maximum use of the economic potential for CHP when natural gas is used as fuel reduces the cost of heat production at the central heating plants by one-third (or up to US$5 per MWh) compared to HOB operation, and by almost two-thirds (or roughly US$14 per MWh) compared to the cost of heat production of building boilers.

The first conclusion to be derived from Table 4-4 is that DH based on optimized gas-fired CHP can compete with building boilers in an average city in CEE/FSU as long as the cost of heat transport to consumers is below about US$14 per MWh. The second conclusion is that the situation concerning the cost of heat production is very site specific. Differences around the average of "allowable" heat transport cost range from US$10 in Orenburg (where the low economic value of gas at the city gate reduces the value of cost savings) to US$20 in Wroclaw.

Table 4-4. Comparative Cost of Heat Production ex Plant (US$/MWh)

	CHP[a] (153%)	Large HOB (85% effic.)	Local HOB (85% effic.)	Build. boiler (80% effic.)	Cost difference CHP and build. boiler	
					US$/MWh	Ratio (%)
Dnipropetrovsk	$7.7	$12.1	$15.4	$19.0	$11.3	44
Kaunas	$8.6	$13.7	$17.6	$21.2	$12.6	45
Orenburg	$6.3	$9.3	$14.8	$17.0	$10.7	39
Sofia	$9.9	$16.1	$19.5	$24.7	$14.8	44
Timisoara	$10.0	$16.3	$18.7	$24.2	$14.2	45
Wroclaw	$9.9	$16.1	$22.4	$30.3	$20.4	36
AVERAGE	$8.7	$13.9	$18.1	$22.7	$14	39

a. Producing 80 percent of annual heat production from CHP with 170 percent efficiency (see Annex C) and 20 percent from HOB with 85 percent efficiency.

Note: Table cost figures exclude heat losses.

Source: World Bank staff estimates based on ESMAP case studies.

When comparing CHP-based DH with building boilers, heat losses in transmission and distribution need to be taken into account. These heat losses require a higher heat output at the level of the DH plants to deliver the same amount of heat to a building as a building boiler. Heat losses are part of the cost of heat transport; these are analyzed in section 4.1.3. Figure 4-1 promotes this discussion by analyzing the impact of the level of heat losses on the difference in the cost of heat production ex-plant between a CHP-supplied system and a system supplied by a building boiler, including the need for higher production.

Whereas an efficient DH system located in an area of high demand density has heat losses of less than 10 percent, more-inefficient systems, or efficient systems located in areas with low demand densities, will have losses of up to 35 percent. Figure 4-1 shows the relatively limited impact of heat losses on the cost advantage of "optimized CHP-production." As long as the cost of heat transport (capital cost + O&M costs, excluding the cost of heat losses) is below US$11.80–13.10 per MWh, the DH system is competitive. For DH based solely on HOB plants, the situation is much less favorable. The cost of transport has to be below US$5.30–7.40.

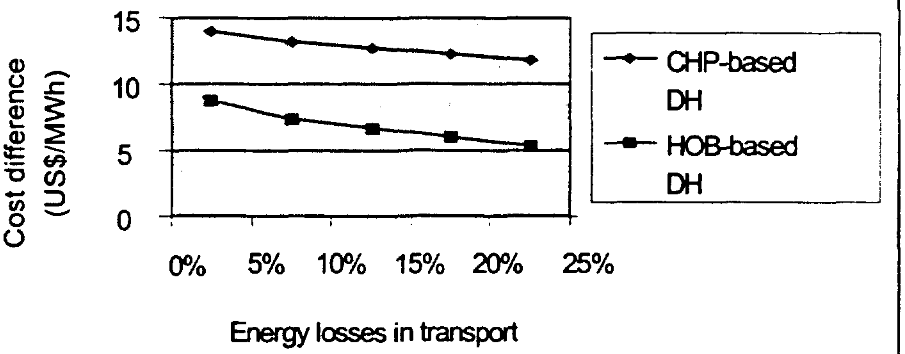
4.1.3 Factors Affecting the Cost of Heat Distribution

4.1.2.4 Structure and Distribution of Heat Demand

The size, structure, and distribution of heat demand within space is a determining factor of the heat distribution costs. Obviously, it will be cheaper to construct a distribution network when customers are concentrated rather than dispersed over a large area. Furthermore, a distribution system for a few big customers (each with large heat demand) will be cheaper than for a large number of small customers (each requiring their own connection pipes). The so-called heat density is a convenient, if simplified indicator that quantifies this relationship. If a high heat demand is concentrated in a small area, heat density is high.

The cost of heat distribution is usually a decreasing function of the density of heat demand.[58] The shorter the network per MW or per MWh of annual demand, the lower is the cost of investment and the lower are the heat and water losses per MWh sold to the consumer.[59]

Figure 4-1. District Heating Versus Building Boilers: Cost Advantage at Plant Level



Source: World Bank staff estimates based on ESMAP case studies; see Tables F-3 and F-4 in Annex F.

Table 4-5 shows the heat density of the cities in the six case studies. The cities have quite different climatic conditions. Nevertheless, there is no significant correlation between climatic conditions and heat density. The other determining factors (e.g., use of land, share of connected buildings, network architecture) seem to have a larger influence. A comparison of the differences and similarities in Orenburg and Wroclaw shows the interaction of the different factors. Orenburg has significantly more degree-days than Wroclaw. Wroclaw has a higher building density, with 18 dwellings per hectare versus 13 in Orenburg. In Orenburg, the high energy consumption per square meter of building area gives a relatively high heat load and heat density, although the supply area is large.

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[58] Several measures can be used to express the density of heat demand. The "density of heat capacity" can be expressed in terms of "MW per km of trench pipeline" or as "MW per km^2". The "density of the heat demand" can be expressed in terms of "MWh per km of trench pipeline" or as "MWh per km^2". Comparisons and calculations performed with the heat density are implicitly based on the assumption that the network "architecture" and the distribution of the individual heat loads are equal or at least similar. See Annex F for a discussion of this indicator, its limitations, and its impact on distribution cost.

[59] Heat losses increase both because the transport network becomes longer and because the pipeline diameters become smaller. The level of heat losses per unit of transported heat decreases with the diameter of the pipeline, as long as the capacity of the pipeline is not over-dimensioned compared to demand.

Table 4-5. Density of Heat Demand: Six ESMAP Study Cities

		Heat Load Density[b]	
City	*Degree-days*[a]	*Network (MW/km)*	*Area (MW/km²)*
Dnipropetrovsk	3430	3.6	N/A
Kaunas	3750	4.2	N/A
Orenburg	5071	3.9	24
Sofia	3000	4.7 / 3.8 [c]	N/A
Timisoara	N/A	2.4	79
Wroclaw	3044	3.1	24

N/A: not available.

a. Degree-days = (the target inside temperature minus the average outside temperature during the heating season), multiplied by the number of days in the heating season.

b. Based on MW peak load.

c. Before and after implementation of demand side measures.

Source: ESMAP case studies.

Box 4-1. Model for Screening of Heat Supply Options: Assumptions for Kiev

- Cost of capital (= discount rate) of 10 percent
- Technical life of 20 years for all options
- Centralized boiler cost of $60,000/Gcal/h
- DH network and substation cost of $487,000 per kilometer per Gcal/h
- Gas network cost of $12,000/Gcal/h, (including reinforcing of the present gas network for building-level boilers, typical (300-meter) connection lines to buildings, pressure regulators, and gas meters
- Individual boiler cost of $116,000/Gcal/h, including installation and construction work required for two boiler units to achieve the required reliability and consistency with the building code
- DH network losses of 8 percent
- Operating and maintenance costs of 1.5 percent and 3 percent of capital costs for centralized and decentralized heating systems, respectively
- Gas price of $82.40/1,000 m^3 or $10.20/Gcal
- Peak load duration of 2,200 hours.

Recently, World Bank staff have developed a simplified model for determining the least-cost heating options based on Western technology in a greenfield situation.[60] The model compares the long-run costs at the user level of:

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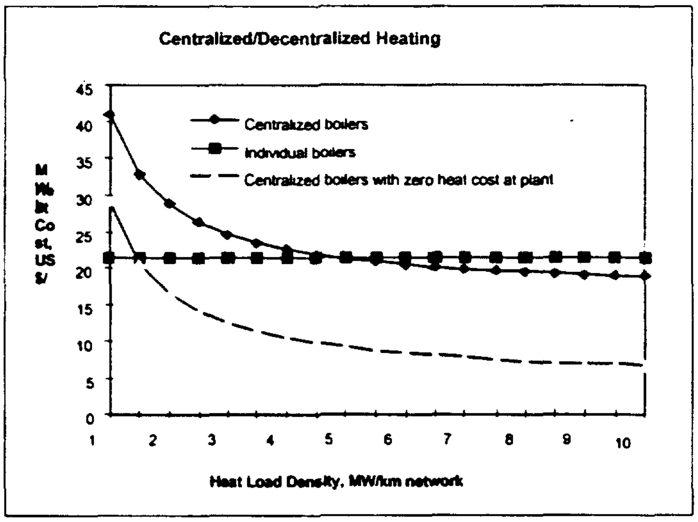
[60] See *Ukraine: Kiev District Heating Improvement Project*, Staff Appraisal Report, (Washington, DC: World Bank, April 1998) p. 34f.

1. a gas-fired centralized HOB plant with hot water DH network, automated substations, and metering;
2. a centralized heat plant with hot water DH network, automated substations, and metering, where the heat cost at the generation plant is zero;[61] and
3. independent gas-fired boilers located in buildings, assuming that existing gas networks reach every building.

For the special case of Kiev, the model assumptions are listed in Box 4-1, and the results are summarized in Figure 4-2.

The results of the screening of heating options are as follows: In areas with a heat density below about 2 MW (1.7 Gcal) per kilometer of network, no form of DH—even if fuel costs are zero—can compete with individual building boilers. Above a heat density of about 5MW (4.3 Gcal) per kilometer of network, DH is the most cost-effective heating option, even if relatively expensive heat from HOBs has to be used. In areas with heat densities between these two values, the available heating options need to be analyzed in detail to determine the most cost-effective heating option. Obviously, the lower and upper limits depend on the specific local costs and requirements.

Figure 4-2. Screening Curves for Heat Supply Options



(Washington, DC: World Bank, April 1998).
Source: Ukraine: Kiev District Heating Improvement Project, Staff Appraisal Report

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[61] Used for comparison purposes for providing the absolute lower limit below which no centralized heat source (whether based on inexpensive or waste fuel, co-generation, free heat from waste incineration or CHP, etc.) can be less expensive than heat from individual boilers in buildings.

4.1.4 Sunk Cost Advantage of District Heating in CEE/FSU

"Sunk costs"—in the form of prior investments that are not past their economic lifetime—reduce the economic and financial costs of heat supply from the DH systems in CEE/FSU. Economic long-run marginal cost calculations do not include the value of past investments because only the cost of future investments is taken into account. This gives an existing DH system a substantial economic cost advantage in economic long-run marginal cost comparisons with decentralized systems that are greenfield investments. Past investments enter the financial cost of supply, and therefore the present tariff, through the depreciation and the payment of interest items in the accounts of a DH company. When past investments have not been debt financed (the situation during the time of the centralized economies), sunk costs reduce the present heat tariff, because the payment of interest on long-term debt is a non-existent cost item.

The existence of such "free" past investments is a social advantage because of the ability-to-pay problems of a majority of the present consumers. An existing DH system will be rehabilitated gradually, starting with the highest priority investments. This permits the DH company to adjust its financial tariffs step-wise toward the level of the true, long-term financial cost of supply. In fact, a DH modernization program may have such high economic and financial rates of return that required tariff increases can be kept low.

Competing options for heat supply, such as natural gas fired building boilers, must be built from scratch. The economic long-run marginal cost of heat supply from these systems includes, from the start, the cost of all investment components that are needed in their heat supply. All of these components also affect the financial cost of heat from the beginning.

All six case studies (and all feasibility studies of larger-sized DH systems in CEE/FSU) show that it is not economic to scrap the existing DH systems and replace them with modern highly efficient DH systems. Rehabilitation of the existing systems leads to a lower cost of heat supply per unit sold. This is the "sunk cost advantage" of the DH systems in CEE/FSU.

The impact of sunk costs is that a DH system that would be inferior in the case of a greenfield investment, may still be the least-cost option for heat supply because the cost of its rehabilitation/ modernization is lower than the cost of a new DH system. This was found to be the case in Sofia, as illustrated in Table 4-6. In the greenfield case, the cost of heat supply from individual gas-fired boilers would be 11 percent less per MWh than the cost of heat supply from a new DH system. The long-run marginal cost of heat supply from rehabilitating the existing DH system, however, is 32 percent less than the cost of a greenfield DH system, and 21 percent less than a switch to building boilers.

Table 4-6. Sunk Cost Advantage of District Heating in Sofia

	Greenfield DHS[a]	*Rehabilitation*[a]	*Building boiler*
Investment	$108,659,000	$45,315,000	$55,260,000
Economic gas price	$11.6/MWh	$11.6/MWh	$14.4/MWh
Unit heat costs	$38/MWh	$27/MWh	$34/MWh

a. Based on LRMC of electricity of US$35/MWh.
Source: ESMAP Sofia case study.

4.2 Least-Cost Supply of Heat in the Six Cities

4.2.1 Scope of Analysis

To identify the least-cost solution for heat supply, the economic and financial costs of the following five different heat supply options were analyzed in the six case studies:

1. *Rehabilitation* of existing DH system with no change in design approach and life extension investments only;
2. *Modernization* of existing DH network;
3. *Modernization plus CHP*: DH network modernization as above and investment in modern, large-scale cogeneration;[62]
4. *Building boilers* on the basis of natural gas; and
5. *Individual gas heaters* for heat and domestic hot water supply in every dwelling.

For every supply option, two demand side options were analyzed:

- ☐ *Business as usual*; that is, only maintenance investment in buildings;
- ☐ *DSM:* that is, investment in energy efficiency measures in buildings with an economic rate of return of at least 10 percent. (For a description of typical packages of measures, see section 3.3 and Annex E, Table E-1.)

The cost allocation issue for CHP was handled in the following way: From the total cost of production the revenue from selling electricity at a price equivalent to LRMC (see Table 4-3) was deducted. The remaining cost are the costs attributable to heat production. They can be compared to the heat costs of the decentralized options 4 and 5. Thus, it is assumed for the economic analysis that the two outputs of a CHP plant have to be competitive on both the electricity market and the heat market in the long term.

Several caveats need to be considered when comparing the results. For each city, the heat supply options were analyzed for the entire area currently supplied with DH. This very general approach, dictated by budget constraints, obviously does not take into account that DH systems supply areas with varying heat densities. Therefore, in a more realistic analysis, in some urban areas, one option might be least-cost, whereas a different one might be able to supply heat in areas with differing characteristics. (See the discussion for Orenburg later in this chapter.) While the aforementioned options and the methodology for the comparative analysis were established for the consulting teams carrying out the case studies, the heat supply and demand options were adapted in some cases because of local circumstances and team preference.

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[62] Decentralized cogeneration on the basis of natural gas and other fuels had been discussed as an option, but in the case studies which evaluated this option, it was usually the most expensive option. For the demonstration project in Dnipropetrovsk (see Annex G), this option turned out to be more expensive than a decentralized gas boiler.

The heat demand to be satisfied by the different heat options was calculated on the basis of a room temperature of 18°C. The level of service was thus assumed uniform independent of consumer preferences or household income. Decentralized heating technologies (such as apartment gas heaters or boilers, as well as modern flexible DH systems) have an added advantage in that households can choose the amount of heat depending on prices as well as their preferences and income. This has not been analyzed explicitly in this report (see section 6.4 in Chapter 6).

4.2.2 Heat Supply Options: The Results

The results of the comparative analysis are summarized in Table 4-7. Although the absolute numbers should not be compared, the ranking of the heat options is informative. Only two of the six case studies clearly came out in favor of DH: Sofia and Wroclaw. In Orenburg and Timisoara, the switch to building boilers would be more attractive than investments in the modernization of the DH system. In Dnipropetrovsk and Kaunas, no option was clearly the most cost-effective.

Table 4-7. Comparison of Heat Supply Options: Six ESMAP Case-Study Cities

Cost/City	*Rehabilitated DHS*	*Modernized DHS*	*Modernized DHS plus CHP*	*Building boilers*
Cost of Heat Supply, US$/Gcal				
Dnipropetrovsk	23.4	23.6	21.1	23.3
Kaunas	35.3	35.1	34.5	34.8
Orenburg	65.5	59.9	36.9	30.2
Wroclaw	44.5[a]		21.3	41.6
Cost of Heat Supply, US$/Gcal (includes DSM)				
Sofia	N/A	31	N/A	39
Timisoara	N/A	N/A	41	31

N/A: not available.

a. The two options (rehabilitated and modernized DHS) coincide; the DH company is already modernizing the system.

Source: ESMAP case studies.

In *Orenburg*, the determining factor for the non-competitiveness of DH is the low economic cost of natural gas in combination with the low long-run marginal cost of electricity. Orenburg is placed on top of huge natural gas resources, which, because of distance, have relatively high transport costs to the borders of the gas importing countries. This makes the netback value of natural gas a low US$45 per 1,000 m^3 (export price minus cost of transport).[63] Since the economic advantage of DH depends on the value of the fuel savings in CHP production compared to individual boiler consumption, the low value of these savings undermines the

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[63] One should note that this economic price is twice as high as the financial price charged by Gazprom to the Orenburg DH company. The former is based on the netback value of the gas; the latter is fixed with reference to the local financial cost of alternative fuels.

economic attractiveness of DH. The long-run marginal cost of electricity is low because of existing surplus capacity in the Russian power system and because of the low economic value of natural gas use in electricity production. The low power price makes investment in the modernization of the CHP plant non-economic. A further factor is the relatively high cost of the investment needed to replace the secondary distribution system with a system of building substations. In Orenburg, DH options would rank even behind apartment heaters, which would result in an economic heat cost of US$36/Gcal.

In *Timisoara*, the essential factor that led to the non-competitiveness of DH is the absence and non-competitiveness of CHP production. In order to make a new CHP plant economically viable, the price per kWh would have to increase to US$0.6/kWh, a price that is 50 percent higher than the cost of power production in modern, gas-fired combined cycle plants. Building boilers would result in lower heating cost even though the secondary gas distribution network would need substantial investment, because it does not have the capacity and ability to meet a higher demand for heating purposes.

In *Wroclaw*, several factors combine to make DH competitive. Even though the heat density is relatively low, the relatively efficient and low-cost heat supply from cogeneration and a DH network that is in relatively good shape—thus requiring less modernization investment—combine to make DH the economically preferred heat supply option. Investment in modern CCGT cogeneration facilities would result in a very low heat price because the cogeneration plants have a higher power as well as heat production capacity, and the additional power would be sold at the system LRMC.

Sofia confirms the results, even though the negative and the positive aspects are less pronounced here than in Wroclaw. Option 3 (modernization of the DH network and a new CHP plant, the latter being part of the so-called greenfield DH system [see Table 4-8]) was not modeled. It might have led to a similar result as in Wroclaw.

Table 4-8. Impact of Demand Side Investments, Sofia DH System

Capacity savings due to investments in:		*Energy savings due to investments in:*		*System efficiency*[a]	
Distribution system[b]	*Adding DSM*	*Distribution system*[b]	*Adding DSM*	*Existing*	*After investment*
5%	20%[c]	19%	43%[c]	65%	78%

a. System = generation, transmission, distribution, and heat transfer (substations).

b. Rehabilitation of the pipeline system and of substations.

c. Internal installations only: installation of thermostatic valves, radiator heat cost allocation for space heating and apartment-based metering for DHW.

Source: Sofia ESMAP case study.

In *Kaunas* as well as in *Dnipropetrovsk*, no heating option stands out as being clearly preferable to others, according to the case studies. In Kaunas, the option of DH network modernization with a modern, large-scale CHP plant has a minimally lower per-unit heat cost than the next-best option, gas-fired building boilers. In Dnipropetrovsk, the unit heat costs are slightly lower for a modernized DH system that is supplied by a modern CHP plant than for the other options. Somewhat as a surprise, the economic heat costs in Dnipropetrovsk are the lowest for all six cities, even though the economic cost of gas—the main fuel—is in a mid-range and only slightly lower than in Kaunas. As mentioned, DH in Kaunas has the disadvantage that there is no demand for the electricity output of the CHP plant due to very cheap and abundant electricity supplied from the Ignalina nuclear power plant. Only a part of Dnipropetrovsk is currently supplied with heat from an old CHP plant. Among the six cities, the heat density in Kaunas is the highest after Sofia. The condition of the networks in Kaunas and Dnipropetrovsk seems to be fairly similar, with losses of about 25 percent in the secondary four-pipe systems. Just like in Orenburg, a more differentiated approach might have led to different heat supply options being chosen for different parts of the city (see Box 4-2).

Box 4.2 Caveats regarding Orenburg, Dnipropetrovsk, and Kaunas

A more detailed analysis of heat supply in the cities would most probably have resulted in mixed results:

In **Orenburg**, the part of the city around the existing CHP plant has a very high heat density. Here, it would probably make sense to modernize the DH system. An existing feasibility study for this area unfortunately was not accessible to the consultants. The areas further south, characterized by a relatively low load density, are either served with the help of a long DH transmission line or by small HOBs. Here, the switch to building boilers is probably least cost.

In **Dnipropetrovsk**, more detailed analysis of one of the separate DH networks was carried out to determine the components of a follow-up demonstration project (see Annex G). Building boilers proved to be more cost-effective than continued DH supply for two buildings with a big heatload at the end of this network. In 1998, they were cut off from DH supply, and a gas-fired building boiler has been installed and basic demand side measures in the buildings have been undertaken.

In **Kaunas**, a feasibility study was undertaken in 1997 for a DH investment project to be financed by the EBRD. A least-cost analysis or heat master plan was not carried out. Investments were proposed in parts of the DH system where the biggest efficiency improvements could be achieved. This resulted in the design of a project with attractive rates of return.

4.2.3 The Impact of Demand Side Investments on the Ranking of Heating Options

Investments in the energy-efficient retrofit of buildings result in reductions in heat demand. This has several implications for alternative options for heat supply:

- Heat capacity savings from demand side improvements can reduce investment requirements for new capacity or delay their necessity by a number of years. If DH supply curtailments exist—not because of economic considerations but because of capacity shortages—then demand side investments may result in the avoided capital costs of constructing new capacity. For Sofia, the beneficial impact of demand side investments both on capacity and on energy savings is demonstrated in Table 4-8. Taking the system as a whole (i.e., generation, transmission, distribution, and heat transfer [substations]) overall efficiency with regard to the ratio of energy output to fuel input would be increased from 65 percent to 78 percent.

- In CEE/FSU, substations are often owned by DH companies. However, the benefits of investments in substation modernization (i.e., installation of flow control devices such as control valves and circulation pumps) should be assigned to the demand side because they reduce the heat demand of a building by more than 15 percent (see also Boxes A-1 and A-2 in Annex A).
- Demand-side improvements can allow old and inefficient heating plants to be shut down. If less efficient or obsolete heat sources still operate because of capacity shortage—a common situation, then, on the margin, the value of shutting down these sources through investments in energy efficiency can be much greater than the average heat production cost.
- Investments in controls in DH systems have short payback times and they could increase the efficiency gains possible from demand side improvements. For example, underheating and overheating of apartments can be addressed through building-level heat controllers, but heat losses in poorly controlled distribution systems may still be high. Coordinated heat control in both buildings and in associated DH systems represents an even more efficient solution.
- With nascent competition in the heat market and/or the implementation of effective performance or/and price regulation for DH companies, awareness of transmission and distribution losses will increase.[64] Demand side metering will place responsibility (and the costs) of distribution pipeline losses on the DH company, which will then have new incentives to directly reduce distribution losses or redesign systems to achieve in lower distribution losses. DH companies in CEE/FSU have had no incentive to invest in improving the energy efficiency of their distribution networks, which have substantial losses. This is because they charge municipal governments or enterprises rather than individual consumers for heat supplied to residential buildings as it leaves the power plant (minus metered industrial loads connected to the same system), *not* as it enters buildings. Under the old system, heating tariffs for building heat consumption have been calculated based on design or theoretical norms of consumption and have included an allowance for distribution losses, so that tariffs are supposed to correspond to heat produced at the power plant, rather than that consumed at the building. Thus, the incentives (with consumers) and responsibility (with the heat supply company) for reducing DH distribution losses are institutionally mismatched. If heat meters were installed in buildings and payments made for heat as it enters the buildings, the incentives for improvements would properly shift to the heat supply companies. Of

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[64] Up to now, DH companies have been able to cover the costs of heat losses in prices and tariffs. Even in Germany, where no price regulation for DH exists, DH is usually slightly more expensive than decentralized heating systems based on natural gas or light heating oil for reasons of greater comfort. Although heat losses are considerably above theoretical figures, they have not been a larger concern to DH companies.

course, installation of heat meters at the building level without any changes in tariffs or consumption results in lower average heating bills; the "excess" distribution losses above the norms are not included in current tariffs. Also, if a building is underheated, its actual consumption will be less than norms. On the margin, assuming no offsetting incentives for the DH company provided through regulation, this reduction in heating bills means a loss for the DH company. Installation of building-level meter on a large scale will push the DH companies management to reduce costs and/or try to convince regulators and politicians to raise tariffs to keep revenues constant.

- DH demand may be significantly affected by changes in consumer incentives, potential consumer rights, and consumers' ability to decide how heat is produced. Changes in incentives brought about by meters and controls may have a big impact on heat supply markets. Households wanting lower bills will turn to building boilers or apartment-level heaters, if allowed, no matter what the "development plans" of the DH company. In many CEE/FSU countries, residential consumption of gas remains unmetered for most buildings. If households begin to pay for heat and hot water according to metered consumption, and if gas remains unmetered, then consumption would shift to gas as households operate their gas stoves instead of consuming metered heat supplied by the DH system. Or households may decide to install gas-fired heaters in their apartments, if allowed by law. In some countries, even inefficient electric heating can be cheaper than DH. In this situation, not only will electric heating displace district heating consumption if apartment-level metering and billing for heat is implemented, but new and retrofitted buildings may elect to disconnect from the DH system entirely and just use electric heating, if allowed by law—a process that has already begun in some countries. To avoid such decisions, which are leading to wrong economic resource allocation, a level playing field has to be established in the form of cost-recovery tariffs for all fuels, removal of cross-subsidies, review of legal and regulatory impediments, and so on.
- Because of the burden of the heating bill for consumers, the central issue for municipal policymakers is the impact of the investment program on the level of the cost-based heat tariff. The results for the case studies shown in Table 4-9 are encouraging. While the resulting heat cost per unit (Gcal) is higher when investing in demand side measures, the total heat bill for a dwelling would be substantially reduced by these measures.

Table 4-9. Economic Heat Energy Cost and Heat Bill, per Dwelling

	1996 Average Annual Household Income (US$)	*No DSM*		*With DSM*		
		Heat cost (US$/Gcal)	*Heat bill (US$/year)*	*Heat cost (US$/Gcal)*	*Heat bill (US$/year)*	*Heat bill in % of average household income or Expenditure*
Dnipropetrovsk	**2000**[c]					
- Existing DHS		23.4	333	27.1	320	16%
- Mod. DHS+CHP[a]		21.1	300	21.1	300	15%
Kaunas	**2705**					
- Existing DHS		35.3	685	45.8	625	23%
- Building boilers[b]		34.7	674	36.4	582	21%
Orenburg	**2760**[c)]					
- Existing DHS		65.5	1135	79.2	980	35%
- Building boilers		30.2	462	33.6	416	15%
Wroclaw	**4950**[c)]					
- Existing DHS[b]		44.5	484	47.2	447	9%
- Natural gas CHP		21.3	231	23.6	224	5%

a. No DSM measures were selected since none fulfilled the criterion of a minimum economic rate of return of 10%.

b. Unit heat costs for modernized DH system with modern CHP are almost identical.

c. For Ukraine and Poland average household expenditures; for Russia median household expenditures.

Source: ESMAP case studies.

4.3 The Impact of Environmental Valuation on the Ranking of Heating Options

4.3.1 The Environmental Effects of Alternative Heating Options

The environmental impacts of heating technologies relate to air pollution (e.g., boiler house emissions), ground pollution (e.g. leakages from fuel tanks), noise, and visual impacts (e.g., of above-ground pipes). Asbestos removal is another environmental hazard frequently encountered when removing insulation during the rehabilitation of boilers or DH networks. Air pollution is considered the most important environmental problem. It can be reduced in several different ways, or through a combination of these:

- ☐ Switch to heating technologies with higher thermal efficiencies, such as replacement of boilers with low energy efficiencies by more efficient boilers; or the rehabilitation of poorly insulated steel pipelines laid in concrete ducts by installing new insulation layers; or replacing old pipes with pre-insulated pipes.
- ☐ Installation of more efficient end-of-pipe emission control technologies, such as desulfurization units.
- ☐ Fuel switching from a dirty fuel such as coal to a cleaner fuel such as natural gas; or by a switch from high sulfur coal to low-sulfur coal, or from HFO to LFO, if fuel price differences allow economically sound switching.
- ☐ Increased use of renewable energy resources such as wood chips, straw, and geothermal energy.
- ☐ Implementation of energy-saving programs at the end-user level.

The last measure is independent of any supply side orientation. The others concern technologies for the supply of heat.

DH has a number of environmental advantages compared to individual boilers or apartment heaters:

- The centralized nature of HOB and CHP plants results in a concentration of the emissions at one or more distinct sources. This, together with the much higher stacks of 90–150 meters of large HOB or CHP plants compared to the 20-meter stacks (or less) of small boilers and of stoves (chimneys on top of houses) leads to a significant improvement of ground-level concentrations.[65]
- Because of scaling advantages, it is cheaper to install sophisticated state-of-the art pollution control technologies at large facilities. Flue gas scrubbers can be installed to remove particulates and reduce SO_2 emissions;[66] and boilers can be retrofitted with low NO_x burners, flue gas recirculation, and selective catalytic reduction techniques to reduce NO_x levels. Larger CHP plants can be equipped with complex desulfurization facilities recovering 80–95 percent of flue gas sulfur.
- The thermal energy efficiency of large boilers is usually higher than that of small building boilers, particularly when coal boilers are used. Large facilities are typically designed more efficiently (e.g., with sophisticated heat recovery systems) and can use better operating and maintenance practices than small individual heating systems and can be operated closer to full capacity where energy efficiency is highest. The individual boilers in a DH plant are

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[65] In many countries in Central and Eastern Europe, emission sources with low stacks generate a large share of emissions. In Krakow, for example, these sources, consisting of coal-fired boilers and stoves, contribute more than 30 percent of emissions of sulfur dioxide (SO_2) and a significant part of the emissions of nitrogen oxides (NO_x), and are the primary sources of particulates and carbon monoxide (CO). These sources have a much higher impact than high-stack sources on air quality during the winter, especially in the downtown area where access to a district heating network is not yet available. A survey of low-stack emission sources by the Krakow Bureau of City Planning listed about 130,000 coal stoves and about 1,300 small coal-fired boiler houses. More than 50 percent are located in downtown Krakow. An improvement in air quality could be achieved through the following measures in downtown Krakow: elimination of local boilers and connection to the district heating system (about 54 percent of boiler capacity), conversion to gas-firing (21 percent) and oil-firing (9 percent), and boiler retrofitting (16 percent). These measures would also contribute to reducing CO2 emissions. (See S. Adamson, R. Bates, R. Laslett, and A. Pototschnig (1996), *Energy Use, Air Pollution and Environmental Policy in Krakow* [World Bank Technical Paper Number 308, Energy Series, Washington, D.C.]) The concentrated nature of production also makes it easier to monitor the compliance with environmental regulations.

[66] The particle removal efficiency of technologies installed in large modern HOBs is 95–98 percent.

phased in one after one during peak hour operation instead of turning a single boiler up and down.[67]

- DH can make use of highly efficient heat generation through the use of CHP plants and by purchasing waste heat from incineration plants and industrial processes.
- Noise associated with the operation of DH plants is concentrated in a single boiler house where the boiler blowers and pumps can be placed practically and cost-effectively behind thick brick or concrete walls fitted with mineral wool noise suppressors.
- By concentrating fuel storage at central facilities, the potential risks associated with leakage or emission of pollutants other than fuel are minimized compared with those from a number of smaller boilers or plants.

Exploiting these advantages does not automatically require huge, centralized DH systems. The development of new decentralized generation technologies in the last 10–20 years proves that smaller units can also benefit from these advantages. The increasing number of small and medium-sized CHP plants mostly based on gas turbines and gas/diesel engines in Western Europe demonstrates that DH companies, as well as industrial concerns producing their own power and heat, have accepted them as a cost-effective alternative. A similar development may occur in CEE/FSU with some delay.

In the past, the potential environmental advantages of DH systems were substantially reduced by two factors. One was the economic need of DH technology to use cheap sources of fuel in order to be competitive with individual boilers; for example, coal instead of natural gas, or HFO instead of LFO. But cheap, low-grade fuels have poorer environmental properties than higher-grade fuels. To some degree, the use of advanced end-of-pipe technology at HOB and CHP plants reflects the need to compensate for the lower quality of the fuel that is used.[68] Gas-fired boilers require neither desulfurization nor particle removal equipment to achieve ambient air quality or emission targets. Gas-fired boilers, however, still contribute to increasing ozone and greenhouse gas levels (the latter through O_3, which is also a local pollutant) and to NOx and PAH (carcinogenic polycyclic aromatic hydrocarbons) emissions.

The other factor is the negative impact of energy losses in DH transmission and distribution networks. In DH systems that use outdated technology, these losses result in a negative environmental impact compared to gas-fired building boilers.

Determining which heating system is environmentally most benign will depend on a number of local circumstances, including the kind of fuel used in the plant and the requirements for

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[67] U.S. investigations dating from the late 1980s showed that building-level boilers typically had efficiencies of 70 percent instead of the 85 percent design efficiency.

[68] This can also be expressed in a positive way, DH technology makes it possible to use low-grade fuels for heating in an environmentally benign way, a factor which contributes to the versatility and security of supply characteristics of the technology.

emission controls. In the following, an illustrative example of the environmental impact of fuel switching and technology choice is provided. The two fuel options are coal and natural gas, and the three different heat supply options are building boilers, block boilers (small, isolated DH systems based on small HOBs), and integrated DH systems based on CHP heat production. A number of assumptions concerning the energy/environmental efficiency of these technologies are shown in Table 4-10. The efficiency assumptions in the table refer to modern technologies in realistic use. In practice, even higher efficiencies can be witnessed in DH systems in Western Europe with regard to energy efficiency and with regard to removal of particles and SO_2 (99 percent and 95 percent, respectively). The efficiency of DH technologies currently in use in CEE/FSU is lower than depicted in Table 4-10.

Table 4-10. Energy/Environmental Efficiency of Different Heating Technologies (percentage)

Technology	*Energy efficiency*	*SO_2 reduction efficiency*	*Ash content transformed into fly ash*	*SPM removal efficiency*
Building Boiler	75/80[a]	10	20	70
HOB - DH	77[b]	90	50	98
CHP - DH	137[c]	90	50	98

a. For coal-fired and gas-fired boilers, respectively.

b. Based on boiler efficiency of 85 percent and distribution losses of 10 percent.

c. Based on 80 percent of production from CHP plant with 170 percent heat efficiency and 20 percent from HOB with 85 percent efficiency; losses in transmission and distribution of 10 percent.

Source: World Bank staff.

Based on the preceding conservative assumptions, Table 4-11 shows the emissions of the different heating technologies per unit of heat delivered to a building and compares them to the flue gas cleaning requirements in European Union countries. The results confirm the superior efficiency of DH based on CHP and highlights the well-known environmental qualities of natural gas as a fuel. Even when the CHP plant is fueled by coal, the environmental performance is acceptable compared to individual gas-fired boilers; SO_2 and SPM emissions are within the limits of acceptability, and the emissions of CO_2 are similar to gas-fired boilers. DH based on gas-fired HOBs is slightly less energy/environmentally efficient than individual gas-fired building boilers. The small coal-fired boilers cannot comply with modern requirements for the achievement of ambient air quality targets. However, in some countries such as Poland, small boilers are exempted from compliance with environmental regulations.

4.3.2 The Economic Costs of Air Pollution

The most important environmental costs of heating concern the environmental impact of emissions of SPM (local ambient air quality impact), of NO_x and SO_2 (local and regional), and of CO_2 (global warming). The calculation of physical emission figures will be sufficient to eliminate some heating options. This is the case when the achievement of local and national norms and standards for ambient air quality and/or for emissions is incompatible with the emissions of a given heating technology, e.g., coal-fired stoves or small coal-fired building boilers. Often, the economically preferred option also has the best environmental performance.

Superiority in environmental performance is closely linked to energy efficiency, and the most energy-efficient solution will often be the most economic option. In some cases, however, the environmentally superior option may be more costly than the alternative option(s). In that case, it is desirable to include the cost of environmental externalities in the analysis of the economic rate of return of a heating project, to see whether including the economic cost of pollution affects the ranking of the options.

Table 4-11. Emissions per Delivered Gcal, by Type of Heating Technology

	EU norms for plants>100 MW, in µg/Nm3	*Flue Gas Cleaning Requirements (kg/delivered Gcal)*	*Building boiler*	*HOB-DHS*	*CHP-DHS*
Coal-fired: [a]					
- Fuel consumption (tons)	N/A	N/A	0.215	0.218	0.110
- SO_2 (kg)	2000	Max. 0.5	3.9	0.42	0.24
- SPM (kg)	50	Max. 0.15	1.5	0.252	0.141
- NOx	650	Max. 0.4	N/A	N/A	N/A
- CO_2 (tons)	N/A	N/A	0.527	0.512	0.289
Gas-fired: [b]					
-Fuel consumption (m^3)	N/A	N/A	139	146	82
- SO_2 (kg)	35	Max. 0.5	0	0	0
- SPM (kg)	5	Max. 0.15	0	0	0
- NOx	350	Max. 0.4	N/A	N/A	N/A
- CO_2 (tons)	N/A	N/A	0.282	0.295	0.165

Note: Flue gas cleaning requirements are defined in µg/Nm3 and vary depending on type of plant technology, type of fuel and size of plan (column 2). The composed figures in column 3 can be used for comparative purposes.

N/A: not applicable.

a. Coal characteristics: HHV=6,200 kcal/kg, Carbon content: 67 percent, Ash content: 12 percent

b. Natural gas characteristics: HHV= 9,000 kcal/m^3, CH_4=92 percent

Source: World Bank staff.

There are considerable uncertainties involved in monetizing the costs of pollutants, and there are huge differences in international estimates of these. Cost estimates can refer to abatement costs (i.e., the cost of eliminating the pollutants or making investments to neutralize their negative effects) or to damage costs (i.e., the economic cost of damages to the physical and biological environment caused by the pollutant). In principle, the lower of the two estimates should be used.

A distinction can be made between local/regional and global pollutants. The estimates of the economic cost of global warming effects from CO_2 emissions are of academic interest but are too uncertain to be used in practice. The estimates of the damage costs of local pollutants are subject to the uncertainties of dose effects and are very sensitive to estimates concerning the value of lost life. (This value tends to be larger than the estimates of the economic cost of lost workdays and hospital cost estimates.) However, damage cost estimates of local pollutants provide useful information for planners and politicians about the scale of the problem. The case studies leading to this report used the abatement cost estimates in Table 4-12. The figures for CEE/FSU are rough estimates that need to be refined for further studies; typical figures used for European Union countries are listed for comparative purposes.

Table 4-12. Economic Cost of Emissions in CEE/FSU and EU (US$/ton)

	SO_2	SPM	NO_x	CO_2
EU	3000	600	2400	20–50
CEE/FSU	100	50	240	10

Source: EU: Environmental Manual for Power Development (see http://www.worldbank.org/html/fpd/em); CEE/FSU: World Bank staff preliminary estimates.

The large difference in abatement costs between the EU and CEE/FSU reflects three factors: (1) the difference in the level of ambition concerning the targeted reduction in pollutants (the more ambitious targets in the EU are obviously more costly); (2) the lower level of energy efficiency and of implementation of abatement measures of CEE/FSU countries (many low-cost opportunities exist to achieve a given energy-saving target); and (3) underestimation of the true level of abatement costs in the CEE/FSU (US$400/ton is probably a more realistic figure for SO_2 and NO_x abatement costs).

4.3.3 Results for the Six Case Studies

All six studies found considerable scope for local environmental efficiency improvements compared to the current situation. Environmental improvement does not necessarily occur when a nation switches from DH to different heating options. If the heat supply from a CHP plant is reduced, the reduction in electricity generation must be made up by other plants in the system, with results that may be either more favorable or less favorable from an environmental standpoint.

For the case studies, the national swing producer is a modern, efficient, gas-fired CCGT plant for the following reasons: If the decision needs to be made to build a new CHP plant based on the combined cycle scheme with heat production, it should be compared to a combined cycle scheme with no heat production. For the options where the original CHP plant is kept to supply the DH network, the need for investment in new CCGT capacity would be reduced. If DH operations were not continued, the plant would be too inefficient to compete with a CCGT plant, and would be closed down. Thus, the total emissions of the original CHP plant and its HOB, minus the emissions from the swing producer, represent the emission impact of DH.[69]

Figures 4-3 and 4-4 show the results of the analysis for Orenburg and Wroclaw, respectively. The incorporation of economic costs of emissions into the annual heat costs increases the latter because the swing producer is a modern, efficient, gas-fired plant with relatively low emissions.

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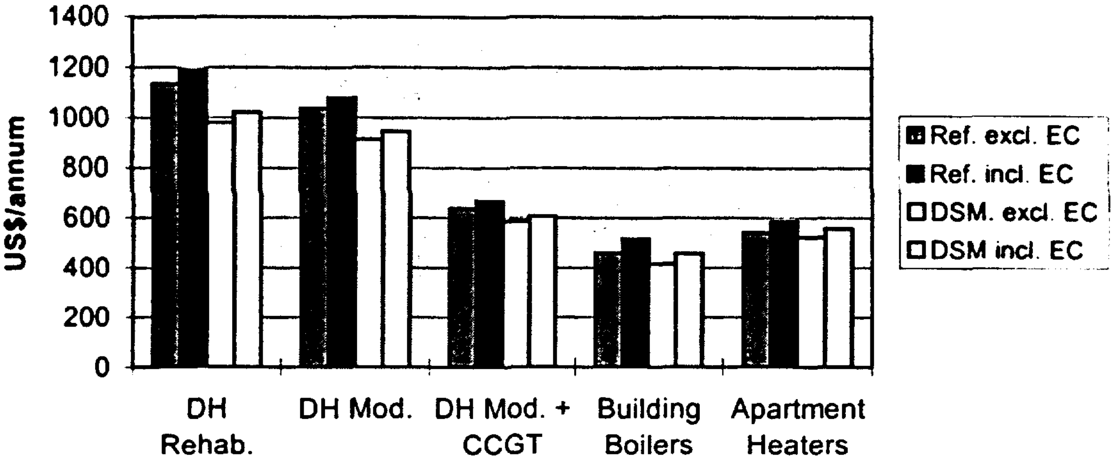
[69] Using a new gas-fired combined cycle power plant as the swing producer leads to the least favorable estimate of the environmental benefits of CHP production. The choice of the marginal plant which is old, inefficient, and uses an inferior fuel on the other hand leads to a more favorable result for DH/CHP-based heating options. See Annex F for the results. Using the average expected production mix in the national or regional power system would give the most realistic environmental impact assessment. As a result, the approach taken for the case studies leads to a slight underestimation of the positive environmental impact of DH.

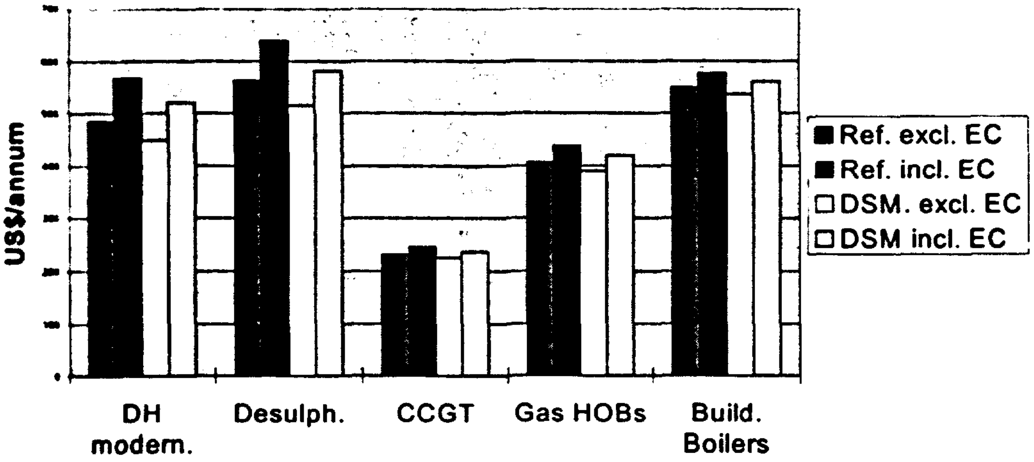
The incorporation does not change the ranking of the options. Building boilers (in the case of Orenburg) and DH with heat supplied from a CCGT cogeneration plant (in the case of Wroclaw) remain the heating options with the least economic cost.

Figure 4-3. Orenburg:
Annual Heat Costs per Dwelling,
Excluding and Including Environmental Costs



Source: ESMAP Orenburg Case Study

Figure 4-4. Wroclaw:
Annual Heat Costs per Dwelling,
Excluding and Including Environmental Costs



Source: ESMAP Wroclaw Case Study

5

Organizational Requirements for a More Efficient Heating Sector

As outlined in the two preceding chapters, the inefficient supply and consumption of heat in CEE/FSU can be improved either by specific energy-saving investments in the existing heating systems and buildings or by investments in new supply systems. Under both options, however, the limits to energy efficiency within the old framework of supply and demand will soon be reached if technology improvements are not accompanied by a restructuring of the heating sector. Only through such a restructuring can further progress be achieved, including international best practice standards of technical, operational, and commercial efficiency in meeting heat demand. This should take place as a parallel process of interrelated changes in the technologies and in the organization structures for the supply and the demand of heat.

In all CEE/FSU countries, change in the heating sector has begun toward a system based on economic incentives. The reforms of the heating sector initiated at the macro level (overall ownership-industry-regulatory structure, pricing policy, subsidy schemes) are usually followed up by a series of initiatives at the micro level (company structure, corporate governance, accounting, planning, financing, investment appraisal, billing). This chapter discusses the changes needed at the political, institutional, and management levels to improve the efficiency of the heating sector in terms of investment, operations, financing, pricing, and social equity. In many respects, the necessary changes are those also being put in place in many other countries worldwide to enhance competition, increase funding for investments, and improve consumer choice in infrastructure sectors previously dominated by public or private sector companies in a strictly regulated environment.

5.1 Ongoing Reforms

In most CEE/FSU countries, new energy laws have been put in place. Recognizing that heat supply and demand is a local affair, they transfer most of the related ownership, planning, and financing responsibilities from central authorities to municipalities.

At the macro level, reforms that affect the heating sector comprise the following:

- The centrally owned DH utilities (typically divisions of a formerly state-owned power company) are transferred to municipal ownership.
- The state-owned, vertically integrated natural gas utilities are broken up into production, transmission, and distribution companies. The latter are usually spun off and either privatized or transferred to municipal ownership. The transfer of ownership also leads to the transfer of some of the debt of the mother company.
- The tariffs for power, natural gas, and DH are gradually raised to reach the goal of full-cost pricing for each consumer group within a few years.
- To protect the affordability of basic heat consumption, the system of general energy price subsidies and discounts to privileged groups is either changed to a system of subsidies targeted at low-income groups or subsumed in a general social safety net program.
- The housing sector also undergoes reform: residential buildings are privatized; ownership of individual apartments in apartment buildings is transferred to individual tenants; and ownership of the building's premises, installations, and land (except in countries where land remains the property of the state) is transferred to the homeowner or to home owners/condominium associations.
- Regulations concerning environmental standards, safety, licensing procedures, and energy efficiency standards for equipment and buildings are adapted to a market-based system.

At the micro level, the following heating sector reforms are essential:

- The "corporatization" of the DH companies separates their budget from the municipal budget and reduces the direct involvement of municipal politicians in daily management affairs. A normal feature is to have both elected municipal politicians and outside professionals and consumer representatives represented on a supervisory board.
- The municipalities reorganize their administration to take care of the new functions that are thrust upon them, i.e., the administration of subsidy payments, the indicative planning of the reorganization of heat supply, and the governance of municipally owned utilities.
- The management and the new supervisory boards of the utilities define appropriate structures for the municipally owned utilities, set up new accounting and financial information systems, define strategies for investments, and engage in financial planning.
- The billing systems for heat and hot water as well as gas are gradually changed from a system of unmetered consumption based on the size of the dwelling and the number of household members to a system of billing according to metered consumption, and middlemen such as housing maintenance organizations are removed from their task of collecting payments.

For each of these areas of intervention, different implementation strategies exist. This chapter provides a step-by-step overview of the key issues in each area, of special considerations that have to be taken, of typical options, and of interesting experiences that have been gained.

5.2 Specific Issues and Lessons for Organizational Restructuring

5.2.1 Introduction

The change toward a market-based system leads to a redefinition of the institutional responsibilities in the sector; these are summarized in Table 5-1. For each of the key actors in the heating sector, critical success factors can be established. Progress can be evaluated through a number of performance indicators; these are also listed in Table 5-1.

The key change is the increased responsibility for the municipalities in local heat supply:

- As policymaker for local infrastructure, the interest of the municipality is to promote the construction and development of an efficient infrastructure that is attractive for the local population and business community. Heat supply used to be the responsibility of outside experts in the national energy companies, but now municipalities have to mediate between the competing interests of power, natural gas, and DH companies.
- As an owner of residential buildings and as administrator of heat subsidy payments to low income groups, the municipality has a direct interest in providing least-cost solutions for heat supply for consumers.
- The municipality must minimize the nuisance from public works undertaken by grid-based energy utilities. It approves the construction and operation of DH and natural gas facilities through local planning and zoning laws.
- As owner of the local DH company, the municipality must ensure its financial viability. This includes approving changes in the level and structure of DH tariffs, as well as assisting in the procurement of low-cost finance from outside sources for investments.

The various functions of a municipality may conflict. For example, as an owner of apartments and a provider of subsidies, it should have a strong interest in reducing heat prices. As owner of the DH company, it should have an interest in the company's long-term viability, which would require adequate, generally increased tariffs that permit self-financing of a certain part of the required investment. If a DH company operates as a commercial entity, political interests should not interfere in its management. This can be realized through by an appropriate corporate structure by reducing the influence of the municipality on the company's supervisory board, and clearly determining the rights and obligations of both management and supervisory board.

The role of the central government in heat supply is reduced, but still important. It includes the following:

- General guidelines at the national level for energy and environmental policy provide utilities with a long-term framework for their investment planning.
- Follow-up policy initiatives, programs, and regulations promote some technology options and reduce or eliminate others (e.g., use of high-sulfur fuels).

- The launching of national-level energy-saving programs and of financial support schemes for the purchase of energy saving technologies is important for the realization of the potential for economic energy savings in buildings.
- In view of the over-capacity in power generation in many CEE/FSU countries, specific policies must be formulated to ensure that both power and heating sector requirements are taken into account when designing dispatch rules or licensing new, more efficient generation capacity. Both could affect the use of cogeneration and, indirectly, the costs of heat and power.
- The legal and institutional framework for the regulation of energy utilities will either promote or block the development of private sector investments.
- Social policy must ease the transition to full-cost pricing in the utilities by providing a framework and funds for targeted income support of poor families.

5.2.2 Organization Structures for Local Energy Companies

Worldwide, the trend in energy sector restructuring is toward (1) introduction of competition by unbundling generation, transmission, and distribution functions and (2) private participation in energy generation and distribution utilities. The objectives of privatization are to make competition sustainable (thereby increasing efficiency), to fund necessary system rehabilitation and expansion at least cost, and to liberate budgetary resources for social priority expenditures.

Generally, private participation is best accomplished through participation in a utility's ownership and operations, either through outright sale of the assets or through long-term leasing or operating concession arrangements that are normally let out for bid on a competitive basis. This process is under way in the power and gas sectors of some countries in Central Europe (the Czech Republic, Hungary, Poland), and it is starting up in FSU countries (Kazakhstan, Latvia, Russia, and Ukraine).

The DH sector is lagging behind in the privatization process for obvious reasons of technical inefficiency, lack of suitable investors, and fear of political interference in business decisions. Therefore, an interim strategy is first "corporatizing" and restructuring the heating companies, divesting any functions that are not directly related to their core business or that could be provided by the private sector on a competitive basis; and imposing strict profit accountability and financial discipline, both short term and long term, on its management and employees. This is also a means of making the utilities more attractive to the private sector and hence, increasing their value.

5.2.2.1 General Considerations

The immediate concern for the municipal owners and for the management of the DH utilities is how to structure the utilities when the different local companies in the DH sector come under unified municipal ownership. The typical pre-reform situation was that the municipality owned and operated the small, isolated DH systems and individual boilers in buildings belonging to the municipality. The municipal utility services department or a specific municipal DH enterprise was responsible for the operation and maintenance of these systems. The large, integrated transmission network was owned and operated by a subsidiary of the state-owned national power company. The connected secondary distribution networks from the substations onwards could be owned and operated either by the transmission company or by a municipal DH company.

The design or configuration of the new, local organization structure for DH should be guided by the following two main considerations:

1. The aim of the central government's transfer of ownership of DH assets to the municipalities is to improve the efficiency of heat supply. For this to happen, the decentralization of company ownership must be followed up by a decentralization of functions at the operating level.
2. The ability to attract financing at least cost is an important determinant for the choice of business form and of sector organization in any major industry. It is essential in the DH sector. Because DH is a more capital-intensive form of heat supply than the competing alternatives, its competitiveness is very sensitive to the cost of capital. The level of the rate of interest and the length of the maturity of loans are important determinants of the ability of a DH company to achieve competitive tariffs.

Another issue to address concerns the policy toward unrelated activities (e.g., ownership of greenhouses, pipe production, etc.) that often are included under the ownership of a DH company in CEE/FSU. The case for divestment is strong. It leads to improved management focus on the core activity, and a successful sale provides finance for investments in the improvement of the DH system (see section 6.3.2).

5.2.2.2 Company Mergers

Merger of local district heating companies. It would be preferable to integrate into one company the various DH entities that come under municipal ownership. The municipal enterprise in charge of the small, isolated systems would be merged with the DH company in charge of the interconnected system. Keeping the companies separate provides few competitive benefits. There is no direct or indirect competition between the two companies. They serve different consumers, and the cost structures of small, isolated and of large integrated systems are too different to allow effective use of benchmarking. The merger of the two entities provides synergy effects in administration, planning, fuel purchases, financing, billing, and maintenance.

When a large, integrated DH system cuts across the boundaries of several municipalities, the normal solution is to organize either the transmission system or the whole DH system as a jointly owned company with equity shares according to the relative sizes of heat demand in the municipalities. Another method is to allocate shares according to the value of the company assets that are located in the different municipalities.

Multi-Energy Utilities. Some countries consider expansion of the municipal ownership of local DH (and water) utilities to include regional distribution companies in power and in natural gas. Such a development offers the possibility to set up horizontally integrated companies dealing in power, natural gas, and DH (sometimes referred to as *multi-energy utilities* or *multi-utilities*).

During the 1960s and 1970s, several of the CEE/FSU countries organized the local utility sector as municipal departments for water, heat, and natural gas. In Western economies, examples of integrated utility companies in distribution can be found both in "local supply monopoly" and in "free supply competition" regulatory frameworks. Examples of the former are the German and Austrian Stadtwerke with municipal majority ownership, and the Dutch integrated energy companies. In the United Kingdom and in the United States of America, liberalization and opening up of competition has led to the formation of a number of diversified water-power, power-natural gas, and power-DH utilities under private ownership.

In principle, a number of potential synergy effects can be realized with the horizontal integration of distribution in electricity, gas, and DH. "Perfect" integration of investments can be achieved. The disadvantage is that the reduced free interfuel competition could lead to x-inefficiency effects.[70] Decision-makers in most CEE/FSU countries are hesitant to embrace the virtues of such multi-utilities, however. The general attitude is that they have previous experience with integrated monopolies and prefer to see how a more competitive system works out in practice.

Integrated utilities will have a future in CEE/FSU. Whether or not they should be promoted in the short term depends on local conditions and local management talents. In the short term, the aim should be to complete the commercialization process of the individual distribution companies and to promote competition in heat supply. The definition of different market and company structures can be left to market forces subject to regulatory supervision.

5.2.3 Promotion of Competition and Privatization in District Heating

5.2.3.1 The Scope for Competition

Municipal ownership of local DH companies should be combined with a policy to exploit the potential for introducing competition within this framework. Competition is the most effective organizational means to promote efficiency on a sustainable basis. There are three main avenues:

- To promote competition in the production of heat for the integrated system;
- To promote the outsourcing of non-core activities presently performed by the company; and
- To promote competition in the operation of the DH networks.

5.2.3.2 Competition in the Production of Heat

DH systems get their heat supply from a variety of sources: CHPs, HOBs, and industrial boilers. The scope for competition in heat generation, however, is generally limited to the provision of reserve and of peak capacity. The possibility exists to contract surplus heat capacity from industrial plants in addition to the HOBs that are owned by the DH utility. In base load, the CHP plants have a "captive" market due to their superior efficiency and related heat production cost

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[70] X-inefficiency = Economic inefficiency in monopolies; potential economies of scope and of scale are not exploited because of the absence of competitive pressure on management performance.

Table 5-1. Responsibility Framework for Heat Supply and Demand

Institution	*Responsibility*	*Critical Success Factors*	*Performance Indicators*
National Government; Ministry of Energy and Ministry of Environment	Definition of a reference framework for planning and implementation of measures to cover the demand for heat	a) Formulation of clear goals for national energy policy b) Drafting of coherent primary and secondary energy laws c) Definition of clear and logically coherent frameworks for sector regulation d) Definition of rules for tariffs that promote the achievement of energy and environmental policy objectives e) Definition of energy saving programs f) Emission fees (SO_2 , particles) reflecting economic costs	a) Broad public support for published energy plans b) Adoption by Parliament of primary and by Government of secondary energy laws c) Broad support to basic principles for sector regulation d) Published rules for tariffs and for CHP power / electricity pricing move the behavior of actors in the wanted direction e) Energy savings attributed to the impact of the programs
Ministry of Social Affairs	Definition of subsidy schemes to make heat affordable to low income households	a) Targeting subsidies to low income households b) Administrative ease c) Minimum of market distortions	a) Cost of subsidies in % of total cost of heat supply is reduced b) Average cost of administration to municipalities and to energy companies in % of energy bills of low income households c) Scheme is neutral with regard to choice of supplier and with regard to energy saving behavior
National regulatory authority	Rules for economic regulation of energy companies	a) Transparent and unequivocal methodology for CHP pricing that satisfies interests of both power and heat companies b) Methodology for setting of tariffs of natural monopolies c) Guidelines for preparation of licenses d) Settling of disputes in a way that balances consumer and investor interests	a) Continued investment in CHP by power companies and by DH companies; CHP share of total heat production b) Time trends in investment and in the level of tariffs
Municipality	Definition of local framework conditions for heat supply and demand	a) Preparation of local heat master plans to guide investors and consumers b) Selection of professionally working supervisory boards for municipal energy companies c) Organization of subsidy payments to low income households d) Non-prejudiced performance of regulatory functions	a) Heat plans prepared by the municipality or by the local energy companies identify the least cost supply and demand side options to cover the local demand for heat b) % of non-political members; attention to management issues c) Specific local cost and speed of administration
Management of energy companies	Provide heat at least cost and reliably to satisfy consumer demand	a) Investment policy b) Organization, outsourcing c) Staff policy d) Introduction of cost-based accounting e) Securing of finance f) Consumer policies	a,b,c) Cost of production; environmental efficiency; DSM programs d) Non-paying consumers in % of total; service complaints

advantage.[71] Only in some cases has competition between CHP plants supplying heat to the same integrated network been observed. This can happen when formerly separated networks, each with its own dedicated heat source, become integrated after a series of modernization investments (for instance, in Gdansk and Krakow, Poland).

Some municipal DH companies have been able to improve their bargaining position vis-à-vis heat suppliers and have thus reduced their heat costs by investing in their own heat generation, or by threatening this kind of investment. Examples are some cities in the former Germany Democratic Republic, such as Leipzig. Here, the municipal utility invested in new, gas-fired CHP capacity. A similar process of potential competition in heat generation can be observed in Russia, where municipalities want to invest in their own HOB capacity in order to reduce heat costs (see section 5.2.6.2).

5.2.3.3 *Divestment*

DH companies in CEE/FSU are characterized by a high technical quality of staff and large staff size compared to DH companies in Western Europe that serve heat markets of a similar size. Thus, while DH companies in Western Europe sell about 40–70 TJ (10,000–17,000 Gcal) of heat per employee per year, annual sales per employee in DH companies in CEE/FSU are closer to 10–20 TJ. Some of the differences in the level of staff represent excess labor; part of it reflects the use of outdated technologies that require much maintenance, such as manual feeding of coal. Part of it reflects the lower cost of labor (justifying fewer automatic control systems) and part of it reflects less outsourcing in CEE/FSU utilities.

Because of the low level of wages, overstaffing has a negligible short-term impact on the price of heat. The "re-engineering" attention of management, therefore, is focused on improving the technical performance of the system, where huge short-term gains can be made. In this situation, the definition of a clear policy for outsourcing becomes a task for the supervisory board of the DH company. While a DH company must ensure the provision of goods and services used in the production process, there is no reason why it should produce those services, unless it can do it more cheaply than outside suppliers. Whether a DH company can produce a good or service more cheaply than outside suppliers can only be established by moving to activity-based costing and opening up services in the production chain to competition.

Outsourcing represents an opportunity for bringing competition into the DH sector. Potentially, outsourcing will reduce the cost of production and make the heat supply industry—which needs to make some painful adjustment in the face of tough competition from natural gas—more dynamic. For this potential to be realized, two conditions must be fulfilled: (1) the responsible line managers of the company must be trained in contracting and in organizing competitive tenders for the activity, and (2) there must be competing suppliers for the service. For example, if divestment of maintenance would create a local monopoly supplier, it is best to keep a strong in-

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[71] See section 5.2.6.3 on the politics of allocating cogeneration benefits to heat and power.

house contingent for maintenance staff to provide competition in the divested activity. For more details, see section 6.3.2.

5.2.3.4 Privatizing the Operation of DH Systems

A more wide-ranging method of introducing competition is to privatize the core activities of DH, that is, the production of heat in the CHPs and HOBs; the transmission and the distribution of heat; and the service function, comprising sales and marketing. Privatization will not increase competition once these activities are privatized. It will do so in the privatization process itself, by asking for bids from potential investors. The winning company will have presented the best business plan for the activity, the lowest cost of finance coupled with the largest investment plan, or the lowest tariff for the output.

The supervisory board, in collaboration with company management, prepares a plan for privatization, which has to be formally approved by the municipal council. Various schemes for this exist:

- The easiest form of privatization is to invite expressions of interest by strategic investors for the purchase of all or some of the equity capital in the company to be privatized. Final negotiations can take place directly with the most interesting investors, or with the winner of an international tender.[72]
- In some CEE/FSU countries, the privatization laws contain the notion of "strategic or public interest industries." Public majority ownership is required for such industries; e.g., the power and the DH companies in Lithuania or the natural gas and DH networks in Ukraine. In countries in which the law prevents privatization of infrastructure assets, or where a municipality would face strong political opposition to a sale of municipally owned assets, the operation of the DH system can be privatized. The concession for the operation and maintenance of the DH system, or parts of it, is awarded to a private operator on the basis of either an international tender or an international call for expression of interest leading to negotiated agreements. The DH infrastructure continues to be owned by the municipality. The utility management company winning the bid would provide private funding for modernization investments, operate the system, and transfer it to the municipal owner after a contractually fixed period (some 10 years or more).

Privatization can be an attractive option if financing is a major difficulty, *inter alia*, because of limits fixed by the ministry of finance for the annual or overall level of sovereign guarantees issued to international lenders such as the IBRD and the EBRD. It allows putting together a flexible package of finance. EBRD or IBRD could fund an initial modernization of the public infrastructure by a loan provided to the municipality. This loan would be backed by a sovereign guarantee. The utility management company would finance follow-up investments. Some of the

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[72] International experience with private participation in infrastructure shows that the terms obtained are similar.

private finance could be provided by IFC or EBRD in the form of a loan to the utility management company, or in the form of IFC/EBRD equity participation.[73]

In a few cases in CEE/FSU, the management of a DH company has been given a lease or a management contract to operate the DH system. Unless leases are provided on the basis of competitive tenders, this is not necessarily a good arrangement. The lease and the management contract options are useful when there is a wish to get access to private finance and/or to bring in new management to restructure a non-performing utility on a long-term basis. To give the lease to an existing management team achieves the goal of separating operation from politics, but it does not bring in new management expertise or private capital.

The lease option poses some practical problems. Investment planning becomes more complicated. The interests of the operating company and the owner may differ if the lease contract specifies that routine maintenance is the responsibility of the operating company, and entrusts major rehabilitation and expansion of the leased infrastructure to the owner. The operator will push for rehabilitation investments to reduce the costs of O&M, whereas the owner would prefer to postpone such investments as long as the cost is born by reduced profits of the operator, and not by increased tariffs to consumers. The practical question will arise as to when a repair is rehabilitation and not a routine maintenance. Although these issues can be solved by a careful drafting of the contract and flexibility in negotiations, they introduce new complexity (or transaction cost).

5.2.4 Promotion of Interfuel Competition: The Role of Heat Planning

The distribution of DH (or of natural gas) is a natural monopoly, in the sense that an expansion of the network will reduce average costs of supply. However, potential competitors are not dependent on access to the network. Generally, there are alternative heating systems available—based on natural gas, light fuel oil, and electricity—that can compete with DH without using the DH network. Especially for DH, economies of scale in distributing heat are so large (see Chapter 4) that one network can supply the whole market with lower unit costs than several smaller networks. In addition, resources would be wasted if DH and gas networks were constructed in the same areas of town, with the result that neither of the two networks might be profitable in the end. Therefore, authorities in Eastern and Western Europe and utilities have usually avoided this destructive competition by giving preference to either DH or natural gas through some kind of planning process. Furthermore, in most countries of Western Europe, the threat of competition by individual heating systems based on light fuel oil could be relied on to prevent DH or gas companies from unduly exploiting their monopoly position for heat supply.

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[73] Governments will in general not extend sovereign guarantees for loans to private companies.

5.2.4.1 Competing Planning Approaches

In Western Europe, two opposing models for the planning of heat supply in a market economy can be found:

- Large investments in the distribution of natural gas and DH are based on heat (master) plans for the municipality that are prepared under the responsibility of the municipal authority. These plans designate specific residential areas for specific sources of heat, based on least-cost analysis.
- The planning of natural gas and DH infrastructure is done by the natural gas and DH utilities, independently of each other, and serves as a basis for their own commercial decisions. If a fuel is found to be competitive, the company starts a marketing campaign, and once enough consumers have signed up for the initial stage, the distribution infrastructure is put in place.

Municipalities in CEE/FSU may need to become involved in heat planning as a result of the decentralization of ownership and of responsibilities in DH supply. Previously, the planning of heat supply was the responsibility of the national authorities and of the national energy companies. Urban planning and planning of heat supply went hand in hand, resulting in the predominance of DH in densely populated areas. Now local energy companies are becoming competitors, and sometimes municipalities are asked to intervene in conflicts of interest. This confronts the municipality with the question of whether market forces, if left alone, are capable of getting the needed structural changes implemented rationally and at the least economic and social cost, or whether an active planning support by the municipality is called for.

Some local politicians argue for "free competition" (usually with the support of the natural gas companies), others (usually with the support of the DH company) for the "planned solution." The debate concerns two main issues:

- In view of the limited financial resources for infrastructure investment in CEE/FSU, municipalities want to promote constructive competition but avoid destructive competition.
- The ability of the market to provide the speed required for the transformation process.

In the "heat plan model," interfuel competition takes place during the planning process in the economic analysis of options; in the "market model," through the marketing of options to consumers.[74] Countries in Western Europe that wanted to achieve a substantial and politically

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[74] In principle, the two modalities should result in choosing the same option: if an option in the economic analysis is found to be cheaper, it should also be the commercially cheaper option (unless there are large differences in externalities between two options). In practice, the heat plan model makes it easier to implement DH systems. Due to the higher up-front investments in DH compared to natural gas, the commercial sensitivity of DH systems is more dependent on a high initial connection rate in the area of supply than a natural gas system. By reserving an area for DH, it is likely that potential customers will hook up faster than otherwise.

defined restructuring of heat supply within a short period have chosen the heat plan model, together with targeted taxation of fuels..[75]

5.2.4.2 Market Distortions and Interfuel Competition

Constructive competition takes place under ideal market conditions on the local fuel market and with well-functioning financial markets in place. The forces of competition will provide household consumers with the least-cost system of heat supply.[76] Through interfuel competition in the heat market, those areas are identified where the existing system is not price competitive. Here, investments in the rationalization of non-competitive systems of heat supply will take place. The least-cost solution will gradually penetrate the market and replace the non-competitive options.

Destructive competition takes place when short-term price movements send consumers the wrong signals about longer-term trends. In the transformation process in CEE/FSU, a number of market distortions can be observed:

- The low ability to pay of the majority of the population has made it necessary to give heat subsidy payments to an important share of households (see section 5.2.5.3). This is a social necessity, but it makes an important share of consumers partially indifferent to the cost of fuel supply.
- Local capital markets are still in the build-up phase and the cost of loans from local banks is very high. Lack of access to low-cost sources of long-term finance prevents the DH company from carrying out investments that are needed to become competitive with decentralized boiler systems. As a result, consumers are faced with the high cost and the inflexibility of an outdated DH system compared to the lower cost and flexibility of a modern, decentralized boiler system.
- The economic advantage of DH in most CEE/FSU is affected negatively by the excess capacity in power production. In the short-to-medium term, there is no demand for electricity generating capacity of new CHP plants, and existing CHP plants get low payments for their electricity. In a balanced market, where power from a CHP plant receives a relatively high

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[75] Heat planning was introduced in Denmark in the late 1970s, driven by security of supply concerns in an energy economy dominated by oil products and by the wish to make use of domestic gas resources that were being developed. The wish to simultaneously expand the heat market share of DH from 30 to 50 percent and of natural gas from 0 to 20 percent called for detailed planning. Sweden has made some use of heat planning since the late 1980s. During the 1990s, heat planning was expanded because of the wish to simultaneously reduce electric heating (due to the planned phasing out of nuclear energy) and CO_2 emissions.

[76] Consumers can chose whether they want to continue with heat supply from DH or prefer to switch either to building boilers or to individual apartment boilers. The consumer chooses by comparing the cost and the comfort of heat supply of different options.

revenue, cogeneration substantially reduces the cost of heat supply in DH (see sections 4.1.2 and 5.2.6).

Other institutional obstacles can be observed that prevent a smooth implementation of the change process:

- On the *demand* side, the dual problem of collective decisionmaking and low household incomes poses an obstacle for change in the *status quo* in the residential sector. The decision to disconnect from the DH system and to switch to an alternative system of heat supply is usually not taken by an individual building owner, but by the homeowners/condominium association by majority voting. A switch to apartment-based heating systems requires investments in new appliances that many apartment owners may not be able to finance. A majority vote may be difficult to get under these circumstances.[77] Lack of collateral for loans, and the problems of getting newly formed homeowner associations to work properly on questions involving the financing of common expenditures, put residential consumers connected to a DH system at a disadvantage, compared to commercial consumers. In a free market, commercial buildings could chose to disconnect, whereas the DH company must continue supplies to the residential buildings connected to the same pipeline, although the loss of heat load increases the cost of heat supply to the remaining customers.
- On the *supply* side, the basic obstacle to the free market approach is that the "collective" nature of DH prevents a gradual change to decentralized boiler systems. The competitive edge of DH depends on a high connection rate of the heat load in the area served by a DH system. "Cherry picking" by competitors erodes the overall cost advantage of a DH system. Due to high fixed costs, a loss of customers increases the cost of supply to the other customers connected to the same network. The resulting increase in the DH tariff reduces the cost competitiveness of DH in the other areas served by DH. Thus, if the decentralized option can cover the demand for heat of consumers in a specific area at a lower cost than DH, it is better to cut off the whole section of the DH system in that area, rather than proceeding in a piecemeal fashion. All consumers connected to a non-economic part of the system should be disconnected within a short period of one to two heating seasons.
- Finally, outdated regulations that discourage the development of a more cost-effective heat supply need to be adapted. This holds true both for regulations that prevent competition for heat consumers, as well as for regulations that make heat more expensive than it needs to be. Among the former are regulations and a plethora of permits that prevent consumers from choosing between different options for heat supply. For instance, rooftop gas boilers, which are common in Western Europe, are still not allowed in many countries in CEE/FSU, and buildings higher than 12 stories cannot have gas supply because of outdated safety concerns. Examples for the latter are regulations determining the cost allocation in CHP plants in such

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[77] Even less controversial and costly decisions, such as investment in energy-efficient rehabilitation of buildings, usually require a lengthy process. This happened, for example, during the earlier stages of implementation of the Bank's Lithuania Energy Efficiency and Housing project.

a way that the cost of heat from CHP is equal to or even slightly above the cost of heat from HOBs. New building regulations are often too demanding, preventing cost-effective investment on the demand side. New windows in Lithuania, for instance, have to be more energy-efficient than in Denmark.

5.2.4.3 Role and Organization of Heat Planning

The above shows that several obstacles prevent the free market from achieving the structural changes in heat supply without undue costs. In this situation, heat planning is a tool for promoting allocation efficiency by providing a reference framework for the investment decisions that have to be made. The DH company needs to know which sections are not economically viable in order to avoid long-term investments for these sections. A natural gas distribution company needs to know in which sections of the town it should start to upgrade its gas grid to satisfy the demand from gas-fired building boilers.

A heat plan will speed up decision making by the energy supply companies and by customers. Therefore, although public planning of economic activities has gone out of fashion in CEE/FSU, the need for the preparation of integrated heat master plans is recognized. Heat master plans have been prepared in a number of cities. Some have been financed by bilateral and multilateral funding institutions as a basis for their lending; others are the result of local initiatives. Normally, the municipal administration is responsible for getting a heat plan prepared, whereas the planning work itself can be done by the utilities, together with outside consultants. Box 5-1 describes the heat planning process in Wroclaw as an example.

Box 5-1. Heat Planning in Wroclaw

The Polish energy law requires municipalities to prepare heat master plans on the basis of the government's energy policy. Before it came into effect in 1997, a particularly promising approach to heat planning was used in Wroclaw. This was a collaborative effort between energy companies and energy consumers. The companies involved in the local energy sector (a municipal DH company, a CHP company, a gas distribution company and an electricity distribution company) worked together in the so-called "Wroclaw Society for Energy Economy" to coordinate their development programs, joined by a scientist from the local technical university, the municipality, and a chairman from the city's three housing cooperatives. The aim of the collaboration was to prepare an energy map of Wroclaw that provides guidelines to answer questions such as which energy carrier is the most economical for energy provision in certain parts of the city. The guidelines are to be used for the development of the energy sector in Wroclaw, but are not obligatory. This approach should provide a strict quality control and the use of previously agreed common assumptions and methodology. The different interests of the stakeholders are to a certain extent reconciled at the feasibility study stage, which reduces the need for later political interventions by the municipality.

5.2.5 Introducing Metering, Cost-based Tariffs, and Targeted Subsidy Schemes

Residential consumers of heat, DHW, and gas in CEE/FSU were traditionally not metered. For DH, the charge was based on the size (square meter) of the dwelling, for DHW, as well as for gas for cooking, on the number of household members. A connection fee was not charged when a new consumer was connected. Cross-subsidies existed, leading to very high charges for industrial and commercial consumers and very low charges for residential and budgetary consumers. In addition, tariffs were uniform throughout each country, not reflecting local variations in the costs of generating and distributing heat or in transmitting gas to various geographical areas.

There is a general consensus now in CEE/FSU on the key principles of energy tariff policy, as follows:

- The tariff for each consumer group should reflect the full cost of supply;
- Cross-subsidies between major categories of consumers should be avoided; and
- Billing should be based on metered consumption.

To make cost-recovery tariffs affordable during an economic transition period, income supports must be provided to low-income households. Furthermore, mechanisms need to be put in place to reduce arrears that have been building up during the last few years, threatening the financial viability of energy companies.

5.2.5.1 Metering

Progress with installation of building meters for heat, DHW, and gas varies by country. In many cities in the Czech Republic, Hungary, and Poland, the metering rate is close to 100 percent. In the Baltic countries progress has also been substantial. In 1996, 50 percent of Lithuania's urban households lived in buildings with building-level heat meters. In Russia and Ukraine, however, fewer than one percent of residential buildings have heat meters installed; the situation for gas metering is not much different.

The progress in metering depends on several factors:

- National requirements to install heat meters in every building. This has been proposed in Lithuania, for example. In Russia, it is required in new buildings and in buildings that undergo capital repairs.
- Attitude of the distribution company. Usually, they are opposed to metering because together with consumption-based billing this provides incentives for consumers to invest in energy-efficiency measures that reduce sales.
- Quality of water in DH systems. Bad water quality can reduce the lifetime of heat meters to less than six months. This can be a particular problem in the four-pipe systems where non-treated water is used.[78]

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[78] In the Bank's Enterprise Housing Divestiture Project in six Russian cities, this has been a problem in the first project phase.

Investments in heat meters at substations and at the point of delivery to apartment buildings are now a standard component of the rehabilitation programs for DH systems. Metering of natural gas used for cooking is introduced to avoid "free" shifts from DH-provided heat to heat provided by gas stoves.

When there is building-level, but no apartment-based heat metering, heating costs continue to be allocated on a lump-sum basis to individual tenants. Although some energy savings can be observed, the existing energy saving potential can be further exploited through introduction of individual metering of heat and DHW at the dwelling level. Together with individual regulation of heat consumption through manual or thermostatic radiator valves (TRVs), this would make it possible to charge households according to their individual consumption. Unfortunately, individual metering is relatively costly and complicated in buildings with central heating systems in general and in CEE/FSU in particular (see Annex E).

A more equitable cost allocation is a second-best solution, and it can be achieved with relatively cheap evaporation devices—the so-called heat cost allocators (HCAs). In Poland, for example, several companies are now installing TRVs and HCAs and provide billing services to housing cooperatives and homeowner associations. Out of 5.5 million apartments in Poland, 1.1 million are now equipped with HCAs. In Western Europe, the combination of TVAs and HCAs has typically achieved savings of 15–20 percent. The costs of these devices and services are listed in Table 5-2.

Table 5-2. Typical Cost of Heat Metering and Individual Controls in Apartments

	Cost per unit (US$)	*Units required per apartment*	*Cost per apt. (US$)*
Total investment cost per apartment			**145**
Heat meter, building level	285	N/A	8[a]
HCA	4.20	4	17
TRV	30	4	120
Annual cost of billing & service per apartment	1.50/HCA 8.50/apartment	N/A	15

N/a: not applicable.

a. Assumes 35 apartments per building.

Source: Supplier information for Poland.

5.2.5.2 Tariff Policy

The introduction of metering and consumption-based billing leads to the issue of appropriate rate structure, particularly the allocation of annual costs between the fixed and the variable, energy-consumption related part of the tariff. In most cases, two-part tariff are applied where the fixed annual rate is supposed to cover the cost of administration and of investment and other fixed assets. The tariff normally depends on the size of the dwelling ($\$/m^2$) or the contracted maximum capacity ($\$/m^3$/hour/year).[79] The variable rate, covering the variable costs of heat supply, is calculated per consumed unit of heat (\$/Gcal) or per cubic meter circulated water ($\$/m^3$). [80]

The tariff structure sometimes involves a trade-off. In Western European DH companies, the share of fixed costs is normally 40–50 percent of the total cost; in CEE/FSU it is closer to 20 percent.[81] Because it is in the financial interest of the DH company to avoid fluctuations in net income from one heating season to the next due to weather conditions, it would prefer high fixed charges.[82] The promotion of energy savings at the end-user level calls for a high percentage of costs to be transferred to the energy charge. An appropriate compromise is to charge between 60 percent and 70 percent of annual costs through the energy charge. In some instances, DH companies in Poland have used one-part, variable tariffs to provide incentives to consumers for investments in energy saving equipment. As a result, heat consumption went down so much that it created financial problems for the companies.

The introduction of variable flow allows consumers to shift load during the day, e.g., by making use of night set-back. Daily load variations may increase up to 20 percent, which causes additional costs in the DH system. Use of appropriate tariff instruments can reduce such load variations.[83]

Whether a connection fee for DH or natural gas supply should cover part or all of the cost of connection depends on the market situation. A low connection fee encourages market penetration; a high connection fee facilitates the financing of investments in DH or natural gas supply and lowers the overall costs of finance of a DH company. In the current circumstances in CEE/FSU, it seems that distribution companies are willing to accept low connection fees if they can extend their consumer base. In the case of DH, potential new consumers are usually those

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[79] This rate is normally scaled so that large consumers pay proportionally less per square meter than smaller consumers.

[80] This rate is normally applied equally to all customers.

[81] The economic advantage of DH is based on low fuel costs, whereas the fixed costs of supply are higher than in the case of a natural gas system. The more energy-efficient the DH system is (the higher the share of CHP production) and the higher the share of cogeneration benefits allocated to DH , the higher the fixed cost of heat will be.

[82] Financial insecurity caused by weather fluctuations can be handled by quarterly revisions of heat tariffs: lower-than-expected sales lead to an increase in the tariff, while higher-than-expected sales lead to a decrease.

[83] The Copenhagen energy utility had problems with return temperatures that were too high (around 65° C on average). The company succeeded in reducing return temperatures by paying up to 10 percent back if the return temperature from the consumer was below average, and adding a surcharge of up to 10 percent if the return temperature was above average. The return temperature dropped by 10–15°; in addition, daily load variations were decreased.

currently supplied from isolated DH networks. In the case of gas, high-load consumers such as hospitals are sought after.

If DH or gas utilities finance demand-side measures for consumers, this would introduce a new component in the cost structure of heat and gas supply. In order to include it, the official formulas for calculating the rate structures of tariffs would have to be reformulated.

5.2.5.3 Affordability of Heating and Subsidies

During the first half of the 1990s, the costs of heat and natural gas increased dramatically in CEE/FSU. Although progress toward implementing full-cost pricing for energy has been impressive, in many countries it is still far from complete (see Table 5-3.) The difference between costs and tariffs for residential and public consumers was covered by state and municipal subsidies paid to the DH and natural gas companies and by cross subsidies from industrial tariffs. In many countries, this procedure was necessary because energy legislation did not allow energy subsidies to be paid to individual consumers. In addition to tariffs below cost recovery, many residential consumers receive privileges, particularly in the FSU.

Table 5-3. Energy Cost Recovery in the Residential Sector (in percent)

Energy Source/ Country	*DH*	*Natural Gas*	*Electricity*
Poland	75 (1995) ~100 (1998)	60–70 (1994)	50–60 (1994)
Lithuania	60 (1995)		
Ukraine	80 (1998)		4–10 (1994)
Russia	40 (1998)	10–20 (1995)	10–15 (1994)
Bulgaria	54 (1998)		10–15 (1994)
Romania	60 (1996)[a]		

a. Based on actual financial cost in Timisoara, which is estimated to be only about 20 percent of true economic cost of DH.

Source: World Bank staff.

The greatest progress can probably be reported from Poland. Two kinds of heat tariffs used to be in place here: standard prices fixed by the ministry of finance for space heating and DHW, and consumer prices agreed between the supplier and the customer. The standard prices determined the maximum price that could be charged by heat suppliers to apartment dwellers. If production costs and therefore consumer prices were higher than the standard prices, the difference was covered by the state budget for housing cooperatives and by the municipal budget for housing administration of public buildings. In 1991 the average subsidy amounted to 70 percent of the cost of supply calculated by the DH companies; by 1996, the average subsidy was reduced to 20 percent. The standard price increased from US$0.17/Gcal in 1989 to US$41.31/Gcal (US$35/MWh) in 1996. In most cities, DH tariffs now cover 100 percent of costs. Starting January 1, 1998, the new national energy law abolished the concept of "official" or standard prices. In principle, prices can now be set between heat supplier and customer. Tariff changes need to be approved by the energy regulatory agency (URE), but, first, DH companies need to receive a license from the URE to supply heat to their service area. The licensing process has started, but it is expected to be relatively slow. For those DH companies that have not yet received their licenses, heat tariffs will be based on "agreed" or maximum price increases set by the ministry of finance.

Box 5-2 shows the results of some of the household energy surveys in Russia, Ukraine and Lithuania. Even though cost recovery at the time of the surveys was still far from complete, households paid between 5% and 20% of their incomes or expenditures for heat and hot water.

Box 5-2. Affordability of Heating: Results from Household Surveys

Within the Bank's Kiev DH project, a household survey was carried out in 1997. On average, people connected to DH spent 6 percent of their expenditures on DH and 4 percent on hot water, a total of 10 percent (discounts and subsidies are deducted). But this varied from slightly above 15 percent for the poorest households to 5 percent for the richest. For Kiev, the average heat tariff at the time of the survey was $22/Gcal (which would cover the cost), and cost recovery from residential customers is currently 80 percent.[84]

Several surveys were carried out in Russia in 1995 for the Bank's Enterprise Housing Divestiture Project. Cost recovery was around 30 percent. According to an internal Bank project appraisal,[85] average housing costs (maintenance + utilities) amounted to about 5 percent of household money incomes. Assuming full cost recovery, this would increase to about 15 percent. The survey results for Vladimir and Volkhov point to an average 10 percent share of housing costs in household income, and 20–25 percent for the poorest households.

A large household energy survey in the Lithuanian cities of Vilnius and Kaunas in early 1995, undertaken as part of the ESMAP project,[86] had the following results: On average, households spent 11 percent on energy (DH is about 50 percent of that), low-income households as much as 20 percent. Cost recovery was then about 30 percent.

Since the mid-1990s the tendency has been to switch to individual payments of subsidies and to eliminate cross-subsidies from industrial tariffs. Almost all CEE/FSU countries have adopted social legislation to provide income support to low-income citizens to help pay their energy bills. In many FSU countries, a housing allowance program has been introduced, where the government covers the portion of the cost of utility services that is above 15 or 20 percent of the

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[84] In early 1998, the cost allocation in CHP plants providing heat to the Kiev DH system was changed, resulting in a decrease of the tariff from US$22/Gcal to US$17/Gcal. See *Ukraine: Kiev District Heating Improvement Project*, Staff Appraisal Report (April 1998).

[85] *Russian Federation: Enterprise Housing Divestiture Project*, Staff Appraisal Report (Washington, D.C.: World Bank, April 1996.)

[86] Josephine Arpaillange, *The Buildings and the People: Lithuania Household Energy Survey, Building Assessment Study, and Homeowner Association Study*, Consultant Report for ESMAP (Washington, D.C.: World Bank, June 1995).

income of a household.[87] In many countries, not the entire utility bill is subsidized in this way, but only that part that can be attributed to heated space below a "social" norm, about 15 square meters per household member.

The switch from subsidized tariffs to social payments has led to substantial savings for public budgets because subsidies are no longer accruing to 100 percent of the population irrespective of income, but only to a subset. In the beginning of the 1990s, subsidies typically covered 70–90 percent of actual costs and represented one-third of the annual budget of a municipality. Now the subsidy payments are lower than 30 percent of the cost of supply in CEE countries.

However, the effectiveness and efficiency of those housing allowance programs should be improved. The programs usually suffer from lack of coverage and to an even greater extent from leakages to non-eligible households. The targeting to poor families needs to be improved through the use of poverty correlates.. Municipalities that usually administer the program need to be strengthened in their administrative capacities, and they must be bound to transfer to the utilities the subsidized shares of charges billed to low-income households.[88]

The need for subsidies will decline with increases in income, which have lagged behind the increase in energy prices. Rehabilitation of DH systems and of buildings, which will lead to substantial energy savings, will also reduce energy bills of consumers and consequently decrease subsidy payments. In the Timisoara case study, the consultants estimated that the full-cost recovery tariffs of a modernized DH system with cogeneration would be affordable to households, consuming about 7 percent of their income in 2005, if incomes increased 5 percent per annum.

Affordability is and will remain in the foreseeable future a serious problem in some countries of the FSU, such as Georgia, Armenia, Moldova and Kyrgyzstan, where per capita GDP is only between US$300 and US$1000. It is questionable whether the infrastructure that was built according to central planning standards can and should be rehabilitated: most inhabitants will not be able to pay cost recovery tariffs, particularly for district heat, for many years to come. Efforts are now under way in some of these countries to develop heat strategies that would identify technical and institutional solutions resulting in a financially, socially and environmentally sustainable heat infrastructure.

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[87] An example of an efficient system for the administration of subsidy payments can be found in the Russian city of Orenburg. According to federal legislation, households should pay no more than 20 percent of their income for utility services. Low-income households apply to the municipal administration for a subsidy. Based on the information received about income and the number of households members, the "Center for Rent Subsidy" calculates the level of subsidy which is justified. The municipality pays the monthly subsidy directly to the accounts of the DH and gas utilities on behalf of the consumer.

[88] Cp. "Russian Federation: Affordability of Cost Recovery in Housing and Communal Services" (Draft Report, Washington, D.C.: World Bank, March 1999).

5.2.5.4 Consumer Arrears and Sanctions for Non-payment

The initial price hikes for energy in the early 1990s led to massive arrears in consumer payments. Consequently, many energy distribution companies were unable to pay their suppliers, triggering a system of triangle debts. The percentage of non-paying consumers was and is particularly high among DH customers. The annual bill for heating is much higher than the electricity and natural gas bills[89] and it is difficult to cut off non-paying consumers.

The problem of consumer arrears is far from being solved.[90] Even in countries like Poland, where the economic situation has improved substantially, DH companies are still faced with substantial arrears. While DH companies in Western Europe usually target a level of "days of net sales receivables" of a maximum of 40 days, it is still closer to 100 days in many Polish companies. In countries further east, levels of more than 300 days are not unusual. The deteriorating quality of heat, through a shorter heating season and lower supply temperatures, certainly has contributed to this situation. In many FSU countries, the problem of arrears is aggravated by the fact that only a small percentage of payments is made in cash; the rest is made in barter, promissory notes, etc.

Arrears still occur in all consumer groups, but mostly in the residential and the public sector. The introduction of targeted subsidies has led to a reduction in the number of non-paying households. The remaining non-paying customers represent a heavy financial burden for the DH companies.[91] Since the approval of a "full-cost coverage tariff" is based on the assumption of all customers paying fully, any arrears lead to financial deficits.

Use of sanctions against non-paying consumers is an efficient instrument for reducing consumer arrears. For instance, in Timisoara, where gas supply is cut off after two months of outstanding payments, the gas company reports arrears in the order of 2 percent of billed sales. In DH, however, the use of sanctions faces legal and technical difficulties:

- Consumer installations for heat transport in the buildings do not allow for individual disconnection. Cutting off a tenant would also cut off customers on the lower floors unless a bypass is installed.

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[89] Typically, the heat and DHW bill is about 60 percent of household expenditures for housing maintenance costs.

[90] For policies and measures addressing the problem of non-payments, cp. *Non-Payment in the Electricity Sector in Eastern Europe and the Former Soviet Union* (Washington, D.C.: World Bank Technical Paper No. 423, June 1999).

[91] Despite the fact that heat tariffs were heavily subsidized, actual payments by residents in the last quarter of 1995 amounted to only 10 percent in Dnipropetrovsk.

- In several countries, laws and regulations do not allow DH and gas companies to cut off supplies to non-paying households or to public institutions of "social" character (hospitals, kindergartens, etc.).[92]
- Interruption to industrial and commercial clients is in theory possible but is rarely put into practice.
- Enforcement of payments is usually not done through the courts (the court system is overburdened), but through social pressure.[93]

When sanctions are not a solution, DH companies have to resort to other methods. These include incentives for timely payments, constant reminders, and bonuses for staff if payment is on time. The introduction of pre-payment systems, which have a fairly good track record for electricity, is also being considered for other utilities, such as water, gas, and heat (see Box 5-3).

Box 5-3. Improving Collections

- In Almaty in Kazakhstan, the rate of paying residential DH customers was increased from 40 percent to 80 percent by cutting off the electricity supply to consumers not paying for their heat supply. Such a method gets around the problem of not being able to cut off DH consumers. However, it presupposes common ownership of the heat and of the local electricity distribution company.
- In Yerevan, Armenia, the Yerevan Heat and Power Plant is in charge of directly supplying customers in some parts of the city. In general, it eliminated housing maintenance companies as collection agents and concluded contracts directly with each end user. In some buildings it introduced a pilot prepayment system. Buildings would receive heat only if inhabitants prepaid at least 50 percent of the heating bill at the beginning of the heating season. In those buildings, collections reached 70 percent of billings (which are based on cost-recovery tariffs) as compared to the average of 10 percent for DH supplied buildings in Armenia in the 98/99 heating season. As a result, the government required that all heating companies introduce prepayment systems in the 99/00 heating season.

The non-collection problem is frequently aggravated by the fact that in many cities in CEE/FSU the DH company has contracts not with individual households but with housing maintenance organizations that are in charge of collecting payments for communal services. If the DH company receives no payments, it does not know whether the culprit is the end user or the collection agent. To improve commercial efficiency and decrease arrears, DH companies need to enter into direct contracts with each consumer and take over billing and collection themselves. This should be done even before metering at the building level is introduced.

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[92] In Dnipropetrovsk in 1996, one-half of consumers (in terms of volume) did not pay their gas bills. One-half of the non-paying customers were hospitals, schools, and prisons.

[93] In the Latvian city of Jelgava, the municipal DH company started to publish in local newspapers the names of well-known citizens who had not paid their heating bills.

Measures to improve the payment morale of public sector customers include dedicated budget items that can only used for the payment of energy bills. To clear old debts, many governments have also agreed to a system of tax offsets (e.g., in Russia, until the end of 1997).

5.2.6 Economic Regulation of the Heating Sector

5.2.6.1 Assignment of Responsibility for Regulation

The break-up of the state-owned DH companies into local municipally owned companies calls for an overhaul of the legal and regulatory framework for the sector. Various regulatory approaches are possible and the debate in most countries has not yet reached a definite conclusion.

At the macro level, the subject of debate concerns the assignment of authority for the economic regulation of the DH utilities. The issue is whether the regulatory responsibility should be assigned to the local municipalities, to regional authorities, or to a national regulatory body.[94]

The case for municipal regulation is not strong. The argument for transferring regulatory responsibility for DH to the local level is that DH is a locally confined activity. Even if this is accepted, however, a national regulatory body is still needed to define general principles for the economic regulation—including the methodology—for tariff approval. Furthermore, such a body should act as a body of appeal. As long as the ministry of finance finances an important share of the subsidies for the energy bills of low-income consumers, there will be a wish to constrain the local influence over the setting of tariffs. Local regulation causes the awkward situation that the municipality is owner as well as regulator of its own company, which subjects the DH company to dual local economic regulation. The supervisory board appointed by the municipality monitors the financial and management performance of the company; the municipal regulator would do the same.

While setting up regional regulatory commissions in a vast and heterogeneous country such as Russia is rational, it would stretch thin the regulatory expertise in smaller countries. Therefore, in general, a national regulatory commission will oversee the DH sector, possibly jointly with the electricity and gas sector.

At the micro level, the discussions are about the legal form for assigning rights and obligations. In the absence of a licensing regime, the rights and obligations of the different parties are defined by the municipal administration through the statutes of the DH company, and through contracts with the DH company and with its managing director. However, most countries are contemplating now the introduction of a licensing regime for DH. Under a local regulatory regime, the local municipality will issue the license. This makes sense, because the municipality

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[94] Natural gas and electricity distribution companies are linked to regional and national grids crossing the border of several municipalities. Therefore, in all countries, national authorities regulate them. In Russia, regional authorities also play an important role.

owns the streets and public areas the DH system uses. With a national regulator, either the national regulator or the local municipality—on behalf of the national regulator—could issue the license.[95]

5.2.6.2 Sources of Heat Supply and Regulatory Tariff Approvals

One advantage of DH is its flexibility in fuel supply with regard to the type and location of heat suppliers and with regard to the type of fuel suppliers use. A larger DH distribution company may get its supply of heat from a CHP plant or a waste incineration plant for base load supply, from industrial cogeneration or HOB for peak load and reserve capacity, and/or from HOBs owned by the DH company and used mainly for peak load production. In many cities in CEE/FSU, all three sources of heat generation can be found to provide base load supply.

A DH company contracts heat from an outside source when this can supply heat energy and heat capacity more cheaply than a plant that is built, operated, and owned by the DH company itself. A contract for heat supply from outside sources has three major tariff components: (1) payment for capacity,[96] (2) payment for fixed costs of operation,[97] and (3) payment for variable costs of operation (fuel and other operating costs).

The question for the newly established regulatory authorities is whether there is a need to intervene in the negotiating process between the DH company and the external suppliers of heat. If the regulatory authority were asked to approve the tariffs of all heat producers, the administrative burden would be huge,[98] and would detract the work of the regulatory authority away from its core responsibility, the regulation of (near) monopoly positions in the production and the supply of energy. In the vast majority of contracts for heat purchases, the prices are the outcome of commercial negotiations between "equal" parties that can both afford to say no to the conclusion of an unfavorable contract. There is need for regulatory supervision only when this is not the case.

There is no need for the regulator to approve the contracts between a DH company in charge of a large integrated network and its industrial heat suppliers.[99] For the industrial firms, heat supply is

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[95] The licensing process, through the national regulator, has just started in Poland; see section 5.2.5.3.

[96] The heat purchaser is obliged to pay only for capacity that is dependable. A contract should therefore contain a clause that stipulates regular inspection of the supplier's heat plant by a qualified third party to ensure that the capacity is available in the quantity contracted.

[97] This element is usually only found in contracts for peak load and reserve/stand-by capacity. For base load purchases, it is incorporated in the payment for energy.

[98] In Lithuania, a small country, this is presently envisaged. The regulatory commission would have to approve the prices of about 3,000 producers.

[99] The regulator would only have to intervene if a formal complaint were received by a consumer of the DH company that the company was paying too high a price for its contracts with external suppliers, and that the "over-price-element" should not be included in the retail tariff.

a non-essential activity that is carried out as long as it pays. For the DH company in many cases, heat from an industrial firm represents a marginal source of supply, which can be replaced by alternative sources. The cost of production for a new HOB plant or the variable cost of production of "surplus" HOB capacity that it owns is the reference point for the DH company; it fixes the upper floor for the negotiated price. The industrial firm needs to cover at least the marginal costs associated with the supply of heat; this fixes the lower floor. The contracted price will be somewhere between the two extremes, with the outcome depending on the strength of the bargaining position between the DH company and its suppliers.

Regulatory supervision is justified for two other cases, at least for a transitional period until general conditions improve:

- Privatized residential buildings that were formerly owned by an industrial company and are supplied by small isolated DH systems belonging to this company are faced with only one source of heat supply. Once the homeowners association in a building becomes fully operational, it could chose to install individual building boilers if it does not get favorable terms from the industrial company. In principle, the residents are protected in this situation by the rules of general competition law that forbid the abuse of a dominant position. However, during a transitional period—preferably with a pre-defined length of time—the regulatory authority should establish principles for the pricing of tariffs of industrial heat supply to small, isolated networks.
- The break-up of the vertical integration of the power sector and its horizontal integration with the DH system puts the CHP plant in a monopoly bargaining position when the terms of supply are negotiated with the DH company. With CHP plants (including their HOBs) covering up to 90 percent of annual heat demand in a large DH system, the DH company has no alternative competing option for its base load. A large HOB plant could be constructed and be ready for the next heating season. But it cannot produce heat as efficiently as a CHP plant. As long as the CHP plant charges a tariff for CHP supply that is not higher than the cost of production in a new HOB plant, it may be in compliance with anti-monopoly law.

Recognizing that the commercial viability of the large DH systems depends on cheap supplies of heat from CHP plants, the authorities in CEE/FSU have the choice between two options. One, as in Lithuania, is to transfer the ownership of the CHP plants to the municipal DH companies. Regulation can then be restricted to one aspect only—to provide the CHP plants with non-discriminatory or preferential access for selling their power output to the national grid. The other option is to leave the ownership of the CHP plants in the hands of the power companies. In that case, the regulators must define rules for calculating the prices of heat supply from the CHP plants to assure that both products of the CHP plant, power as well as heat, can be competitive in their respective markets. This may require a more equitable sharing of the cost-saving benefits of combined heat and power production (see below).

The old rules from the times of central planning shifted all the combined cost advantage to the pricing of power. In some countries, for example, Poland, the tariff for heat deliveries from CHP plants charged to the DH companies was equal to the cost of production of a HOB plant. In other countries, such as Russia, the cost of CHP plant production was allocated to electricity and heat production according to the relative energy content of the output. Since the energy conversion efficiency of heat production is higher than that of electricity production, this rule transfers the cost advantage to electricity.

In Russia, the separate ownership of CHP plants (including related transmission) and of heat distribution has left many municipalities depending on one major heat source that charges high tariffs. This provides an incentive for municipal DH companies to invest in their own HOB capacity, which might result in lower heat generation costs. From a system point of view, this is clearly a sub-optimal decision illustrating the need for regulatory action.

5.2.6.3 Principles for Pricing Heat and Electricity from CHP plants

Technically, the calculation of the economic and financial cost of heat in a CHP plant is straightforward. (See Annex C for details.) Politically, the allocation of the joint costs of CHP between electricity and heat is an issue of contention. In circumstances of a "free" negotiation, the risk of new entities entering the market for heat supply fixes an upper limit to the heat price that a CHP plant can obtain from a DH company. The highest heat price that a CHP plant can charge, is the lower of the following two:

- A price close to the cost of production of a new HOB plant.
- The price that makes the DH consumer tariff break even with the cost of a unit of heat supplied by a building boiler. Otherwise, the CHP plant would lose its market for the output of its heat production. This "net-back" price for CHP-produced heat can be calculated by deducting the cost of heat distribution and transmission[100] per Gcal from the generation cost per Gcal of the building boiler.

The contentious issue arises when this "free market price" is higher than the economic and financial cost of heat production at the CHP plant. Charging the market price for heat gives the power company owning the plant an economic rent.[101] If the DH company owned the plant instead, its cost of heat supply would fall to the cost of heat production at the CHP plant. The heat consumers would benefit from the "economic rent" in the form of lower heat prices.

No objective way of allocating the economic rent can be designed. Social equity considerations (and duopoly bargaining) tend to favor a sharing of the joint production benefits between the electricity consumers (all citizens) and the heat consumers (the minority). Energy/environmental policy considerations tend to allocate most of the cost-saving benefits to DH, in order to promote the application of energy-efficient cogeneration. There is sufficient power capacity in most

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[100] Including the cost of the necessary HOB operations for peak supply.

[101] When a power company is subject to rate of return regulation, the economic rent will be distributed to its consumers through lower electricity prices and to its employees through higher salaries. When the CHP plant operates in a free market, the economic rent will be distributed to the owners in the form of higher profits and to the employees.

countries of CEE/FSU and investment needs in power are therefore relatively low. On the other hand, a huge need for investments in the modernization of the heating sector exists. It would be rational to transfer most of the combined cost advantage to DH in order to facilitate the financing of these investments. This would have the potential of reducing heat bills to consumers, while at the same time having little impact on the electricity bills. In Kiev, for example it was decided in early 1998 to assign a part of the benefits of cogeneration to heat. This resulted in a decrease of the retail heat tariff from $22/Gcal to $17/Gcal without any impact on electricity tariffs.

In a future free market system, new capacity additions in the power sector will be put out for bidding, either directly by a national power system operator, or indirectly through the operation of a power pool. In such a system, there is little need for regulatory intervention. If a CHP plant is a lower-cost option than a dedicated power plant—that is, the price for heat it can get from the local DH company generates a revenues more than sufficient to amortize the extra cost of CHP plant operation—it will win the bid. Since a CHP plant can be owned and operated either by a power company or by a DH company (both could bid for the construction), it is likely that joint share holding will become a common feature for CHP investments. If a power company wants to be the sole owner, it must conclude a long-term contract with the DH company for the supply of heat before it undertakes the investment in a CHP plant. The DH company is in a monopoly buyer position and can extract a favorable price from the CHP investor. Thus, both ownership structures will lead to a balanced sharing of the cost advantages of CHP production. A reason for regulatory intervention in an otherwise well-functioning market could be to take externalities into account—for example, environmental costs, which are not reflected in market prices because adequate environmental levies are not imposed on production.[102]

The reason for regulatory intervention in the present transitional period is that there are no long-term contractual relationships and well-functioning competitive markets for power and heat that guarantee an adequate allocation of the benefits of CHP operation. The concession for the ownership and the operation of a CHP plant was given to the power company under a system in which the power company had a monopoly for power production, and where the state administered prices for heat and for power. Regulatory intervention is justified in order to mimic the tariff that would have resulted from a free market negotiation uninfluenced by monopoly conditions.

The market situation for power in most CEE/FSU countries justifies regulatory intervention in securing access to the national power market for CHP plants that are owned by DH companies. The sharp fall in the industrial demand for electricity has generated substantial over-capacity in

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[102] An illustrative example is the following: Based on "pure" market prices, coal-fired power plants built close to the coal mines are the cheapest option for electricity generation in Poland. But by preventing the construction of CHP plants, production of power and heat will be less energy-efficient and more CO_2 intensive. If the government should decide that the additional cost of CHP operation is a cost-effective investment in CO_2 reduction, it has a motive to intervene in favor of the CHP option.

power production.[103] This over-capacity pushes bulk power tariffs down to the level of the variable cost of production. Laws should facilitate qualified independent power producers access to the grid at economic prices as a means to promote investments by DH companies in medium and small-scale CHP plants. In Russia, the draft law for energy savings provides independent power producers with guaranteed access to the electricity and heat grids, and at prices that amount to 85 percent of the average wholesale tariff.

The contracts for heat and for electricity supply from CHP should promote economic dispatching from the point of view of a total heat and power system.[104] Heat supply contracts for power utility-owned CHP plants should contain clauses that allow the operator to dispatch according to least-cost production of the total system. At peak load demand for electricity, it may be cheaper to reduce heat production at the CHP plant and bring HOBs into operation, rather than to start up production at an inefficient power plant.[105] For shorter periods of time, the heat storage capacity of the DH network can be used, allowing increased power production. Electricity tariffs for CHP plants owned by DH companies should be time-of-day based.[106] This provides the proper incentive for a DH company to respond to the economic costs of the national/regional power system and to optimize investments in CHP, HOB, and heat storage capacity.

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[103] In Lithuania, the market outlook for CHP-generated electricity is particularly serious. National and export demand (to Latvia and Belarus) has fallen by about 50 percent, making it possible for the nuclear power plant Ignalina to meet all national demand. The CHP plants are needed for stand-by purposes only. Basically, they are operating as HOB plants, getting payment for capacity only. Since they have more capacity than is needed by the national power company in the form of stand-by and emergency capacity, their income from electricity is minimal. However, the Lithuanian government intends to close one unit of Ignalina in 2005.

[104] In principle, regulatory tools in the form of prices and appropriate contracts permit the achievement of "optimal total system dispatching" irrespective of ownership. In practice, total optimization is easier to achieve when the CHP plants are under power utility ownership. This is at least the experience in Denmark. In the eastern part of Denmark—in the Elkraft power utility area—the CHP plants are owned by the power companies. In the western part—in the Elsam power utility area—the CHP plants are owned by DH companies. The Elsam power companies (which may not be completely neutral and unbiased in their opinion) claim that power system optimization is more difficult for them than for their Elkraft colleagues.

[105] The tariff for sales of heat from the large CHP extraction plants in Copenhagen has 10 components of fixed and variable costs. One cost component is calculated on the basis of weekly simulations of the power system. It takes into account that the value of CHP electricity depends on the situation in the power market. When there is cheap surplus hydropower available from Sweden and Norway, e.g., during a weekend in spring, it may be more economical for the DH companies to use their HOBs instead of paying for the operation of a CHP unit. This cost component ensures that the DH company pays for the true cost of heat production.

[106] In Denmark, small CHP plants (below 80 MW_{el}) are often owned by DH companies. They are paid a very favorable electricity price of 90 percent of the city gate price, and with the same time-dependent structure.

In the long run, heat supply is a competitive business because there always exists an alternative (such as building boilers), the cost of which will provide an upper limit for DH tariffs. So even if there is a regulatory body, this will be the way that heat tariffs will settle in the long run. For political reasons, municipalities usually want to see heat tariffs based on "actual" costs, so the heating enterprises must bring their actual costs into line with the alternative option. Heat enterprises then act in a way as to extend their networks into areas where the marginal costs are just below the alternatives, thus also ensuring that an economic optimum of the size of the networks is achieved.

5.2.7 Institutional Aspects of Energy Efficiency Investments in the Building Sector

The residential sector is the most important consumer of district heat. All buildings in CEE/FSU are in need of rehabilitation investments that would trigger substantial energy savings (see section 3.3.) Whether and how this can be achieved depends largely on the institutional mechanisms that would provide the owners of the buildings and apartments with incentives and financing sources for investing in building rehabilitation. For the residential building sector, Martinot (1997) presents an overview of the barriers, opportunities, and the limited experiences to date.

Privatization of dwellings has proceeded at different paces in different countries. Since 1992 in Russia for example, households have privatized about one-third of the housing stock previously owned by the state. Together with the 20 percent of housing that was in private hands before 1992, about one-half of the housing stock in Russia was privately owned in 1996. In Lithuania, privatization of housing started earlier and was more widespread; almost 90 percent of all dwellings had been privatized by 1995, the highest rate among all FSU countries. In Estonia, about two-thirds of dwellings had been privatized by 1996. In Ukraine, after privatization began in 1993, about 32 percent of all dwellings targeted had been privatized by 1995, with most of these in urban areas. (Before privatization, over 90 percent of rural housing was already privately owned, while the majority of urban housing was municipal or enterprise housing.) In all cases of privatization, the land on which residential buildings stand is still state-owned, except in the case of single-family houses.

However, privatization of individual dwellings in multi-family buildings cannot necessarily be equated with private owner responsibility for the buildings themselves. In practice, privatization may simply mean transfer of the deed to a particular dwelling, giving the owner the right to sell it or to pass it along to heirs. In many situations, institutional and management structures associated with responsibility for buildings have not changed at all following partial or full privatization. Households can only be collectively responsible for their buildings after they organize into homeowner associations. Such associations can make decisions about maintenance, operations, and capital investments, and hire their own housing maintenance organization for improvements or maintenance in common areas of buildings, such as the renovations to heating systems, or repairs to windows, staircases, and roofs. Until this happens, municipal governments or enterprises are still responsible for these buildings. However, municipal building maintenance enterprises typically do not engage in renovation investments, only building operation and basic repairs. Even in countries in which homeowner associations are starting to form (the leader in this respect is Lithuania, with about 15 percent of all households currently organized), this responsibility is still not firmly in place. While households may jointly own and share responsibility for common areas, very little maintenance or improvement activities are taking place, as neither habit nor law compel homeowners to take charge of their joint property.

Several social, legal, and institutional factors suggest that voluntary formation of homeowner associations and transfer of responsibility for building repair and maintenance to them will be difficult in these countries. For example, residents are understandably reluctant to assume financial and legal responsibility for a potentially dangerous building in need of substantial repairs. Another common disincentive is that, upon formation of an association responsible for utility payments, potential financial losses from some households not paying their utility bills would be shifted from local institutions (municipal governments, local utility companies, or enterprises) to the households themselves.

Yet under collective ownership of buildings, the formation of a homeowner association is a prerequisite to any collective actions for achieving energy efficiency. Households can make some improvements to their own dwelling (probably on a cash basis rather than through credit), but most energy efficiency improvements in multi-family buildings must be made to the entire building and require a collective decision among all the households in a building. The viability of collective decisionmaking by homeowner associations is highly dependent on social and institutional changes. If a clear law and mechanisms for formation of homeowner associations do not exist, households must start from scratch in organizing themselves, and the legal basis of such an organization may not be clear. Key factors affecting the ability of a homeowner association to make effective decisions are the management and leaderships skills available and the time commitment of its chairman. The time demands of this position are high (chairmen are frequently retired persons), as is the need for a strong personality who can motivate and convince fellow homeowners of the need for collective action.

In some countries in CEE, some progress has been achieved in residential building renovation. Particularly in Poland, such investment has taken place, primarily in buildings owned by housing cooperatives that existed even under the former communist regime. These cooperatives always had to make common decisions about their buildings and had access to cheap credit. In the 1990s, they received substantial subsidies (50–80 percent, depending on the type of measure) for the renovation of buildings. As a result, and due to higher income levels, energy-efficient rehabilitation of residential buildings is much more common in Poland than in most other countries in CEE/FSU.

Public buildings such as hospitals, schools, kindergartens, and public office buildings face severe financial constraints, but fewer institutional constraints with respect to energy efficiency investments. These types of buildings have been targeted in Western countries, as well as in CEE, by energy service companies (ESCOs; see section 5.2.8).

5.2.8 Identification of New Sources of Finance

The financing of investments in the heating sector requires the identification (1) of appropriate sources of finance in terms of cost, quantity, and maturity, and (2) of appropriate channels for receiving the finance for investments in energy supply and in energy efficiency. In this regard, the need to adjust to the institutional requirements of international capital markets has been and will continue to be an important determinant for the organization and business form of an energy utility.

Investments in energy efficiency and in DH and gas infrastructure can be financed from the following sources:

- Utilities' own funds;
- Contributions from municipal budgets;
- Suppliers' credits;
- Grants and concessional financing from bilateral cooperation programs;
- Loans from international financial institutions such as the EBRD, World Bank, EIB, and others;
- Loans from private foreign and national banks and lending institutions;
- Private equity contributions from strategic investors; and
- Project financing from foreign project developers.

The sources of finance above are listed according to the degree of market sophistication and institutional requirements they entail. The first five "classical" sources of finance for infrastructure can be accessed under any industry or regulatory structure. Access to the last three "new" sources of finance requires the partial privatization and the de-monopolization of the industry structure. This is often resisted by local politicians and, above all, by local managers and labor unions. It is a necessity, however, because the scale of the investments required during the next 5–10 years is beyond the lending capacity of the "classical" sources of finance.

Under normal circumstances, the depreciation allowance would be sufficient for an established DH company in Western Europe to self-finance most of its renovation investments. The problem in CEE/FSU is that DH systems are in need of very *substantial* investments for modernization. Even though DH companies in many CEE/FSU countries by now have been allowed to move towards a cost-coverage tariff structure, self-financing capacity is still low. It does not permit the utilities to self-finance more than about 20 percent of their investment needs from their own cash flows because the depreciation allowance is based on past investments. Consumer arrears further diminish the cash flow of the DH companies.

From a commercial lender's point of view, the DH and most natural gas companies in CEE/FSU are not first-rate borrowers. Their financial positions are too weak to allow "balance sheet financing." Their past record of below-cost billing and large arrears in customer payments do not allow project financing on a limited recourse basis. Therefore, even when a DH company is organized as a joint stock company (usually with the municipality as the sole owner), commercial lenders will look for guarantees by the municipality for any loans made to a DH company.

The ministries of finance in some CEE/FSU countries are concerned about the level of sovereign guarantees that have been issued in connection with municipal borrowing from World Bank/IBRD and EBRD. Some ministries of finance are fixing limits for the annual level of sovereign guarantees, which accelerates the search for private sources of finance. In addition, local capital markets are still too underdeveloped to permit publicly owned utilities to raise finance for long-term investment through bond and equity issues.

Therefore, private capital in the form of PPI (private participation in infrastructure) project financing must be allowed to enter the DH sector and fill the financing gap. The entry of private investors brings direct finance in the form of equity capital and widens the scope for financing from the multilateral lending institutions, World Bank/IFC and EBRD. Both institutions make loans to private investors for infrastructure development without asking for sovereign guarantees, and engage in equity participation jointly with these private investors. The institutions operate with "pull out" strategies for their equity participation, which foresee selling their shares after a period of five to eight years. One pull-out strategy could be to sell the shares to the private foreign equity investor; another could be to sell the shares to local investors or pension funds.

To attract PPI financing, the DH system must have an organization structure that allows entry of private capital. One possibility is the "niche strategy": The local DH sector is vertically separated into companies for heat production, transmission and distribution, and energy services. Different private investors could find different companies for entry, taking minority or majority holdings in the companies, (see section 6.3.3.) The generation company may have the best chance for attracting private capital; this will require guaranteed long-term sales contracts. To facilitate coordination of investments and realization of benefits for all parts and owners of the DH system, the municipality could hold some shares in each company.

Another possibility is the "operating concession strategy": The system is kept under the ownership of an integrated utility, but the (municipal) ownership of the infrastructure is separated from the operational responsibility, which is given to a private operator through a concession (see section 5.2.3.4).

The search for efficiency gains (through the transfer of modern management know-how) and for investment capital (through equity) is the motive for inviting foreign strategic investors to become equity shareholders in energy utilities in CEE/FSU. Foreign strategic investors have already invested in shares of natural gas and electricity distribution companies in CEE/FSU and are showing interest in investing in CHP plants. Until recently, a similar tendency was not evident in DH transmission and distribution. The pool of potential investors is not very large because most DH companies in Western Europe are either consumer-owned, non-profit companies that by definition have no capital to invest in outside ventures, or local municipal companies that are subject to a number of constraints on their commercial freedom by their statutes and by decisions of regulatory authorities. Exceptions are Finland, where, since the mid-1990s, shares in municipal DH companies have been sold to private investors; and the Netherlands, where a number of regional integrated DH/gas/electricity companies have been formed.

The situation is slowly changing, however. For instance, in Almaty, Kazakhstan, the Belgian company Tractebel signed an investment-*cum*-concession agreement for the operation of the DH system. The company also purchased the power distribution franchise and the CHP units supplying Almaty. Increasingly, the large potential for energy savings in DH systems in

CEE/FSU offers scope for joint implementation investments in CO_2 reduction, which may attract Western energy companies.

Thus, a mix of new and traditional sources can be used to finance the investments that are needed. The rehabilitation of the DH distribution network in a city, for example, could be financed by multinational lending institutions, whereas the modernization of the CHP and HOB units could be co-financed by private investors through joint ventures (share capital contribution) or through the build-own-(operate-) transfer mechanism. The point is that there is no lack of finance; there is only lack of adequate institutional structures to channel available finance.

Another area in which innovative financing must be developed is that of investment to improve the energy efficiency of buildings. The commercial banks that might extend credit for building renovations to municipal governments, households, or homeowner associations are unfamiliar with this type of lending. They may not understand the returns possible from such projects, or may view the creditworthiness associated with these clients as poor. The lack of contract enforcement mechanisms, collateral, mortgage laws, and land registration institutions (to certify land ownership) can further reduce the willingness of commercial banks to lend.

One avenue being tried in CEE/FSU with the help of the European Union, the EBRD, and the World Bank is the setting up of revolving funds for financing such investments, using local banks as intermediaries. Municipalities have also been setting up revolving funds for this purpose. However, revolving funds have a number of built-in weaknesses and drawbacks. They must be supplemented by other means, such as helping potential borrowers to prepare sound proposals for the investments to be financed. Local contractors and suppliers of energy-efficient building materials need to be nurtured as well.

Another possibility is that the DH company or a dedicated energy service company (ESCO) receives a loan for energy efficiency investments in buildings. Investments in individual substations (which in many countries belong to the building owners) are among the most viable investments. They could be financed by the DH company and be leased either to the tenants or the homeowner association on behalf of the tenants. An extra fixed (lease) fee that is charged to the customer until the investment has been amortized could recover the cost of the investment. In the commercial and public sectors, such arrangements for investments are already taking place. In general, the ESCO shares the savings with the owner of the facility as a means of recovering the investment. However, because individual behavior largely determines the amount of savings that will ultimately be realized, the residential sector is still considered too risky for this kind of arrangement.

6

Conclusions: Recommendations for Heating Sector Policies and Projects

The objective of this report is to provide answers to some basic questions about the competitiveness of DH in CEE/FSU. These basic questions are:

1. Which factors determine the choice of the economically preferred heating option from a given set of alternatives, and under which circumstances is DH, decentralized heating with natural gas, or another alternative the preferred option?
2. How does the institutional environment have to change in order to provide an enabling environment for cost-effective heat supply and demand?
3. How can the preferred option be implemented when the countries in CEE/FSU are in a period of economic and political transition?

As a way of concluding this report, the answers developed in the preceding chapters will be summarized in this chapter. Readers should note, however, that although some general conclusions can be drawn, each individual investment project must be thoroughly evaluated at the local level. How heating services are best provided depends on the interaction and the state of heat supply facilities; connected buildings; consumer reactions; the governance of energy companies; and the rules, regulations, and policy framework that are largely determined at the national level.

Finally, it needs to be pointed out that few of the optimal solutions will be implemented in the short-to-medium term. The needs for funding for investment and for a change in attitude on the part of many of the stakeholders are just too great to be satisfied within a few years. Experience with the Bank's DH projects, (e.g., in Poland) shows that it takes several years to implement basic rehabilitation measures and to change the corporate culture of the DH companies and the institutional framework within which the heating sector in CEE/FSU operates. Completing the task will be a matter of many more years to come. Because the institutional setup is more complicated, investments in the energy-efficient rehabilitation of buildings will take even longer. In the meantime, it is important to choose those policy measures and investments that will not jeopardize implementing the preferred options in the long run.

This chapter ends with a discussion about the role of the World Bank in contributing to a more efficient heating sector in CEE/FSU.

6.1 Competitiveness of District Heating with Alternative Heating Options

As previously noted, the source of the competitive advantage of DH is the ability to produce heat at a lower cost than individual boilers because of

- the fuel savings of combined heat and power (CHP) production (compared to the separate production of heat and power, cogeneration saves about 30 percent of fuel);
- economies of scale in fuel purchases;
- the ability to use cheap fuels in an environmentally compatible manner; and
- the energy efficiency gains from larger boiler sizes, from merit order operation and from systematic maintenance.

Main Factor for Competitiveness of DH: Source of Cheap Heat

The first is probably the most important factor. However, as the example of Orenburg shows, in cogeneration, a high value of fuel savings must be obtained; otherwise, building boilers will have an advantage. If the CHP plant can achieve a good price for its outputs, especially for power, this favors DH. But the price of power from CHP is largely determined by the power situation in each particular country. A surplus of cheap power will lead to a low tariff for bulk power, so that heat sales have to cover most of the cost of production.

Box 6-1. Merits and Problems of DH

DH supplied by CHP:

- improves energy efficiency by utilizing waste heat
- reduces space heating costs
- diversifies fuel sources for space heating to cheaper fuels
- reduces urban air pollution

But DH distribution network costs are very high; therefore, application is limited to areas with:

- substantial space heating demands
- relatively high urban densities
- high connection rates
- low-cost sources of heat

The source of the competitive disadvantage of DH is the high cost of transport of heat to consumers, broken down as follows:

- The annual capital cost of the investment in the transmission and distribution system;
- The cost of O&M of the transmission and distribution system:
  - energy and water losses in the system
  - cost of electricity for pumping
  - pipeline maintenance and rehabilitation.

The size, structure, and distribution of the heat demand in the service area, for which the density of heat demand can serve as a useful indicator, is the chief determinant for the cost of distribution.

Investments to improve the energy efficiency of the existing DH systems in CEE/FSU can lead to a considerable decrease in heating costs, thereby making DH more affordable and more competitive. To illustrate this point, the basic energy economic differences of typical DH systems in CEE/FSU countries (Eastern) and in Western Europe (Western) are shown in Table 6-1. This simple example is not based on any particular DH system, but represents average values.

Table 6-1. Comparison of DH System Energy Economy in CEE/FSU and in Western Europe

Energy Economy of DH	*"Eastern"*		*" Western"*		*Unit*
Fuel energy		155		100	MWh
-combustion losses	-15%	-23	-9%	-9	MWh
To network		132		91	MWh
-Transmission losses	-25%	-33	-8%	-7	MWh
To customers		99		84	MWh
- loss of poor regulation	-15%	-15	0%	0	MWh
A. Heat energy to customer		**84**		**84**	MWh
Costs					
Fuel price	20		20		$/MWh
Fuel cost for heating		3100		2000	$
Profit	10%	310	10%	200	$
B. Customer's energy cost		**3410**		**2200**	$
Unit cost for customer	B/A	**40.60**	B/A	**26.30**	$/MWh

Source: World Bank.

Only fuel costs are taken into account, with the price of fuel assumed to be $20/MWh. The energy costs, which are the biggest cost component in DH, lead to a substantial difference in the customer price of heat since substantial losses occur at every stage of DH systems in CEE/FSU. For the same amount of received heat energy, a customer in a typical DH system in CEE/FSU pays more (in terms of economic costs) than a heat customer in Western Europe. In the example of Table 6-1, the heat energy cost is about 50 percent more in the CEE/FSU system. The real difference may be even larger, because the differences in the energy economy of the building envelopes in CEE/FSU and in Western Europe are not taken into account in this example. Furthermore, household incomes in CEE/FSU are considerably lower than in Western Europe.

The six case studies showed that, based on the economic cost of gas in each city and a remuneration of US$0.04/kWh for electricity output of CHP plants, heat can be produced at an average cost of US$9/Gcal (CHP) and US$23/Gcal (building boilers). For DH to be competitive, the economic cost of heat distribution, including distribution losses, would need to be below

US$14/Gcal on average. These averages hide wide, local differences for "allowable" heat distribution costs; from about US$11 (Orenburg) to US$20 (Wroclaw). Thus, if the heating network needs substantial rehabilitation investment, or if the heat load is rather low, low heat generation costs may not be sufficient to make DH competitive.

The DH systems investigated in the case studies exhibited very different circumstances in terms of heat supply facilities, heat density, price of fuels, and the current state of the DH and natural gas networks. This resulted in very different cost structures. For example, Orenburg has the lowest economic cost of gas, a relatively high heat load density, and a relatively high share of cogeneration. Among the six case study cities, however, it has the highest economic cost of heat based on the rehabilitation of the existing DH network. If heating were based instead on building boilers, heating costs would go down considerably. At the other end of the spectrum is Wroclaw. Even though the heat density in this city is relatively low, the relatively efficient and low-cost heat supply from cogeneration and a DH network that is in relatively good shape (thus requiring less modernization investment) combine to make DH the economically preferred heat supply option.

Building boilers based on natural gas are the main competitors for DH. More decentralized systems such as gas heaters or boilers in apartments are not an alternative when switching heating systems in existing apartment buildings is considered, despite their obvious advantages of flexibility for the end user. Their costs are very high, and they would have a significant environmental impact. Furthermore, implementing a switch to individual heating would be very difficult: households in an apartment building would have to make joint decisions about this and would have to bear the considerable investment costs. (See below for the related transitional problems.)

District Heating and Cogeneration: The Need for Political and Regulatory Action

The case studies have shown that low heat costs, usually stemming from cogeneration, are of vital importance for viable DH systems. In CEE/FSU, at least two factors currently prevent DH systems from making use of these lower costs:

- In most cities, less than the optimum amount (about 80–90 percent) of total heat production originates from cogeneration.
- The energy efficiency benefits of cogeneration do not translate into cost savings for heat. Instead, in most countries, only power benefits from the cost savings.

While it can be established in principle that DH would be more cost-effective than more decentralized systems in a particular location, most existing DH systems require substantial investments to realize this potential. If DH does not become competitive in price and in technical performance, customers will start to switch to heating alternatives. This process may be slow in starting up, but could accelerate very fast. First, the best and largest customers will leave the system. Tariff revenues from the remaining customers need to cover the original level of fixed costs and slightly reduced variable costs. This means increasing tariffs for DH customers, which would give them even greater incentive to leave the system. The alternative is a deteriorating DH system. The problems of the DH system would also create problems for the power sector. The heat load would be reduced and with it, the potential for CHP as well. The peak load duration time of CHP plants would shorten and the costs of electric power from CHP would increase. These trends would ultimately lead to uneconomical and environmentally unsound energy systems.

One could argue that, over time, the CHP plants will realize that their existence depends on the existence of a cost-competitive DH system. They would then become more inclined to allocate benefits to heat as well, as long as they remain competitive in the power market. For many potentially viable DH systems, this insight may come too late when they have already started the decline. Therefore, political and regulatory action is required while market forces are still in the early phases of development. If there is some merit in preserving potentially very efficient and clean energy systems, policies should be put in place to encourage the rehabilitation and extension of CHP and the modernization of viable DH systems. The sharing of cogeneration benefits and secured dispatch of CHP plants are two potential measures. Whether CHP should get more support—for example, by establishing an attractive power bulk price—should be based on a rigorous analysis of the costs and benefits to society, such as environmental benefits or reduced import dependence for fuels. This would be necessary if, during a transitory period, the economic cost of power is very low due to over-capacities. Under the guiding principles that benefits should be allocated more equitably and that both heat and power need to be competitive in their respective markets, it should be investigated for each CHP plant whether most of the combined cost advantage could be allocated to heat production for a period of several years to facilitate the financing of large DH modernization investments.

6.2 Policies and Organizational Reforms for Improved Heat Supply and Demand

Technical solutions alone are not sustainable. Restructuring of the heating sector needs to happen both on the technical side (supply as well as demand of heat) and on the organizational and institutional side. Currently in most CEE/FSU countries, the economic costs of heating are very high due to outdated technology and lack of finance for even routine maintenance work. Consumers have few choices about heating options or the level of heating and the related expenditures. With the advent of market-based economies and the emerging competitive pressures, there is a chance that the cost of heating will come down.

Commercialization of companies in the heating sector is a *sine qua non* for a more cost-effective heat supply. This sector is lagging behind other energy sectors for obvious reasons of technical inefficiency, lack of suitable investors, and fear of political interference in business decisions. Therefore, an interim solution is to corporatize and restructure the heating company, divesting any functions that are not directly related to its core business (or that could be provided by the private sector on a competitive basis); and then to impose strict profit accountability and financial discipline (both short- and long-term) on its management and employees. A commercially oriented heating sector would be able to attract financing, either in the form of commercial loans or participation by the private sector.

Restructuring of the energy sector needs to take into account the **interaction between the power sector and the heating sector**. The operation of CHP plants and the ownership of heat transmission facilities by power companies creates strong linkages between the DH and electricity sectors in several large cities in CEE/FSU. The integration between power and heating sectors that existed in CEE/FSU under central planning broke down when dedicated CHP plants and heat distribution networks were divested to different owners. In the short-term, with nascent **competition** for the most profitable DH customers from gas distribution utilities and manufacturers of gas appliances, this may jeopardize DH. It may ultimately jeopardize the development of an energy-efficient and environmentally sound power and heat generation technology, if the power sector insists on reaping all the benefits of cogeneration.

Two options exist to reconcile the interests of both sectors. If ownership of CHP plants is transferred to the municipal DH companies, regulation can be restricted to one aspect only—to provide the CHP plants with non-discriminatory or preferential access for selling their power output to the national grid. If the ownership of the CHP plants is left in the hands of the power companies, the regulators should define rules for establishing the prices of power and heat from the CHP plants to assure that both products of the CHP plant, power as well as heat, can be competitive in their respective markets.

Social equity considerations (and duopoly bargaining) tend to favor a **sharing of the joint production benefits** between the electricity consumers (all citizens) and the heat consumers (the minority). Energy/environmental policy considerations tend to allocate most of the cost-saving benefits to DH in order to promote the application of energy-efficient cogeneration. Because there is sufficient power capacity in most countries of CEE/FSU, investment needs in power are relatively low. On the other hand, a huge need exists for investments to modernize the heating sector. It would be rational to transfer most of the combined cost advantage for a period of time to DH to facilitate the financing of these investments. This would have the potential of reducing heat bills to consumers, while it would hardly have an impact on their electricity bills.

Experience from Western European countries shows that a special **regulation** for the DH sector is not required. Although DH distribution has the characteristics of a natural monopoly, competing suppliers of alternative heating fuels and systems do not depend on access to the DH distribution system. In several CEE/FSU countries, such competition in the heating market is starting to be effective. Industrial customers increasingly disconnect from DH and install their own heating sources. It will only be a matter of time before other consumer groups will also disconnect. Currently and in a transition period, financial barriers and lack of access to alternative heating systems will prevent residential customers from changing their heating system, thus preventing market forces from achieving the rationalization of non-competitive systems of heat supply without undue costs. This will require effective regulation, especially in the area of retail pricing at a time when alternative heating systems are not yet available or are prevented from competing effectively by outdated regulations.

In the meantime, **heat planning** is a tool for promoting the efficiency of allocating scarce resources, by providing a reference framework for the investment decisions in local heat markets. The DH company needs to know which sections of the DH network are not economically viable, to avoid that long-term investments are made in these sections. The natural gas distribution company needs to know in which sections of the town it should start to upgrade its gas grid, in order to satisfy the demand from gas-fired building boilers. A heat plan that has been elaborated jointly by all actors in the local heating sector would speed up decisionmaking by the energy supply companies and by customers. Thus, although public planning of economic activities has gone out of fashion in CEE/FSU, the need for preparation of integrated heat master plans is recognized.

Heat planning could thus provide a mechanism for making potential investors in new generation capacity aware of existing heat loads. This in turn would provide a basis for CHP capacity, which could reduce fuel costs and fuel imports, as well as CO_2 emissions. By incorporating a sound analysis of existing and future heat demand and of the complete DH system, heat planning would also improve the optimization of the entire system, including the demand side.

Compared to most other heating systems, DH tends to improve the **fuel security** of a country since most large heat generation units have a dual-fuel capacity. This fuel flexibility is particularly important in countries that depend largely on fuel imports. This advantage of DH over, say, gas-based systems is not captured in the economic analysis. It can be incorporated, however, in the political framework for the energy sector, e.g., by establishing differential taxes and mandatory guidelines for the development of energy systems that improve fuel security.

Substantial barriers prevent the realization of the **enormous energy efficiency potential on the demand side** of heating in CEE/FSU, especially in buildings connected to DH. Two of the most important measures to support vis-à-vis these barriers are (1) forming and educating homeowner associations that must decide on investments in common spaces and (2) giving those associations and individual households access to financing.

Effective heat planning, as well as decisions about cost-effective investments on the supply and demand side need to be based on **prices** that give the right signals and that provide a level playing field for the actors in the heat markets. There is a general consensus on the key principles of energy tariff policy:

- The tariff for each consumer group should reflect the full cost of supply.
- Cross-subsidies between major categories of consumers should be avoided.
- Billing should be based on metered consumption.

Pricing reform, together with modernization investments in DH and the introduction of metering and controls at the end-user level, will convert the previously inflexible DH systems into ones that consumers can influence according to their preferences and financial means.

6.3 The Need for Transitional Strategies

A restructured, modernized, efficient system of heat supply and demand cannot be achieved overnight. A number of economic, financial, and institutional obstacles delay the rationalization of heat supply in CEE/FSU:

- High costs of production and a limited ability to pay of DH consumers are compounded by a combination of below-cost tariffs and arrears in consumer payments. This general statement does not do justice to the large variations between countries. In some countries, such as Poland, very substantial progress has been achieved.[107]
- Feasibility studies show a substantial scope for cost-reducing investments that could narrow the gap between the level of a full-cost tariff and the ability to pay of the average consumer. The long-run marginal cost (LRMC) is lower than the present economic cost of supply.[108] However, the implementation of the cost-reducing investments is often blocked by lack of finance and an inadequate macroeconomic and sector framework.
- Pending issues of ownership of apartments, responsibility for undertaking necessary investments in buildings, and identifying institutional mechanisms to initiate investments delay otherwise very profitable investments on the demand side that would further reduce the heat bills of households in CEE/FSU.
- Unresolved ownership issues also exist in small DH systems that are operated by industrial firms, and for individual boilers in a number of apartment blocks formerly owned by the municipality and serviced by the municipal DH company.

The starting point in the process of achieving greater efficiency is usually to sever the very close ties between DH and municipal politics. When DH supply was divested to municipalities, a municipal department was put in charge. The first step in making DH a commercial activity is to establish DH as a joint stock company with a commercial identity and accounts separate from those of the municipality. For the next steps, although there are no simple solutions, a number of measures can improve the situation. The list proposed in the following sections is not exhaustive, but provides an overview of possibilities. The measures are grouped into financial and fiscal measures, streamlining of business activities, and streamlining of the organization.

6.3.1 Financial and Fiscal Measures

6.3.1.1 Reforms of Tariffs and Tax Payments

In many countries in CEE/FSU, it is still difficult to increase heat tariffs to the level of full cost coverage within a short period. The tax system, especially in some FSU countries, is very inefficient and tax revenues on the municipal level may not always be sufficient to pay for the subsidies targeted at low-income consumers. Many public institutions will find it difficult to pay for higher fuel prices. There is a risk that higher tariffs will lead to an increase in arrears. Yet, as an absolute minimum, the average tariff should cover the full cost of operation and maintenance

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[107] See section 5.2.5.

[108] In Timisoara in 1995, the economic cost of heat supply in the DH system was estimated at US$34/MWh, the average tariff was US$4, and the LRMC of supply US$24/MWh. In Sofia, the heat tariff in 1995 was US$ 14/MWh, the short-term cost-covering heat tariff US$25, and the LRMC US$34/MWh.

and allow the DH company to self-finance about 20 percent of investments in the modernization of the DH system. The following other measures are recommended.

- ☐ The rate of depreciation is calculated according to ordinances issued by the ministry of finance (or tax authorities) regarding the depreciation of assets, and immaterial and legal values, as well as actualization of asset values. During the first years after the introduction of the market economy, the historical nominal value of assets was not adjusted for inflation, which in most CEE/FSU countries reached two- or even three-digit levels. New ordinances permit basing the depreciation allowance on the inflation-adjusted value of the assets. To avoid sudden jumps in tariffs, adjustment to the full economic cost of depreciation should be done gradually.[109] To reconcile the requirement for a smoother transition to full cost recovery tariffs and the maximum amount of self-financing, depreciation should be calculated at two different levels:
- ▪ For calculation of tax payments, the highest allowable depreciation rate should be used and the value of assets should be based on full replacement value minus accumulated depreciation.
- ▪ For the calculation of the tariff, realistic economic cost depreciation should be used in those cities where consumers can pay the full economic cost of supply; in other cities, depreciation should be set at levels that permit an adequate self-financing of the investments to be achieved.
- ☐ Other measures to reduce the tax burden comprise:
- ▪ Realistic write-off facilities for bad debts.
- ▪ Payment of taxes on "net revenue after investments" (100 percent tax deduction of investments), or other forms of accelerated depreciation during an interim period of, say, the next five years.
- ☐ Existing discrimination of heat generation at CHP plants in the form of tariff rules that pass the full combined cost advantage on to the electricity tariff should be replaced by a more equitable treatment for heat and electricity. Under the guiding principles that benefits should be allocated equitably and that both heat and power need to be competitive on their respective markets, it should be investigated for each CHP plant as to whether most of the combined cost advantage could be passed on to heat for a period of several years. This would facilitate financing of the needed large modernization investments.

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[109] In Poland, the adjustment process started in 1995, when the DH companies were allowed to recalculate the value of their assets. That year, only 24 percent of the difference between the original and the inflation-adjusted value could be included in the depreciation calculations; in 1996, an additional 38 percent, and the last 38 percent in 1997.

6.3.1.2 Subsidies and Financing of Consumer Installations

In most CEE/FSU countries, the switch from energy price subsidies to social subsidies is under way. Social assistance payments should compensate for housing-related cost escalations for low-income households. Households that are not able to pay their housing-related bills can apply for a subsidy at the municipality, which has a special (partially state-financed) budget for this purpose. Households that fulfill the conditions set by the municipality, or social assistance administration, qualify. The subsidy is usually paid to the official customer of the supplier of the service. For instance, if a housing cooperative has a contract with the municipal DH company and an inhabitant is entitled to a subsidy, the cooperative receives the subsidy for payment to the DH company. It is not uncommon for these intermediaries to fail to pass on the subsidy to the DH company. To avoid such diversion, payments of households for heating bills and the accompanying subsidy payments by municipalities should be made directly to the DH company.

The heating bills of households and other DH customers could be lowered considerably if buildings were more energy-efficient and consumers had an incentive to use less heat. A DH system is highly complex and a successful rehabilitation strategy has to accept it as system, and not just as a composite of individual parts. In practice however, rehabilitation strategies and the corresponding investment plans are often developed separately, depending on the ownership. The main reasons are:

- ☐ DH company managers are usually reluctant to implement demand side measures. Under a regime of cost-plus regulation there is surely no incentive for such measures. Demand side measures aim at reducing energy consumption, thus adversely affecting profits.
- ☐ According to the ownership boundaries, DH companies are not responsible for any activities beyond the meter, which usually means in the buildings.
- ☐ Demand side measures usually have high rates of return, but are rarely implemented due to the institutional and financial barriers.

The risk therefore exists that rehabilitation measures in the heat supply system will be implemented, while those on the demand side will be postponed. Thus, a large energy saving potential will not be exploited and significant reduction of investment due to reduced capacity demand will not be realized. Furthermore, the quality of the heat service depends on the quality of supply, as well as on the quality of the consumer installations. The DH company is responsible only for the former. The satisfaction of consumers and sometimes their willingness to pay depend on the results of the interaction. As long as tenants and building owners lack the means and organizational structure to invest in demand side measures, the DH company would be the second-best choice for implementing measures on the demand side.

Normally, the individual consumer or the homeowner association finances the heat installations inside the buildings, such as substations, internal pipes, thermostats and radiators. But in practical terms, these installations—the building substations in particular—are an integrated part of the DH system. In World Bank projects, building substations are common components of an investment project. This could be extended by including basic measures that would ensure that the quality of supply within the building is improved, such as balancing valves, thermostatic valves, etc., when these are cost-effective (see section 3.3). The costs could be recuperated by a monthly fee charged to the consumer over a period of several years. The overall heating bill would not increase due to savings. If the installations become the property of the consumers only after the DH company has recuperated the cost, the DH company could depreciate the cost of investment, thus reducing its tax bills.

6.3.1.3 Arrears

Strict measures need to be taken to address arrears in the heating sector, in terms of both accounts receivable and accounts payable. The most obvious measure, in terms of preventing further growth in arrears, is to either cut off supply to or require pre-payment (deposits) from customers who have failed in the past to make timely payments. Imposing high penalties for late payment or providing discounts for timely payment are also options that can be tested. In terms of addressing the accumulated stock of arrears, a number of solutions are available: cutting off supply if it is apparent that the enterprise has funds available; negotiating a rescheduling of payment arrears at concessionary rates of interest rather than high penalties; instituting bankruptcy proceedings against debtors; arranging mutual settlements of offsetting debts; and selling collection rights on an account, either to a collection agent or to an enterprise/agency that is able to hold or trade the debt for other considerations. The best combination of solutions needs to be determined on a case-by-case basis, depending on the particular characteristics and circumstances of each debtor. At the same time, an open and transparent settlement mechanism needs to be put in place for both accounts receivable and accounts payable, to minimize the opportunities and incentives for tax avoidance and fraud. This mechanism should be reinforced by regular and detailed audits by an independent auditor accountable to the municipal government. Finally, municipal governments must take steps to ensure that they are able to provide funds to cover the heating bills of municipal facilities and social assistance payments for low-income families, either through more rigid adherence to budgeted expenditures on other items, and/or through better performance in collecting revenues.

6.3.2 Streamlining of Business Activities

An important means of reducing the cost of supply is to streamline the business activities of the DH companies by moving out of loss-making activities and developing others in which the company has a strong competitive profile, thus concentrating on its core activities. A core activity is an activity that distinguishes the company's business from the field of activity of other industries and makes up the industry-specific expertise in the production process. The core businesses of a DH company are heat generation (operations planning and boiler operation being core activities), heat distribution (network planning, network O&M, and consumer connections being core activities), and energy services (marketing and contracting being core activities).

6.3.2.1 Rationalization of the Core Business

Heat planning—cutting loss-making sections in heat supply. The introduction of market reforms has led to competition for heat customers between the local DH and natural gas companies. In new residential areas outside the existing service areas for DH, the choice of supply can be left to market forces. Unfettered competition for existing DH customers is more of a problem. If some customers in a section of the DH system switch to natural gas, the cost of supply to the remaining customers increases. It is more economic to close down non-economic sections of the DH system in a planned manner rather than to let the market do it in a piecemeal fashion. A heat plan should therefore be prepared under the responsibility of the municipality, with active involvement of experts from the DH company and other energy suppliers. For obvious reasons, the switch to natural gas lowers the cost of heat supply to these customers. However, because the heat plan leads to the elimination of the most costly sections of the DH system, the average cost of DH supply will be reduced as well.

Cutting loss-making district steam systems—use of leasing. DH companies must verify the cost-effectiveness of continued steam supply to industrial customers. Few steam supply systems are economic; most represent a commercial burden instead of a business opportunity for the DH companies. In the case of non-economic systems, the switch to individual steam production reduces the economic cost of steam consumption. If the DH supplies steam at loss-making tariffs to industrial customers,[110] the closure of the steam system would reduce costs and the average heat tariff.

When a DH company closes a district steam system, it is obliged by its long-term contracts to assist its industrial customers in their switch to self-production of steam. Some companies will be able and willing to self-finance their own steam production plants. Others will not be in a financial position to do so. The DH company could offer to lease steam generating systems to these customers, in addition offering related maintenance or operation and maintenance contracts. Most DH companies lack the financial resources to finance a leasing arrangement and would have to ally themselves with a professional leasing firm to provide the finance. The role of the DH company in such a joint venture would be to provide the contacts to the customers and the technical expertise in planning, designing, installing, operating and maintaining the steam generation systems.

6.3.2.2 Rationalization of Non-core Activities

Selling unrelated activities. A number of DH companies are involved in activities such as greenhouse production and pipe manufacturing that are not related to the daily core activities of DH. These activities should be sold off so that the company can concentrate on its core activities and is not tempted to cross-subsidize one activity with the other. The revenue from such sales can be used to co-finance investments in DH.

Commercialization of ancillary activities. A number of service activities are usually performed inside a DH company that are not specific to DH. In many cases, a market as well as alternative suppliers outside the DH company are beginning to appear for these services, such as transport and building maintenance. These services should be commercialized and compete on non-

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[110] Competition from natural gas companies has motivated DH companies to set steam tariffs below the cost of production. Until the mid-1990s, the situation was reversed: DH companies overcharged industrial consumers in order to subsidize below-cost supply of residential consumers.

subsidized terms with external suppliers for internal services, as well as for services sold to outside customers.

6.3.3 Streamlining the Organization of District Heating Companies

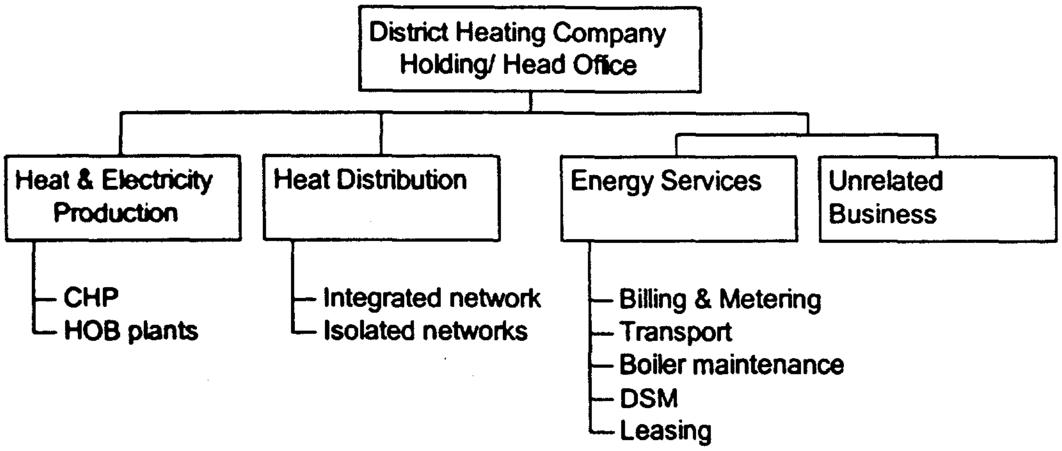
The streamlining of business activities should be followed up by a streamlining of the organization structure of the DH company. Since the choice of organization structure involves trade-offs, the starting point in the design of an organization structure is to identify the most important objectives to take into account. Theses are promoting management efficiency, facilitating financing investments in DH, promoting maximum transparency in the setting of prices and tariffs and emphasizing the need of the organization to adjust to the paradigm shift that has occurred in its external environment

An efficient way to achieve the above objectives is to structure the DH company around the four priority tasks in the restructuring of heat supply:

- ☐ Securing of finance and the introduction of cost-based accounting;
- ☐ Rationalization of heat production;
- ☐ Rationalization of heat transmission and distribution; and
- ☐ Development of new commercial relationships with suppliers and consumers.

A generic organization chart for such a structure is shown in Figure 6-1. The company could be set up as a holding company with three daughter companies organized as independent joint-stock companies, or as one company with three divisions, each of which has an independent set of accounts and management structures. This structure is increasingly becoming the norm in West European energy companies, and it is likely to become the dominant form of organization in CEE/FSU as well.

Figure 6-1. Divisional Structure for a District Heating Company



6.4 Role of the World Bank Group

The World Bank can contribute to increasing the efficiency of the heating sector in CEE/FSU through a set of actions that incorporates funding of investment in infrastructure as well as technical assistance:

- Support policy reforms in the energy sector that enable full-cost recovery tariffs for all energies and eliminate barriers to interfuel competition. Structural adjustment loans and investment loans in the energy sector, as well as targeted technical assistance are potential instruments.
- Bridge the gap between the power and the heating sectors through policy and regulatory reform. In addition, the Bank could support governments and regulators in analyzing the costs and benefits of changing the cost allocation in cogeneration facilities in favor of DH.
- Continue to support specific investments in the modernization of DH infrastructure where DH is competitive. In municipalities where part or all of the DH system is not competitive, the transition to more decentralized heating systems should be actively encouraged.
- Support investments to improve the energy efficiency of buildings as an integrated measure in DH projects, as well as in housing sector projects. Activities of ESCOs in this area should be encouraged.
- Facilitate investment in cogeneration. This should not be limited to IFC-financed private sector projects. The Bank might consider the financing of CHP projects by municipal heating companies. World Bank guarantees would be another instrument to encourage the private sector to invest in an environmentally superior technology in countries where considerable risks still exist. Projects cofinanced under Joint Implementation or with support of the GEF or the Prototype Carbon Fund are other possibilities.
- Include investments in heat supply and demand measures as part of municipal development projects, because subsidies for heating as well as heating bills for public buildings tend to take up a large share of municipal budgets.
- The private sector could take over many activities previously carried out by municipal heating or building maintenance companies. Private sector development loans or projects supporting small and medium-sized enterprises could support the transfer of these activities to the private sector

Finally, this study has shown the need to investigate a range of issues related to heating in more detail than is possible here. The topics for further research and studies on heating aspects include the following:

- The impact of different schemes for allocating production costs in cogeneration plants to heat and electricity on heat and electricity tariffs and on the income of heat and electricity consumers. It is recommended that this be done on the basis of case studies on a local or regional level.
- The role and potential of district heating and cogeneration in reducing green house gas emissions. The use of CHP leads to large energy savings and reductions in local and global

emissions. Financing through GEF, joint implementation or the Prototype Carbon Fund is now increasingly considered.

- Technical options, financing and implementation of replacing HOBs by CHP plants. With cost reductions for small cogeneration units, CHP is close to becoming a viable option also in smaller DH system where the costs of HOB-based DH are typically higher than in bigger systems. Problems remain with the financing and the choice of a delivery mechanism. Those smaller CHP could be installed in industrial facilities, e.g., as a joint venture between companies in the industrial sector and local or regional energy companies. In addition, the legal and regulatory framework needs to be revised to abolish barriers discriminating against cogeneration.
- Impact of industrial and big commercial consumers leaving the DH network and strategies for DH companies to keep them as customers for heat, hot water, and steam.
- The role of local governments in the heating sector with respect to choice of heating modes, heat planning, approval of tariffs, licensing, etc., and the support and training they need to fulfill those roles.
- In several countries in the FSU, such as Armenia, Georgia, Kyrgyzstan, and Moldova, income levels of populations are much lower than in the rest of the FSU. For instance in Kyrgyzstan, GDP per capita in 1998 was about US$350, while the average annual heating bill of households connected to DH was about US$100. Numbers in the other countries are similar and they indicate that the incomes of most households would not be sufficient to pay for the full cost of heat from DH or other systems providing a similar quantity of heat. Just improving the thermal performance of buildings or the efficiency of DH systems or replacing centralized heating with decentralized heating (and thereby reducing costs somewhat) would not resolve this basic problem. On the other hand, the climate in these countries requires a certain amount of heat to protect the population from health problems and infrastructure from further serious deterioration. It is therefore recommended to develop heat strategies for low-income transition countries to identify technical and institutional solutions that would result in a heat infrastructure that is financially, socially, and environmentally sustainable. The analyses would consider developments in fuel sources, fuel prices, and other energy subsectors; competitiveness of different technical options on the supply and the demand side; constraints in the ability and willingness to pay of end users; institutional issues; environmental implications; financing requirements; and availability of funding. They will not focus merely on the existing centralized heating systems, but will encompass also decentralized heating systems that are used by the overwhelming majority of the populations. The studies would also examine the present institutional and organizational arrangements for heat supply in each country, and recommend institutional and financial delivery mechanisms that would enable a more efficient provision of heat services on a fully commercial basis to the population, including participation by the private sector. The heat strategies would thus be guiding the transition towards affordable heat services and would form the basis for deciding which areas investments should be targeted.

INCREASING THE EFFICIENCY OF HEATING SYSTEMS IN CENTRAL AND EASTERN EUROPE AND THE FORMER SOVIET UNION

AUGUST 1998

IBRD 29791

Annex A

World Bank Activities in the Heating Sector

TABLE A-1. SELECTED WORLD BANK PROJECTS IN THE HEATING SECTOR

Project Approval and Closing Date	Project Cost/Loan Amount (US$ Million)	Main Project Components	Status (as of 1998)
A. PROJECTS DEALING PRIMARILY WITH THE SUPPLY SIDE OF DISTRICT HEATING			
POLAND **HEAT SUPPLY RESTRUCTURING AND CONSERVATION** 1991-1999	739/203	• Reduction of water/heat losses and improvement of water quality • Implementation of a metering program • Retrofitting, automation and load management program • Implementation of an interconnected operation control system • Replacement of small boilers.	Implementation of optimization programs in Gdansk, Gdynia, Krakow and Warsaw is progressing satisfactorily. Significant efficiency gains are being achieved in all cities. Slower implementation due to financial constraints and other factors.
CHINA **BEIJING ENVIRONMENTAL** 1991-1998	299/125	• Construction of a pressurized hot water piping system for district heating to alleviate air pollution from the burning of coal and domestic residues	Project implementation performing well. Heating tariffs have been raised by about 80% in November 1995 and January 1996, but they still are insufficient.
ESTONIA **DISTRICT HEAT AND CONSERVATION** 1994-1999	65/39	• Conversion and replacement of small boilers to use local fuels (peat, wood) • Rehabilitation of DH systems • Improvement of power plant (CHP)	Overall physical progress of the project is satisfactory. Contracts have been awarded for rehabilitation of DH equipment.

Project Approval and Closing Date	Project Cost/Loan Amount (US$ Million)	Main Project Components	Status (as of 1998)
POLAND **KATOWICE HEAT SUPPLY** 1995-2000	93/45	• Reduction of water losses • Improvement of water quality • Reduction of heat losses • Substation automation, control an metering • Network monitoring • Variable flow control • Small boiler elimination and conversion program	Project implementation progressing satisfactorily but slower than projected due to PEC (District Heating Enterprise) financial constraints and other factors. Efficiency improvements implemented during 1992-94 are already bringing benefits in terms of cost savings and significant reduction of water and heat losses.
LATVIA **JELGAVA DISTRICT HEAT** 1995-2000	18/14	• Program to upgrade the system to a variable flow regime • Increase boiler efficiency • Abate leakage • Install heat meters • Eliminate environmentally unsound, low-stack coal- fired boilers	Overall progress of the project is satisfactory. Automated substations and heat meters save 30% heat on an annual basis. Piping works have resulted in a reduction by 50% of the make-up water in the main DH network. Project components concerning boiler efficiency improvements and elimination of low stacks are planned to be implemented during summer 1997.
LITHUANIA **KLAIPEDA GEOTHERMAL DEMONSTRATION** 1997-1999	18/6 7 (GEF)	• Demonstrate feasibility and value of using low-temperature geothermal water for DH • Reduce GHG and SOx emissions	

Project Approval and Closing Date	Project Cost/Loan Amount (US$ Million)	Main Project Components	Status (as of 1998)
BOSNIA **EMERGENCY DISTRICT HEATING RECONSTRUCTION** 1996-1998	?/20	• Rehabilitation of District Heating in Sarajevo: boilers, distribution network, substations, remote control center, internal building installations, and metering.	
KYRGYZ REPUBLIC **POWER AND DISTRICT HEAT** 1996-1999	98.2/20	• Electricity tariff restructuring	Loan Effective 1996. In May 1998, a supplemental credit of US$15 million was approved to cover cost overruns of the CHP rehabilitation component.
	(25.4)	• Technical losses reduction program for power system	
	(25.6)	• Loss reduction through DH pipeline and insulation replacement	
	(17.9)	•Turbine commissioning for CHP plant	
SLOVENIA **ENVIRONMENT PROJECT** 1996-2001	38/24	•Conversion of boiler houses and household heating systems based on polluting fuels to use clean fuels or heating systems.	Loan effective in 1997 During a pilot period of 3 months in 1995, loans for the conversion of 193 household heating systems and 5 boiler houses, amounting to approximately DM 1.5 million, were approved.
RUSSIA **ENERGY EFFICIENCY PROJECT** 1996-2002	?/70	• Increase efficiency of energy use, especially in DH and electricity • Support government's reform program through technical assistance	

Project **Approval and** **Closing Date**	**Project Cost/Loan Amount** **(US$ Million)**	**Main Project Components**	**Status** **(as of 1998)**
BULGARIA **DISTRICT HEATING PILOT** **(Amendment to the Loan Agreement for water companies restructuring and modernization project)** 1997-2002	13/10	• Installation of heat meters in substations of district heating networks, mostly in Sofia.	Amendment effective FY 1997
CZECH REPUBLIC **KLADNO COGEN** 1997	375/125	• Upgrading and extension of coal/gas-fired cogeneration plant which supplies heat to industrial facility and to the town of Kladno	**IFC project, effective in FY 1997**
RUSSIA **SEVERSTAL HEAT AND POWER** 1998	102/67	• New gas-fired cogeneration plant which will supply heat (and power) to large steel mill and to local DH network	**IFC project, effective in FY 1998**

B. PROJECTS DEALING PRIMARILY WITH THE DEMAND SIDE OF DISTRICT HEATING			
LITHUANIA **ENERGY EFFICIENCY/ HOUSING** 1996-1999	21/10	• Energy efficiency rehabilitation of residential buildings • School energy efficiency rehabilitation • TA for potential borrowers	Loan Effective in FY 1997 Loan agreements signed with 35 homeowners associations, and investments in seven schools implemented by March 1999. Extensive training program for energy consultants and homeowners associations
RUSSIA **ENTERPRISE HOUSING DIVESTITURE** 1996-2002	?/300	• Retrofitting of 350,000 apartments in 3,500 buildings in 6 cities • TA in metering heat production, distribution and consumption (generation of baseline data, implementation of billing system, monitoring system)	Loan effective in FY 1997 Base building meter installation and isntrumentation completed in 1997 Meters installed in 360 buildings, 72 buildings were retrofitted in 1998/99 In 53 central heating points meters were installed.
TOTAL LOAN AMOUNT FOR PROJECTS UNDER IMPLEMENTATION (A+B)	**1078**		
C. PROJECTS UNDER PREPARATION			
UKRAINE **KIEV DISTRICT HEATING IMPROVEMENT** 1998-2002	370/200	• Rehabilitation and replacement of old boiler and construction of new boilers, • Network improvements in the main transmission and distribution pipelines, • Installation of automated substations, • Institution support component: training, equipment and software for project management, review of heat tariffs and structures.	Project presented to the Board 5/98

UKRAINE **SEVASTOPOL HEATING IMPROVEMENT** 1998-2002	35/30	• Support introduction of a decentralized heating service • Support development of a new heating enterprise	Loan to be effective in FY 2000
RUSSIA **MUNICIPAL HEATING** 1998-2002	?/100	• Investment in about 5 cities in rehabilitation of district heating networks and/or conversion to individual building boilers as well as demand side measures.	Loan to be effective in FY 2001
LATVIA **RIGA DISTRICT HEAT REHABILITATION**	?/30	• Rehabilitation of District Heating Systems • Support strengthening of DH enterprises	Loan to be effective in FY 2000
LITHUANIA **ENERGY/DISTRICT HEAT EFFICIENCY**	?/30	• Rehabilitation of Vilnius District Heating System	Loan to be effective in FY 2001
BULGARIA **DISTRICT HEATING**	?/65	• Rehabilitation of Sofia and Pernik DH systems • Add cogeneration capacity to those systems	Loan to be effective in FY 2000
POLAND **RENEWABLE ENERGY/ GEOTHERMAL**	?/50	• Use of geothermal water for DH	Loan to be effective in FY 2000
HUNGARY **GEF BIOMASS**	?/60	• Conversion of HOBs to Biomass Cogeneration	Loan to be effective in FY 2000
UKRAINE **KIEV ENERGY EFFICIENT REHABILITATION OF PUBLIC SECTOR BUILDINGS** 1998-2002	?/30	• Energy-efficient retrofitting of schools and hospitals in Kiev	Loan to be effective in FY 2000
TOTAL LOAN AMOUNT FOR PROJECTS UNDER PREPARATION (C)	**795**		

Box A-1. District Heating Projects in Poland

The results so far of the **Polish heat supply projects in Gdansk, Gdynia, Katowice, Krakow and Warsaw** are very satisfactory. The implementation of the optimization programs in the five cities since 1992 has led to:

- ☐ reduction of overall heat energy losses of between 15-24 percent from their 1992 level;
- ☐ reduction of water losses to between 28-62 percent from their level before project start; and
- ☐ significant improvement in water quality, allowing for the installation of energy conservation measures at the building level (automation of substations).

In addition:

- ☐ Almost 100 percent of heat purchases as well as a large percentage of heat sales are now metered.
- ☐ Air pollution has been reduced considerably, as a result of the energy savings achieved and the replacement of small, coal-fired, inefficient HOBs with either a connection to the main DH network or a conversion to gas firing.
- ☐ As a result of the energy savings achieved, heat sources (CHP plants) are now experiencing a reduction in heat sales. This has allowed for the closing down of obsolete production capacity, or in some cities, for the extension of DH into areas where DH is competitive or the further elimination of HOBs.
- ☐ DH enterprises have improved their commercial performance considerably, by reducing accounts receivable and in some cases, by exceeding the financial requirements of the loans by more than 100 percent.
- ☐ On the sector policy level, direct subsidies to residential consumers have been reduced from almost 80 percent of cost in 1991 to about 6 percent on average for Poland as a whole, and to basically zero in the above five cities. This reduction in subsidies is providing incentives to implement energy efficiency and conservation measures at the end-user level. The price subsidies previously given to some housing cooperatives for district heating are now being used for improving the energy efficiency of buildings (metering at individual building level, and improving internal heat installation and external building insulation).

The following provides some concrete results from one of the Polish borrowers (data are based on standardized degree days):

Energy savings (measured as reduction in heat purchases, excluding the impact of the HOB elimination program) between 1994 and 1996 amounted to 15 percent and will reach at least 25 percent by the end of the project in 1998. Improvements in the network contribute about one-third of those savings, and energy conservation measures at the substation level the other two-thirds.

Reductions in emissions through elimination of coal-fired HOBs (not counting emission reduction through reduced pumping needs of 33percent and reduction of heat purchases from heat sources) are as follows:

SO_2: 15% NOx: 10% Ash: 22% CO_2: 16%

Source: Rachid Benmessaoud, 1997 and Arto Nuorkivi, 1998

Box A-2. District Heating Project in Latvia

The **DH project in Jelgava, Latvia** started in 1995. It is proceeding well, ahead of schedule and below budget. As of July 1997 it is completed about 80%. Some encouraging results are emerging:

☐ *Savings through automation.* About half of the buildings have now automated substations. This has resulted in approximately 25% reduction of the consumption of heat in the automated buildings, the highest savings reaching up to 40%. The city council has decided to distribute these savings between the tenants and the DH company which installed the substations.

☐ *Reduction of piping and network losses.* After implementation of about 60% of the planned piping program (about one third of original company network length), water losses have been reduced by about 60% and heat losses about 37%. The corrosion of the piping system has been reduced from 14% annually to less than 5% due to better internal water quality and preinsulated pipes.

☐ The total fuel efficiency of heat production has increased from 79% to 85%. The corrosion of boiler piping has been reduced from 33%/year to 8%/year, and the boilers can now be fired with heavy fuel oil supplied by competing fuel oil companies on a continuous basis, thus facilitating better price offers from the gas company.

☐ *Cost savings through competitive procurement.* The original price level of equipment used during project appraisal was the "Scandinavian price level." However, competitive bidding according to the Bank's rules is leading in some areas to substantially lower prices . Therefore, the project implementation cost in total is about 10% lower than expected. This may result from two factors: (a) the Scandinavian bidding process is not as strict as the Bank's and leads sometimes to "negotiated prices", and (b) much of the equipment is actually manufactured in Estonia under licenses from Finland and Sweden (an indication of technology transfer taking place).

☐ *Further heat cost reductions through cogeneration.* Now that the DH system has been rehabilitated and dispatching heat from any source has become possible, Jelgava wants to reduce the heat production cost further by better utilization of the existing, privately held CHP plant that sells heat to the system. The DH enterprise is ready to enter into a long-term index-linked heat purchase agreement with the CHP plant.

Sourcce: Pentti Aro, 1998

Annex B

Determination of Heat Demand: A Market Analysis

Market Analysis in the Context of Heating Services

In cold climates, demand for heating services is substantial. In countries in which infrastructure sectors become more and more competitive, companies in the business of providing heating services will eventually find it necessary to conduct a market analysis. Typically, the objectives are to determine the kinds of products to be marketed, the types of market segments, and finally, the size of the market. The same tools and approaches can be adopted as would be used in normal market analysis. These comprise:

- Determination of the products. In addition to the traditional products such as hot water for space heating and domestic hot water (DHW), and steam, new products, the so-called new energy services, are starting to appear.
- Determination of the market segments and size. Who are the customers? What are the needs that can be covered by the products (for example, both natural gas and district heating can be used for cooling purposes)?
- Defining a marketing strategy. In the past there was really no marketing for heating services. The kind and magnitude of heating service was determined by planning authorities. In the future, energy supply companies have to implement effective marketing activities in order to keep old and attract new customers.

Market for Traditional Products

In the context of this study, the critical product is heat, which comprises heating for space heating, DHW, and hot water or steam for industrial purposes. The need for these final products can be satisfied by various energy carriers being converted by various technologies. After determining the size of the final products, energy carriers, and technologies, the next step is to estimate the quantity of these products and then the resulting quantities of intermediary and primary inputs. In effect, the entire energy chain has to be simulated, taking into account efficiencies and losses at the various levels (see Figures B-1 and B-2).

Determination of Heat Demand

The size of the market is usually determined by the final heat demand. This figure is by no means a fixed or naturally determined figure. Climatic, physical, and other factors have a large impact on the demand for heat but in market-based systems, economic and social factors play an important role as well. Last but not least, the magnitude of the heat demand is determined and influenced by the heat supply system itself.

The following procedures should typically be performed:

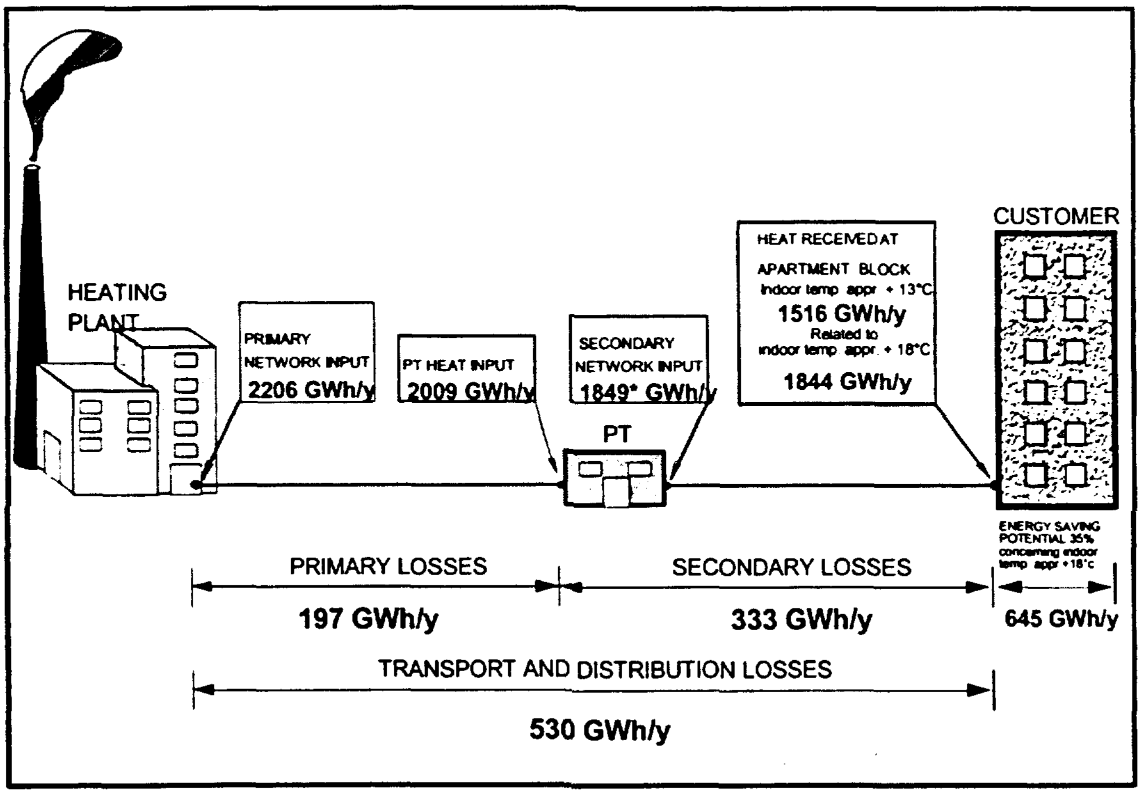
- Calculation of the heat demand according to the standards and norms existing at construction time. Usually these figures are available, for example, in the offices of the municipal city planning department. It should be taken into account that this is a hypothetical figure and that actual heat demand will differ for various reasons. For example, norms for heat demand are based on specific construction materials. In real life, different materials are used, e.g., if the materials originally selected were not available.

- If several customers are connected to one heating facility or energy source, the coincidence factor should be taken into account. Since not all customers use the supplied energy at the same time, the coincidence factor is below 1 -- usually around 80-85 percent for space heating and even lower for DHW, depending on the technology of hot water preparation.

- In the network and transmission system, some losses of heat and water will occur. In CEE/FSU, it is very difficult to determine or even to estimate these losses, since only a few metering devices exist. In large DH systems, metering devices usually are installed in the heat generation plants. During the last few years, many DH companies have started to install heat and hot water meters for customers in order to apply consumption-based tariffs. But installation is usually slow and heat and water losses must therefore still be mostly estimated, based on an assessment of the state of the network.

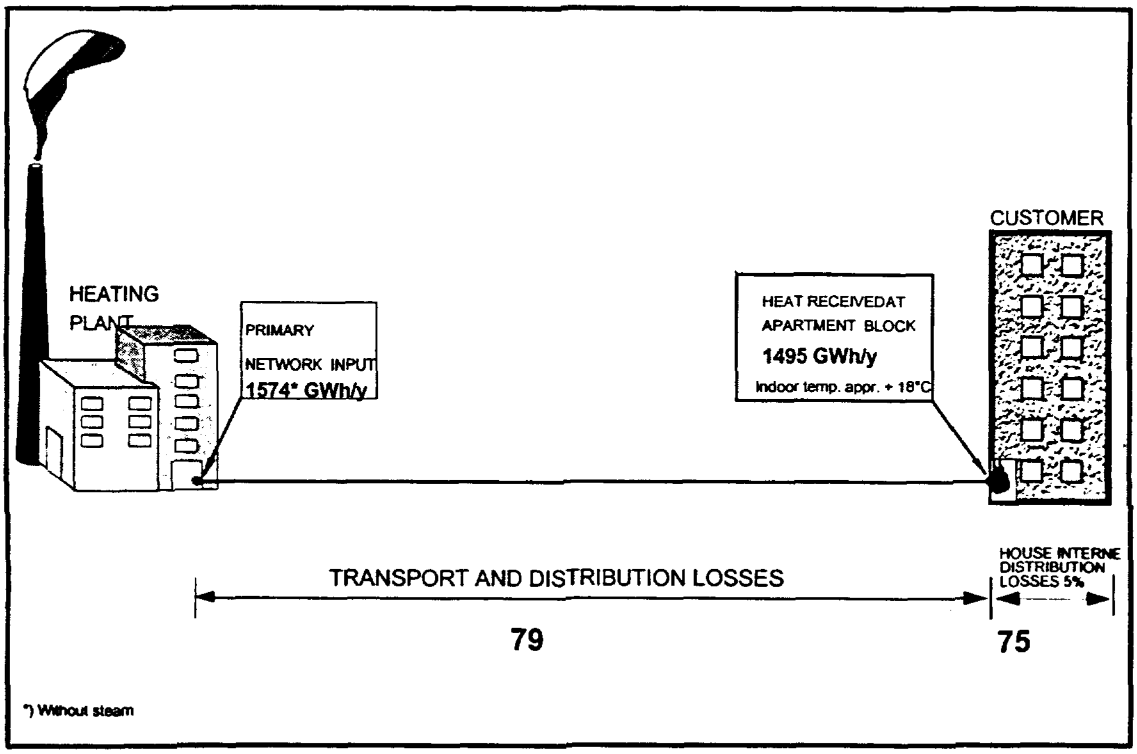
Figures B-1 and B-2 illustrate the approach to determining heat demand by tracking the energy flows in the DH system of Timisoara, Romania. The situation in 1995 is based on estimates of energy inputs, losses, and useful energy delivered by the current system. For 2015, it is assumed that energy saving measures have been applied in the DH system as well as in the buildings, resulting in a substantial decline in heat demand.

Figure B-1. Heat Losses in the District Heating System, Timisoara, 1995



Source: ESMAP Timisoara case study.

Figure B-2. Estimated Heat Losses in the District Heating System, Timisoara, 2015



Source: ESMAP Timisoara case study

After determining the present heat demand, the next step is to forecast future demand. Since investment in heat supply and demand systems usually has a long lifetime (up to 25 years and more), the time horizon should be at least 10 or 20 years. Various factors influence the development of heat demand, such as:

- industrial development
- economic development
- population increases or decreases
- comfort needs of customers and customer behavior
- family incomes
- energy-saving measures
- construction standards
- legal and regulatory framework

☐ availability and costs of competing alternative heating systems.

Markets for New Energy Services

In most CEE/FSU countries, the markets for traditional heat services have shrunk dramatically. This is partly due to the prevailing economic situation, but also to the past economic system which fostered energy waste. Even if the economic situation improves, heating needs will most certainly not recover to their original levels, due to the implementation of energy efficiency measures and technological changes in production processes. If a study or project proposal projects an increase in heat demand, the reasons for this assumption should be carefully examined. Absent any factors contributing to a substantial increase in heat demand, the heat supply system can be reduced.

In some situations, there will be a market for additional customers. But for DH, this additional market will probably be quite small, since in the existing DH service areas, the potential is more or less fully exploited, and in areas in which new buildings are to be supplied, other heating systems will compete for this market.

Still, some additional products and services might successfully be supplied by the existing DH company, mitigating difficulties connected with their restructuring process, such as overstaffing. These include:

☐ Installing and operating customer facilties for DH (such as automated building substations, metering and regulation devices), thus overcoming the problems on the demand side to get organized and identify financing.

☐ Replacement of small, heat-only boilers by connecting small, isolated networks to the main DH network (see section 3.1.5.7).

Consumer Budgets and Affordability

Up to now the analysis has focused on heating needs. Actual demand and consumption may be different from needs. Heat needs correspond to what end-users would like to have, in terms of a certain inside temperature and level of comfort in their dwellings. Demand indicates the quantity of heat they are ready to pay for. Actual demand may be lower than need if customers cannot afford the corresponding heat quantity. [111]Consumption in the end, indicates what the consumer

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[111] Affordability is a particular problem in some countries of the FSU, such as Georgia, Armenia, Moldova and Kyrgyzstan, where per capita GDP is only between US$400 and 1000. It is questionable whether the infrastructure which was built according to central planning standards can and should be rehabilitated, since most inhabitants will not be able to pay cost recovery tariffs, particularly for district heat, for many years to come.

ultimately uses or obtains. Under the previous economic system, due to the well-known phenomenon of overheating, consumption used to be greater than demand, and even greater than heating needs.

A comprehensive market analysis will therefore answer the following questions:

- What can be realized technically?
- What is feasible, given competing heating systems?
- What can be financed?
- What is affordable?

As a result of this analysis, the actual market size can be determined, as well as the obstacles to expansion in the market. It should be taken into account that affordability is not only connected with economic development, but can also be influenced by the heating system itself; for instance, via the tariff system.

Annex C

Cogeneration of Heat and Power: Energy Efficiency and Cost of Heat Production

The Energy Efficiency of Cogeneration

Compared to separate production of heat and power in heat-only boilers (HOB) and condensing power plants, respectively, the same amounts of heat and power can be produced in combined heat and power (CHP) plants using about one-third less fuel. The exact savings depend on the types of power and heat plants, on the cogeneration technology, and on types of fuel used. The most commonly used prime mover for cogeneration is the steam turbine, where turbines fall into two categories according to the exit pressure from the turbine: backpressure turbines and condensing-extraction turbines. For other technologies, see Table 3-2 in the body of this report.

Backpressure CHP Plant. In a conventional condensing power plant, the steam is condensed at about 40 degrees Celsius to create as good a vacuum as possible in the condenser for maximizing electricity yield from the turbine, to about 40 percent of the fuel input. This temperature is too low for DH. Therefore, in a backpressure CHP plant, the steam is "condensed" in a heat exchanger at a higher temperature to enable DH water to reach temperatures of 85-130 degrees Celsius. The relatively high cooling temperature increases the near vacuum of the condenser to about 0.5-1.5 bar pressure in the heat exchanger (thus the term "backpressure"). This limits the electricity output to approximately 35 percent of fuel input energy content, but enables the heat output (about 55 percent of total fuel input) to be used for heating DH water. This results in an overall energy conversion efficiency of 90 percent and a ratio of power output to heat output (=Cm) of 0.64. The backpressure CHP plant has a fixed ratio Cm in pure CHP operation mode, but the proportions can be made flexible by installing a turbine bypass valve and/or an additional cooler, thus enabling independent heat and electricity production. The fuel efficiency of electricity produced with the additional cooler is poor, and it is usually used only for emergency or peaking electricity.

Condensing-extraction CHP plant. In this type of plant, steam is extracted from the turbines at temperature and pressure levels that are high enough for purposes of DH. The steam that has not been extracted continues to the condensing part of the plant. This type of CHP plant has a variable Cm ratio: the greater the steam extraction for hot water production, the smaller the amount of power generation of the condensing part. Condensing-extraction CHP plants can operate anywhere between almost full back pressure operation (electric efficiency of maximum 35 percent and heat efficiency of maximum 50 percent of the total fuel input in coal-fired power plant) and full condensing operation (electric efficiency of maximum 40 percent and no heat production in coal-fired power plant).[112] The average energy efficiency of a CHP plant will be in the range of 60-85 percent, depending on the connected heat load.

The energy savings of cogeneration can conveniently be illustrated in a "Sankey diagram" (see Figure C-1), which depicts the fuel inputs, sources of losses, and outputs of power and heat for separate and joint production. To generate 55 units of electricity and 100 units of heat, the fuel consumption in the CHP case (176 units) is 31 percent less than in the separate generation case (256 units). The values in Figure C-2 are typical for cogeneration technologies based on the use of solid fuels currently used in Western Europe. In cases in which natural gas is the fuel of choice, the C_m ratio is higher. Where gas and steam processes are integrated or where a gas engine is used, the C_m ratio may have the value of about one.[113]

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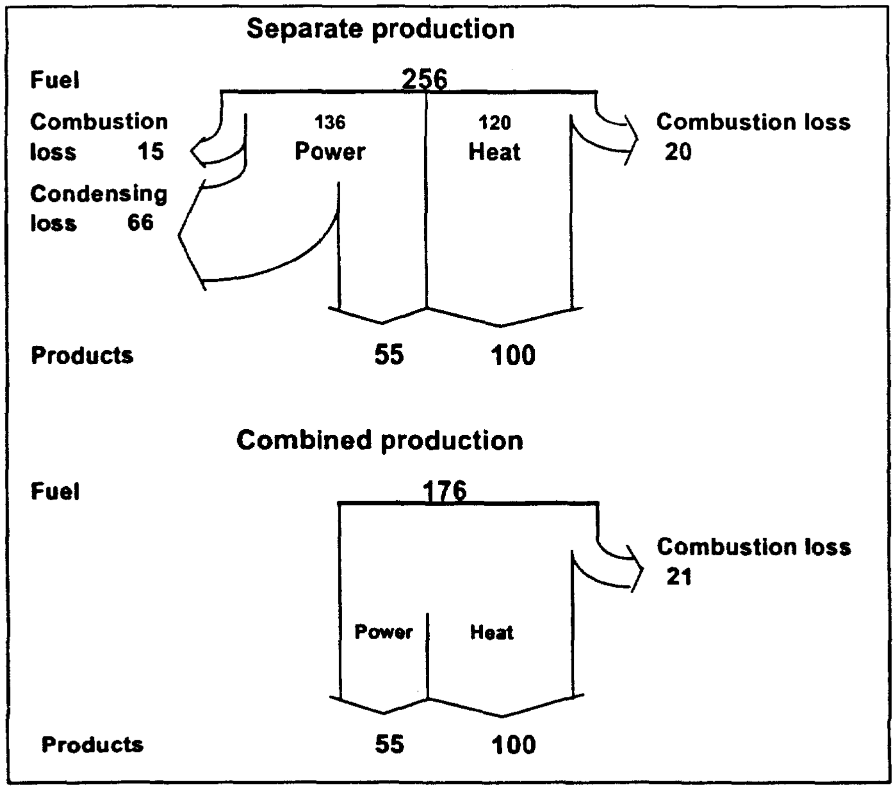
[112] Power plant efficiency is defined here as net efficiency (with own electricity use subtracted from the electricity production). Coal-fired plants have a higher own use (coal mills, conveyors, fans) compared to oil- or gas-fired plants. The net efficiency of a coal-fired condensing plant is about 40 percent.

[113] The Cm ratio is typically about 0.5 to 0.6 for solid-fuel fired CHP plants; about 0.4 to 0.6 for gas-fired single gas turbine (process) CHP plants; about 1.0 to 1.1 for combined cycle gas turbine plants; and about 0.8 to 1.0 for small-sized gas engines.

Figure C-1. Energy Balance of Separate and Cogeneration of Power and Heat (for Solid Fuels)



Source: World Bank staff

The energy efficiency of heat production in a CHP plant can be calculated in the following way:

An efficient HOB plant has a heat production rate or "efficiency of heat production" of about 85 percent. The marginal fuel consumption for producing the same amount of heat in the turbines of a condensing-extraction CHP plant or in a backpressure CHP plant (which have a higher specific fuel consumption above the level needed for pure electricity production) is roughly half of the fuel consumption in a HOB. This gives an "efficiency" of 170 percent (=0.85/0.5) for the heat production at the CHP plant.[114] This assumes that the same amount of fuel consumption is allocated to electricity in the cogeneration process as in stand-alone production. The value of 170 is used in the calculations in chapter 4.

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[114] On the basis of the numbers from Figure C-1, the resulting efficiency of heat production would be 250 percent =100/(176-136) x100 percent.

At an condensing-extraction plant, electricity output will fall when heat is extracted for DH purposes as the fuel consumption remains constant. This lost electricity production has to be produced elsewhere in the national power system; e.g., by another condensing power plant. With the values for the condensing-extraction power plant above, a loss of five percentage points (from 35 to 40) in electrical efficiency has to be made up by this alternative condensing power plant. With an efficiency of 40 percent, the fuel consumption there equals 12.5 units (5 units produced at 40 percent efficiency), resulting in a heat energy "efficiency" of about 440 percent (55/12.5). This calculation assumes that heat from the turbine is allocated only that fuel amount that is needed to replace the lost electricity production. Since the level of heat extraction varies during the year, the "efficiency" of heat production at a condensing-extraction plant on an annual basis is well below 400 percent.

Similar rules of thumb cannot be established for investment savings in CHP plants compared to separate HOBs and power plants with similar levels of heat and power output. There are large investment cost differences in CHP plants (see table 3.3 in the main body of this report). The cost of converting a large-scale existing or planned 100-600 MW power plant to CHP is small; a heat extraction unit typically adds no more than 15-20 percent to the cost of a power plant. The cost per installed MW of capacity of a small, decentralized 20 MW_{th}/ 20 MW_{el} CHP plant used to be much higher than for a large thermal power plant, but costs have come down considerably during the past few years.

The Economic and Financial Costs of Heat Production in a CHP Plant

Financial and economic costs of production

The general differences between financial and economic costs of heat production in a CHP plant are well known:

- Financial costs do not include external benefits and costs (mainly environmental impacts).
- Economic costs do not include taxation, duties, and subsidies.

The economic value of electricity production at a CHP plant is equal to the long-run marginal cost (LRMC) of electricity supply, that is, the production cost of a modern power plant. The financial value is equal to the sales tariff.

Case I: Adding a heat extraction unit to an existing power plant

The financial cost of heat production is equal to:

- the cost of the investment in the heat extraction unit,
- plus the cost of the extra amount of fuel consumption,

- plus other increases in the variable cost of production at the plant,
- plus the loss of revenue from the decline in electricity production.

Case II: Converting a HOB plant to cogeneration by adding a gas turbine or gas combustion engine.

The annual financial cost of the electricity output is equal to the levelized cost of the investment, plus increased fuel costs and increases in other operating costs. The annual financial cost of heat production in a HOB plant converted to CHP production can be viewed from two angles. It can be calculated as either:

- The total annual cost of CHP production minus the revenue from electricity sales.
- Or, as the total annual cost of CHP production minus the financial cost of the electricity output (increased fuel and non-fuel O&M costs + levelized cost of investment). This figure gives the true cost of heat production as such.

The difference between the first and the second estimate provides the financial cost advantage of CHP production that is passed on to the DH consumers.

Case III: Construction of a new CHP plant

In the case of a new CHP plant, the financial (economic) cost of heat production can be calculated in two different ways:

- As the difference in the annuitized cost of investment and of O&M (including fuel) between the CHP plant and an electric power plant producing the same electricity output.[115]
- Or, by allocating the total annual cost of the CHP plant to heat production and deducting the revenue (economic value) of electricity production.[116]

In principle, since the economic value of electricity production is equal to the LRMC of electricity supply (the production cost of a modern power plant), the two methods should arrive at the same economic cost of heat production.[117]

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[115] The optimal size of a power plant is 600-1200 MW (although economies of scale are less pronounced in modern combined cycle technology than in conventional thermal power plants). If the CHP plant's capacity in MW_{el} is smaller, as usual, one should not compare the extra investment at the CHP plant to the cost of a power plant of similar size. The relevant alternative is the cost of construction of a big plant. This cost must then be pro-rated according to the relative size of electric capacity.

[116] In the case of a financial analysis, the income from the sale of electricity is deducted from total costs to arrive at the cost of heat production.

Calculating the break-even electricity tariff for a CHP plant:

The maximum price of a unit of heat supplied by the CHP/HOB plant is equal to the cost per unit of heat produced by the competing technology (building boilers in practice) minus the cost of heat transmission and distribution. The maximum price arrived at by this method can be used to calculate the minimum kWh price that a CHP plant must obtain for its electricity output to compete in the heat market:

- Multiplying the maximum price per Gcal with the annual heat output in Gcal provides the maximum revenue from heat sales.
- The difference between the maximum revenue from heat sales and the total annual cost of production at the CHP plant is the revenue which must be generated from the sale of electricity.
- Dividing this revenue by the number of kWh that are generated in an average year provides the minimum average electricity tariff that the CHP plant must obtain.

The above method was used in the case studies. In the study for Timisoara, for example, the resulting electricity tariff needed to make district heat competitive with heat from a building boiler was much higher than the current long-run marginal cost of electricity in Romania. If the latter is an indication of the level of the bulk power tariff, not even DH based on cogeneration is currently competitive in Timisoara.

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[117] The LRMC hypothesis assumes that the CHP plant replaces an alternative investment in a modern power plant. The replaced emissions due to electricity production from the CHP unit are emissions of a modern coal or gas-fired power plant, not of an old worn-out thermal plant; see Section 4.3.3 and Annex F.

Annex D

Technologies for Heat Distribution

Overview

The typical district heating (DH) systems in CEE/FSU consist of heat production plants from where the heat is transported in the primary network to so-called "district heating points" or central substations, each feeding a secondary network by which the heat is distributed to the heat receiving stations of the buildings.

In any DH system there is a point where the useful heat media (space-heating water and DHW) are separated. This requires to some extent the parallel laying of 3 or usually 4 pipes (space heating requires two pipes for flow and return, DHW requires two, if circulation is requested). In some systems, this separation takes place in the individual buildings. In others, it occurs in the heat transfer stations.

The heat transport from the heat production plant to the central substations is usually realized by a two-pipe system: one supply pipe and one return pipe. The structure of secondary systems can be described as follows:

- With regard to the transport of water for space heating one distinguishes between direct and indirect systems. The difference concerns whether or not there is a hydraulic separation of the water used in the district heating system, and the hot space water system inside the building of the consumer. In direct systems, the water flows directly from the source of production to the heat receiving system. In indirect systems, the heat from the primary system is transmitted via heat exchangers to the water, which circulates through the radiators of the consumer. The heat exchangers can be located either at the block substation or at a building substation. In the former case, make-up water is produced at the substation or taken directly from the primary network to compensate for water losses in the secondary distribution system.

- Another difference concerns the place of domestic hot water (DHW) production. In the four-pipes systems, the heat exchangers for DHW production are located in the central substations. From there, the DHW circulates via a two-pipe system (one supply, one return pipe) to the consumer buildings and back again. Refilling of potable water takes place at the substation to compensate for the amount of consumed DHW.

Direct Systems

Four-pipe direct system

From the central substation to the heat receiving station in the building, some times a four pipe system is applied: one supply and one return pipe for heat to be used for space heating, and a circulation system (also consisting of a supply line and a return line) for DHW. From the receiving-station in the building, the four-pipe distribution is continued inside the building. During summer time, the two space heating pipes from the central substation to the building substation are switched off; only the pipes for DHW are kept in operation.

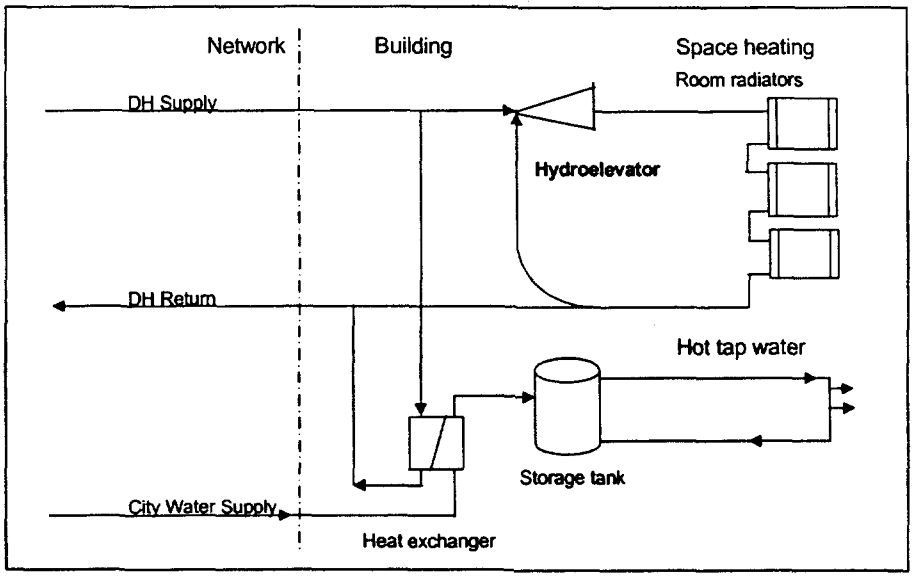
In direct systems, the primary pipe network (from the heat production plant to the central substation) and the secondary network (from the central substation to the heat receiving stations in the buildings) are directly connected by valve devices. Also the secondary network and the building heat distribution system are directly connected at the building substation (without heat exchangers), where mixing pumps and valves or hydro-elevators are applied.

DHW is heated in a heat exchanger in the central substation and therefore not "directly connected" with the DH water. For the circulation of DHW, a pump is required at the central substation.

Two-pipe direct system

In a two-pipe direct system the DHW is not produced at the central substation, but at the building substation. The heat flows from the central substation to the building substation through a two-pipe system (see Figure D-1).

Figure D-1. Direct DH connection with hydro-elevator supplying mixed supply and return water to radiators connected in series



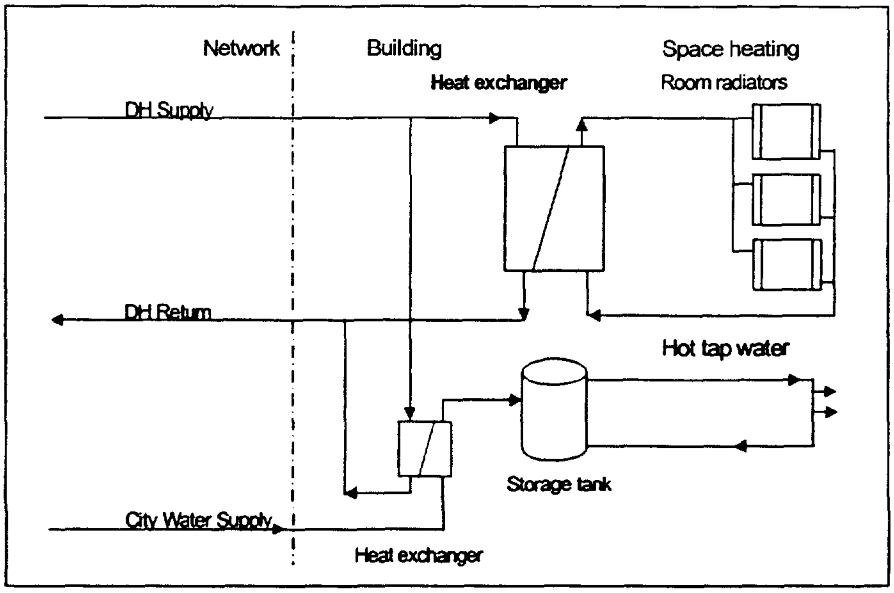
Source: World Bank Staff

At the building level a four-pipe system is applied, or a three-pipe system (one pipe for space heating water, two pipes – supply/return – for DHW) when no circulation system is installed. It is also possible that at the building level two pipes are applied; in such cases the DH water is also used as DHW. In the six case studies such systems were not found.

Indirect systems

The indication "indirect system" in four-pipe or two-pipe systems refers to the use of heat exchangers isolating the primary from the secondary space heating networks (see Figure D-2).

Figure D-2. Indirect DH connection (with radiators connected in parallel)



Source: World Bank Staff

Temperature and pressure regimes in the networks

The design capacity of the DH systems in CEE/FSU will usually be delivered at a maximum supply temperature of 150°C delivered from the heat production plants and at a return temperature of 70°C to these plants. In smaller systems lower supply temperatures may be applied, typical temperatures are 130, 110 or 95°C. As a consequence of the high supply temperatures the distribution networks need to be kept under pressure: supply pressures ranges from 5 - 16 bar, while return pressures ranges from 1 - 5 bar.

In a constant flow system, the flow through the networks is kept at a constant rate. The supply temperature at the production plants is adapted according to outdoor temperature, following the so-called "graphic." The lowest supply temperature - at outdoor temperatures of 8-10°C, when the heat demand is low, and space heating systems are about to be switched off - is approximately 70°C. For the production of DHW in summer time a network supply temperature of 60-70°C is applied.

At the building substations the maximum supply temperature to the consumers is 90°C. The supply water temperature is lowered at the substation by mixing the supply water from the network with return water from the building system. The mixing and circulation is realized by using the pressure difference between supply and return lines by application of ejectors, the so-called "hydro-elevators." The mixing ratio is constant but requires a high pressure difference between supply and return line. High pressure requirements increase the need for pumping.

The DHW which is produced in the heat exchangers at central substations or at building substations is provided at temperatures between 45 and 65°C. The pressure in the DHW network is kept at the same pressure level as in the cold potable water distribution network to allow mixing of hot and cold water at the end-user. When DHW demand is zero, typical in summer nights, the hot DH water is not cooled in the heat exchanger and enters the return lines at high temperatures.

Mode of operation: constant flow and variable flow

There are two distinct models for designing and operating a DH network:[118]

- Constant flow (**quality** control referring to supply temperature regulation). The water flow is kept constant whilst the supply temperature at the heat source is varied according to outdoor temperature to match the system output with expected heating need. This mode does not require flow regulation equipment. Water flow can change during the heating season but this is normally a stepwise consequence of "summer/winter" arrangement of system configuration. In other words, **the heat source regulates** how much heat the customers are expected to need.

- Variable flow (**quantity** control referring to water flow regulation). Both the supply temperature and the water flow are varied according to outdoor temperature to match the system output with real heating need. This mode requires flow regulation valves at points of consumption. The circulation pumps at heat sources are usually equipped with speed control to save electricity in variable flow systems. In other words, **the heat consumer regulates** how much heat they really need and the heat source has to adjust the supply temperature according to the outdoor temperature.

The use of constant flow technology has a number of disadvantages:

- More heat energy is sent through the system than necessary:

  The concept of constant flow means that the distribution of energy is determined by a number of fixed valves, orifices or other throttling equipment in the system, which are set manually every now and then. The heat production plant via its setting of temperature of the supply water decides the heat output for each radiator. Because of imbalances in the system, some customers receive more and others less heat than needed. Especially in spring and autumn, the supply temperature of the primary system must be higher than needed for space heating needs in order to maintain the DHW temperature at an acceptable level. This causes high space heating temperatures resulting in excess room heat that must be ventilated out through open windows. The annual average temperature in the piping system (supply and return water

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[118] The terms variable/constant flow control are used in Western literature, and quantity/quality control in Eastern literature.

temperatures) is lower in the variable flow system than in the constant flow system leading to lower heat losses and higher power production at CHP plants.

- Since consumers cannot control their heat intake, the constant flow system makes it impossible to achieve the full benefits of a modern, incentive based system of heat supply and demand.
- Pumping costs are higher. In constant flow systems, electricity consumption for the secondary network in relation to the heat supply ranges between 12 and 20 kWh/MWh (used electricity/supplied heat); in variable flow systems, the value is 5-8 kWh/MWh. However, some of the higher electricity consumption benefits the heating system, as friction heat is passed on to the DH water.
- There is a higher need for heat production capacity. Due to the constant flow design, the coincidence factor of peak demand is close to one. In a variable flow system the coincidence factor of peak demand is 0.6 to 0.8, and therefore the capacity of the heat sources can be 30-40 percent less.[119]
- Variable flow allows for a lower temperature in the system at peak demand, which again makes it possible to increase electricity production at the CHP plant.
- Constant flow does not allow for merit order dispatching of heat plants along the transmission system. Load dispatching (connection of decentrally located alternative supply sources) is not possible without manual isolation of specific supply areas. It means that the capability of adapting to changes in demand and production is very limited. Variable flow permits the establishment of peak and reserve load boilers in the local supply areas and dispatching of the plants according to merit order.
- Constant flow requires slow flow velocities and respectively larger pipes (otherwise, the pumping cost would be very high), which leads to higher investment cost. Variable flow can provide the same heating capacity with use of smaller diameters. In variable flow, the velocities in the pipes can be twice as high as in a constant flow system for the short time when the maximum transmission capacity is really needed. However, because the higher transport capacity of variable flow is used to lower the maximum temperatures in the system, the difference in diameter sizes is relatively small in practice.

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[119] Even after switching to variable flow, DH systems in CEE/FSU will not get to a coincidence factor of demand as low as 0.5-0.6. In Western Europe, the coincidence factor is low because of the important share of residential consumers in individual houses, and because of the prevalence of two string radiator systems with thermostatic valves. In CEE/FSU, single family houses make up an insignificant proportion of heat demand and many high rise buildings have one-string radiator systems. This reduces the demand variations.

Modernization: Transition from constant to variable flow

When customer installations are equipped with flow regulating devices, the system turns from the constant to the variable flow operation mode. In a typical DH system having thousands of consumer substation some years are required to implement the transition process. The basic problem in the transition phase is how to organize the mixed constant/variable flow operation when one part of the substations regulate the flow and the others do not. If the transition is not properly organized, the constant flow customers will suffer underheating in winter and overheating in spring and autumn.

In order to smoothen the inconveniences, the rehabilitation should take place branch by branch. As one main network branch is rehabilitated, the other mains have to be equipped with pressure difference control valves which keep the pressure difference constant for the old fashioned customers of the branch to enable them to function as they used to.

Distribution of heat and domestic hot water inside the buildings

Unlike most heating systems in Western Europe, many radiators applied in CEE/FSU are not installed in parallel (Figure D-2), but in series (Figure D-1). Radiators are vertically connected to each other. From the sub-station a distribution ring is installed in the basement, from which risers go up to the top level and are connected to the top radiators of the vertical strings. The bottom radiators of the strings are connected to a collector pipe in the basement. Such system is referred to as a one-pipe system, instead of the two-pipes, which are connected to each radiator when radiators are installed in parallel.

One consequence of the one-pipe system is that the entrance temperature to each following radiator is lower than that of the previous one. In the design, the drop in temperature from one radiator to the next is compensated for by increasing the radiator area. A second consequence is that an apartment is crossed by several vertical strings. If one intended to measure the heat consumption of individual apartments, it would not be possible to measure the heat for an apartment by only one heat meter. The contribution of each string has to be measured separately. Introduction of control of heat at the level of radiator is also complicated. Potential thermostatic valves must have low resistance. By-passes need to be installed to allow continuation of the flow to next radiators when the valve is closed.

In many buildings in CEE/FSU, the internal heating system is unbalanced, meaning that the division of the flow amongst the individual risers is poor; some risers receiving too much, others too little water. By installation of balancing valves in each string the situation can be improved. However, the consequence of such measures is that it increases the required pressure drop between the supply of the risers and the return in the collectors.

Comparison with Western heat distribution systems

Table D-1 compares typical values for performance indicators which have been observed in heat distribution systems in CEE/FSU and in Western Europe.

Table D-1. Performance Indicators for DH Distribution Systems

	Unit	CEE/FSU	W. Europe
Customer heat consumption (annual energy/building volume)	KWh/m3	70...90	45...50
Heat transmission loss (% from heat supply)	%	15...25	5..10
Change of circulation water (Annual make-up water volume/network water volume)	Refills per year	10..30	1..5
Heat production loss (% of fuel energy)	%	15...40	5...15

Source: World Bank Staff

Annex E

Energy Efficiency Investments in the Building Sector[120]

Passive Technology Measures to Reduce Energy Losses in Buildings

Technical measures for reducing heat losses in buildings include additional insulation on roofs, exterior walls, and basement ceilings; hot water and heat pipe insulation; window replacement, renovation, or simple weather stripping; improved caulking and sealing of building panel joints; new building entrance doors; and improvements to building ventilation systems. In particular, studies in CEE/FSU have highlighted the high thermal losses associated with building ventilation, leaky windows, and the low thermal insulation properties of exterior walls. Heat balancing valves for balancing the heat flows within the building also can reduce heat losses by eliminating overheated sections of a building.

Basic technical measures can be grouped into three tiers, representing different levels of economic viability under full economic cost (unsubsidized) heat prices common in CEE/FSU countries.

Tier I: Basic measures. These measures have short-to-medium payback times (often less than five years) and are typical of basic retrofit packages.

Tier II. These measures present higher or more variable or uncertain (but potentially short) payback times, and their use is more dependent on building characteristics and the overall retrofit package design.

Tier III. These measures are generally not cost-effective by themselves, but may be included in building retrofit packages whose goal is to provide a high degree of energy consumption reduction and/or in conjunction with more extensive building modernization or renovation.

Tier I - Basic measures

Improve windows. Window improvements includes weather stripping, refitting, caulking, painting, and hardware where required. Significant energy savings of up to 10% or more have been estimated from this measure alone, and payback times are generally on the order of just a few years.

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[120] This annex is based to a large extent on Martinot, Eric (1997), Investments to Improve the Energy Efficiency of Existing Residential Buildings in Countries of the Former Soviet Union. *Studies of Economies in Transition 24*, Washington, DC, The World Bank.

Replace or install heat pipe insulation in basements.[121] Pipes carrying hot water in basements are not usually insulated or suffer from insulation degradation, so insulating or re-insulating these pipes can reduce heat losses in unheated basements.

Install attic floor insulation. If an attic exists, insulation installed on attic floors is an inexpensive way to significantly reduce heat losses through the roof. This measure may provide much better building heat flow balance if the building is overheated to compensate for colder temperatures on the top floor, further reducing consumption.

Renovate or replace building substation. The building substation distributes heat within the building. It sometimes includes a heat exchanger, which may suffer from high energy losses. Savings and paybacks are generally lumped together with building-level heat control (see paragraphs below), since the two measures may be installed together. Installation of a heat exchanger where none existed provides benefits both within the building and in the DH system, including lower stress and corrosion of pipes and radiators within the building, and better pressure control on the supply side.

Renovate or replace building entry doors, including door closers. Heat loss through open or poorly closing entry doors is a prevalent problem, often resulting in significant heat loss from building common areas.

Improve staircase windows. As with windows in apartments, windows in common staircase areas can be tightened. Window improvements includes weather stripping, refitting, caulking, painting, and hardware where required.

Renovate or replace apartment doors to staircases. Staircases are significantly colder than apartments, yet apartment doors and frames are often poorly insulated, resulting in heat loss from apartments.

Improve passive ventilation systems. Measuring experiments and analyses for building heat flow have shown that air infiltration into apartments often significantly exceeds Western norms for ventilation, and that reducing air infiltration can result in significant energy savings without reducing indoor air quality. Redesigned ventilation orifices and mechanical systems can reduce infiltration.

Install low-flow showerheads and faucets. These measures will reduce hot water consumption which is usually several times above Western norms. However, the water quality must be acceptable for these devices to work, so water softeners or other decalcifying devices must exist in the water system.

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[121] Existing heat pipe insulation in residential buildings in FSU countries is often composed of materials containing asbestos. Asbestos hazards will mean added costs and project management attention for proper asbestos removal and disposal.

Tier II measures

Add additional roof insulation. Roof insulation by itself is a high priority, with short payback times, but it can be costly if roof repairs are required because of the poor condition of the buildings. If lower roof maintenance costs are included, payback times can be reduced. Estimates of payback time for flat roofs are generally less than 10 years if no repair work is needed, but may increase to 30 years or more, including the costs of necessary roof repair work. New sloped roof structures built over existing flat roofs are another alternative, and can reduce long-term maintenance costs even more and provide additional energy efficiency benefits when installed with adequate insulation. Roof insulation can also have indirect effects, such as potential savings from a more balanced building top-to-bottom and the consequent reduction in lower floor overheating. Roof maintenance costs may also be reduced after insulation and renovation, which would lower payback times.

Install heat riser balancing valves and controls. Different sections of a building may receive different levels of heating, thus creating air temperature imbalances within the building. Heat balancing valves and controls can improve the effectiveness of building-level heat controls by balancing the distribution of heat within the building. Balancing eliminates overheating and underheating and allows the building-level controller to regulate heat supply at the minimum level possible while maintaining uniformly comfortable temperatures. Without a building-level heat controller, balancing may improve occupant comfort, but won't change the total heat consumption of the building.

Improve hot water temperature control and availability. In non-circulating systems, especially without a heat exchanger for hot water in the building, hot water consumption increases because residents must run hot water taps for extended periods (up to several minutes) to get hot water, and thus waste significant quantities of both cold and hot water. Hot water system reconstruction or control to provide instant hot water availability can reduce the volume of water consumption.

Renovate selected windows or add a third window pane. A third window pane only on the top floor apartments can improve the balance of heat distribution within the building and allow reduction of overheating on lower-floor apartments.

Install slot ventilators in windows. Slot ventilators allow occupants to control ventilation without resorting to opening or closing windows, and provide improved passive ventilation.

Tighten outside joints between exterior wall panels. A mastic compound may be used to better insulate the outside joints between exterior wall panels.

Tier III measures

Install exterior or interior wall insulation. Insulation can be applied to gables (window-less end walls) and/or facades (walls with windows). While substantial energy savings are possible with additional wall insulation, payback time estimates for exterior insulation (either gables or facades) range from 15 to 50 years with conventional mineral wool or rigid foam insulation applied to frameworks on building exterior surfaces. It should be noted that the cost-effectiveness of exterior wall insulation remains a subject of debate because of potential technologies for cheaply insulating exterior walls that have not yet been considered for buildings and conditions in the FSU (like spray-on polyurethane foam).

Install active ventilation systems. A few demonstration projects have included active ventilation systems, but most studies have concluded that roof fans and other types of active ventilation systems are not cost-effective, and that passive ventilation systems can provide good regulation of air infiltration at low cost.

Replace radiators. No direct financial benefits exist for this measure, except reduced long-term maintenance costs in open hot water systems; but aesthetics may be improved.

Replace one-pipe systems with two-pipe systems. This may require extensive renovations, since holes must be drilled in floors and ceilings to accommodate the additional pipe. In general, this measure does not result in energy savings. The benefits of this measure are the subject of debate and depend on the condition of the existing piping and any existing problems with heat flow distribution within the building. If the existing pipes must be replaced, then converting to a two-pipe system while installing new piping reduces the added cost of this measure.

Replace windows. Window replacement is expensive and difficult to justify on the basis of cost-effectiveness of energy efficiency improvements. But if window replacement is viewed as a building renovation measure to improve the quality and amenities of building services, then the incremental costs of high-quality and high-efficiency windows can be viewed as highly cost-effective.

Major building improvements, like roof repair in conjunction with insulation, exterior wall insulation, and new windows, present a higher cost per unit of energy saved and, consequently, longer payback times. But since many buildings in CEE/FSU have badly deteriorated roofs that urgently need repair, roof insulation is likely to include new roof assemblies that fix immediate problems (such as leaking), ensure a longer period of low maintenance costs, and provide superior insulation. Conversely, if a roof must be repaired, that is a good opportunity to add extra insulation, as the additional costs of the insulation will be highly cost-effective. Similarly, the additional costs for exterior wall insulation will be much more cost-effective if undertaken when major facade renovations are going to be made. When considering such longer-term improvements, the expected lifetime of the building becomes an important factor in estimating returns. Some of these measures may offer more intangible returns, and therefore may be undertaken in spite of the longer payback times. For example, the sloped roof represents a cultural icon in Estonia, and Estonians may be willing to pay a premium for it.

For some types of building renovations, there is also the issue of opportunity and sequence: some measures can only be undertaken in conjunction with major renovation work (those that only can be undertaken if walls are opened, for example, to repair moisture damage). In evaluating economic possibilities, it must be known which measures can be undertaken profitably only when other measures are also undertaken (whether or not related to energy), or which measures are dependent on others occurring first.

Investments in Metering and in Regulation of Heat Demand

While many retrofit strategies are straightforward (i.e., windows, insulation, and heating equipment renovation), heat metering and controls in buildings are of special importance, pose special problems, and deserve even greater attention. Measures for metering and regulation of heat demand include both building-level heat meters, valves, and automatic control systems for controlling the heat entering the building, and apartment-level heat meters and thermostatic radiator valves for controlling the heat to individual apartments. Building-level meters (metering of total building consumption) are an essential part of any retrofit strategy. But the question of metering at the apartment level is more complex. Based on experience in the Nordic countries, there is little doubt that households in collectively metered buildings (i.e., with building-level meters but not apartment-level meters) consume more heat per square meter than households in buildings with apartment-level meters; occupants tend to be more responsive when they can see (and have to pay for) their individual consumption. Controls are equally important. If the occupants of each unit are to be responsible for their own consumption, they must have control over what they actually use. In the Nordic countries, a variety of systems—including thermostatic valves on each radiator, outdoor temperature sensors controlling the flow of heat to the building (or combustion in the boiler), or shunts that permit closing of any room or radiator—all permit occupants to throttle back heat. Technical measures are described in detail below.

Install building-level heat meters. These measure heat and hot water flow into the building from the DH system. No payback or energy savings are directly associated with these meters, but it is necessary to create proper incentives for further energy efficiency improvements and changes in behavior. Because average actual consumption tends to be significantly lower than design consumption (partly because of higher-than-estimated distribution system losses), energy bills may decline by 10-20% or even more and "payback periods" for the meter can be less than one year, even while there are no physical energy savings. (Note, however, that during especially cold winters, households may pay more according to the meter than according to design consumption.)

Install building-level heat controls. These control heat delivered to buildings and thus indoor temperatures, based on outdoor temperature and/or heat supply temperature. Estimates of energy savings depend greatly on assumptions about building overheating and the heat supply regime used in practice (if curtailed or not), as well as on the degree of imbalance between different parts of a building. Sometimes building-level heat control is included together with heat riser balancing as an integrated measure (see riser balancing above). Savings from building-level heat controls will generally be higher if no apartment-level controls exist, and will be lower if they do.

Building-level heat controls may also be integrated with a new building substation containing heat exchangers (see above).

Install radiator thermostat valves. This is one of the most complicated measures to analyze because of the confounding variation from so many variables, and thus has been the subject of considerable debate. Estimates of energy savings in buildings without building-level heat controls vary because of the uncertainties in occupant behavior and depend on whether apartment-level billing exists. With individual billing and no building-level heat controls, savings of up to 25-30% are realistic (with payback times of less than five years), but with building-level heat control and no individual billings, savings may only be 5-10% (with payback times of up to 20 years or more). There is some debate about the sufficient levels of water quality (levels of suspended particulate matter) required for long-term reliable operation of these valves (valves can clog), and water quality from one DH system to another may vary significantly.

Install apartment-level heat meters. Installation of heat meters on heat pipes to measure ingoing and outgoing heat flows to an apartment are very expensive because each radiator in an apartment would require its own heat meter, due to the physical piping arrangements within buildings.[122] But inexpensive ($5-$10 each), evaporative-type heat "allocators" may be attached to each radiator and will measure the heat output from that radiator. These types of meters are in common use in some Nordic countries and also have been adopted in Eastern European countries such as Poland.[123] These types of meters require annual replacement of the recording element. Because experience in the former Soviet Union with these "allocators" has been limited, uncertainties remain about the use of these meters because of the social and institutional issues involved. Some analysts have cautioned against apartment-level meters, citing measurement inaccuracy and unfair billing if readings are not corrected for the location of an apartment within a building; e.g., for equal levels of comfort, corner apartments consume more heat per square meter than "middle" apartments.

At the level of the apartment in two-string internal distribution systems, evaporation meters should be installed at radiators that are fitted with regulating valves, possibly thermostatic valves. Evaporation meters are a cheap solution. The drawback is that the meter has a margin of error of +/-30%. However, since an apartment has at least three radiators, the margin of error in billing is lower.

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[122] Heat distribution within multi-family buildings is typically designed so that radiators are connected in series with hot-water pipes running vertically through the building. Thus each of the four or five radiators in a typical apartment is connected to a different vertical pipe, so separate meters would be required for each radiator.

[123] Historically, Sweden has generally not used apartment-level metering, but apartment-level meters have been mandatory since 1997.

Install apartment-level hot water meters. Usually two meters are required for each apartment—one for the kitchen and one for the bathroom. Unlike the inexpensive evaporative apartment-level heat meters, hot water meters require physical connection to the hot water pipes. The expense and benefits of such meters have rarely been discussed in the existing literature.

Demand Side Measures: The Example of Orenburg

The demand side measures which were used in the modeling of the demand side options are based on packages developed for the Bank's Lithuania Energy Efficiency/Housing Pilot *Project (Staff Appraisal Report No. 15397-LT, June 1996)*. The preparatory work for this project was in part done within the framework of this ESMAP project with support from the Thermie program of the European Commission, see *BCEOM (1995): Cost-effective Technologies for Thermo-Rehabilitation of Buildings in Lithuania. ESMAP consultant report.*

Table E-1. Demand-Side Measures

BUILDING CHARACTERISTICS (PRE-FABRICATED CONCRETE, 1964)		
Floors:	5	
Staircases:	6	
Apartments:	100	
Total heated m2:	4960	

CHARACTERISTICS OF DEMAND-SIDE MEASURES PER BUILDING				
	total cost (US$)	**cost/dwelling (US$)**	**energy saved (kWh/y)**	**lifetime (years)**
Heat meter	1250	13	0	15
Temperature control package	5525	55	249206	15
Pipe insulation	2780	28	54825	10
Thermostatic valves	11700	117	88635	25
Staircase refurbishment	2410	24	72685	10
Window refurbishment	29264	293	356220	15
Wall insulation	57270	573	192097	15
Roof insulation	44640	446	187167	20
Basement insulation	14880	149	124778	20
Window change	124250	1243	565761	25

CHARACTERISTICS OF DEMAND-SIDE MEASURES,

COMPLETE BUILDING STOCK

	Investment (million US$)	Savings (TJ/year)	Fuel savings (million US$/year)	Savings pump energy (million US$/year)
Reference	0.00	0	0.00	0.00
Heat meter	0.97	0	0.00	0.00
Temperature control package	4.28	694	1.74	0.07
Pipe insulation	2.15	153	0.38	0.02
Thermostatic valves	9.06	247	0.62	0.03
Staircase refurbishment	1.87	203	0.51	0.02
Window refurbishment	22.65	993	2.49	0.11
Wall insulation	44.33	535	1.34	0.06
Roof insulation	34.55	522	1.31	0.06
Basement insulation	11.52	348	0.87	0.04
Window change	96.17	1576	3.95	0.17

INTERNAL RATE OF RETURN OF DEMAND-SIDE MEASURES

	IRR	
Heat meter	NA	included
Temperature control package	73.71%	included
Pipe insulation	22.28%	included
Thermostatic valves	4.09%	not included
Staircase refurbishment		included
Window refurbishment	11.22%	included
Wall insulation	-4.39%	not included
Roof insulation	-2.37%	not included
Basement insulation	5.43%	not included
Window change	-1.57%	not included

DEFINITION OF DSM PACKAGE

Energy savings		
-Total:	TJ/year	2042.25
- Per building:	GJ/year	2638.57
- Per dwelling	GJ/year	26.39
Investment		
-Total:	million US$	31.91125
- Per building:	US$	41229.00
- Per dwelling	US$	412.29

(Source: ESMAP Orenburg case study)

The fuel savings are calculated based upon the following assumptions:
24% of the heat savings would have been produced in the heat-only boilers
76% of the heat savings would have been produced in the combined heat and power plants
The share produced in the heat only boiler is twice as much as in the current operation

- The heat losses remain the same in an absolute sense.
- The pump energy from the distribution of heat decreases in proportion to the energy decrease.
- The pump energy amounts to 25% of the own consumption of the power plant.

- Economic cost of fuel (natural gas): 1.226 US$/GJ
- Economic cost of electricity production: 0.024 US$/kWh

Fuel savings can be easily calculated as follows:
- Fuel savings in heat-only boiler: 24% times energy savings divided by efficiency of HOB
- Fuel savings in combined heat and power plant: 76% times energy saving divided by efficiency of CHP plant

Other assumptions:
- Efficiency of HOB: 92.5 %
- Efficiency of CHP plant: 42.6 %
- Pump energy: 4.5 MWh/TJ heat

Annex F

Economic Cost of Fuels, Heat Production and Distribution Costs, and Environmental Impact of Heating Systems

Economic Cost of Fuels

Natural gas

The *economic price* of natural gas is made up of:

- the price of natural gas at the border; in 1996 it was typically around US$78 per 1000 m3;
- plus the cost of transmission, including the cost of seasonal storage from the border to the city gate (= the tariff for a large CHP plant);
- plus the cost of primary distribution (= tariff for a local HOB plant);
- plus the cost of secondary distribution, including the cost of building connection (=tariff for building boiler); and
- tariffs for households (apartment-level supply) are still higher, as they include the high cost of billing and servicing small consumers.

The *financial tariffs* may differ from the economic cost of supply, as a natural gas company having a supply monopoly will tend to use the substitute fuel pricing principle, pricing gas such that for every consumer class it remains competitive with other fuels, for example HFO in the industrial sector. But even then, the structure of the financial tariffs will resemble the economic cost structure. In practice, one will see that the financial natural gas tariff for households is about twice as high as the tariff for large industrial consumers. This ratio reflects the price ratio between HFO and LFO (substitute fuel pricing). It seems to be a good reflection of the differences in the economic cost of supply to the two categories of consumers as well. Some of the price difference is due to recourse of the CHP plant to HFO-fired units to cover the peak demand for heat. This makes the demand curve for gas flatter than it would be with just individual consumers, thus reducing investment in pipelines and storage capacity. In Orenburg, for example, the economic cost of gas for individual apartment boilers was calculated at $9.6/MWh; the cost of gas used by the CHP plant amounted to 61% of this.

In a competitive environment, there will be a clear cost advantage for large customers, as the long-run marginal cost of their supply is lower. However, decentralized technologies should be able to offset the disadvantage of high distribution cost of large DH systems, as the transport of hot water is significantly more expensive than of natural gas. As a thumb rule, one can assume that hot water transport costs three times more. The incremental gas cost for the smaller heat generator is, ideally, the additional transport of the gas from the site of the big plant to its own site. This distance is equal to the distance over which the hot water has to be transported.

Table F-1 presents the estimated economic cost of gas and the related cost components for the six ESMAP study cities.

Table F-1. Estimated Economic Costs of Natural Gas at City Gate, July 1996

Country	City Gate	Economic Cost at Importer's Border	Transmis. Cost within Country	**Economic Cost at City Gate**	
		$/mcm	$/mcm	**$/mcm**	**$/Gcal** [13]
Bulgaria	Sofia	103.8 [1,3,4]	11.0 [1]	**114.8**	13.2
Lithuania	Kaunas	81.5 [8,9]	4.0 [5]	**85.5**	9.8
Poland	Wroclaw	102.6 [8]	15.0 [12]	**117.6**	13.5
Romania	Timisoara	99.8 [3]	15.0 [11]	**114.8**	13.2
Russia	Orenburg	45.0 [2]	0.0 [10]	**45.0** [2]	5.2
Ukraine	Dnipropetrovsk	80.0 [6]	3.3 [7]	**83.3**	9.6

Source: World Bank Staff Estimates

Notes:

1. ESMAP: Bulgaria - Natural Gas Policies and Issues, Report No. 188/96
2. Delivery cost @City gate (SAR Enterprise Housing Divestiture Project, based on Gas Distribution Project, April 1996)
3. Through Ukraine: 19.8, based on (Lovei, July1996): $1.65/mcm/100km. Weighted average of length of transit lines, as computed by Ukrgazprojekt, is 1,190 km. Above value is slightly below the transit fee set by Ukrgazprojekt, 1992 ($22); no reference is made to royalty gas. WB estimate gives an economic cost of transit fee of $15/mcm; royalty gas would be around 6.5% of throughput value, ca $6/mcm. Total transit fee+royalty gas under conventional method would be $21/mcm.
4. Through Romania: 4.0. In 1992, Bulgaria paid the transit fee in kind; the amount of gas left with Romania was 4% of amount of the gas imported from Russia by Bulgaria.
5. Considered @ ($2/mcm/100km)*200 km
6. (Lovei, July 1996)
7. Based on transit fee calculation (Dniepropetrovsk is 200 km from Russian border @Novopskov).
8. Gas is sold at the importer's border. Based on transit fee calculations for Ukraine, transit fee through Belarus would be around $9/mcm (length of pipeline through Belarus=500 km). Poland appears to be charged a much higher price than Lithuania.
9. (Nocius, July 1996)
10. Orenburg is located close to a major gas field. No transmission cost is considered.
11. Average transmission cost within Romania in the range of $11-15/mcm (Esmap: Natural Gas Strategy for Romania, July 1996). Higher value considered due to location of Timisoara at western-most tip of country. Cost of gas at city gate might change if Timisoara supplied through Hungary.
12. Same value as for Romania (Wroclaw located in western part of Poland). Needs to be refined.
13. Based on 1cm=8,700kcal (LHV).

Economic Costs of Other Fuels

For the economic costs of fuels other than natural gas in the six ESMAP study cities, see Table F-2

Table F-2. Economic Costs of Coal, Power, and Fuel Oil in CEE/FSU

Basic Parameters for Case Studies: Economic Costs of Fuels
Base year: 1995

		World market	**Poland**		**Ukraine**		**Russia**		**Bulgaria**	**Romania**	**Lithuania**
		Rotterdam	Wroclaw CHP	Wroclaw Residential	Dnipropet.	Orenburg	Orenburg	Orenburg	Sofia	Timisoara	Kaunas
	Units										
Coal, national						Kuzbass	Urals	average	Lignite Maritza	Lignite	NA
heating value	kcal/kg		5012	7160	5500	5500	4500	5000	1700	1600	
cost ex mine	US$/ton		30	99	42	9	16	13	16	20	
financial loss, subsidy	US$/ton		3	3							
transport cost in country	US$/ton		10	10	12	25	8	17	20	10	
economic cost	US$/ton		43	112	54	34	24	29	36	30	
at heating value 7000	**US$/ton**		**60**	**109**	**69**	**43**	**37**	**40**	**148**	**131**	
	US$/Gcal		**8.6**	**15.6**	**9.8**	**6.2**	**5.3**	**5.8**	**21.2**	**18.8**	
sulphur content, (%)			0.8-1.0%		0.7-0.9%						
ash content, (%)			21%	5-7%							
Coal, import											
heating value	kcal/kg	6000	6000	na	5500	na	na	na	6000	6000	6000
steam coal import parity											
= border price	US$/ton		48		35				50	50	48
transport cost in country	US$/ton		10		15				22	32	5
economic cost	US$/ton	45	58		50				72	82	53
at heating value 7000	**US$/ton**	**53**	**68**		**64**				**84**	**96**	**62**
	US$/Gcal	**7.5**	**9.7**		**9.1**				**12.0**	**13.7**	**8.8**
Electric power											
long-run marginal cost	**cents/kWh**		**4.5**		**3.5**		**2.5**		**3.35**	**4.2**	**2.8**

Source: World Bank staff estimates

The Economic Cost of Heat Production

The comparison of heat production costs of CHP or HOB plants supplying a DH network with the heat production costs of building boilers needs to be adjusted for heat losses in transmission and in distribution. Due to these heat losses of DH based-systems, there is a need for higher heat output at the level of the DH plants to deliver the same amount of heat to a building as with a building boiler. Heat losses are part of the cost of heat transport, which are analyzed in section 4.1.3. The two tables below analyze the impact of the level of heat losses on the difference in the cost of heat production, ex-plant, between a CHP-supplied system and a system supplied by a building boiler, including the need for higher production.

An efficient DH system located in an area of high demand density has heat losses of around 10%. More inefficient systems, or efficient systems located in areas with low demand densities, will have losses of around 25%. Table F-3 shows the relatively limited impact of heat losses on the cost advantage of "optimized CHP-production"—as long as the cost of heat transport (capital cost + O&M costs, excluding the cost of heat losses) are below US$11.8-13.1 per MWh, the DH system is competitive. For HOB-based plants, as shown in Table F-4, the situation is much less favorable. The cost of transport then has to be below US$5.3-7.4. For a graphical presentation, see Figure 4.1 in the body of this report.

Table F-3. Difference in Cost of Heat Production: CHP-DH versus Building Boilers, as Function of Heat Losses

Losses	0%	10%	15%	20%	25%
Dnipropetrovsk	$11.3	$10.5	$10.2	$9.8	$9.4
Kaunas	$12.6	$11.7	$11.3	$10.9	$10.5
Orenburg	$10.7	$10.1	$9.8	$9.4	$9.1
Sofia	$14.8	$13.8	$13.3	$12.8	$12.3
Timisoara	$14.2	$13.2	$12.7	$12.2	$11.7
Wroclaw	$20.4	$19.4	$18.9	$18.4	$17.9
AVERAGE	$14	$13.1	$12.7	$12.2	$11.8
AV.COST RATIO	39%	42%	44%	46%	48%

Source: World Bank staff, based on ESMAP case studies

Table F-4. Difference in Cost of Heat Production:
HOB-DH versus Building Boiler as Function of Heat Losses

Losses	0%	10%	15%	20%	25%
Dnipropetrovsk	$6.9	$5.7	$5.1	$4.5	$3.9
Kaunas	$7.5	$6.1	$5.4	$5.8	$4.1
Orenburg	$7.7	$6.8	$6.3	$5.8	$5.4
Sofia	$8.6	$7.0	$6.2	$5.4	$4.6
Timisoara	$7.9	$6.3	$5.4	$4.6	$3.8
Wroclaw	$14.2	$12.6	$11.8	$10.5	$10.2
AVERAGE	$8.8	$7.4	$6.7	$6.0	$5.3
AV.COST RATIO	61%	67%	70%	74%	77%

Source: World Bank staff, based on ESMAP case studies

Density of Heat Demand and Distribution Costs

The cost of heat distribution is usually a decreasing function of the density of heat demand. Several definitions are being used to determine the density of heat demand. The "density of heat capacity" can be expressed in terms of "MW per kilometer of trench pipeline" or as "MW per km^2". The "density of the heat load" can be expressed in terms of "MWh per kilometer of trench pipeline" or as "MWh per km^2".

The density of heat demand in terms of heat capacity demand per area (MW/km^2) is determined by:

- the (calculated) heat demand of the buildings in the respective area; this includes the type of the building (high-rise, low-rise); and
- the size of the supplied area, determined by building grouping and use of the area (streets, parks, buildings, etc).

The density of heat demand in terms of heat demand per length of pipeline is determined by:

- Total heat demand of that area; and
- Total length of the pipelines in that area.

For the calculation and comparison of heat densities, the input values need to be well-defined in terms of answers to the following questions:

- ☐ Capacity demand: connected load or peak load?
- ☐ Energy demand: consumed or supplied energy?
- ☐ Length of the pipeline system: length of supply and return pipes or length of the loops?
- ☐ Area: including or excluding non-settled areas (parks, ponds, etc.), where are the boundaries of the supplied area?

Typically, the following principle can be applied:

- The shorter the network per MW or per MWh of annual demand, the lower is the cost of investment and the lower are the heat and water losses per MWh sold to the consumer.

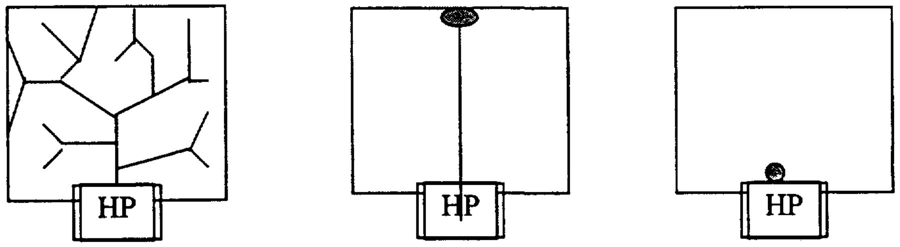
Heat losses increase both because the transport network becomes longer and because the pipeline diameters become smaller. The level of heat losses per unit of transported heat decreases with the diameter of the pipeline, as long as the capacity of the pipeline is not over-dimensioned compared to demand.

This principle is implicitly based on the assumption of a typical network "architecture," with customers more or less equally distributed over the service area, and a network with many branches. Figure F-1 illustrates that the determination of heat densities cannot substitute for a prudent analysis of a DH system, since the same heat densities (in terms of MW/km^2) can hide totally different network architectures and correspondingly, different investment and distribution costs.

The relationship between investment cost and heat losses and heat demand density, respectively, are further illustrated in Figures F-2 and F-3. Using the size of the pipelines as a proxy for the density of heat demand and assuming that the flow velocity is the same for all diameters, Figure F-2 shows that the cost of investment per unit of heat transport capacity falls to 50% by moving from a 200-milimeter pipeline to a 400-milimeter pipeline, and to 30% by moving to an 800-milimeter pipeline. The heat losses per unit of transport capacity decrease even further to 13% and 11%, respectively. The differences in demand density explain the huge differences in heat losses between systems that otherwise use the same technology. In German DH systems found in the largest urban centers, average heat losses are around 10%. In Denmark, where DH has a residential penetration of more than 50%, average losses are 22%; in small village schemes, losses are as high as 40%. In the Netherlands, DH systems are a rather late phenomenon; and mainly found in new, less densely populated areas; average losses are 24%.

Figure F-1. Heat Density and Network Architecture

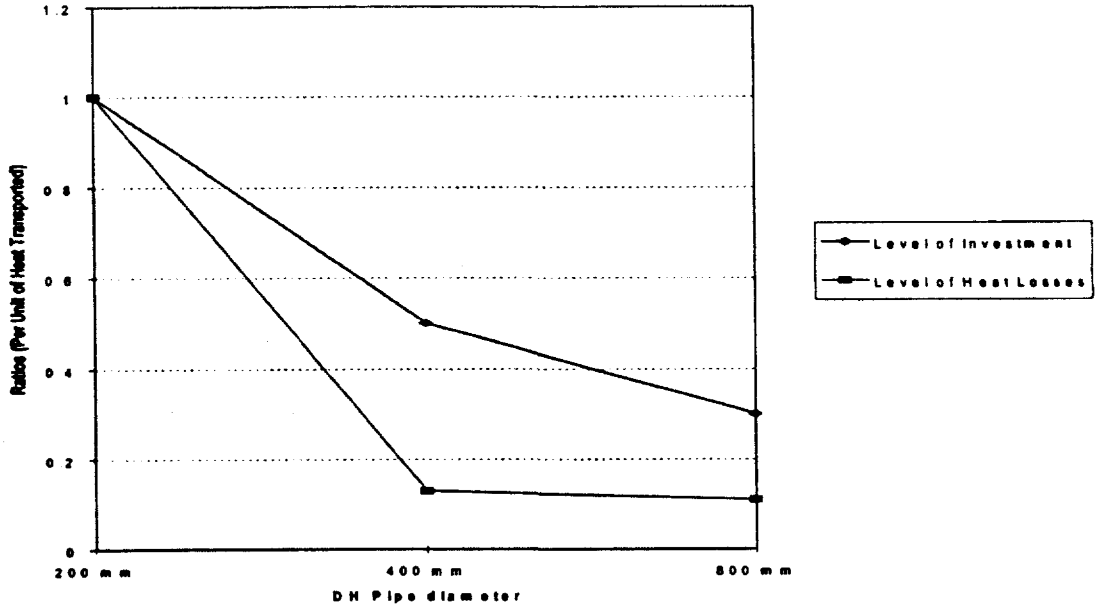
Heat Demand 50 MW	Heat Demand 50 MW	Heat Demand 50 MW
Network Length 25 km	Network Length 1 km	Network Length 0 km
Heat Density = 2 MW/km	Heat Density = 50 MW/km	Heat Density = ∞
Heat Density =50 MW/km^2	Heat Density =50 MW/km^2	Heat Density =50 MW/km^2



HP: heat plant

Source: World Bank staff

Figure F-2. Cost of Investment and Heat Losses as a Function of Pipe Diameter

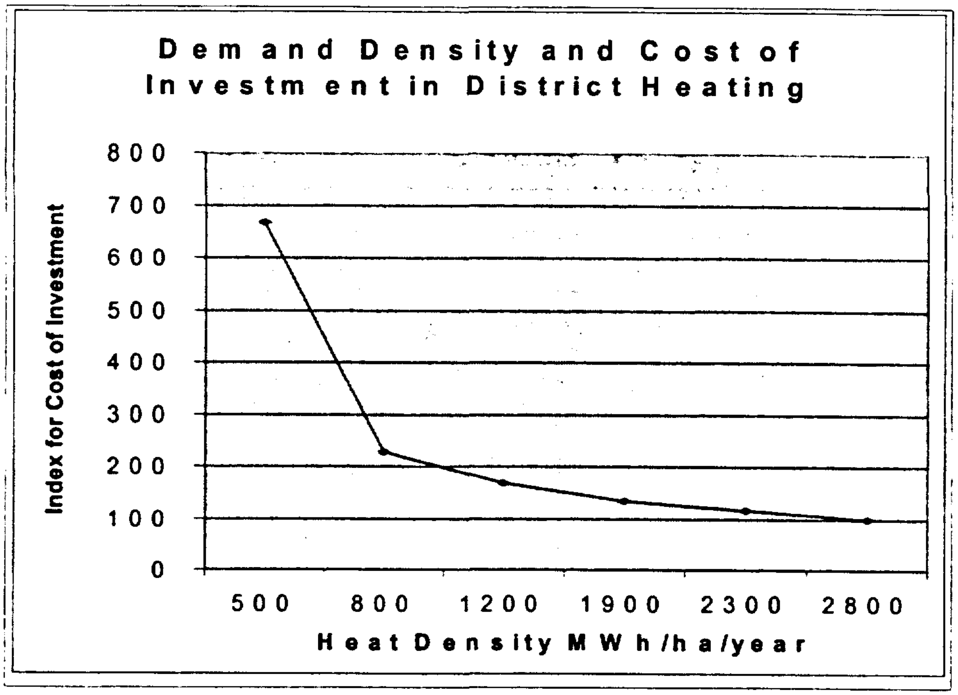


Source: Calculated from Dnipropetrovsk ESMAP case study, table 3.13 and Figure 3.7.

Note: Assuming a constant flow velocity for all diameters.

The decline of investment cost in a DH system with increasing density of heat demand is illustrated in Figure F-3. The decline in demand density has a larger impact on increasing investment cost than in increasing heat losses (see Figure F-2). This is probably due to the high cost of service lines and building connections, when the same load is distributed to a number of different buildings instead of to one large building (see Figure F-1).

Figure F-3. Demand Density and Cost of Investment in District Heating



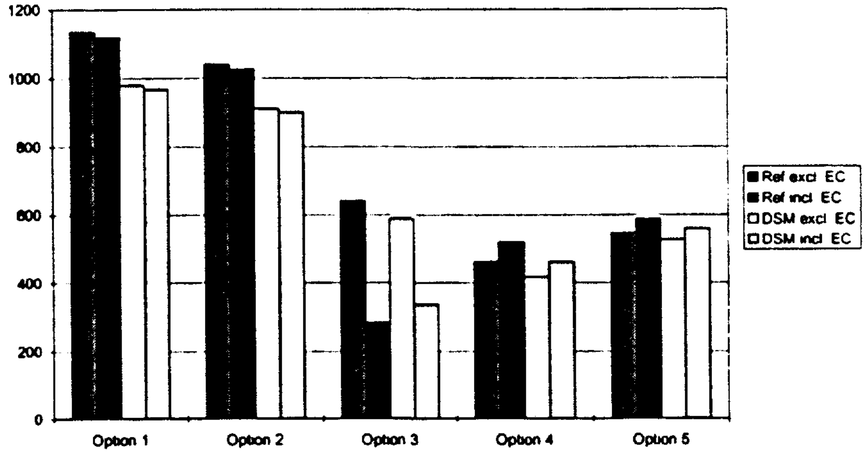
Source: Witold Cherubin, Institutional Requirements for Increasing the Efficiency of Heating. ESMAP Consultant Report. Washington, DC: The World Bank, 1996 (Quoted in Wroclaw ESMAP case study, Table 33.)

Many studies use the density of the heat demand as a first indication for the economic borderline between DH and natural gas systems. As soon as the increasing cost per MWh of heat transport with a decline in heat density eliminates the cost advantage per MWh of heat production, natural gas becomes the favored option (see Table 4-2 in the main body of the report). This approach permits a quick screening of areas in a city suitable for DH supply, but it does not eliminate the need for a more thorough analysis.

Environmental Impact of Heating Options

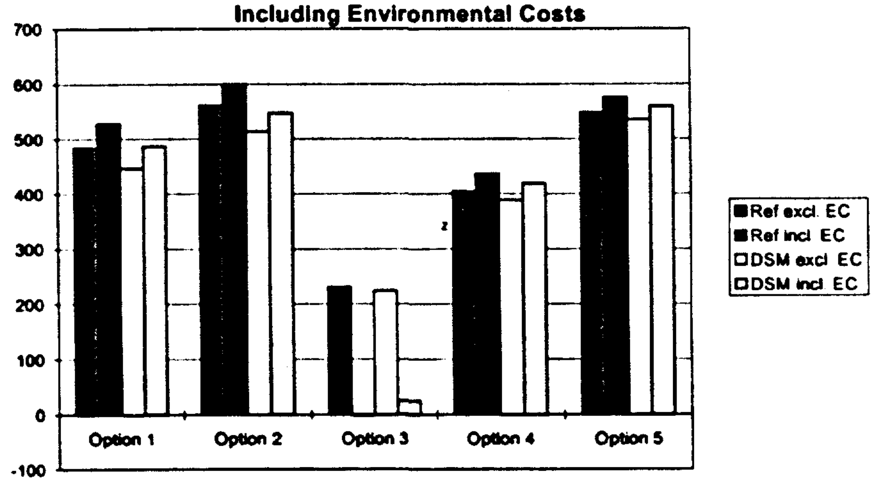
When an old, inefficient coal-fired plant is chosen as the national swing producer, its emissions are higher in contrast to the provider in section 4 than the emissions of the existing CHP plant or the proposed modern CHP option. Switching to building or apartment boilers in Orenburg would therefore increase overall emissions, reflected in an increase in heat costs when including environmental costs. Emissions of the DH-based heating options would be lower than the emissions of the swing producer. As a result, overall heat costs in the reference or DSM scenarios including environmental costs are lower than the heat costs in the "without environmental costs" case. In the CCGT options the effect is particularly pronounced; see Figures F-4 and F-5. In the case of Orenburg, the relatively lower emissions of the CCGT option lead to a change in the ranking in favor of the CCGT option. For Wroclaw, the CCGT option would result in emissions savings the value of which is higher than the total heat cost, thereby leading to "free heat."

Figure F-4. Orenburg: Total Annual Heat Costs per Dwelling Exluding and Including Environmental Costs



Source: Orenburg ESMAP case study.

Figure F-5. Wroclaw: Total Annual Heat Costs per Dwelling Exluding and Including Environmental Costs



Source: Wroclaw ESMAP case study.

Annex G

Dnipropetrovsk/Ukraine: Integrated Heat Demonstration Project

Objectives

The project will demonstrate cost-effective and energy-efficient measures, both within the heat and hot water supply system, as well as in buildings, which have a potential for replication on a large scale to improve the efficiency of heat supply companies, reduce the energy consumption of the residential sector in Ukraine, and lead to a decrease in the heating budgets of both the municipalities and consumers.

Background

Under the ESMAP project, Increasing the Efficiency of Heating in Central and Eastern Europe, one of the cities chosen for a case study was Dnipropetrovsk in Ukraine. The municipal government, as well as the DH company in Dnipropetrovsk were very interested in implementing some of the results of the case study. The terms of reference for the Ukraine case study were therefore supplemented to include the project definition for a demonstration project consisting of two components: improvement of the heat supply facilities within a limited part of the network, and energy efficiency measures in some buildings. The heat supplied to two buildings -- with a total of about 300 apartments -- at the end of one of the twelve DH networks in Dnipropetrovsk was insufficient. The DH company proposed to disconnect the buildings from the DH network and, instead, supply them with heat from a new local boiler. In addition, reducing the heat load and improving the level of comfort in the buildings by investing in certain energy efficiency measures was proposed.

The following alternative options for heat supply were evaluated:

1. Improvement of the status quo, including upgrading of the existing HOB plant and network and substation rehabilitation.

2. Decentralization of heat supply with the following options:

    a) Construction of a local boiler house with gas-fired boilers;

    b) Local cogeneration unit.

Option 2a turned out to be the most cost-effective heat supply option. An investment of US$0.5 million was proposed for this project component.

The energy-efficiency measures in the two buildings would reduce the heat load, improve the heat distribution within the buildings, and make it possible to control the heat in each building.

The proposed measures for each building would consist of a combination of the following: heat meters, heat balancing valves, pipe insulation in a basements and attics, staircase improvements (doors and windows), insulation of a basements, improvement or change of windows, roof insulation, etc. Based on experience with similar projects in other parts of the FSU, it was estimated that with a total investment of $100,000 (about $300 per apartment), total heat consumption could be reduced by about one-third. A relatively modest investment would thus lead to high energy savings, thereby decreasing heat load, fuel consumption, and emissions.

Implementation

The project is being implemented in three phases:

Phase 1

- Preparation of the detailed cost estimates;
- preparation of an information and education campaign for the building inhabitants. This will include investigating the possibility of (partial) cost recovery of energy-saving investments from building inhabitants and ensuring the participation of the inhabitants in the future dissemination of the project results;
- carrying out a household survey; and
- launching of a measurement campaign in the two buildings. This will result in baseline energy consumption data against which future energy savings will be evaluated.

The result of this first phase were the project cost estimates and a binding budget definition for the second phase.

Phase 2

The actual implementation of the project was carried out under a turnkey contract, consisting of:

- detailed engineering of the project;
- preparation of tender documents;
- preparation of the agreements with local subcontractors;
- procurement of equipment and services (PSO);
- supervision of project implementation; and
- testing and commissioning of the equipment.

Phase 3

The equipment will be monitored during the heating season and a second measurement campaign in the buildings will be carried out to determine the actual energy savings. A post-investment survey of the participating households will also be conducted. Finally, a brief report on the results and the performance of the equipment and energy-efficiency measures will be prepared and a workshop will be held in Dnipropetrovsk to present and discuss the results of the demonstration project.

Expected Output

The demonstration project will result in the improvement of the heat supply in a part of Dnipropetrovsk and in improved comfort and reduced energy costs for inhabitants of the buildings supplied. The municipality and the energy supply companies of Dnipropetrovsk will acquire knowledge about the technical, economic, financial, and environmental evaluation of alternative supply options and the interaction of supply and demand side of heating options. A dissemination workshop will serve to make other Ukrainian municipalities and energy supply companies, as well as government agencies aware of the cost-saving impact of these technologies on municipal, company, and household budgets. Finally, the project will demonstrate within the World Bank how supply and demand-side heating options can be combined to provide cost-efficient heat and hot water and improve the level of comfort in residential buildings.

Schedule

The project was scheduled to start in March 1997. The first phase would extend through May 1997. The first four items of the second phase would be carried out in April and May 1997, so that the actual construction work could be done during the non-heating season between May and September, 1997.

Considerable delays due to obtaining import permits, tax exemption, operating licences, etc., led to a delay of more than six months. The equipment, as well the renovation of the buildings was finally ready for use in July 1998, even though it still had to be manually controlled. Adjustments were made in the spring 1999. During the first part of the heating season 1999-2000, the equipment will be monitored and another measurement campaign will be conducted in the buildings. Between October 1998 and January 1999, a second household survey was conducted, showing increased satisfaction of inhabitants with the heating system. A report on the experience with the demonstration project will be issued, and a workshop will be held in Dnipropetrovsk in the winter of 1999 with participants from national, regional, and local governments.

Financing

The demonstration project is implemented by ESMAP in collaboration with the Government of the Netherlands. While ESMAP is responsible for the technical assistance part of project phases 1 and 3, the hardware was procured and installed and the corresponding technical assistance funded under parallel co-financing of the Dutch Ministry of Economic Affairs/SENTER. The total budget was approximately US$0.9 million. In addition, the municipality through the DH company financed and carried out the following project-related works: all civil works (including the boiler house and chimney; connection of the boiler house to the medium pressure gas distribution network, as well as electricity and water distribution networks; any necessary upgrading of the internal plumbing, civil, and electrical works; and connection of new heat exchangers for DHW in the buildings).

Annex H

Definitions

Annex I countries	OECD countries plus the Czech Republic and Hungary who have committed themselves under the 1992 Climate Convention in Rio to stabilize their CO2 emissions in the year 2000 at 1990 levels.
Autonomous heating system	Heating boiler located within or attached to a residential building and providing heat and hot water to the entire building (and perhaps to a neighboring building), but not feeding into a district heating network.
Average load	Total energy production in kWh (or Gcal or GJ) divided by annual operating hours. Expressed in MW, Gcal/h, or GJ/h.
Backpressure CHP plant	In a conventional condensing power plant, the steam is condensed at about 40 degrees Celsius to create as good a vacuum as possible in the condenser for maximizing electricity yield from the turbine, to about 40 percent of the fuel input. This temperature is too low for DH. Therefore, in a backpressure CHP plant, the steam is "condensed" in a heat exchanger at a higher temperature to enable DH water to reach temperatures of 85-130 degrees Celsius. The relatively high cooling temperature increases the near vacuum of the condenser to about 0.5-1.5 bar pressure in the heat exchanger (thus the term "backpressure"). This limits the electricity output to approximately 35 percent of fuel input energy content, but enables the heat output (about 55 percent of total fuel input) to be used for heating DH water. This results in an overall energy conversion efficiency of 90 percent and a ratio of power output to heat output (=Cm) of 0.64. The backpressure CHP plant has a fixed ratio Cm in pure CHP operation mode, but the proportions can be made flexible by installing a turbine bypass valve and/or an additional cooler, thus enabling independent heat and electricity production.
Back-pressure steam	The steam from the low-pressure end of a steam turbine.
Building boiler	see "Autonomous heating system"

Building substation	Substation, located in building basements, which distributes heat within a particular building. A distinction is made between direct types and indirect types; the latter have heat exchangers.
Capacity factor	Average load (in MW) divided by installed plant capacity (in MW).
Central heating	A heating system in which the heat source is not located in individual apartments or rooms.
Coincidence factor	The degree of simultaneous occurrence of the peak demand of all customers connected to a district heating system which equals the ratio of peak load at the consumer level to the connected load.
Condensing	The steam turbine mode whereby steam surplus to site requirements is expanded to the lowest practicable pressure (vacuum stage) to generate more electricity, then exhausted to a condenser and the condensate returned to the boiler.
Condensing-extraction CHP plant	In this type of plant, steam is extracted from the turbines at temperature and pressure levels that are high enough for purposes of DH. The steam that has not been extracted continues to the condensing part of the plant. This type of CHP plant has a variable Cm ratio: the greater the steam extraction for hot water production, the smaller the amount of power generation of the condensing part. Condensing-extraction CHP plants can operate anywhere between almost full back pressure operation (electric efficiency of maximum 35 percent and heat efficiency of maximum 50 percent of the total fuel input in coal-fired power plant) and full condensing operation (electric efficiency of maximum 40 percent and no heat production in coal-fired power plant). The average energy efficiency of a CHP plant will be in the range of 60-85 percent, depending on the connected heat load.
C_m ratio	The power to heat ratio -- the ratio of electricity to heat production in a CHP plant – is measured in energy equivalents, e.g. MW output.
Connected load	The sum of the individual demands for maximum heat capacity of the customers connected to the district heating system in a given service area.

Degree days	Measure of the intensity of the heating season. Defined as the temperature difference between the desired indoor temperature (usually 17 degrees Celsius = 20 degrees minus 3 degrees “free” temperature supplied by domestic appliances and body heat) and the average daily outdoor temperature during the heating season multiplied by the number of days of the heating season. The latter two are based on long-term averages.
Demand side measures	Investment measures that affect the level and structure of heat demand.
Design temperatures	Used to calculate the peak demand for capacity of a building. Outdoor: The lowest temperature realized during 10 to 20 days per year (based on the weather statistics of the past 20 years). Indoor: Desired indoor temperature, normally 20 degrees Celsius.
District heating	A centralized heat supply system serving at least several buildings through a distribution network.
District heating point	“PTs” or central substations are heat substations that separate the primary heat transmission system from the secondary heat distribution system by means of heat exchangers (hydraulic separation of primary and secondary network).
Distribution substation	A substation located within a district heating supply system that divides heat flows among several buildings. A distinction is made between direct types and indirect types; the latter have heat exchangers.
Energy service company	An ESCO is a business that develops, finances and implements projects designed to improve the energy efficiency and thereby reduce operating and maintenance costs for the customer. The projects often have a long duration, normally ranging from two to ten years. ESCOs differ from, e.g., consulting firms offering energy efficiency services or equipment manufactures by using the concept of performance contracting. A performance contract ties payment and financing directly to the amount of energy actually saved in the customer’s facility.
External benefit	Tangible or intangible benefits associated with an activity which has no market price.

External cost	Tangible or intangible costs associated with an activity which do not influence the market price of the activity.
Heat Exchanger	A device in which heat is transferred from one fluid stream to another without mixing. There must be a temperature difference between the streams for heat exchange to occur. Heat exchangers are characterized by the method of construction or operation, e.g. shell and tube, plate or rotary.
Installed heat capacity	Generating capacity installed to supply a service area.
Joint implementation	Investments in a non-annex I country to reduce CO_2 emissions with co-financing of an entity, e.g., a utility, from an annex I country.
Limited recourse financing	Lending arrangement under which repayment of a loan and recourse in the event of default relies mainly on a project's cash flow.
Load factor	Ratio between average demand for heat during a heating season and peak heat demand.
Non-recourse financing	Recourse for debt repayment, or default, or both belongs exclusively to the project company / investing utility.
Non-technical losses	System losses caused by theft (or diversion of water for non-space heating purposes) and by deficient metering.
Pass-out steam	Also called extraction steam. Steam taken part-way along a steam turbine to serve a requirement for that particular pressure, the remainder remaining in the turbine to the exhaust stage to generate more power. There may be more than one pass-out tapping to serve differing site requirements.
Peak heat load	The maximum heat demand at the consumer level that is required at any one time during a heating season. (At the heat production plant level, it refers to the maximum heat production during the winter season).
Prime mover	A prime mover is the drive system for a CHP scheme. The systems that are currently available are all based on engines. There are three commonly used prime movers: gas turbines, reciprocating engines, and steam turbines.
Reserve capacity	Difference between installed heat capacity and peak heat load.

Steam turbine	One of the prime movers for cogeneration systems. High-pressure steam raised in a conventional boiler is expanded within the turbine to produce mechanical energy, which may then be used to drive an electric generator. The power produced depends on how far the steam pressure can be reduced through the turbine before being required to meet heat energy needs. This system generates less electrical energy per unit of fuel than a gas turbine or engine-driven cogeneration system, although its overall efficiency is higher.
Stakeholders	Persons and institutions that have a right to ensure that their interests are taken into account in decision-making on a particular issue.
Technical losses	System losses caused by the loss of energy during transmission and distribution.
Utilization factor	Peak load (in MW) divided by plant capacity (in MW).
Water refilling number	Total water losses within a year divided by the volume of water in the transmission and distribution system (volume of pipeline system).
Weatherization measure	Measures aimed at reducing heat transfer through the building shell.

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Joint UNDP/World Bank

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

LIST OF REPORTS ON COMPLETED ACTIVITIES

SUB-SAHARAN AFRICA (AFR)

Region/Country	*Activity/Report Title*	*Date*	*Number*
Africa Regional	Anglophone Africa Household Energy Workshop (English)	07/88	085/88
	Regional Power Seminar on Reducing Electric Power System Losses in Africa (English)	08/88	087/88
	Institutional Evaluation of EGL (English)	02/89	098/89
	Biomass Mapping Regional Workshops (English)	05/89	–
	Francophone Household Energy Workshop (French)	08/89	–
	Interafrican Electrical Engineering College: Proposals for Short- and Long-Term Development (English)	03/90	112/90
	Biomass Assessment and Mapping (English)	03/90	–
	Symposium on Power Sector Reform and Efficiency Improvement in Sub-Saharan Africa (English)	06/96	182/96
	Commercialization of Marginal Gas Fields (English)	12/97	201/97
	Commercilizing Natural Gas: Lessons from the Seminar in Nairobi for Sub-Saharan Africa and Beyond	01/00	225/00
Angola	Energy Assessment (English and Portuguese)	05/89	4708-ANG
	Power Rehabilitation and Technical Assistance (English)	10/91	142/91
Benin	Energy Assessment (English and French)	06/85	5222-BEN
Botswana	Energy Assessment (English)	09/84	4998-BT
	Pump Electrification Prefeasibility Study (English)	01/86	047/86
	Review of Electricity Service Connection Policy (English)	07/87	071/87
	Tuli Block Farms Electrification Study (English)	07/87	072/87
	Household Energy Issues Study (English)	02/88	–
	Urban Household Energy Strategy Study (English)	05/91	132/91
Burkina Faso	Energy Assessment (English and French)	01/86	5730-BUR
	Technical Assistance Program (English)	03/86	052/86
	Urban Household Energy Strategy Study (English and French)	06/91	134/91
Burundi	Energy Assessment (English)	06/82	3778-BU
	Petroleum Supply Management (English)	01/84	012/84
	Status Report (English and French)	02/84	011/84
	Presentation of Energy Projects for the Fourth Five-Year Plan (1983-1987) (English and French)	05/85	036/85
	Improved Charcoal Cookstove Strategy (English and French)	09/85	042/85
	Peat Utilization Project (English)	11/85	046/85
	Energy Assessment (English and French)	01/92	9215-BU
Cape Verde	Energy Assessment (English and Portuguese)	08/84	5073-CV
	Household Energy Strategy Study (English)	02/90	110/90
Central African Republic	Energy Assessement (French)	08/92	9898-CAR
Chad	Elements of Strategy for Urban Household Energy The Case of N'djamena (French)	12/93	160/94
Comoros	Energy Assessment (English and French)	01/88	7104-COM
	In Search of Better Ways to Develop Solar Markets: The Case of Comoros	05/00	230/00
Congo	Energy Assessment (English)	01/88	6420-COB
	Power Development Plan (English and French)	03/90	106/90
Côte d'Ivoire	Energy Assessment (English and French)	04/85	5250-IVC
	Improved Biomass Utilization (English and French)	04/87	069/87

Region/Country	*Activity/Report Title*	*Date*	*Number*
Côte d'Ivoire	Power System Efficiency Study (English)	12/87	--
	Power Sector Efficiency Study (French)	02/92	140/91
	Project of Energy Efficiency in Buildings (English)	09/95	175/95
Ethiopia	Energy Assessment (English)	07/84	4741-ET
	Power System Efficiency Study (English)	10/85	045/85
	Agricultural Residue Briquetting Pilot Project (English)	12/86	062/86
	Bagasse Study (English)	12/86	063/86
	Cooking Efficiency Project (English)	12/87	--
	Energy Assessment (English)	02/96	179/96
Gabon	Energy Assessment (English)	07/88	6915-GA
The Gambia	Energy Assessment (English)	11/83	4743-GM
	Solar Water Heating Retrofit Project (English)	02/85	030/85
	Solar Photovoltaic Applications (English)	03/85	032/85
	Petroleum Supply Management Assistance (English)	04/85	035/85
Ghana	Energy Assessment (English)	11/86	6234-GH
	Energy Rationalization in the Industrial Sector (English)	06/88	084/88
	Sawmill Residues Utilization Study (English)	11/88	074/87
	Industrial Energy Efficiency (English)	11/92	148/92
Guinea	Energy Assessment (English)	11/86	6137-GUI
	Household Energy Strategy (English and French)	01/94	163/94
Guinea-Bissau	Energy Assessment (English and Portuguese)	08/84	5083-GUB
	Recommended Technical Assistance Projects (English & Portuguese)	04/85	033/85
	Management Options for the Electric Power and Water Supply Subsectors (English)	02/90	100/90
	Power and Water Institutional Restructuring (French)	04/91	118/91
Kenya	Energy Assessment (English)	05/82	3800-KE
	Power System Efficiency Study (English)	03/84	014/84
	Status Report (English)	05/84	016/84
	Coal Conversion Action Plan (English)	02/87	--
	Solar Water Heating Study (English)	02/87	066/87
	Peri-Urban Woodfuel Development (English)	10/87	076/87
	Power Master Plan (English)	11/87	--
	Power Loss Reduction Study (English)	09/96	186/96
	Implementation Manual: Financing Mechanisms for Solar Electric Equipment	07/00	231/00
Lesotho	Energy Assessment (English)	01/84	4676-LSO
Liberia	Energy Assessment (English)	12/84	5279-LBR
	Recommended Technical Assistance Projects (English)	06/85	038/85
	Power System Efficiency Study (English)	12/87	081/87
Madagascar	Energy Assessment (English)	01/87	5700-MAG
	Power System Efficiency Study (English and French)	12/87	075/87
	Environmental Impact of Woodfuels (French)	10/95	176/95
Malawi	Energy Assessment (English)	08/82	3903-MAL
	Technical Assistance to Improve the Efficiency of Fuelwood Use in the Tobacco Industry (English)	11/83	009/83
	Status Report (English)	01/84	013/84
Mali	Energy Assessment (English and French)	11/91	8423-MLI
	Household Energy Strategy (English and French)	03/92	147/92
Islamic Republic of Mauritania	Energy Assessment (English and French)	04/85	5224-MAU
	Household Energy Strategy Study (English and French)	07/90	123/90

Region/Country	*Activity/Report Title*	*Date*	*Number*
Mauritius	Energy Assessment (English)	12/81	3510-MAS
	Status Report (English)	10/83	008/83
	Power System Efficiency Audit (English)	05/87	070/87
	Bagasse Power Potential (English)	10/87	077/87
	Energy Sector Review (English)	12/94	3643-MAS
Mozambique	Energy Assessment (English)	01/87	6128-MOZ
	Household Electricity Utilization Study (English)	03/90	113/90
	Electricity Tariffs Study (English)	06/96	181/96
	Sample Survey of Low Voltage Electricity Customers	06/97	195/97
Namibia	Energy Assessment (English)	03/93	11320-NAM
Niger	Energy Assessment (French)	05/84	4642-NIR
	Status Report (English and French)	02/86	051/86
	Improved Stoves Project (English and French)	12/87	080/87
	Household Energy Conservation and Substitution (English and French)	01/88	082/88
Nigeria	Energy Assessment (English)	08/83	4440-UNI
	Energy Assessment (English)	07/93	11672-UNI
Rwanda	Energy Assessment (English)	06/82	3779-RW
	Status Report (English and French)	05/84	017/84
	Improved Charcoal Cookstove Strategy (English and French)	08/86	059/86
	Improved Charcoal Production Techniques (English and French)	02/87	065/87
	Energy Assessment (English and French)	07/91	8017-RW
	Commercialization of Improved Charcoal Stoves and Carbonization Techniques Mid-Term Progress Report (English and French)	12/91	141/91
SADC	SADC Regional Power Interconnection Study, Vols. I-IV (English)	12/93	–
SADCC	SADCC Regional Sector: Regional Capacity-Building Program for Energy Surveys and Policy Analysis (English)	11/91	–
Sao Tome and Principe	Energy Assessment (English)	10/85	5803-STP
Senegal	Energy Assessment (English)	07/83	4182-SE
	Status Report (English and French)	10/84	025/84
	Industrial Energy Conservation Study (English)	05/85	037/85
	Preparatory Assistance for Donor Meeting (English and French)	04/86	056/86
	Urban Household Energy Strategy (English)	02/89	096/89
	Industrial Energy Conservation Program (English)	05/94	165/94
Seychelles	Energy Assessment (English)	01/84	4693-SEY
	Electric Power System Efficiency Study (English)	08/84	021/84
Sierra Leone	Energy Assessment (English)	10/87	6597-SL
Somalia	Energy Assessment (English)	12/85	5796-SO
South Africa Republic of	Options for the Structure and Regulation of Natural Gas Industry (English)	05/95	172/95
Sudan	Management Assistance to the Ministry of Energy and Mining	05/83	003/83
	Energy Assessment (English)	07/83	4511-SU
	Power System Efficiency Study (English)	06/84	018/84
	Status Report (English)	11/84	026/84
	Wood Energy/Forestry Feasibility (English)	07/87	073/87
Swaziland	Energy Assessment (English)	02/87	6262-SW
	Household Energy Strategy Study	10/97	198/97
Tanzania	Energy Assessment (English)	11/84	4969-TA
	Peri-Urban Woodfuels Feasibility Study (English)	08/88	086/88
	Tobacco Curing Efficiency Study (English)	05/89	102/89
	Remote Sensing and Mapping of Woodlands (English)	06/90	–

Region/Country	*Activity/Report Title*	*Date*	*Number*
Tanzania	Industrial Energy Efficiency Technical Assistance (English)	08/90	122/90
	Power Loss Reduction Volume 1: Transmission and Distribution SystemTechnical Loss Reduction and Network Development (English)	06/98	204A/98
	Power Loss Reduction Volume 2: Reduction of Non-Technical Losses (English)	06/98	204B/98
Togo	Energy Assessment (English)	06/85	5221-TO
	Wood Recovery in the Nangbeto Lake (English and French)	04/86	055/86
	Power Efficiency Improvement (English and French)	12/87	078/87
Uganda	Energy Assessment (English)	07/83	4453-UG
	Status Report (English)	08/84	020/84
	Institutional Review of the Energy Sector (English)	01/85	029/85
	Energy Efficiency in Tobacco Curing Industry (English)	02/86	049/86
	Fuelwood/Forestry Feasibility Study (English)	03/86	053/86
	Power System Efficiency Study (English)	12/88	092/88
	Energy Efficiency Improvement in the Brick and Tile Industry (English)	02/89	097/89
	Tobacco Curing Pilot Project (English)	03/89	UNDP Terminal Report
	Energy Assessment (English)	12/96	193/96
	Rural Electrification Strategy Study	09/99	221/99
Zaire	Energy Assessment (English)	05/86	5837-ZR
Zambia	Energy Assessment (English)	01/83	4110-ZA
	Status Report (English)	08/85	039/85
	Energy Sector Institutional Review (English)	11/86	060/86
	Power Subsector Efficiency Study (English)	02/89	093/88
	Energy Strategy Study (English)	02/89	094/88
	Urban Household Energy Strategy Study (English)	08/90	121/90
Zimbabwe	Energy Assessment (English)	06/82	3765-ZIM
	Power System Efficiency Study (English)	06/83	005/83
	Status Report (English)	08/84	019/84
	Power Sector Management Assistance Project (English)	04/85	034/85
	Power Sector Management Institution Building (English)	09/89	–
	Petroleum Management Assistance (English)	12/89	109/89
	Charcoal Utilization Prefeasibility Study (English)	06/90	119/90
	Integrated Energy Strategy Evaluation (English)	01/92	8768-ZIM
	Energy Efficiency Technical Assistance Project: Strategic Framework for a National Energy Efficiency Improvement Program (English)	04/94	–
	Capacity Building for the National Energy Efficiency Improvement Programme (NEEIP) (English)	12/94	–
	Rural Electrification Study	03/00	228/00

EAST ASIA AND PACIFIC (EAP)

Region/Country	*Activity/Report Title*	*Date*	*Number*
Asia Regional	Pacific Household and Rural Energy Seminar (English)	11/90	–
China	County-Level Rural Energy Assessments (English)	05/89	101/89
	Fuelwood Forestry Preinvestment Study (English)	12/89	105/89
	Strategic Options for Power Sector Reform in China (English)	07/93	156/93
	Energy Efficiency and Pollution Control in Township and Village Enterprises (TVE) Industry (English)	11/94	168/94

Region/Country	***Activity/Report Title***	***Date***	***Number***
China	Energy for Rural Development in China: An Assessment Based on a Joint Chinese/ESMAP Study in Six Counties (English)	06/96	183/96
	Improving the Technical Efficiency of Decentralized Power Companies	09/99	222/999
Fiji	Energy Assessment (English)	06/83	4462-FIJ
Indonesia	Energy Assessment (English)	11/81	3543-IND
	Status Report (English)	09/84	022/84
	Power Generation Efficiency Study (English)	02/86	050/86
	Energy Efficiency in the Brick, Tile and Lime Industries (English)	04/87	067/87
	Diesel Generating Plant Efficiency Study (English)	12/88	095/88
	Urban Household Energy Strategy Study (English)	02/90	107/90
	Biomass Gasifier Preinvestment Study Vols. I & II (English)	12/90	124/90
	Prospects for Biomass Power Generation with Emphasis on Palm Oil, Sugar, Rubberwood and Plywood Residues (English)	11/94	167/94
Lao PDR	Urban Electricity Demand Assessment Study (English)	03/93	154/93
	Institutional Development for Off-Grid Electrification	06/99	215/99
Malaysia	Sabah Power System Efficiency Study (English)	03/87	068/87
	Gas Utilization Study (English)	09/91	9645-MA
Myanmar	Energy Assessment (English)	06/85	5416-BA
Papua New Guinea	Energy Assessment (English)	06/82	3882-PNG
	Status Report (English)	07/83	006/83
	Energy Strategy Paper (English)	--	--
	Institutional Review in the Energy Sector (English)	10/84	023/84
	Power Tariff Study (English)	10/84	024/84
Philippines	Commercial Potential for Power Production from Agricultural Residues (English)	12/93	157/93
	Energy Conservation Study (English)	08/94	--
Solomon Islands	Energy Assessment (English)	06/83	4404-SOL
	Energy Assessment (English)	01/92	979-SOL
South Pacific	Petroleum Transport in the South Pacific (English)	05/86	--
Thailand	Energy Assessment (English)	09/85	5793-TH
	Rural Energy Issues and Options (English)	09/85	044/85
	Accelerated Dissemination of Improved Stoves and Charcoal Kilns (English)	09/87	079/87
	Northeast Region Village Forestry and Woodfuels Preinvestment Study (English)	02/88	083/88
	Impact of Lower Oil Prices (English)	08/88	--
	Coal Development and Utilization Study (English)	10/89	--
Tonga	Energy Assessment (English)	06/85	5498-TON
Vanuatu	Energy Assessment (English)	06/85	5577-VA
Vietnam	Rural and Household Energy-Issues and Options (English)	01/94	161/94
	Power Sector Reform and Restructuring in Vietnam: Final Report to the Steering Committee (English and Vietnamese)	09/95	174/95
	Household Energy Technical Assistance: Improved Coal Briquetting and Commercialized Dissemination of Higher Efficiency Biomass and Coal Stoves (English)	01/96	178/96
Western Samoa	Energy Assessment (English)	06/85	5497-WSO

Region/Country	*Activity/Report Title*	*Date*	*Number*
	SOUTH ASIA (SAS)		
Bangladesh	Energy Assessment (English)	10/82	3873-BD
	Priority Investment Program (English)	05/83	002/83
	Status Report (English)	04/84	015/84
Bangladesh	Power System Efficiency Study (English)	02/85	031/85
	Small Scale Uses of Gas Prefeasibility Study (English)	12/88	--
India	Opportunities for Commercialization of Nonconventional Energy Systems (English)	11/88	091/88
	Maharashtra Bagasse Energy Efficiency Project (English)	07/90	120/90
	Mini-Hydro Development on Irrigation Dams and Canal Drops Vols. I, II and III (English)	07/91	139/91
	WindFarm Pre-Investment Study (English)	12/92	150/92
	Power Sector Reform Seminar (English)	04/94	166/94
	Environmental Issues in the Power Sector (English)	06/98	205/98
	Environmental Issues in the Power Sector: Manual for Environmental Decision Making (English)	06/99	213/99
	Household Energy Strategies for Urban India: The Case of Hyderabad	06/99	214/99
Nepal	Energy Assessment (English)	08/83	4474-NEP
	Status Report (English)	01/85	028/84
	Energy Efficiency & Fuel Substitution in Industries (English)	06/93	158/93
Pakistan	Household Energy Assessment (English)	05/88	--
	Assessment of Photovoltaic Programs, Applications, and Markets (English)	10/89	103/89
	National Household Energy Survey and Strategy Formulation Study: Project Terminal Report (English)	03/94	--
	Managing the Energy Transition (English)	10/94	--
	Lighting Efficiency Improvement Program Phase 1: Commercial Buildings Five Year Plan (English)	10/94	--
Sri Lanka	Energy Assessment (English)	05/82	3792-CE
	Power System Loss Reduction Study (English)	07/83	007/83
	Status Report (English)	01/84	010/84
	Industrial Energy Conservation Study (English)	03/86	054/86
	EUROPE AND CENTRAL ASIA (ECA)		
Bulgaria	Natural Gas Policies and Issues (English)	10/96	188/96
Central and Eastern Europe	Power Sector Reform in Selected Countries	07/97	196/97
	Increasing the Efficiency of Heating Systems in Central and Eastern Europe and the Former Soviet Union	08/00	234/00
Eastern Europe	The Future of Natural Gas in Eastern Europe (English)	08/92	149/92
Kazakhstan	Natural Gas Investment Study, Volumes 1, 2 & 3	12/97	199/97
Kazakhstan & Kyrgyzstan	Opportunities for Renewable Energy Development	11/97	16855-KAZ
Poland	Energy Sector Restructuring Program Vols. I-V (English)	01/93	153/93
	Natural Gas Upstream Policy (English and Polish)	08/98	206/98
	Energy Sector Restructuring Program: Establishing the Energy Regulation Authority	10/98	208/98
Portugal	Energy Assessment (English)	04/84	4824-PO

Region/Country	Activity/Report Title	Date	Number
Romania	Natural Gas Development Strategy (English)	12/96	192/96
Slovenia	Workshop on Private Participation in the Power Sector (English)	02/99	211/99
Turkey	Energy Assessment (English)	03/83	3877-TU
	Energy and the Environment: Issues and Options Paper	04/00	229/00

MIDDLE EAST AND NORTH AFRICA (MNA)

Region/Country	Activity/Report Title	Date	Number
Arab Republic of Egypt	Energy Assessment (English)	10/96	189/96
	Energy Assessment (English and French)	03/84	4157-MOR
	Status Report (English and French)	01/86	048/86
Morocco	Energy Sector Institutional Development Study (English and French)	07/95	173/95
	Natural Gas Pricing Study (French)	10/98	209/98
	Gas Development Plan Phase II (French)	02/99	210/99
Syria	Energy Assessment (English)	05/86	5822-SYR
	Electric Power Efficiency Study (English)	09/88	089/88
	Energy Efficiency Improvement in the Cement Sector (English)	04/89	099/89
	Energy Efficiency Improvement in the Fertilizer Sector (English)	06/90	115/90
Tunisia	Fuel Substitution (English and French)	03/90	--
	Power Efficiency Study (English and French)	02/92	136/91
	Energy Management Strategy in the Residential and Tertiary Sectors (English)	04/92	146/92
	Renewable Energy Strategy Study, Volume I (French)	11/96	190A/96
	Renewable Energy Strategy Study, Volume II (French)	11/96	190B/96
Yemen	Energy Assessment (English)	12/84	4892-YAR
	Energy Investment Priorities (English)	02/87	6376-YAR
	Household Energy Strategy Study Phase I (English)	03/91	126/91

LATIN AMERICA AND THE CARIBBEAN (LAC)

Region/Country	Activity/Report Title	Date	Number
LAC Regional	Regional Seminar on Electric Power System Loss Reduction in the Caribbean (English)	07/89	--
	Elimination of Lead in Gasoline in Latin America and the Caribbean (English and Spanish)	04/97	194/97
	Elimination of Lead in Gasoline in Latin America and the Caribbean - Status Report (English and Spanish)	12/97	200/97
	Harmonization of Fuels Specifications in Latin America and the Caribbean (English and Spanish)	06/98	203/98
Bolivia	Energy Assessment (English)	04/83	4213-BO
	National Energy Plan (English)	12/87	--
	La Paz Private Power Technical Assistance (English)	11/90	111/90
	Prefeasibility Evaluation Rural Electrification and Demand Assessment (English and Spanish)	04/91	129/91
	National Energy Plan (Spanish)	08/91	131/91
	Private Power Generation and Transmission (English)	01/92	137/91
	Natural Gas Distribution: Economics and Regulation (English)	03/92	125/92
	Natural Gas Sector Policies and Issues (English and Spanish)	12/93	164/93
	Household Rural Energy Strategy (English and Spanish)	01/94	162/94
	Preparation of Capitalization of the Hydrocarbon Sector	12/96	191/96

Region/Country	***Activity/Report Title***	***Date***	***Number***
Bolivia	Introducing Competition into the Electricity Supply Industry in Developing Countries: Lessons from Bolivia	08/00	233/00
Brazil	Energy Efficiency & Conservation: Strategic Partnership for Energy Efficiency in Brazil (English)	01/95	170/95
	Hydro and Thermal Power Sector Study	09/97	197/97
	Rural Electrification with Renewable Energy Systems in the Northeast: A Preinvestment Study	07/00	232/00
Chile	Energy Sector Review (English)	08/88	7129-CH
Colombia	Energy Strategy Paper (English)	12/86	--
	Power Sector Restructuring (English)	11/94	169/94
	Energy Efficiency Report for the Commercial and Public Sector (English)	06/96	184/96
Costa Rica	Energy Assessment (English and Spanish)	01/84	4655-CR
	Recommended Technical Assistance Projects (English)	11/84	027/84
	Forest Residues Utilization Study (English and Spanish)	02/90	108/90
Dominican Republic	Energy Assessment (English)	05/91	8234-DO
Ecuador	Energy Assessment (Spanish)	12/85	5865-EC
	Energy Strategy Phase I (Spanish)	07/88	--
	Energy Strategy (English)	04/91	--
	Private Minihydropower Development Study (English)	11/92	--
	Energy Pricing Subsidies and Interfuel Substitution (English)	08/94	11798-EC
	Energy Pricing, Poverty and Social Mitigation (English)	08/94	12831-EC
Guatemala	Issues and Options in the Energy Sector (English)	09/93	12160-GU
Haiti	Energy Assessment (English and French)	06/82	3672-HA
	Status Report (English and French)	08/85	041/85
	Household Energy Strategy (English and French)	12/91	143/91
Honduras	Energy Assessment (English)	08/87	6476-HO
	Petroleum Supply Management (English)	03/91	128/91
Jamaica	Energy Assessment (English)	04/85	5466-JM
	Petroleum Procurement, Refining, and Distribution Study (English)	11/86	061/86
	Energy Efficiency Building Code Phase I (English)	03/88	--
	Energy Efficiency Standards and Labels Phase I (English)	03/88	--
	Management Information System Phase I (English)	03/88	--
	Charcoal Production Project (English)	09/88	090/88
	FIDCO Sawmill Residues Utilization Study (English)	09/88	088/88
	Energy Sector Strategy and Investment Planning Study (English)	07/92	135/92
Mexico	Improved Charcoal Production Within Forest Management for the State of Veracruz (English and Spanish)	08/91	138/91
	Energy Efficiency Management Technical Assistance to the Comision Nacional para el Ahorro de Energia (CONAE) (English)	04/96	180/96
Panama	Power System Efficiency Study (English)	06/83	004/83
Paraguay	Energy Assessment (English)	10/84	5145-PA
	Recommended Technical Assistance Projects (English)	09/85	--
	Status Report (English and Spanish)	09/85	043/85
Peru	Energy Assessment (English)	01/84	4677-PE
	Status Report (English)	08/85	040/85
	Proposal for a Stove Dissemination Program in the Sierra (English and Spanish)	02/87	064/87
	Energy Strategy (English and Spanish)	12/90	--

Region/Country	*Activity/Report Title*	*Date*	*Number*
Peru	Study of Energy Taxation and Liberalization of the Hydrocarbons Sector (English and Spanish)	120/93	159/93
	Reform and Privatization in the Hydrocarbon Sector (English and Spanish)	07/99	216/99
Saint Lucia	Energy Assessment (English)	09/84	5111-SLU
St. Vincent and the Grenadines	Energy Assessment (English)	09/84	5103-STV
Sub Andean	Environmental and Social Regulation of Oil and Gas Operations in Sensitive Areas of the Sub-Andean Basin (English and Spanish)	07/99	217/99
Trinidad and Tobago	Energy Assessment (English)	12/85	5930-TR

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	Energy End Use Efficiency: Research and Strategy (English)	11/89	--
	Women and Energy--A Resource Guide The International Network: Policies and Experience (English)	04/90	--
	Guidelines for Utility Customer Management and Metering (English and Spanish)	07/91	--
	Assessment of Personal Computer Models for Energy Planning in Developing Countries (English)	10/91	--
	Long-Term Gas Contracts Principles and Applications (English)	02/93	152/93
	Comparative Behavior of Firms Under Public and Private Ownership (English)	05/93	155/93
	Development of Regional Electric Power Networks (English)	10/94	--
	Roundtable on Energy Efficiency (English)	02/95	171/95
	Assessing Pollution Abatement Policies with a Case Study of Ankara (English)	11/95	177/95
	A Synopsis of the Third Annual Roundtable on Independent Power Projects: Rhetoric and Reality (English)	08/96	187/96
	Rural Energy and Development Roundtable (English)	05/98	202/98
	A Synopsis of the Second Roundtable on Energy Efficiency: Institutional and Financial Delivery Mechanisms (English)	09/98	207/98
	The Effect of a Shadow Price on Carbon Emission in the Energy Portfolio of the World Bank: A Carbon Backcasting Exercise (English)	02/99	212/99
	Increasing the Efficiency of Gas Distribution Phase 1: Case Studies and Thematic Data Sheets	07/99	218/99
	Global Energy Sector Reform in Developing Countries: A Scorecard	07/99	219/99
	Global Lighting Services for the Poor Phase II: Text Marketing of Small "Solar" Batteries for Rural Electrification Purposes	08/99	220/99
	A Review of the Renewable Energy Activities of the UNDP/ World Bank Energy Sector Management Assistance Programme 1993 to 1998	11/99	223/99
	Energy, Transportation and Environment: Policy Options for Environmental Improvement	12/99	224/99

Region/Country	***Activity/Report Title***	***Date***	***Number***
Global	Privatization, Competition and Regulation in the British Electricity Industry, With Implications for Developing Countries	02/00	226/00
	Reducing the Cost of Grid Extension for Rural Electrification	02/00	227/00

8/31/00

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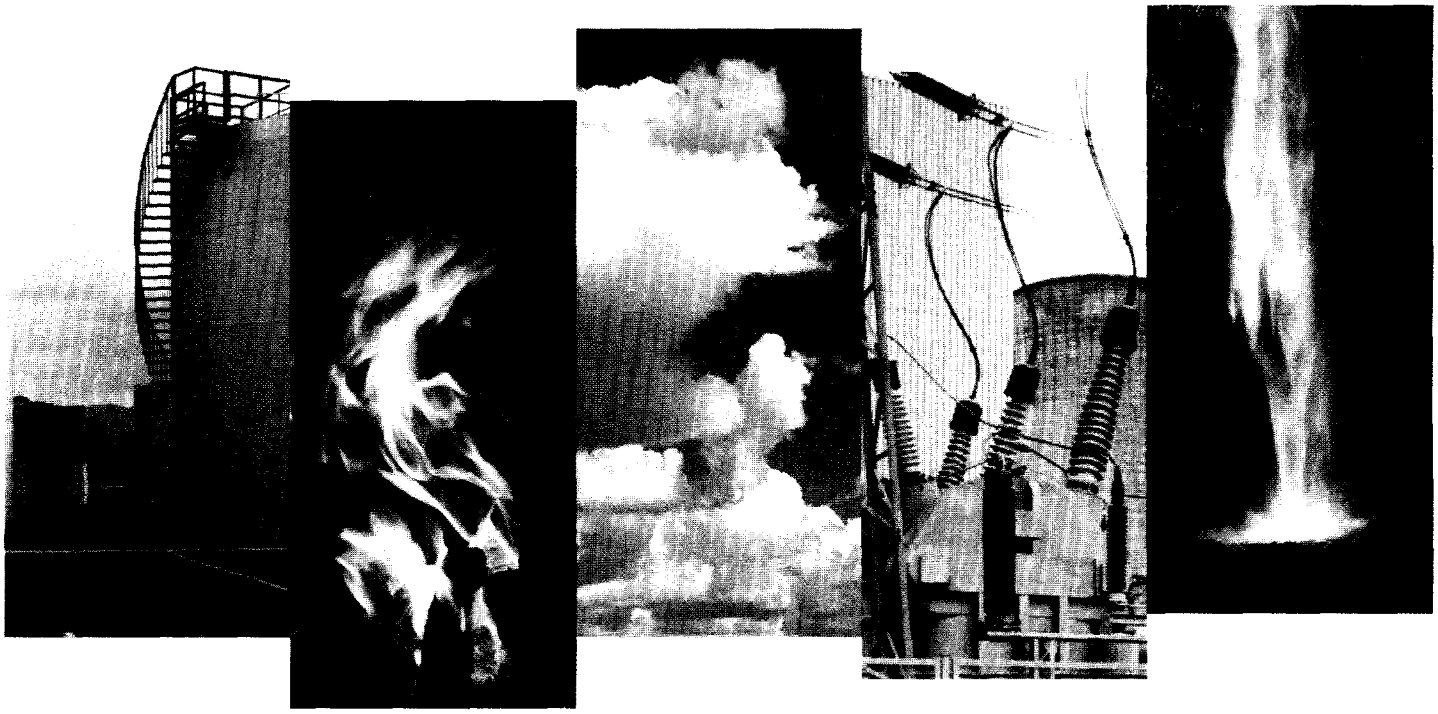

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