Investments to Improve the Energy Efficiency of Existing Residential Buildings in Countries of the Former Soviet Union

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“All our salaries and pensions are burning up in the stoves of municipal heating stations”

--First Deputy Premier of the Russian Federation Boris Nemtsov,
as quoted by the Los Angeles Times, March 1997

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ABSTRACT

Investments to improve the energy efficiency of existing residential buildings in countries of the former Soviet Union (FSU) are an important adjunct to fundamental housing-sector transitions that have been underway since the demise of the centrally planned Soviet economy in 1991. This report analyzes the linkages between energy efficiency investments in multifamily buildings in FSU countries and the institutional, policy, and social aspects of those housing-sector transitions. Energy efficiency improvements can have a large impact on the speed and extent of these transitions; conversely, many features of these transitions enable or constrain energy efficiency investments.

There are large technical opportunities to improve the energy efficiency of multifamily residential buildings with attractive financial returns. These returns are not difficult to achieve technically; the key challenges are financial, social and institutional in nature. As energy efficiency investments in residential buildings are considered and implemented, several types of energy-related policy development and capacity building may be necessary to create the proper incentives, overcome transaction barriers, and provide the maximum returns from those investments. Investment project designs should provide flexibility, controlled experimentation, tenant participation, and adequate technical, institutional and social monitoring and evaluation. A "systemic view" of district-heating systems is necessary, in which technical and policy changes on both the supply and demand sides are considered simultaneously. Future research and project preparation activities are also needed.

This report captures the substantial experience accumulated by the World Bank during preparation of several lending projects in FSU countries from 1994 to 1996. This experience 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. The report is intended for policy makers, multilateral and bilateral agency staff, private-sector managers, and others tackling housing and energy problems in FSU countries.

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CHAPTER 1
INTRODUCTION

Transitions in the housing sector represent some of the greatest challenges facing countries of the former Soviet Union (FSU). These economies are undergoing a major paradigm shift in the provision of basic housing and utility services. In the Soviet centrally planned economy, housing and utility services were provided practically free of charge by either the government or by state enterprises, and the costs of these services were not subjected to market forces. With the move to a market economy, governments and enterprises are trying to reduce their direct involvement in housing and reduce the substantial financial burden of housing and utility services. The "housing problem" means the problem of how to accomplish a variety of interacting transitions that accompany this paradigm shift. These transitions include:

- Privatizing housing
- Creating new housing-management structures
- Divesting social assets held by enterprises
- Increasing cost-recovery of actual housing and utility costs from households
- Developing real-estate markets
- Developing competitive markets for building maintenance services
- Restructuring utility management, regulation, and heat-supply markets
- Renovating district-heating systems and buildings
- Deploying new heat-supply technologies
- Revising building codes and standards
- Creating new housing-finance and mortgage-lending institutions
- Making new provisions for targeted housing allowances to low-income households

These transitions have been underway since 1991 and are long-term processes.

1.1 The Importance of Energy Efficiency to the Housing Problem

Energy efficiency investments can have a large impact on the speed and extent of these housing-sector transitions. There is an urgent need for new investments in housing and district-heating to address serious existing infrastructure inefficiencies and a historical lack of maintenance and rehabilitation. These infrastructure deficiencies mean that housing and utility costs need to be reduced and housing and utility services need to be improved.[1] Without housing and utility cost reductions, many of the housing-sector transitions listed above will prove even more difficult. Yet cost reduction is hindered by the many market distortions and institutional barriers that exist even after privatization and energy price reform. In addition, governments lack the financial resources to make investments, long-term commercial financing is still scarce compared with

[1] Housing and utility services include such parameters as indoor temperatures and comfort; hot water availability and temperature; and the safety, cleanliness, appearance, functionality, and management of buildings. Housing and utility costs include payments for space heat, hot water, cold water, gas, electricity, maintenance services, capital repairs, and building renovations.

investment needs, and housing-related financial flows among households, governments, utilities, and enterprises are still complex and intertwined.

Multifamily residential buildings in FSU countries are generally in poor condition and suffer from high energy losses and inefficiencies compared to buildings in Western countries with similar climates. For example, residential space-heating intensity in Lithuania in 1990 was 2½ times higher than in Sweden and 1½ times higher than in the United States.[2] The delivery and control of heat in district-heating networks and buildings can also be very inefficient. A combination of demonstration-project experience and technical analyses from FSU countries demonstrates convincingly that energy efficiency improvements to multifamily residential buildings are an economically and technically viable way to reduce the costs of operating these buildings and to improve energy services.

Existing infrastructure inefficiencies mean that energy costs present a large financial burden, one that has led to undesirable and even public-health-threatening reductions in energy services. The financial burden on households, municipal governments, enterprises, and even national governments is quite serious, and one which is proving difficult to relieve:

Households. In countries such as the Russian Federation, Estonia, Lithuania, and Ukraine in 1996, actual monthly heat and hot-water costs for a typical apartment represented up to 40 percent of the average monthly wage. Households are unable to afford the level of service that centralized district-heating systems were designed to provide, given large system inefficiencies, maintenance problems, and existing utility regulation and management. With the proper incentives and means, households would consume less heat and use what heat they did consume more efficiently. Yet households have neither incentives nor means to reduce energy costs--there are no heat and hot-water meters and associated institutional arrangements that would allow consumption-based metering and billing. Households also do not have heat controls to adjust consumption, organized owner associations with which to make collective investment decisions for their building, access to long-term financing for building renovations, and information about energy efficiency investments.

Municipal Governments. In some countries, such as the Russian Federation, municipal governments continue to heavily subsidize residential housing and utility costs for households living in municipal or private housing (typical subsidies in the Russian Federation average 70 to 80 percent of actual costs), and may spend up to 40 percent of their total municipal budgets on these subsidies (one city reported spending almost half of its budget). Because of the high costs of energy, which households have difficulty affording by themselves, municipal governments face strong pressures to maintain subsidies.

Enterprises. One legacy of the Soviet era is that enterprises (both state-run and private) in some FSU countries still operate social assets such as residential buildings, schools, and

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[2] Residential space-heating intensity is a measure of how much heat is required for given levels of indoor comfort, adjusted for different climatic conditions. The figure for Lithuania in 1990 was about 200 KJ/m²/degree-day, compared to 130 in the United States and 80 in Sweden (Kazakevicius et al 1996; Schipper and Meyers 1993). Many Western countries had intensities of 200 KJ/m²/degree-day in the 1970s but have increased the efficiency of residential buildings substantially since then.

hospitals. Enterprises are responsible for maintaining these assets and for providing utility services. In countries where housing and utility subsidies still exist, enterprises must provide the same subsidies to households living in enterprise housing as the government provides to households living in municipal or private housing. The management and financial burden of social assets prevents enterprises from becoming as competitive as they could be, but because of the energy-costs burden, there are few willing recipients (public or private) for these buildings.

National Governments. FSU countries that lack sufficient domestic energy resources, such as Ukraine and Estonia, have been hard hit by the need to pay international prices for imported energy. The impact of energy costs on their balance of payments is a major policy concern in these countries and a major factor behind national governments' interest in promoting energy efficiency. Energy costs also affect national governments directly in countries where residential housing and utility costs are subsidized by national rather than municipal governments.

Everything in the housing sector is changing except for the buildings themselves. Energy efficiency improvements to multifamily residential buildings in FSU countries have so far been extremely slow to materialize, for a variety of reasons discussed throughout this report. But policy solutions to the housing problem and housing-sector transitions are underway--although proceeding at different rates in the different FSU countries (see Table 1). Privatization of dwellings, increased cost-recovery from households, formation of homeowner associations, provision of targeted housing allowances, and divestiture of social assets from enterprises are all examples of transitions that began with the demise of the centrally planned economy. Progress has been slow, particularly because these transitions were starting during a multi-year period (1992-1995) of economic decline in most FSU countries. Although macroeconomic conditions are important, the speed and extent of these transitions also depend on investments and physical changes to the buildings themselves. Reductions in housing and utility costs are essential to housing-sector transitions, and yet these cost reductions can only occur to the degree necessary through investments in energy efficiency.

1.2 Origins and Objectives of the Report

Understanding the linkages between energy efficiency and the institutional, policy, and social issues and transitions within the housing and district-heating sectors in FSU countries is one of the main purposes of this report. Although a significant number of prior research studies and physical demonstrations provide insight into how to improve the energy efficiency of multifamily residential buildings in FSU countries, this research has often been confined to narrower technical and technical-economic perspectives. While necessary, these perspectives are inadequate because, as noted above, improved energy efficiency in residential buildings is tightly interconnected with the “housing problem” introduced in the previous section. Thus, energy efficiency investments need to be viewed within a broader housing-sector context.

Table 1. Housing-Sector Policy Summary

Policy area	*Russian Federation*	*Ukraine*	*Estonia*	*Lithuania*
Housing Privatization	Privatization law passed in 1991. More than 35% of eligible dwellings were privatized by 1996.	Privatization law passed in 1992. More than 30% of eligible dwellings were privatized by 1996.	Privatization law passed in 1992. More than 65% of all dwellings were privately owned by 1996.	Privatization law passed in 1991. More than 90% of all dwellings were privately owned by 1995
Housing and Utility Cost Recovery	Varies by city. Averaged from 20% to 30% by 1995. Mandated to reach 100% by 2003.	Fixed nationally. Reached 40% by 1995. Scheduled to reach 60% by 1996.	100%	Varies by city. Averaged from 60% to 70% by 1996.
Homeowner Associations	Less than 1% of multifamily buildings have associations. First national law on homeowner associations passed in 1993.	Less than 1% of multifamily buildings have associations. Homeowner-association law passed in 1995.	Several hundred co-ops have converted to homeowner associations. Homeowner-association law passed in 1995.	10% of multifamily buildings have associations. Homeowner-association law passed in 1995.
Targeted Housing Allowances for Low-Income Households[a]	Housing allowances introduced in 1994. Qualified housing and utility costs subsidized above 15% of household income.	Housing allowances introduced in 1995. Qualified housing and utility costs subsidized above 15% of household income.	Housing allowances introduced in 1994. Qualified housing and utility costs subsidized above 30% of household income.	Qualified heating costs in excess of 15% of household income and hot water costs in excess of 5% of income are subsidized.

a. Targeted housing allowances generally set limits on the apartment size that qualifies for allowances; any apartment larger than the limits receives only partial allowances.

Source: Freinkman and Starodubrovskaya 1996; Turner 1995a and 1995b; World Bank 1993b, 1996a, 1996b, 1996c; and other World Bank data.

During preparation of several World Bank lending projects in FSU countries between 1994 and 1996, the World Bank has accumulated substantial experience related both to the "housing problem" in these countries and to the specific opportunities and constraints of energy efficiency investments in multifamily residential buildings. This report surveys and analyzes the available information and experience from these efforts, and also provides guidance on approaches to energy efficiency and investment-project design in the context of the complex financial, institutional, social, and policy issues in FSU countries. Investment projects that aim to improve the quality and affordability of energy services in residential buildings or that address the broader housing problem will benefit from a better understanding of these issues. This report concludes with recommendations for technical-assistance strategies and research to fill important gaps in experience.

1.3 Organization of the Report

This report reviews the housing problem in FSU countries, continues with a survey of existing studies of the technical-economic opportunities for energy efficiency in multifamily residential buildings in FSU countries, and then analyzes the linkages between energy efficiency and the "housing problem." Based on these views, recommendations for energy efficiency project design and implementation are given.

Chapter 2 describes the housing problem in terms of its infrastructural, technical, institutional, financial, political, and social dimensions. This chapter begins with a characterization of existing multifamily buildings, their energy use, and the district-heating systems that serve them. A review of ongoing housing-sector transitions follows, including housing privatization and responsibility, restructuring of enterprise social assets, utility regulation, housing finance and mortgage lending, housing and utility subsidies and targeted housing allowances, and changes in the domestic construction and building-materials industries.

Chapter 3 surveys and analyzes existing knowledge and studies of technical-economic opportunities for energy efficiency improvements to multifamily residential buildings. Individual technical measures are characterized, and the economic returns from different combinations of these measures are analyzed based on the available results from a significant number of technical studies and pilot demonstration projects. This chapter also explains important technical issues bearing on demand-side energy efficiency improvements, including the need for energy efficiency improvements to district-heating systems, the relationship between improvements on the district-heating supply side and on the demand (building) side, the opportunities for autonomous building-level heat supplies, and the translation of energy savings at a building served by district heating into fuel savings at the heat plant.

Chapter 4 draws upon Chapters 2 and 3 to analyze the many linkages between energy efficiency investments and transitions in the housing sector. Chapter 4 extensively describes investor incentives, transaction barriers to investments, and the different types of returns possible from energy efficiency investments, while at the same time analyzing the large influence of housing-sector transitions on these incentives, transaction barriers, and returns. This chapter also shows how many of these linkages are different if households are collectively making investments rather than if governments or private enterprises are making investments. Social issues affecting incentives, transaction barriers, and returns are also covered in this chapter, including willingness to pay for energy efficiency and the problems of income stratification within buildings. Finally, this chapter shows how the many institutional and regulatory issues of evolving heat-supply markets affect the linkages between energy efficiency investments and housing-sector transitions.

Chapter 5 examines investment project approaches to energy efficiency. Most significantly, this chapter identifies energy-related policies and capacity-building requirements and strategies that should accompany energy efficiency investments. These energy-related policies and capacity building are related to: consumption-based metering and billing systems; district-heating regulation and tariff-setting; formation and operation of homeowner associations; information, education, and training aimed at households; commercial lending and real-estate markets; development of the engineering, consulting, building-materials and equipment industries; and development of autonomous sources of heat supply. This chapter also provides two examples of different approaches to lending for energy efficiency improvements. Both examples show institutional, financial, and implementation strategies for achieving energy efficiency investments in the current transitional setting in FSU countries. Finally, this chapter discusses project monitoring and evaluation: technical monitoring to measure investment returns, and social and institutional monitoring to assess long-term impacts and to learn from the experimental aspects of projects.

Chapter 6 summarizes the report's main conclusions. This chapter also notes the importance of a "systemic view" of district-heating systems, in which technical and policy changes on both the supply and demand sides are considered simultaneously. Finally, this chapter recommends future research and project preparation activities.

CHAPTER 2
THE HOUSING PROBLEM IN COUNTRIES OF THE FORMER SOVIET UNION

The "housing problem" in FSU countries means how to improve the condition of housing and utility infrastructure and how to achieve transitions in housing and utility ownership, management, and financing. This chapter reviews the many features of the housing problem, including:[3,4]

- Predominance of poorly insulated multifamily buildings
- Large district-heating systems with poorly controlled distribution systems and high losses
- Poorly maintained buildings with large deferred maintenance needs
- High utility costs relative to household incomes and municipal budgets
- Fixed payments for heat, hot water and gas by households because meters do not exist
- Increasing cost-recovery of housing and utility costs by federal or municipal governments
- Housing privatization, ownership transitions, and emerging real-estate markets
- Divestiture of enterprise housing and other social assets
- Emerging markets for private housing maintenance services
- Non-transparent structures of utility ownership, and weak utility management and regulation
- New or restructured systems of targeted housing allowances
- Emerging market-oriented construction and building-materials industries

Table 2 highlights the macroeconomic backdrop to housing-sector transitions with selected macroeconomic and structural indicators for four FSU countries.[5]

2.1 Residential Buildings, Energy Consumption, and District Heating

During its history, the Soviet Union evolved into a highly urban society. By 1990, more than two-thirds of the population lived in urban areas (Lydolph 1990). Most urban dwellers live in large multifamily apartment buildings, which vary in height from three stories to more than twenty stories. Throughout the 1950s and 1960s, most multifamily buildings constructed were

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[3] English-language technical descriptions and analyses of district-heating systems and residential-building energy consumption in the former Soviet Union include Cooper and Schipper 1992; Cooper et al. 1992; Finnish Energy Conservation Group 1994; International Energy Agency 1995 and 1996; Kattner and Andersson 1994; Kazakevicius et al. 1996; Martinot et al. 1995; Martinot 1995b; Matrosov et al. 1994; Meyers et al. 1995; Opitz 1994; Schipper et al. 1994; Stork Comprimo 1996; Tebodin 1996; USAID 1992a and 1992b; and World Bank 1997.

[4] A wide variety of references is available on the policy, regulatory, social and financing aspects of the housing problem reviewed in sections 2.2 through 2.7: Buckley and Gurenko 1995a, 1995b, and 1995c; Buichkovsky and Mints 1995; Commander et al. 1996; Freinkman and Starodubrovskaya 1996; Guzanova 1997; Herrling 1996; International Energy Agency 1995 and 1996; Jaffee and Renaud 1996; Pohl and Claessens 1994; Struyk and Kosareva 1994; Struyk 1994 and 1996; Turner 1995a and 1995b; and World Bank 1995, 1996a, 1996b, and 1996c.

[5] For general background on the economic transitions that have been occurring in these countries, see, for example, World Bank 1993a, 1993b, 1994b, 1996d, and 1996e.

no more than five stories high. Later, in the 1970s and 1980s, more 9-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 led to larger population densities farther away from city centers than in the centers themselves, an opposite pattern from urban development in many Western countries. By 1990 the size of the Soviet housing stock had reached an average of roughly 17 square meters (m^2) of floor area per capita, about half of per-capita levels found in Japan and Germany and one-third of per-capita levels found in the United States and Denmark. But in comparison with countries of similar per-capita incomes, FSU countries have a relatively higher per-capita volume of housing stock, leading some to conclude that FSU countries are now "overhoused" relative to their economic ability to support this housing stock (World Bank 1995).

Table 2. Selected Macroeconomic and Structural Indicators

Indicator	*Russian Federation*	*Ukraine*	*Estonia*	*Lithuania*
Population, 1995 (million)	147.6	51.7	1.5	3.7
GDP, 1995[a] (billion US$)	345	80.1	4.3	8.0
GNP/capita, 1995[b] (US$)	2250	1630	2670	1900
Average annual GDP growth, 1990-95 (percent)	-10	-14	-8	-16
GDP growth, 1995 (percent)	-4	-12	3	3
Average monthly wage, 1995[c] (US$)	120	50	260	130
Average monthly pension, 1994-95 (US$)	45	---	45	30
Average annual inflation, 1993-95 (percent)	250	620	34	39
Inflation, 1995 (percent)	189	180	29	36
Housing stock, 1994, m^2/capita	18	18	21	20
Average persons/dwelling, 1994[d]	3.5	---	2.6	3.0
Residential space heating intensity, 1990-91 (KJ/m^2/degree-day)	---	---	180	200

--- Not available.

a. GDP calculated at average exchange rate for 1995.

b. GNP per capita calculated by the Atlas method.

c. Estonia 1995 average monthly wage as reported for December 1995.

d. Estimated for the Russian Federation; figure for the Soviet Union as a whole in 1985 was estimated at 4.0.

Source: CIS Statistical Committee 1996; Kazakevicius et al. 1996; Schipper and Martinot 1993; Schipper et al. 1994; World Bank 1994b, 1996b, 1996d, 1996e, 1996f; other World Bank data.

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 (1984-1987) permitted heat-transmission values more than twice those of Germany and Great Britain, and about five times those of Sweden for the same period (World Bank 1996b). Pre-1979 Soviet norms were considerably less demanding. In addition, the actual design and installation of building assemblies did not always meet the established norms to begin with, and the performance of buildings has deteriorated over time because of poor or absent maintenance. Opitz (1994) notes that Russian literature sources show actual heat losses in residential buildings as 25 to 40 percent higher than design values. He attributes these deficiencies to a variety of reasons related to both the building envelopes and the heating systems inside buildings. Opitz concludes that the design of heating-related systems in multifamily buildings focused on "meeting worst-case weather conditions, with relatively little attention paid to providing the proper amounts of heat to all consumers under all conditions" (p.105). This conclusion supports field evidence that heat consumption in residential buildings in mild weather conditions can be much greater than necessary.

Multifamily residential buildings in different regions of the former Soviet Union were all constructed from the same standards and with similar methods, so there is a high degree of consistency in building designs among the Soviet Union's successor states. But building experts from FSU countries agree that seemingly identical buildings display enormous differences in actual construction and thermal properties; in other words, energy consumption in buildings with identical design characteristics can vary markedly.

Multifamily buildings consume energy in several forms, described below.

Space Heat and Hot Water. Space heat and hot water typically account for about two-thirds to three-quarters of total residential energy consumption (Battelle 1996b, Kazakevicius et al. 1996; Schipper et al. 1994; Nekrasov et al. 1993). Most space heat to multifamily buildings is supplied from district-heating systems (either centralized systems serving many buildings or local systems serving just a few). Inside the building, space heating is produced by radiators (typically one per room, or 3 to 5 radiators per apartment), heated wall panels, or convectors.[6] Hot water is supplied either from the same district-heating system or from individual gas-fired water-heaters in each apartment. Virtually no heat or hot water metering existed in residential buildings prior to 1991; heat was metered only at the distribution substation[7] level or at the production facilities. Since 1991, installation of heat meters has varied by country. In the Russian Federation and Ukraine, very few residential buildings have heat meters installed (less than 1 percent). In contrast, about 50 percent of Lithuania's urban households lived in buildings with building-level heat meters by 1996.

Electricity. Electricity consumption per household in FSU countries averages less than half the household consumption in Nordic countries (Nekrasova 1992; Schipper et al. 1994). Most apartments in FSU countries contain refrigerators and televisions, and most also have small clothes washers. Soviet-made refrigerators appear to be less efficient than Western models, but are also significantly smaller and thus consume less electricity per household than in the West. Some apartments have electric stoves. Clothes dryers, dishwashers, microwave ovens and other household appliances are virtually absent although a small number of newly wealthy households are buying these appliances along with much larger refrigerators. Electric lighting is typically

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[6] Arrangements of heating pipes supplying radiators within buildings are commonly one-pipe systems, in which the hot water flowing through one radiator continues through several more before returning to the source. Some systems, especially newer ones, are two-pipe systems, in which a supply and return pipe connect to each radiator.

[7] Two types of substations are referenced in this report. "Distribution substations" are located within district-heating supply systems and divide heat flows among several buildings. "Building substations" are located in building basements and distribute heat within a particular building. Both types of substations may include heat exchangers.

supplied from a small number (less than 10) of low-wattage incandescent light bulbs (typical total wattage can be on the order of 500 watts). Virtually all dwellings have an electricity meter.

Natural Gas and Liquid Propane Gas (LPG). Natural gas and LPG consumption is limited mostly to gas stoves. In some buildings, individual gas-fired water heaters in each apartment supply hot water on demand without a storage tank (i.e., the burner must be ignited at the time hot water is required). A small fraction of households (less than 5 percent) use gas or LPG for space heating. Most buildings that use natural gas for cooking and heating do not have gas meters.

Wood and Coal. A very small fraction of households use wood or coal for cooking or heating.

Heat consumption (both space heating and hot water) in general and residential heat consumption in particular represent substantial shares of total energy consumption in FSU countries. For example, in the Russian Federation in 1990, heat consumption accounted for 30 to 35 percent of the country's total primary energy consumption (Nekrasov et al. 1993). Of total heat consumption, about 44 percent went to residential and commercial consumers and the rest went to industry and agriculture. In Lithuania in 1995, because of the decline in industrial production, the residential sector accounted for more than half of total heat consumption nation-wide (Kazakevicius et al. 1996).

District heating[8] plays an enormous role in the energy systems of FSU countries. Most residential and commercial heat consumption--about 75 percent in the Russian Federation, 65 percent in Ukraine, 60 percent in Estonia, and 50 percent in Lithuania--is supplied by district-heating systems; the remaining amounts are produced by autonomous heating boilers[9] serving single buildings or by individual apartment-level heaters. In a district-heating system, heat can be produced from a variety of sources: large combined-heat-and-power plants (cogeneration units), large heat-only boiler plants serving entire city districts, and cogeneration and heat-only boilers in industrial enterprises that feed into large common district-heating networks. Another common source of district heating is the smaller, dispersed heat-only boiler, which serves small neighborhoods or groups of buildings through local distribution networks. Although large cogeneration plants are common, heat-only boilers dominate heat production. Heat-only boilers produced about half of all district heat in the Russian Federation (Nekrasov et al. 1993), more than two-thirds of all district heat in Ukraine and Lithuania (International Energy Agency 1996; Kazakevicius et al. 1996), and most district heat in Estonia.[10]

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[8] The term “district heating” denotes a centralized heat supply serving at least several buildings through a distribution network. The common English-language term “central heating” includes district-heating systems, but is broader; “central heating” denotes any system where the heat source is not located in individual apartments or rooms.

[9] There is no standard English term to distinguish a heating boiler that is located within (or attached to) a residential building and provides heat and hot water to the entire building (and perhaps to a neighboring building), but that does not feed into district-heating networks. In other languages, such as those for countries where district-heating systems exist, standard terms exist that distinguish such boilers from district-heating boilers. In this report, “autonomous heating boiler” denotes such boilers.

[10] Because virtually 100 percent of Estonia’s electricity comes from oil-shale-fired power plants concentrated in one region, cogeneration is much less common there.

District-heating systems supply heat to buildings through extensive networks of underground pipes carrying pressurized hot water (with a typical maximum design temperature of 150°C in large systems). In many systems, primary distribution pipes carry hot water to heat exchangers in distribution substations, which then provide lower-temperature hot water (typically 95-100°C) via secondary distribution pipes to a group of several buildings. In other systems, the hot water from the power plant feeds directly into building radiators or through heat exchangers located in individual buildings. If a distribution substation exists, domestic hot water may be produced at the distribution substation with a separate heat exchanger, and hot water for radiators and for hot-water taps is supplied via two separate sets of secondary pipes to each building. In systems without a distribution substation, domestic hot water is usually produced at a heat exchanger in the building substation. In some systems, the domestic hot water flowing out of the tap comes directly from the power plant. In the great majority of dwellings, domestic hot water is provided by the same district-heating system that supplies space heating (the alternative being some type of apartment-level hot water heater).

The design of district-heating systems carries back to the era before and immediately after World War II, and has not changed much since. District-heating systems are designed for fixed-flow operation, which means that heat output from a power plant or boiler is controlled by adjusting the temperature of the outgoing hot water, typically based on the current ambient outdoor temperature. Systems have become very complicated as they have been extended to serve growing cities. Complicated and inflexible systems have been difficult to control optimally. District-heating systems are designed to maintain a minimum indoor air temperature in buildings (typically 18°C) for any outdoor air temperatures that are above the system "design temperature." Typical system design-temperatures range from minus 20°C to minus 35°C, depending on the climate where the system is located. But these systems are poorly designed to accommodate more moderate outdoor air temperatures. In conditions of mild outdoor temperatures, many buildings experience overheating because of inadequate heat-flow controls (even if systems are operated properly), so significant amounts of heat can be wasted.

Maintenance is a serious problem for many district-heating systems for several reasons: (a) because the systems are vast and complex; (b) because poor quality materials were used in constructing many systems; (c) because of the way systems are operated technically; and, most significantly, (d) because historically maintenance has been inadequate for long-term reliable system operation. Water leakages in pipes waste both heat and water. Circulating water is often not chemically treated, leading to a major problem of accelerated internal pipe corrosion; heating pipes designed to last 20 to 30 years may fail after only 5 to 10 years. This problem is exacerbated by the design of some district-heating systems; a number of hot water systems are designed as "open systems." This means that the domestic tap water comes directly from the district-heating network, so large amounts of make-up water (often untreated) must be continually fed into the system. External corrosion on pipes from ground-water flooding in buried-pipe systems is also serious.[11] Accidents and supply disruptions to these systems are major concerns. Necessary expenditures for maintenance are large, and add to the economic

[11] A typical distribution pipe is made of steel and laid in concrete ducts, with rockwool insulation and asbestos cement or bituminous canvas for the outer casing.

costs of district heating as compared to other sources of heat supply such as building-level autonomous boilers.

2.2 Stakeholders in the Housing Problem

Many different economic agents have a stake in the housing problem. A brief look at these stakeholders is provided below.

Municipal Governments. Municipal governments can own and/or regulate providers of housing and utility services (such as heat-supply and building-maintenance enterprises). Municipal governments may be responsible for operating and maintaining residential buildings within the municipality, and may be owners (or defacto owners--see footnote in section 4.2) of unprivatized apartments and/or the common spaces of buildings. Municipal governments are interested in reducing expenditures on housing maintenance and utilities by reducing the actual costs of housing and utilities and by greater recovery of these actual costs from households. Municipal governments may also supply targeted housing allowances based on the need of low-income groups; thus lowering housing and energy costs reduces the need for targeted housing allowances. Because many district-heating production and distribution enterprises are municipally owned (see section 2.5), municipal governments may be both consumers of heat (for municipal housing) and stakeholders in heat production and distribution.

Households. Households may own their dwelling, or may live in a government-provided or enterprise-provided dwelling. Even if households are not owners, they retain strong rights to occupancy and housing services. Households are interested in receiving high quality utility and housing services at low cost. Households are interested in low utility bills, indoor apartment comfort, responsive housing maintenance companies, and uninterrupted supplies of utilities. Households may pay for their services directly to the municipal government, to utility companies, or to private or municipal service providers through a homeowner association (if one exists).

Homeowner Associations. In a small percentage of multifamily buildings, homeowner associations (also called “tenant associations” and “condominium associations”) have formed. Through these associations, households can make collective decisions about their building. Homeowner association are supposed to represent the interests of all households. Associations may or may not be legal entities, and their formation and operation is governed by recent and evolving national laws and local regulations that vary from country to country and from city to city.

Cooperatives. A small number of cooperatives formed in the Soviet era as collective private owners of multifamily residential buildings. Most of these cooperatives remain today. In principle, the responsibilities of cooperatives are similar to those of homeowner associations, although there are clear legal differences between the two forms of ownership. A cooperative as a legal entity owns the building and its members own shares in the cooperative, while a homeowner association as a legal entity does not own the building--individual households own their apartments and own shares in the building’s common spaces. This report treats cooperatives and homeowner associations similarly although cooperatives differ from homeowner associations in at least one significant respect: cooperatives do not have a problem providing collateral for loans, while homeowner associations do (see section 4.4). Like newly established homeowner associations, most cooperatives have yet to engage in collective investments in energy efficiency.

Enterprises. Enterprises, either private or state-owned, may legally own residential buildings, but enterprises are more commonly “defacto” owners responsible for building operation, maintenance, and subsidies (in the case of “defacto” ownership, buildings are legally owned by the national government). In many cases enterprise workers will be employed in providing housing and utility services, and enterprise-produced heat may supply the buildings. Most enterprises, especially private ones, are interested in divesting these social “assets” to improve the enterprise's financial position and competitiveness. Even enterprises without social assets may be stakeholders if they supply heat to a common district-heating network; their delivery of heat to the common network may be affected by changes in system demand or heat-supply markets.

Municipal Housing-Maintenance Organizations. Where a homeowner association has not taken over responsibility for maintenance and operation of a building, a municipal housing-maintenance enterprise is responsible for maintaining and operating the building, for contracting with utility suppliers (heat, hot water, electricity, cold water, etc.) and other services (sewer, garbage, etc.). In some cases, the housing-maintenance enterprise must also collect utility payments from households and subsidies from a government administration and pay utility suppliers. Municipal housing-maintenance organizations may play a large role in renovation of existing buildings. Even if renovations are performed by private contractors, municipal housing-maintenance enterprises may be involved because of their knowledge of the building stock.

Private Housing-Maintenance Organizations. Private housing-maintenance organizations are relatively new and still few in number. If a homeowner association has taken over responsibility for maintaining and operating a building, the association may contract with private housing-maintenance organizations for specific services. City administrations may also contract with private housing-maintenance organizations for city-maintained buildings.

Municipal District-Heating and Water/Sewage Enterprises. Several different enterprises may provide utility services to residential buildings, including district-heating enterprises, water/sewage enterprises, and electricity distribution enterprises. A single municipal heat-production and distribution enterprise may produce and deliver heat, or these functions may be separated into separate enterprises. Utility providers are obviously impacted by changes in demand brought about by energy efficiency improvements (see sections 3.8, 4.3, and 4.8).

Combined Heat-and-Power Plants. Large combined-heat-and-power plants may supply heat to municipal district-heating enterprises. These plants are typically owned by regional or national electric power utilities. Sales of heat to municipal district-heating enterprises may be affected by changes in residential-building energy demand resulting from energy efficiency improvements. Future capacity planning and cost and profit structures (in terms of fixed versus variable costs) can be affected by changes in residential demand.

Regional and/or National Governments. In some countries, national governments may play the same roles as municipal governments described above, particularly for subsidies to housing and utility services. National or regional governments may be asked to provide loan guarantees for municipal-government investments in residential buildings and may thus have a direct stake in the financial performance of renovation projects. Regional or national energy-regulatory commissions may have a stake in residential-building energy consumption to the extent that these commissions regulate residential tariffs or regulate electric power utilities that supply electricity or heat to residential buildings. National governments have a stake in any environmental benefits from reduced energy consumption. National governments also have a stake in and responsibility for construction or renovation standards, privatization rules, and other national-level policies.

Commercial Banks. If commercial banks decide to extend credit to municipal governments, households or homeowner associations for building renovations, then banks will become stakeholders. But banks may be unfamiliar with energy efficiency projects, may not understand the possible returns, and may see housing investments as risky, so banks may be unwilling to become stakeholders. The lack of contract enforcement mechanisms, collateral, mortgage laws, and land registration institutions (to certify land ownership) can further reduce commercial bank willingness to lend.

2.3 Housing Privatization, Responsibility, and Markets for Maintenance Services

Privatization of dwellings has proceeded at different paces in different countries. For example, since 1992 in the Russian Federation, 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, more than half of the housing stock in the Russian Federation was privately owned in 1996. In Lithuania, privatization of housing started earlier and was more widespread; almost 90 percent of all dwellings were privately owned by 1995, the highest rate among FSU countries. In Estonia, about two-thirds of dwellings were privately owned by 1996. In Ukraine, since the beginning of privatization in 1993, about one-third of all dwellings targeted were privatized by 1995, with most of these newly privatized dwellings located in urban areas (as in most FSU countries, prior to the beginning of privatization, most rural housing was already privately owned). In almost all cases of privatization, the land on which residential buildings stand is still state-owned (the main exception is for single-family houses, where the land can be privately owned).

Privatization of individual dwellings in multifamily buildings has not necessarily equated to private-owner responsibility for the buildings themselves, however. In practice, privatization may simply mean the owner gets a deed to a particular dwelling, which gives him or her the right to sell it or leave it to heirs. In many situations, institutional and management structures associated with responsibility for buildings have not changed at all after privatization. Households can only be collectively responsible for their building after they organize into a homeowner association that can make decisions about maintenance, operation, and capital investments. As an association, households can collectively make decisions about improvements or maintenance in common areas of the building, such as renovations to heating systems, or repairs to windows, staircases, and roofs. Until an association forms, a national or municipal government or an enterprise is still responsible for the building. Even in countries where homeowner associations are starting to form (Lithuania leads this trend, with about 10 percent of all households organized into homeowner associations), the responsibility for the building as a whole is still not firmly established. Homeowner associations are not assuming these responsibilities because neither habit nor law compel households to take charge of their joint property.[12]

Very few homeowner associations have formed in FSU countries. Effective legal frameworks that clearly delineate the procedures and minimum requirements for homeowner associations to form have been slow in emerging. Even less common are specific guidelines and models of how homeowner associations should behave once they are formed. In addition, several social, legal, and institutional factors suggest that voluntary formation of homeowner associations and the transfer of responsibility for building repair and maintenance to the association will be difficult. For example, residents are reluctant to assume financial and legal responsibility for a potentially dangerous building, one which could be in need of substantial and costly repairs. Another common disincentive is that, once an association forms and assumes responsibility for utility payments, the potential financial losses resulting from households that do not pay their utility bills become the responsibility of the association (as opposed to being the responsibility of local institutions like municipal governments, local utility companies, or enterprises) and thus are shared by all households within the building.

Municipal housing-maintenance organizations still dominate housing maintenance markets as monopolies because private housing-maintenance firms are rare. Even in Lithuania, where privatization and homeowner-association formation is well advanced, the majority of households still rely solely on municipal housing-maintenance companies (which perform very limited services for small monthly fees). In the Russian Federation and Ukraine, few private housing-maintenance firms yet exist. However, experiences from pilot projects in private housing-maintenance suggest that private firms are capable of delivering good service at a competitive price if they are selected on a competitive basis, given a clear contract, and subjected to reasonable oversight. Private firms could also assume broader managerial responsibilities for residential buildings, including rent collections, leasing of commercial space, and contracting for specialized services (including energy efficiency renovations).

2.4 Restructuring of Enterprise Social Assets

In the Soviet era, state enterprises provided many social services, including housing, to their employees and to the general public. In the post-Soviet era, continued provision of these services diverts enterprises from their core activities, raises their costs, and keeps them from

[12] The ownership of common areas within multifamily buildings varies by country, and instances exist where existing laws do little to clarify such ownership. In general, common areas may be the collective property of private apartment owners, may belong to the federal or municipal government even in cases of full apartment privatization, or may be "on the balance" (a term meaning defacto but not legal ownership) of the homeowner association, as in the case of Russia.

being competitive. For example, in 1995 in the Russian Federation, social spending by enterprises represented as much as 20 percent of gross wage costs. One prevailing view is that housing in particular should be divested from these enterprises through a transitional strategy that transfers responsibility to municipal governments until both ownership and management can ultimately be transferred to the private sector.

In the Russian Federation during the mass privatization program of 1992-94, defacto ownership of the enterprise housing stock was assigned to municipal governments as enterprises were privatized. Despite the transfer of defacto ownership, many enterprises remained responsible for financing and managing their former housing stock pending divestiture of these responsibilities to local authorities. Although a presidential decree stipulated that local authorities had to take over the enterprise housing stock, the process itself required negotiation between individual enterprises and cities, creating considerable delays.

In addition, municipal governments in the Russian Federation have been reluctant to take over the added costs of the enterprise housing stock because they already spend an average of one-quarter to one-third of their budgets on maintaining and operating the municipal housing stock. Municipal housing maintenance organizations are, in general, poorly managed and do not make efficient use of even the limited resources available for maintaining the municipal housing stock. Local authorities are reluctant to further overburden a poorly functioning system. In addition, much of the housing stock--both municipal and enterprise--is in need of serious capital repair. Local authorities fear that responsibility for this repair may fall on them in the absence of a private market for financing housing rehabilitation. Consequently, in 1996, some 20 percent of the housing stock in the Russian Federation continued to be financed, maintained, and operated by enterprises (World Bank 1996a).

2.5 Utility Services Restructuring and Regulation

Since the demise in 1992 of central economic planning and exclusive state ownership of energy infrastructure, utility ownership and regulation have been in flux (Association of Local Authorities of Lithuania et al. 1996; Battelle 1996a; Buichkovsky and Mints 1995; Buichkovsky 1995; International Energy Agency 1995 and 1996; World Bank 1996a and 1996b). Ownership of electric utilities now exists at local, regional, and national levels, both public and private. In some countries, such as the Russian Federation, electric power production has been completely privatized; electric-power utilities are joint-stock companies with partial government ownership of shares. Ownership of district-heating systems also varies considerably. In Lithuania, most systems are owned by a national-level private enterprise and regulated by a national-level state committee (some heat-production boilers and distribution systems are owned by municipal governments), but plans exist to decentralize ownership to local-level private or municipal enterprises and to decentralize regulation to municipal governments (see Estache 1995 for a discussion of decentralizing infrastructure). In the Russian Federation, many district-heating systems and electric-power distribution networks are owned by either municipal enterprises (as municipal property, with the enterprise director usually appointed by the head of the municipal government) or by private enterprises at the local level. Other systems are owned by privatized regional electric-power utilities. In Ukraine, heat and electricity production is controlled primarily by state-owned regional electric utilities, and local district-heating systems are owned and operated by municipal governments.

Energy regulatory structures have also been in transition. In the Russian Federation, utility regulation has become the responsibility of a federal-level energy commission and one regional-level energy commission in each of the Russian Federation's 89 regions. Prior to 1995, these commissions were not legal entities and lacked budgets and staff. A law in 1995 allowed these commissions to become legal entities with budgets and staff; regional governments are now responsible for funding regional energy commissions but have not yet provided significant resources. These commissions still need substantial training and capacity-building before they can perform their mandated functions well. Regional energy commissions set regional tariffs for electricity and heat to industrial consumers. For residential energy consumption, commissions are responsible for setting electricity tariffs, while municipal governments are responsible for setting residential heat tariffs (at the commission-set industrial price minus municipal subsidies).

Industrial heat and electricity prices vary considerably, even though fuel prices for oil, coal and natural gas are fairly consistent and equivalent to those in the world market (see Table 3). Gas prices in the Russian Federation have been fixed at one nation-wide price level, but according to a government program will be allowed to vary by region starting in 1997 (after which regional commissions should have jurisdiction over tariffs). This change will probably increase the regional variation in electricity and heat prices. Heat prices also vary depending on the point of sale and the organizations involved. In many countries and regions, the ownership of heat producers and resellers is in flux. In some cases in the Russian Federation, heat is resold up to four times between producer and household. Companies that produce and distribute heat are structured, or are being structured, to operate as profit-oriented firms with regulatory oversight from regional and municipal commissions. Reported production costs may vary as much as a factor of two among companies with seemingly similar physical production and distribution infrastructures and facing near identical factor prices (World Bank 1996a). Lithuania is an exception; in 1995, prices for heat were fixed nationally and did not reflect variations in local production costs. Although these heat and electricity prices all reflect production costs (operation, maintenance, and fuel), the degree to which they include capital replacement costs varies considerably, and many tariffs do not yet reflect the capital costs.

Utilities have also been severely affected by the so-called “non-payments crisis.” Many customers, both residential and industrial, simply do not pay their energy bills. Utilities, in turn, do not pay fuel suppliers (to the degree they can get away with doing this without interrupting fuel supplies), and enormous chains of debt accumulate throughout all sectors of these economies. This situation also varies greatly from country to country. In Ukraine, an estimated 30 to 50 percent of all households did not pay heating bills during the winter of 1994-95 (International Energy Agency 1996). Social surveys in three cities in the Russian Federation in 1995 indicated that from 10 to 40 percent of Russian households were two months or more behind in their housing payments (Guzanova and Diachenko 1995a and 1995b). In contrast, only an estimated 3.7 percent of all Lithuanian households failed to pay their heating bills in 1994 (World Bank 1996b). Municipal governments may also be delinquent in payments of residential utility-cost subsidies to district-heating companies. If a municipal government does not pay required subsidies to the utility, the utility is either forced to curtail service, petition energy regulators to raise tariffs to cover the delinquencies, or become delinquent in payments to its own suppliers or employees (all three occur in practice).

Table 3. Approximate Industrial Energy Prices, 1995

	Russian Federation	*Ukraine*	*Lithuania*
Heat and hot water	Vary from \$10 to \$30 per gigacalorie (Gcal) depending on the city; with \$20 to \$25 per Gcal common	\$10 per Gcal	\$21 per Gcal fixed nationally
Electricity	Vary by region from 3 to 15 cents per kWh[a]	3.7 cents per kWh national average	5 cents per kWh
Natural gas	\$60/tcm	\$80/tcm	\$80/tcm

a. Residential rates were 15 to 50 percent of industrial rates through cross-subsidies from industry, although cross-subsidies were decreasing in 1996 as regional energy commissions gained the authority to regulate residential electricity tariffs.

Source: World Bank data.

2.6 Financing, Mortgage Lending, and Commercial Banks

Real-estate markets have developed in parallel with dwelling privatization, as households have bartered dwellings or bought and sold them for cash. Differentiating factors affecting price--location, amenities, quality of construction, size, and energy performance--are slowly manifesting themselves in these markets. But the transition from the Soviet era, when the "value" of all dwellings was supposedly equal, is a slow process, especially outside major metropolitan areas. Transactions in the emerging rental and housing market are still rare, and homeowners appear to have little sense of the economic value of their property. The absence of an effective urban cadastre and mortgage system impedes interactions otherwise typical of a housing market, such as active involvement of banks and availability of financing.

Thus in terms of financial-sector development, housing finance has remained in a primitive state compared to the rapid development of banking and other financial markets in post-Soviet economies. A number of risks have hindered the development of mortgage markets although specific mortgage instruments are being created and some banks have started mortgage lending. The lack of financing for households and real-estate developers remains an obstacle to growth in the housing market and to renovations in existing buildings. Until the housing-finance market develops, most private housing construction and renovation is done on a "pay as you go" basis--meaning that financing is provided by home buyers, who are asked to make a down payment and additional payments as construction progresses.

A large backlog of administrative housing "demand" from the Soviet era awaits the availability of private or public financing. Because housing was centrally planned and essentially free in the Soviet era, "housing shortages" (waiting lists for new housing) were acute. These shortages persisted despite massive housing construction programs. In 1989, more than 17 percent of the Soviet population still lived in communal apartments (apartments shared with other households), or in dormitories, or had no permanent home (Struyk 1994). Since the breakup of the Soviet Union in 1991, housing construction policies in the successor states have diverged. But in all FSU countries, new public and private housing construction has plunged in the 1990s. Demand (in the form of Soviet-era waiting lists) for new publicly financed dwellings is still very high. Affordability and lack of financing have so far limited the number of new, privately financed dwellings.

2.7 Housing and Utility Subsidies and Targeted Housing Allowances

The housing sector traditionally received budget subsidies in the former Soviet Union. Rents were set below maintenance costs, investment capital was administratively allocated to local utility companies, and higher prices for industrial consumers cross-subsidized lower energy tariffs for households. In 1991, households only spent an estimated two percent of their total consumer expenditures on housing, much less than actual costs (World Bank 1996a). In post-Soviet economies, the transition to recovery of full housing and utility costs from households has been proceeding at different rates in different countries.

Under full cost recovery, utility and housing maintenance costs could reach 30 to 40 percent of average household income. In contrast, Western households typically spend 15 to 20 percent of total household income on housing (including rent or ownership, repairs, water, fuel and electricity). Even without full cost recovery, households in FSU countries are now paying more substantial shares of their income, as evidenced by social survey results. In the Russian Federation, average payments for communal services (rent and utilities) by Russian households were about 10 percent of total household income in the cities of Vladimir and Ryazan in 1995 (Guzanova and Diachenko 1995a and 1995b). The poorest households had communal services bills up to 20 to 25 percent of total household income. Similarly, Lithuanian households reported in 1995 that they spent, on average, 11 percent of their monthly income on energy (electricity, heating, hot water, gas, etc.); wintertime bills were higher--on average 15 percent of monthly income (Arpaillange 1995b). For low-income Lithuanian households, energy bills absorbed at least 20 percent of their monthly income (up to 26 percent in wintertime). A majority of Lithuanian households (73 percent) stated that they have financial problems paying for energy.

In general, household expenditures for energy are still roughly equal for all households because of fixed payments for heat and hot water based upon apartment size and the number of occupants. But this situation hides the huge variation in actual energy consumption across buildings and across apartments that is not reflected in household expenditures. It is doubtful that households realize the extent of these variations and thus the importance of new energy efficiency measures that will tend to equalize heat consumption across apartments and even among buildings.

In most FSU countries, national or municipal governments continue to subsidize residential heat and hot water. Municipal governments may spend significant shares of their annual budgets on these subsidies. In the Russian Federation, cost recovery averaged from 20 to 30 percent at the end of 1995 (Freinkman and Starodubrovskaya 1996), with many cities spending up to one-third of the municipal budget on these subsidies (one city reported spending 50 percent of its budget). In Lithuania, cost recovery was estimated to be around 60 to 70 percent in 1996 (World Bank 1996b). In Ukraine, cost recovery reached 40 percent in 1995 (World Bank 1996c). Plans to increase cost recovery vary from country to country; in the Russian Federation, full cost recovery is mandated by 2003 (originally scheduled for 1998); in Lithuania full cost recovery is planned by 1997; and Ukraine had been planning 60 percent cost recovery by 1996 but this was delayed.

The affordability of energy services impedes full cost recovery. Because many households cannot afford to pay the full costs of energy services, national and municipal governments face strong pressures to maintain subsidies (in some countries national elections have been strongly influenced by this issue). Thus future energy subsidies are at least partly tied to future household income growth and to reductions in housing and energy costs and/or services, and will vary from country to country dependent partly on the variation in per-capita incomes. Another problem with increasing cost recovery is associated with the potential for non-payments. For example, regulations exist that make it difficult to evict households that do not pay housing and utility bills, and there are technical and political difficulties in shutting off heat to households that do not pay their heating bills.[13]

In countries such as Estonia and Lithuania where households pay close to the full costs of energy services, targeted housing allowances to the poorest households are designed to offset these high energy costs. For example, in 1994 the Lithuanian government established an indirect subsidy program to reduce the burden of heat and hot water costs on needy households (World Bank 1996b). Households in dwellings connected to district-heating systems and/or local boilers operating on metered natural gas are eligible for these subsidies. Heat billings that exceed 15 percent of household income (and hot water billings that exceed 5 percent of household income) can be deducted from the bill and not paid; district-heating companies then claim reimbursement from the municipal government. Approximately 30 percent of urban households are estimated to be eligible for this subsidy.[14]

In the Russian Federation, local authorities were mandated to institute a targeted housing allowance scheme to protect vulnerable households--those whose housing expenditures exceed 15 percent of household income (World Bank 1996a). The number of recipients has been limited because average housing costs have remained less than 10 percent of household incomes in most regions.

Declining subsidies and reduced energy services have influenced the public's perception of the housing problem. Social surveys in Estonia, Lithuania, and the Russian Federation (see

[13] Gas and electricity are routinely shut off for non-payment of bills, but heat represents a special case.
[14] The number of eligible households is probably less than the actual number participating in the program, because households simply declare income and very little checking is possible or done in practice (World Bank 1996b).

Annex D) show overall dissatisfaction with housing and energy services. Principal causes of dissatisfaction are high rent and utility payments coupled with inadequate heating and hot water supply. From one-third to more than one-half of households experience indoor temperatures that are too cold in wintertime. Other prevalent problems include leaking roofs, poor roof insulation, leaky windows, and poor hot water availability (summertime shutdowns of 30 days or more are typical, and emergency interruptions can occur several times per year). Dissatisfaction with heating systems is much greater among those connected to district-heating systems than among households that use apartment-level gas heaters. Many households have taken steps themselves to improve their comfort, including makeshift weatherization and insulation of windows, balconies, and front doors. A significant fraction of households use supplemental heating sources, such as electric heaters and gas kitchen stoves during the coldest portions of the winter.

2.8 The Construction and Building-Materials Industries

In the 1950s, Soviet premier Khrushchev launched a crash program of new housing construction. The program was motivated in part by the loss of housing for 25 million people during World War II and in part by a desire to match social development in the West. Khrushchev's program heralded the industrialization of housing construction in the Soviet Union. Building designs and floor plans were standardized into a small number of models or "series," building components were prefabricated in a few large state enterprises and assembled on site, and success was judged solely by production volume--the quantity of square meters of floor area constructed. But like much of Soviet industrialization, quantity came at the expense of quality and the result was poorly manufactured and constructed products using the cheapest materials. Inadequate inspection and oversight and lack of incentives for construction enterprises to produce high-quality housing added to these problems. Quality, longevity, appearance, amenities, thermal insulation, and low maintenance requirements were sacrificed in the name of production rates and low costs. This paradigm of housing construction continued to dominate through the 1970s and 1980s and persists to the present day although it is changing slowly. One effect of this standardized approach has been to make the construction industry less flexible in adapting to new demands of varying scale and of competition in the market.

Nevertheless, private housing developers are beginning to emerge in the construction industry. For example, in Ukraine some construction enterprises are now building housing for sale to individual households in response to major cutbacks in government-sponsored construction. Many groups are beginning to operate as developers and to display an entrepreneurial spirit. As a result, there is increasing competition among housing construction enterprises, and a market for new housing is developing--primarily for larger, more luxurious apartments targeted at higher- income groups. The market for building renovations is still quite small.

In Lithuania, the construction industry is adapting to market conditions; virtually all construction enterprises have begun to operate without state support. Encouraged by favorable tax treatment, small companies have been entering the construction market to meet demand for small-scale private construction. Practical familiarity within the construction industry with new energy conservation methods, materials, and devices is embryonic but growing. According to industry managers, design and construction professionals are readily available, including an abundance of skilled architects and engineers. However, energy consultants specifically trained to address energy efficiency questions are badly needed, especially those able to integrate technical knowledge with economic and financial analysis. There are few of these energy consultants, and their number, along with the number of architect/engineering and other firms with knowledge of energy efficiency in residential buildings, must increase dramatically. Technical specialists must also be specifically trained to communicate their knowledge of energy efficiency to households and other customers.

Lithuania also provides a good example of the transformation of the building-materials and equipment industries. Local building materials are readily available--local industry produces the basic products of cement, lime, wood, glass, clay, metals, and plastics. European-style windows and doors are now being produced locally and are significantly cheaper than imports. Although heating system equipment is available domestically, Lithuanians are turning to foreign suppliers for better quality and more advanced technology. Foreign companies are beginning to be active and are seeking partnerships with Lithuanian companies. For example, the production of mineral-wool insulation is expected to start soon through a joint venture. A large number of local agents for foreign building-materials are registered with the government. Local manufacturing of European and American materials under license is beginning, and some local enterprises are endeavoring to compete by developing their own materials at much lower prices. Several foreign suppliers are training local companies to select and install their products.

Building codes and design standards have improved over the years but in 1990 were still significantly less energy efficient than equivalent standards in the West. In recent years building codes and standards have been undergoing major revisions. In Lithuania, the Ministry of Construction plans to introduce new regulations concerning building thermal performance and materials, fashioned after the thermal standards common to European Union countries. In the Russian Federation, building codes addressing energy efficiency in both new and existing buildings have been under development at both the national and regional levels (Zhuze 1996); the city of Moscow led the way by enacting its own building thermal-performance standards in 1994 (Moscow City Government 1994). Some codes and standards under consideration specify minimum thermal standards and other requirements that apply when buildings undergo significant rehabilitation. Clearly, the extent of rehabilitation that requires adherence to these standards will have important implications for energy efficiency improvements; if even minor renovation projects are subject to the standards and are forced into major thermal rehabilitation, households may be reluctant to undertake renovations.

In the short- to medium-term, potential energy efficiency gains and economic returns from improvements to the existing building stock are far greater than those possible from enhanced standards for new building construction because of the current low rates of new construction. Therefore, codes and standards aimed at building renovations are far more important in the short-term than new construction standards.

Many building engineers have reflected on the changes in “engineering mentality” that must accompany changes in building codes and standards in FSU countries. Engineering practice, developed under the Soviet system where norms were prescriptive, needs further development before it is comparable to that of Western Europe, where architects and engineers are more used to meeting performance specifications. Changes in "administrative mentality" are also warranted; many existing codes and standards are too bureaucratic, time-consuming, and costly to be effective, and can hinder the process of renovations.

CHAPTER 3
TECHNICAL-ECONOMIC OPPORTUNITIES FOR ENERGY EFFICIENCY

This chapter analyzes existing knowledge of technical-economic opportunities for energy efficiency improvements to multifamily residential buildings in FSU countries. Individual technical measures are characterized, and the economic returns from different combinations of these measures are analyzed based on the available results from a significant number of analytical studies and pilot/demonstration projects. This chapter also explains important technical issues bearing on demand-side energy efficiency improvements, such as energy efficiency improvements to district-heating systems, the relationship between improvements on the district-heating supply side and on the demand (building) side, autonomous building-level heat supplies, translation of energy savings in buildings into fuel savings at the power plant or boiler, and problems with energy-savings performance estimates.

This chapter is based on many recent technical studies and demonstration projects of energy efficiency in multifamily residential buildings in the former Soviet Union.[15] Further details of these studies and projects are described in Annexes A, B, and C.

3.1 Overview of Technical-Economic Opportunities

Technical measures for reducing heat losses from buildings include: additional insulation on roofs, exterior walls, and basement ceilings; window replacement, renovation, or weather-stripping; improved caulking and sealing of building panel joints; new building entrance doors; and improvements to building ventilation systems. In particular, studies have highlighted high thermal losses associated with building ventilation, leaky windows, and the low thermal insulation properties of exterior walls. Measures for improving the heating systems within existing buildings include new or replacement heat exchangers in building substations; building-level meters, valves, and automatic control systems for regulating the heat entering the building; apartment-level heat and hot-water meters; thermostatic radiator valves for controlling the heat to individual apartments; heat balancing valves for balancing the heat flows within the building; and hot water and heat pipe insulation. Measures for reducing electricity and gas consumption include replacing or renovating electric or gas appliances, such as stoves, refrigerators, lights, and hot water heaters. Other measures in all of these categories exist, and are discussed later in this chapter, although the above-mentioned measures are generally considered to be the most practical.

Integrated combinations of these measures can be designed to offer payback periods[16] of five years or less although there is some variation depending on building type and climatic zone.

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[15] Axovaatio 1996; Battelle 1996a, 1996b, 1996c, and 1996d; BCEOM 1995; Danish Building Research Institute and COWIconsult 1993a, 1993b, 1994, 1995a, and 1995b; EXERGIA et al. 1995 and 1996; Finnish Energy Conservation Group 1996; Fjärrvärmebyran 1994; Masso 1995; Martinot 1995a and 1995b; Matrosov et al. 1994; Rolén et al. 1994; Rolén 1995; Sogelerg 1995; SWECO 1995 and 1996; Swedish National Board 1995; Virudan 1993; World Bank 1996a and 1996b.

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. Applying a fairly complete set of technical measures to residential buildings, including heating controls, can reduce heating needs by up to 40 percent. Heat consumption can be reduced even more if exterior wall insulation is added. Applying only the simplest measures, including window weather-stripping, affords an energy consumption reduction up to 15 to 20 percent. Replacing, renovating, or weather-stripping existing windows alone can provide substantial savings (for example, modern Swedish or Finnish windows have only around 30 percent of the heat transmission of existing windows in Estonia (Schipper et al. 1994; Schipper et al. 1985)).

Although it is possible to analyze the energy efficiency potential of individual measures, most building renovations will include combinations of measures, and the net effect results from the interaction of the individual effects. Extensive research in Sweden has shown clearly that the actual savings from measures depends on how they are combined. Therefore, integrated analysis of packages of measures is preferable. For example, large apartment buildings have complex heating systems. Changes in heat losses through outside surfaces affect both the basic heat load of the heating system and air infiltration. Thus the thermal resistance of exterior building surfaces should not be improved 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 caulking of cracks, as well as improving windows, ignores the obvious problems of air infiltration. This is especially important in tall 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 many retrofit measures are straightforward (e.g., windows, insulation, and heating equipment renovation), heat metering and controls pose special problems because their energy-saving effect depends on household behavior and the existence of administrative and regulatory structures that support consumption-based metering and billing (see section 4.3). Building-level meters (metering of total building consumption) are essential for any retrofit strategy because of the clear incentives created. But the question of metering at the apartment-level is more complex. Experience in the Nordic countries leaves little doubt that when the building is metered but individual apartments are not, households consume more heat per square meter than households in buildings where apartments are metered; occupants tend to be more responsive when they see (and 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 technologies, 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 allow occupants to reduce heat consumption.

[16] The term "payback period" refers in this report to simple payback time calculated as total investment cost divided by annual financial savings. A heat price of $20/Gcal is used throughout.

The generalizations in this chapter about technical measures, energy savings, and financial returns are just that--they provide an aggregate picture based on knowledge of the overall characteristics of the building stock, district-heating systems, climate, technologies, costs, and existing energy prices. Despite the standardized nature of building design and provision of centralized district-heating systems in the Soviet era, conditions vary greatly from one building to another, even among buildings of identical type (see Battelle 1996b and Annex C). Opitz (1994, p.3) concludes that "diversity in Russian apartment buildings and district-heating system designs was found to be substantial . . . extrapolations of end-use savings from a single building to other buildings should be limited to a narrow group of similar buildings in a single city. . . ." 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 a large number of buildings, actual results, on average, will tend to agree more closely with analytical estimations. Thus actual investments for a specific building should be chosen based on a detailed audit of that particular building.

3.2 Basic Technical Measures

Technical measures can be grouped into three categories: (a) ***passive-technology measures***, such as insulation, ventilation improvements, improved balancing, and low-flow shower heads, which all reduce the energy required to produce given levels of comfort and service[17] independent of occupant behavior; (b) ***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 (c) ***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. The effects of behavior-related measures may depend not only on household and homeowner association behavior, but also on the decisions and actions of municipal or other regulatory authorities (see Chapter 4). As noted above, the effects of meters depend on the existence of institutions and administrative systems for consumption-based metering and billing.

Technical measures can also be grouped into three tiers. Each tier represents a different level of economic viability under full-economic-cost (unsubsidized) heat prices prevailing in FSU countries as of 1996, and also reflects some degree of the most-common to least-common measures emerging in practice. These tiers are described below, along with the characteristics of individual measures.

Tier I: Basic Measures. These measures have short to medium payback periods and are typical of basic retrofit packages. They include: building-level heat meters, building-level heat controls, window weather-stripping, replacement or insulation of heat piping in basements, attic floor insulation, basement ceiling insulation, renovation or replacement of building substations,

[17] The terms "comfort" and "service" may be quantifiable factors, such as indoor air temperature and humidity, or less quantifiable, such the qualitative change in service if occupants opt not to run water taps during dish washing, or if heat to certain rooms of a dwelling is lowered at night.

and replacement or renovation of external doors (including door closers). Payback periods for these measures taken individually are typically less than five years.

- Install building-level heat meter. A building-level heat meter measures heat and hot water flow into the building from the district-heating system. No payback or energy savings are directly associated with meters, but meters are necessary for creating the proper incentives (see also Chapter 4). 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 to 20 percent or even more if the tariff structure allows for consumption-based billing, and "payback periods" for the meter can be less than one year even if there are no energy savings (see Chapter 4 and Annex A). (During especially cold winters, however, households may pay more according to the meter than according to design consumption.)

- Install building-level heat control. This measure regulates indoor temperatures by controlling the quantity of heat delivered to the building from the district-heating system. Regulation is usually based on the outdoor air temperature and/or the heat supply temperature. Estimates of energy savings from this measure depend greatly on assumptions about building overheating and the heat supply regime used in practice (if curtailed or not), as well as the degree of imbalance between different parts of a building. Sometimes building-level heat control is included with riser balancing (see below) as an integrated measure. Savings from building-level heat control will generally be higher if no apartment-level controls exist and lower if they do. Building-level heat control may also be integrated with a new building substation containing heat exchangers (described below).

- Improve windows. Window improvement includes weather-stripping, refitting, caulking, painting, and adding new hardware where required. Significant energy savings of up to 10 percent or more have been estimated from this measure alone.

- Replace or install heat pipe insulation in the basement.[18] Pipes carrying hot water in the basement are usually uninsulated or suffer from insulation degradation or poorly installed insulation, so insulating or re-insulating these pipes can reduce heat losses into 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 lower floors of a building are being overheated to compensate for colder temperatures on the top floor because of heat losses through the roof.[19]

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[18] Existing heat pipe insulation in residential buildings in FSU countries is sometimes composed of materials containing asbestos. Asbestos hazards will mean added costs and project management attention for proper asbestos removal and disposal.

[19] If the building has a "hot" attic (ventilation exists through attic), then there is less of a problem of heat loss from the top floor and no attic insulation may be required.

- Install basement ceiling insulation. Insulation attached to the ceiling of unheated basements can prevent heat loss from first-floor apartments. If heat-pipe insulation is installed in basements, heat loss from first-floor apartments may increase, making this measure more important.

- Renovate or replace building substation. The building substation distributes heat and/or hot water within the building. The building substation sometimes includes a heat exchanger, which may suffer from high energy losses. Energy savings from new substations are generally lumped together with building-level heat control (see above) because the two measures may be installed together. Installation of a heat exchanger where none exists benefits both the building and the district-heating system, lowering stress and corrosion on pipes and radiators within the building, and allowing better pressure control on the supply side.

- Renovate or replace building entry doors, including door closer. Heat loss through open or poorly closing entry doors is a prevalent problem which results in significant heat loss from the common areas of buildings and consequent losses from apartments to the colder common areas.

- Improve staircase windows. Losses in common staircases can be significant because of the high infiltration of outside air. As with windows in apartments, windows in common staircase areas can be tightened. Window improvement includes weather-stripping, refitting, caulking, painting, and adding new 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. Building heat-flow measuring experiments and analyses have shown that air infiltration into apartments often significantly exceeds Western norms for ventilation, and reducing air infiltration can result in significant energy savings without reducing indoor air quality (Rolén et al. 1994; also Annexes A and C). Redesigned ventilation orifices and mechanical systems can reduce infiltration.

- Install low-flow showerheads and faucets. These measures reduce hot water consumption. Water quality must be acceptable for these devices to work, so water softeners or other decalcifying devices must exist in the water system.

- Replace refrigerator door seals. Refrigerator door insulation gets worn and can add significantly to the electricity consumption of refrigerators. This is a very cost-effective measure. One social survey of households in the city of Ryazan in the Russian Federation indicated that more than one-fifth of refrigerators should have the seals replaced (Guzanova and Diachenko 1995b).

Tier II: Design-Dependent Measures. The payback periods of these measures are generally longer, more variable, or more uncertain than for those in Tier I, and their use is more dependent on building characteristics and the overall retrofit package design. Nevertheless, some of these measures can offer short payback periods in the right circumstances. Tier II measures include: roof insulation, radiator thermostat valves, apartment-level heat allocators, heat-riser balancing valves and controls, hot-water temperature control or system reconstruction, renovation of windows, and addition of a third window pane to existing windows.

- Add additional roof insulation (to buildings without an attic). Roof insulation by itself is a high priority with short payback periods. Roof insulation can be costly if roof repairs are required, although the incremental costs of installing roof insulation are quite low if the roof is being repaired anyway. Payback periods 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 any necessary roof repairs. New sloped roofs built over existing flat roofs are another alternative; they 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 building that is better thermally balanced from top to bottom and a consequent reduction in overheating of lower floors. Roof maintenance costs may also be reduced after the insulation and renovation, which would decrease payback periods.

- Install radiator thermostat valves. This is one of the most complicated measures to analyze because of the confounding effects of many other variables; it has therefore been the subject of considerable debate. Estimates of energy savings from thermostat valves in buildings without building-level heat controls vary because of uncertainties in occupant behavior and dependence on whether apartment-level billing exists. With apartment-level billing and no building-level heat control, savings of up to 25 to 30 percent are realistic (with payback periods of less than five years), but with building-level heat control and no apartment-level billing, savings may only be 5 to 10 percent (with payback periods of up to 20 years or more). There is some debate about the degree of water quality (levels of suspended particulate matter) required for reliable long-term operation of these valves (particulates in the water can clog valves). Water quality from one district-heating system to another may vary significantly, and the water quality in many cities of FSU countries is poor relative to Western or even Eastern European countries. But Western thermostat-valve manufacturers have pointed to valves that have been in operation for decades without problems in modern hotels and government buildings in the Russian Federation.

- Install apartment-level heat allocators. Installation of heat meters on heating pipes to measure ingoing and outgoing heat flows to an apartment is prohibitively expensive because the physical arrangements of heat pipes within buildings require that each radiator in an apartment have its own heat meter (see section 4.3). But inexpensive evaporative-type heat allocators (costing perhaps $5 to $10 each) may be attached to each radiator to measure the heat output from that radiator. The recording element of these types of meters requires annual replacement. Heat allocators are in common use in Denmark, Germany, and France, for example, and also have been adopted in some Eastern European countries such as Poland

(Wilhite et al. 1993; Battelle 1996e).[20] Because experience in the former Soviet Union with heat allocators has been limited (for two case studies in Estonia, see Annex A), uncertainties remain about their use because of social and institutional issues (see also section 4.3). 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.

- Install apartment-level hot-water meters. Usually two meters are required for each apartment--one for the kitchen and one for the bathroom. Unlike evaporative apartment-level heat allocators, hot-water meters must be physically connected to the hot-water pipes. The expense and benefits of such meters have rarely been discussed in the existing literature.

- Install heat-riser balancing valves and controls. Different sections of a building may receive different levels of heating, which creates 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 space heating delivered to all parts of the building, thus creating more uniform temperatures throughout 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 (or without a change to the hydroelevator), 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 those without a heat exchanger for hot water located 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, wasting 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. If the top floor of a building is colder than the lower floors, a third window pane added to windows on the top floor can improve the balance of heat distribution within the building and reduce overheating of lower-floor apartments.

- Install slot ventilators in windows. Slot ventilators allow occupants to control ventilation without resorting to opening or closing windows, providing improved passive ventilation.

- Tighten outside joints between exterior wall panels. A mastic compound may replace deteriorated rubber gaskets and seals, better sealing out wind and water from the joints between exterior wall panels.

[20] Historically, Sweden has generally not used apartment-level metering, but apartment-level meters will be mandatory starting in 1997.

Tier III: Premium. These measures are often 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. They include exterior wall insulation, mechanical ventilation, replacement of radiators, replacement of one-pipe heat distribution systems with two-pipe systems, and replacement of windows.

- Install exterior or interior wall insulation. Insulation can be applied to gables (windowless end walls) and/or facades (walls with windows). Substantial energy savings are possible with additional wall insulation, but payback period estimates for exterior insulation (either gables or facades) range from 15 to 50 years for conventional mineral-wool or rigid-foam insulation applied to frameworks on building exterior surfaces. The cost-effectiveness of exterior wall insulation remains a subject of debate because some potential technologies for cheaply insulating exterior walls that have not yet been considered for buildings and conditions in the former Soviet Union (e.g., spray-on polyurethane foam).

- Install active ventilation systems. A few demonstration projects (see Annex A) 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 lower cost.

- Replace radiators. No direct financial benefits exist for this measure, except reduced long-term maintenance costs in open hot-water systems, but building aesthetics may be improved. Changes in radiator sizing on a floor-by-floor basis, however, can provide better heat balance between floors.

- Replace one-pipe system with two-pipe system. This measure may require extensive renovations because holes must be drilled in floors and ceilings to accommodate the additional pipe. In general, this measure does not save energy, but its benefits are the subject of debate and depend on the condition of existing piping and existing problems with heat-flow distribution in the building. If existing pipes must be replaced, converting to a two-pipe system while installing new piping reduces the cost of this measure.

- Replace windows. Window replacement is expensive and difficult to justify on the basis of the cost-effectiveness of energy efficiency improvements alone. But if window replacement is carried out to improve the quality and amenities of building services, then the incremental costs of high-quality, 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 periods. But since many buildings 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, a roof that must be repaired provides a good opportunity to add extra insulation, as the incremental 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 made. When considering such longer-term improvements, the expected lifetime of the building becomes an important factor in estimating returns. Some measures may offer more intangible returns, and therefore may be undertaken in spite of their longer payback periods. For example, the sloped roof represents a cultural icon in Estonia, and Estonians may be willing to pay a premium for it (although life-cycle costs of sloped roofs may be no more than flat roofs, as sloped roofs cost more but require less maintenance).

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 (such as measures 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 only be undertaken profitably when other measures are also undertaken (whether or not related to energy), and which measures are dependent on others occurring first.

3.3 Costs and Energy Savings from Combinations of Measures

Combinations of measures produce energy savings potentials and payback periods based on their combined effects. These combined effects are usually different from a sum of the effects of the individual measures. Although there may be good information on the cost-effectiveness of individual measures taken in isolation, estimating a measure's 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, since households periodically use the gas range and/or fill the bathtub with hot water for generating extra heat. In addition, motors of household appliances, as well as lights, generate waste heat which may contribute to total heating energy. Little information is available on the relative contributions of these factors to total apartment and building heat loads for multifamily housing in FSU countries. When retrofits are substitutes, one eliminates the need for another, e.g., exterior insulation will likely mean that radiator reflectors will not be cost-effective.

Because of the diversity of applications and measures and the paucity of actual retrofit projects thus far in FSU countries, the actual performance of various combinations of measures is not available as a definitive, comprehensive picture. But demonstration projects in FSU countries in recent years have begun to provide data (see Annex A). Building types, costs, energy savings, and payback periods of the demonstration projects described in Annex A are summarized in Table 4. These projects display a wide variety of estimated energy savings and payback periods from different combinations of measures, reflecting uncertainty, variation in assumptions and heat supply conditions (particularly if buildings are under- or overheated), materials costs, and different building types and state of disrepair. Nevertheless, there are some common and consistent features. The costs and payback periods are also reflective of the "one-of-a-kind" nature of these demonstration projects; actual costs of future projects can be expected to be less.

In addition to the retrofit project experience, a number of analytical studies were carried out for the World Bank and through bilateral assistance to understand the economics of different combination of measures. These studies are reviewed in Annex B and summarized in Table 5. Costs vary significantly depending on the size, design, and condition of the buildings, ranging from $100 per apartment to $4,300 per apartment. Costs also may vary substantially among FSU countries because of variations in wage and material costs. In these studies, payback periods may be high for low-cost, high-savings packages because of the composition of the packages and the size of the buildings retrofitted. 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 periods. Energy savings 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. Because of the significant diversity of technical characteristics of apartment buildings and district-heating systems (even though designs were highly standardized), there is no single (or simple) solution applicable to all buildings. Opitz (1994) cautions that accurately extrapolating energy savings from a single building to a larger group of buildings is difficult because of this diversity.

Nevertheless, generalizing from the existing studies and demonstration projects, the following conclusions are possible: a basic package of measures, including heat meter, window weather-stripping, heat balancing, building-level heat control, and perhaps a heat-exchanger, can cost about $300 to $900 per apartment and can be expected conservatively to save 10 to 20 percent of heat and hot-water consumption. The next higher-level package includes roof or attic insulation, basement ceiling insulation, additional piping insulation, and perhaps window renovation or radiator valves, and can cost about $600 to $1,300 per apartment; a package of this type can be expected to save 15 to 30 percent of heat and hot-water consumption. A more-extensive renovation can cost from $1,500 to $3,000 or more per apartment and can be expected to save 40 to 50 percent of heat and hot-water consumption. Some existing analytical studies and demonstration projects provide energy-savings estimates significantly greater than these conclusions, but have probably overestimated energy savings and payback periods due to analytical assumptions or lack of accurate measurement baselines and comparisons.

Table 4. Experience from Retrofit Demonstration Projects

Location (and primary reference)	*Building type*	*Retrofit measures*[a]	*Cost per building (US$)*[a]	*Cost per apart-ment (US$)*[a]	*Energy savings (per-cent)*[b]	*Payback period (years)*[a, b,c]
Tartu, Estonia (Fjärrvärmebyran 1994)	5-story, 60-apt.	window tightening	3,700	60	6	5
Tartu, Estonia (Fjärrvärmebyran 1994)	5-story, 60-apt.	heat control and window tightening	6,800	110	6	9
Tartu, Estonia (Fjärrvärmebyran 1994)	5-story, 60-apt.	heat control and balancing, window tightening	12,000	200	28	4
Haljala, Estonia (Virudan 1993)	3-story, 18 to 36 apts.	thermostat valves	5,600	230	15 to 27[d]	3 to 7
Petrozavodsk, Russian Federation (Finnish Energy Conservation Group 1996)	5-story 60-apt.	heat control and substation	25,000[e]	420[e]	22[e]	4[e]
Ryazan, Russian Federation (Battelle 1996d)	5-story 60-apt.	heating system retrofits	40,000	670	---[f]	---[f]
Vilnius, Lithuania (Danish Building Research Institute/COWI 1995b)	16-story 65-apt.	heating system, pipe insulation, apt.-level meters	45,000	690	19	8
Tallinn, Estonia (Rolén et al. 1994)	9-story 72-apt.	basic package	60,000	830	15 to 28[g]	5 to 11
Tallinn, Estonia (Danish Building Research Institute/COWI 1995a)	5-story 40-apt.	basic package	45,000	1,100	24	14
Ryazan, Russian Federation (Battelle 1996d)	5-story 60-apt.	insulation and sealing of walls, doors, windows	75,000	1,250	---[f]	---[f]
Ryazan, Russian Federation (Battelle 1996c)	9-story 144-apt.	extensive package	180,000	1,250	---[f]	---[f]
Tallinn, Estonia (Swedish Natl. Board 1995)	5-story 60-apt.	basic package	90,000	1,500	15 to 28	7 to 20
Tallinn, Estonia (Axovaatio 1996)	5-story 60-apt.	extensive package	170,000	2,800	30 to 50[h]	7 to 14
Kiev, Ukraine (Sogelerg 1995)	---	heat control and insulation	---	---	---[f]	---[f]

--- Not available.

a. Costs and payback periods include a building-level heat meter in all projects, which in the case of simple investment packages significantly increases the package payback period (as in Tartu, Estonia). Costs and payback periods are based on direct material, equipment, and installation costs, including taxes, but do not include project management and design costs, which varied substantially because of the demonstration nature of the projects. All costs are actual unless noted as estimates.

b. Variation in energy savings and payback period reflect differences between theoretical estimates and actual measurements (actual tend to be lower than theoretical), different scenarios of district-heat supply conditions, the range of uncertainty in measurements, and variations among multiple buildings in the same demonstration project. Some payback periods and energy savings are author's best estimates based on data presented in project reports and field research (see also Martinot 1995a) and may vary from the payback periods and energy savings given in those reports.

c. Heat prices used in payback period estimates are all $20/Gcal.

d. Haljala project estimates for energy savings were 28% based on measurement of the total heat consumption of a small town from one year to the next, including industrial consumption, uncorrected for degree-days. Author's conservative estimate is 15% energy savings.

e. Costs and savings for Petrozavodsk are pre-retrofit estimates.

f. Estimates for energy savings and payback periods for the projects in Ryazan and Kiev will be available in 1997 after analysis of building measurements taken during the 1996/97 heating season.

g. Original project estimate was 28% energy savings under a normal heat supply regime while actual measured savings were 15% under a curtailed heat supply regime.

h. Original project estimate was 40 to 50% energy savings under a normal heat supply regime while measured energy savings relative to a partially calibrated reference building were 30% under a partially curtailed heat supply regime.

Source: case study descriptions and references in Annex A.

Table 5. Costs, Savings, and Payback Periods from Analytical Studies

Study	*Building size (stories)*	*Number of apart-ments*	*Retrofit package type*	*Cost per apart-ment (US$)*	*Energy savings (percent)*	*Payback period (years)*
Lithuania, World Bank	5	100	basic	100	22	2
Lithuania, World Bank	5	32	basic	250	17	6
Lithuania, World Bank	5	100	medium	400	34	5
Russian Fed., Stork	5	100	basic	410	28	4
Lithuania, BCEOM	9	72	medium	430	26	5
Lithuania, BCEOM	5	100	medium	520	32	6
Lithuania, BCEOM	10	36	basic	540	31	4
Lithuania, SWECO	5	100	basic	610	40	13
Lithuania, World Bank	5	32	medium	750	44	7
Russian Fed., EHDP	9-14	---	---	750	30	3
Lithuania, SWECO	9	81	basic	800	40	7
Lithuania, BCEOM	5	60	medium	870	42	5
Russian Fed., EHDP	5-8	---	---	980	30	4
Lithuania, SWECO	5	60	basic	1,050	41	12
Lithuania, BCEOM	4	16	medium	1,100	29	6
Russian Fed., EHDP	2-4	---	---	1,130	30	4
Estonia, COWI	4	32	medium	1,130	30	15
Lithuania, SWECO	5	20	basic	1,150	45	12
Estonia, COWI	7	144	medium	1,150	20	13
Lithuania, SWECO	9	32	basic	1,300	58	13
Lithuania, SWECO	5	100	medium	1,300	53	20
Lithuania, SWECO	9	81	medium	1,400	45	10
Lithuania, World Bank	5	32	extensive	1,400	42	13
Lithuania, BCEOM	9	72	extensive	1,450	47	10
Lithuania, World Bank	5	100	extensive	1,500	45	15
Estonia, COWI	5	45	medium	1,600	25	18
Lithuania, SWECO	5	60	medium	1,850	50	18
Lithuania, SWECO	9	32	medium	1,950	65	18
Lithuania, SWECO	5	20	medium	2,050	57	18
Lithuania, BCEOM	5	60	extensive	2,050	52	9
Russian Fed., Gabrielsson	5	118	extensive	2,400	33	15
Lithuania, BCEOM	10	36	extensive	3,400	48	16
Lithuania, BCEOM	4	16	extensive	4,300	53	13

--- Not available.

Note: Heat prices used in payback period estimates are all $20/Gcal. For further descriptions of these analytical studies, see Annex B.

Source: Battelle 1996a; BCEOM 1995; Danish Building Research Institute and COWIconsult 1993a; Kazakevicius et al. 1996; Stork Comprimo 1996; SWECO 1995; World Bank 1996a and 1996b; Gabrielsson 1995.

3.4 Rates of Return and Sensitivity Analysis

Technical-economic analyses of energy efficiency measures typically assume current costs for equipment, materials, and energy. For investment purposes, these characteristics must be translated into financial and economic rates of return and sensitivity (risk) analysis, which incorporate project lifetimes, discount rates, and estimates about future prices and costs. Very little of this type of analysis has been presented in the literature on residential energy efficiency improvements in FSU countries. Under the Russian Federation Enterprise Housing Divestiture Project (World Bank 1996a; see section 5.3), financial rates of return corresponding to packages with payback periods from 2 to 3 years were 40 to 55 percent; economic rates of return (using a lower economic valuation for natural gas) varied from 32 to 45 percent. The Lithuania Energy Efficiency/Housing Pilot Project (World Bank 1996b; see section 5.4) calculated economic rates of return which varied from 10 to 41 percent for small buildings (associated with investment packages having payback periods from 5 to 13 years), and economic rates of return which varied from 15 to 56 percent for large buildings (associated with investment packages having payback periods from 2 to 15 years).

Sensitivity analysis can identify factors likely to have the greatest impact on the projected rates of return. Rate of return analysis employs expected-value or “best guess” estimates of each variable. But expected values provide no insight into the risk and uncertainty associated with a proposed investment. Key factors affecting the quantitative estimates of the rates of return should be evaluated and those factors should be identified for which small changes are likely to have the largest relative impact on the rates of return. For energy efficiency investments, key factors include building types, building characteristics, climate types, future fuel prices, future energy supply maintenance and capital costs, value of energy saved, labor rates, technical measure lifetimes, escalation rates, tax rates, and discount rates. The rates of return should be recalculated by varying the magnitude of these key factors one at a time. An important objective is to quantitatively define the conditions under which the rates of return fall below acceptable levels and to question the likelihood of such conditions actually occurring.

One of the few examples of sensitivity analysis for energy efficiency retrofits was done for the Enterprise Housing Divestiture Project. Not surprisingly, this sensitivity analysis showed that the value of heat saved and the total installed cost of the technical measures had the greatest potential for impacting the rates of return. One of the most uncertain components of the total installed cost was the cost of management and labor. For the six cities involved in the project, little information was available on the current and projected Russian wage rates for the different skill levels required by the project, partly due to overall macroeconomic uncertainties. Sensitivity analyses demonstrated how much these costs would have to change before unacceptable rates of return resulted. For example, both the current heat price and current cost of natural gas would need to fall by over 50 percent in order to produce unacceptable rates of return from an investment perspective. Sensitivity analyses also showed that Russian real-wage rates could increase by a factor of five without any impact on project viability, even assuming a ratio of five Russian labor hours per hour of Western labor. However, a relatively small increase in Western labor costs had a large impact on rates of return, implying that a high percentage of Russian labor would reduce the sensitivities. Thus the sensitivity analysis indicated that the cost of natural gas would need to drop sharply and the total installed costs of the measures would need to be significantly greater than projected for the rates of return to become unacceptable.

3.5 Problems with Energy-Savings Performance Estimates

While a fairly robust aggregate picture of energy-savings potentials emerges from both analytical studies and retrofit demonstration projects (those described in Annexes A and B and other projects and studies), individual energy-savings performance estimates must be viewed with some caution. There are many difficulties in making accurate energy saving performance estimates, including:

Lack of Consumption Baseline. If no meters and metered data existed prior to retrofits, there is no baseline with which to compare consumption after retrofits. Comparison with design consumption norms is usually misleading because actual building performance can vary substantially from the norms. Comparison with similar buildings that have not been previously calibrated against the target building is unreliable because the experience with building measurements in the former Soviet Union shows that even seemingly identical buildings can vary substantially in energy consumption under identical conditions. The initial experience with metering in the city of Ryazan in the Russian Federation (Battelle 1996b) shows that neighboring identical buildings connected to the same district-heating system can vary in heat consumption by up to 40 percent (with corresponding differences in indoor air temperatures). Even if metering exists, the baseline data may be inadequate; ideally, baselines should be established over a period of months or years.

Lack of Supplementary Information. Simple metering of energy flow into a building is insufficient to draw meaningful conclusions; accompanying information is needed on corresponding outdoor and indoor air temperatures in order to accurately characterize the building's thermal behavior. Even if metered data are available, the data may not include associated indoor and climate conditions, so proper corrections cannot be made in comparing one year's metered data with another year’s.

District-Heating Service Level Variation. Underheating and overheating of buildings both affect energy savings. For many types of retrofit measures, energy savings vary depending on the amount of heat supplied to a building. If buildings are undersupplied with heat, energy savings attributable to the retrofit measures may be significantly less than estimated; conversely, if buildings are oversupplied, energy savings may be greater than estimated.

Uncertain Occupant Behavior. The performance of energy conservation measures that depend on occupant behavior, such as thermostat control valves, suffer from uncertainties because there is little reliable experience on which to anticipate future behavior.

The best performance data will come from experiments in which identical buildings are monitored and calibrated against each other prior to retrofitting one of them, and then the future performance of the retrofitted and unretrofitted buildings is compared (see section 5.5). This approach was taken with the metering and retrofit activities in Ryazan under the Enterprise

Housing Divestiture Project (see Annex C). Two separate sets of three similar buildings each were involved. All six buildings first underwent metering to establish a baseline calibration. Then for each set of three buildings, one building remained unretrofitted and the two others received different retrofit packages. Performance data from less sophisticated measurement approaches are still useful. But when no baseline consumption exists, caution is necessary when metered data for a building after retrofit is compared with design or estimated consumption for the building before retrofit.

3.6 Improvements in District-Heating Supply and Distribution Systems

In addition to energy efficiency opportunities in the buildings they supply, district-heating systems also offer large scope for energy efficiency improvements on the supply-side. Many studies and field investigations in FSU countries, including project preparation activities for World Bank lending, have found that in many cities the condition of distribution networks, especially the secondary distribution networks, is poor--critically poor in some cases (see for example Finnish Energy Conservation Group 1994; Kattner and Andersson 1994; Martinot 1995b; Stork Comprimo 1996; Tebodin et al. 1996; USAID 1992a and 1992b; World Bank 1994a). For example, several cities in the Russian Federation have reported system failures of varying duration in cold winter months. Even under normal operation, huge energy wastage is almost universal in these systems because of poorly insulated distribution pipelines. Water losses from leaking pipes can also be significant. Improvements to district-heating systems typically fall into one of three categories: more efficient heat production in boilers, improved regulation and control of heat flows within distribution systems, and improved insulation of distribution system pipelines. Many of the measures in these three categories are relatively low-cost, with payback periods of less than five years.

More Efficient Heat Production. While combined-heat-and-power plants can be quite efficient when both electricity and heat outputs are considered, district-heating systems typically also contain many heat-only boilers. Often these boilers only operate during peak winter periods, but where heat-supply-capacity deficits exist these boilers may operate continuously. Measures to improve the efficiency of these boilers include new or automated combustion controls and variable speed drives on motors and pumps.

Better Distribution System Control. District-heat distribution systems are poorly controlled (if at all). Optimization of heat production and distribution according to real-time fluctuations in heat demand, hydraulic conditions, and outdoor temperatures can be provided by controls in heat plants, distribution substations, and individual buildings and apartments. "Automation of the heat supply systems is of great importance for the national economy" concluded a noted Russian heat supply specialist (Chistovich 1992). He estimated that 8 to 10 percent of total fuel consumption for district heating in the former Soviet Union as a whole could be saved with better regulation and control.

Reduction of Distribution Pipeline Losses. Many district-heating supply and distribution pipes are old, poorly insulated, and in poor technical conduction. Heat losses in these pipelines, although theoretically only 10 to 15 percent according to design parameters, can often reach 25 to 30 percent or more in poorly maintained systems. This gap between theoretical and actual losses has been verified repeatedly in a variety of published sources and field investigations (Martinot 1995b; Schipper et al. 1994; Stork Comprimo 1996; Tebodin et al. 1996). Further, circulating water is often untreated, which results in severe pipeline corrosion problems, consequent water leakages, and additional energy losses. Thus important improvements in district-heating systems include leak detection and repair (often simple and cheap), circulating water treatment, replacement of distribution pipes at the end of their useful life with modern pre-insulated pipes, and upgrade of distribution substations. Installation of new lower-loss heat exchangers in substations can also improve system control and reduce heat losses. Additional valves that allow segmentation of distribution networks can reduce water losses when repairs to pipelines are made. In addition to energy efficiency benefits, some of these measures also can reduce system maintenance costs, especially if pipe corrosion is a serious problem.

Besides the measures cited in the above three categories, more-extensive long-term renovations to district-heating systems are also possible but with more moderate financial returns. For example, existing systems in FSU countries were all designed as constant-flow, variable-temperature systems. Efficiency gains are possible by converting to variable-flow, constant-temperature systems, although this typically requires extensive renovations to production, distribution, and consumption equipment. Other key long-term investment issues for district-heating systems include the form and extent of new heat production capacity, additions to distribution systems, and renovation of existing boilerhouses to extend their service life. The need for investment may arise due to new demand or due to the end of the service life of existing heat sources. However, renovation of heat-only boilerhouses to extend their service life may not be the most cost-effective solution.

Existing district-heating development plans may not coincide with the most cost-effective measures, cited above, so these plans may need to be reevaluated. Existing long-term development plans of many district-heating systems were created before 1991. Although economic and institutional conditions have changed drastically since 1991, district-heating companies may still envisage future development according to these (usually highly supply-oriented) plans. But the assumptions underlying these plans may no longer be valid, especially because of six key transitional trends: (a) changes in the relative prices of fuel and capital investments; (b) changes in energy tariffs; (c) changes in future heat demand (associated with the decline or virtual halt of new housing construction); (d) the emergence of electric power capacity surpluses, which can make the economics of new cogeneration plants less favorable (for example in the Russian Federation, some think that new electric capacity will not be required for the next several years in many regions); (e) the emergence of competitive heat-supply markets and the economic viability of autonomous sources of heat supply (see section 3.7 below); and (f) the increase in industrial cogeneration by some enterprises using combined-cycle gas turbines (which can affect total heat-supply capacity and also the need for certain distribution-system improvements).

Supply-Side vs. Demand-Side Improvements in District-Heating Systems

In general, the debate about the relative merits and timing of improvements on the supply side versus improvements on the demand side of district-heating systems has not produced a clear consensus. Rather, this debate has indicated that both sides should be addressed simultaneously in ways that make short-term economic sense while ensuring that long-term issues are confronted. The above discussion suggests that short-payback-time improvements in district-heating systems in conjunction with renovations to the buildings they supply are important. 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. Heat control in both buildings and on the supply side represents an even more efficient solution.

The problem of improving district-heating systems and residential buildings as an integrated system lends itself well to concepts of least-cost, integrated-resources planning. Housing rehabilitation, district-heating system rehabilitation, new autonomous (building-level) heat sources, and new district-heating system additions can all be considered together in the context of least-cost solutions to deliver necessary energy services. In the least-cost perspective, heating-capacity savings from demand-side improvements (see section 4.5) can reduce or delay investment requirements for new capacity. After analyzing five different district-heating development alternatives for the city of Orenburg in the Russian Federation, Stork Comprimo (1996) concluded that demand-side improvements were economically feasible under all supply-side options considered. The problem with integrated supply-and-demand solutions is that different parts of the system have different owners, and the cheapest long-term technical solutions might only be feasible if one institution was responsible for the entire system or if all owners cooperated. Innovative regulatory solutions could address this problem.

3.7 Autonomous Sources of Heat Supply

Overcentralization of heat supply in FSU countries, in part a result of the prevailing ideologies of the Communist era, has resulted in heat delivery systems that are far from economically optimal (Chistovich 1992). As noted by Soviet district-heating experts, the Soviets considered large centralized district-heating systems (where 100,000 people or more may be connected to one system) to be better a priori, without properly investigating more decentralized alternatives using real economic costs or life-cycle analyses. Large, centralized systems mean that district-heating system efficiency from heat production to final consumption is often as low as 50 percent because of production losses (up to 35 percent), distribution losses (up to 30 percent), and poor control of heat flows throughout the system from production to final consumption (resulting in large temperature imbalances and overheating and underheating of many buildings and apartments).

As noted in the previous section, district-heating systems in FSU countries can become significantly more efficient. The experience with district heating in Denmark, Finland, and Sweden shows that district heating can be efficient, and these countries continue to develop their district-heating systems (Danish Energy Agency 1993). Recent studies conducted in Eastern Europe have shown that the economically optimal spread and size of centralized district-heating systems depend on urban geography, population densities, absolute heating loads, and any regional differentiation of gas prices and other fuel costs (Kalkum 1995; see also World Bank 1997). In light of these and other studies, it appears that a significant portion of the district-heating infrastructure in FSU countries is overextended and does not correspond to economically optimal designs if evaluated using current fuel, capital, and maintenance costs.

There is no question that Soviet-era district-heating systems will undergo long-term technical and institutional restructuring (and are doing so already). A key element of that restructuring will be a transition to much greater use of autonomous heating boilers serving individual buildings (and also apartment-level heaters). While acknowledging that cogeneration in Western district-heating systems is usually more efficient than autonomous heat sources, both domestic and foreign experts have recognized that for greater economic and technical efficiency in the appropriate geographical and technical circumstances, autonomous heat sources should play a much greater role in future heat supply in FSU countries. For example, after examining several different heat supply options for the city of Orenburg in the Russian Federation (including rehabilitation and developing autonomous sources of heat), Stork Comprimo (1996) concluded that the existing system is the most expensive option among the five considered. Stork Comprimo also concluded that autonomous sources of heat were one of the most cost-effective options.

There still exist large information gaps and uncertainties associated with autonomous heat supplies because few feasibility studies or demonstration projects have been undertaken in FSU countries. Uncertainties include technical performance, installation and operating costs, the scope of necessary upgrading and restructuring of gas distribution systems, and the impacts on the economic viability of existing district-heating systems. In addition, institutional issues associated with autonomous heating boilers are unresolved. Ownership is an important issue; the advantages and constraints of different possible owners--gas suppliers, households, building maintenance companies, district-heating companies, or municipal governments--need investigation. Other unresolved institutional issues include responsibility for operation and maintenance, metering and billing, and the limitations on placement locations in buildings dictated by existing construction standards and structural factors.

This last issue, placement location, is quite important for the Russian Federation on a national level because construction standards have historically prohibited gas-fired equipment in building basements. Although one rationale for this prohibition was supposedly the danger of explosions, basement boilers are common in the West, where codes are well-developed and well-enforced. Thus some experts think the issue of basement boilers is more an institutional development question than a technical one. Other placement alternatives, like placement in nearby detached buildings or on rooftop locations, may be more costly and problematic than basement locations.

In the long-term, increased household incentives and opportunities to reduce energy costs, resulting from metering, controls, and competitive heat-supply markets, may hasten the spread of autonomous heat sources. There is no question that autonomous heat sources are an important part of district-heating system restructuring. The trajectories of this restructuring will depend on heat-supply markets, the existing district-heating infrastructure, gas transmission and distribution infrastructure, energy tariffs, and other regulatory developments. But whatever trajectories occur, energy efficiency improvements to buildings will still provide more efficient use of heat, from whatever source.

3.8 Financial Savings vs. Fuel Savings and the Marginal Cost of Heat

Most estimates and analyses of energy efficiency potential in buildings focus on the amount of energy at the entrance (boundary) of the building, assign some monetary value to this energy, and calculate the resulting financial savings. From a consumer perspective, if heat is billed according to a meter at the building entrance, this is correct; financial savings to the consumer are determined only by heat consumption and existing tariffs. But the broader supply-system must be considered because those tariffs ultimately depend on heat production costs, real fuel expenditures, and heat-supply markets. From macroeconomic and environmental perspectives, the fuel savings resulting from reducing a building's energy consumption are a major determinant of the economic and environmental value of the energy saved. These fuel savings depend on both the technical and institutional characteristics of the district-heating system which supplies the buildings (for a good treatment of the technical side of this issue see Opitz 1994).

In the case of a heat-only boiler plant supplying a district-heating system, improved building energy efficiency means that the plant can lower heat output to maintain given indoor temperatures, and consequently fuel consumption at the plant will be reduced. Depending on the structure of heat-supply markets and whether heat capacity is in deficit, the economic benefits of the energy efficiency may be measured in fuel savings at the heat-only boiler for the district-heating company. Alternatively, if the district-heating company is able to sell the "saved" heat to another customer, such as a nearby industrial enterprise that would otherwise produce heat in its own (usually more expensive) boiler, then the fuel savings have been shifted to the enterprise. If heat tariffs for the industrial customer are higher than for the residential buildings (as has been the case in some parts of the Russian Federation), then the district-heating company also benefits from such a shift in consumption.

In the case of combined-heat-and-power (cogeneration) plants supplying district-heating systems, overall system efficiency and the economic cost of heat produced are more difficult to determine, and may also depend on the technical type of cogeneration plant, the season of the year, the nature of heat-supply markets, and whether production capacity is in deficit or surplus.

Although large district-heating systems in the Soviet Union were originally justified on the basis of utilizing free "surplus" heat from electricity production, the heat output in most conditions and at most times of year cannot be regarded as a zero-marginal-cost "by-product." Rather, in many situations the heat is the *primary* product of the cogeneration (this surprises many Westerners). Electricity is often the by-product and would not be produced if the heat wasn't needed (especially in some regions of the Russian Federation that now face a surplus of electric power capacity). In general, however, allocation of cost between heat and electricity is a complicated issue that specialists admit can be arbitrary or impossible to definitively determine--involving institutional considerations as well as technical ones. In addition, not all heat from cogeneration plants is produced through cogeneration; some plants may produce heat with peaking heat-only boilers to supplement their output. For example, in Moscow, a full 50 percent of the district-heating capacity in cogeneration plants comprises heat-only peaking boilers (Opitz 1994).

Does energy savings in buildings result in reduced fuel consumption in a cogeneration plant? As in the previous case with the heat-only boiler, if a cogeneration plant can sell its heat output to another customer instead, then the avoided fuel consumption shifts to that customer (for example an industrial plant with a heat-only boiler). If a cogeneration plant must reduce its heat output, fuel savings will result if a peaking heat-only boiler is in operation or if the plant is operating to supply heat as the primary product, with electricity as a by-product. Otherwise, the type of turbine in use and the season will determine primary fuel savings. The one situation in which there will be no fuel savings (marginal cost of heat production is zero) is if no peaking boiler is in use, no alternative demand exists for the heat, if the heat output is “uncontrollable” (a technical term used to designate certain types of cogeneration plants), and if summer operation requires use of a steam condenser. If the heat output is controllable, a plant may reduce heat output heat, sacrificing some electric power generation efficiency or electric power output. According to Opitz, many Russian authors suggest that controllable cogeneration plants usually set output according to local heat demand.

One technical complication is that district-heating systems are designed as constant-flow,[21] variable-temperature systems. So if one building consumes less heat from the network, the only way that a heat plant can “lower” heat output is to reduce its output temperature, which will lower heat consumption in all buildings in the network unless changes are made to the heating equipment (either a hydroelevator or heat exchanger) in each building connected to the network.[22] Thus renovations to large groups of buildings may be accommodated by changes in heat-plant-output temperature regime (the “graphic” in Russian). But in cases where the temperature regime doesn't change because only a small number of buildings are renovated, the avoided heat consumption is returned to the heat plant via a higher-temperature flow in the return line; in this manner the heat plant consumes less primary fuel to generate the same output temperature (several buildings connected in series along the same heat supply line pose special problems). This indirect method of fuel savings is less efficient than reducing heat-plant output-temperature or changing flow rates because of the losses in the unconsumed heat as it travels around the network and back to the plant (in which case return temperatures are higher than needed, resulting in greater losses in the return line). In addition, the transmission of heat savings back to the power plant depends on the type of hot-water connections (open or closed) and the type of space heating connections (dependent or independent).

Summarizing the above discussion, Opitz (1994) concludes that:

> End-use savings may not show up as primary fuel savings in central heat stations for any of several reasons. First, in all buildings a manual readjustment of the jet pump or heat exchanger in the buildings' heating system is required to transmit a lower heating load to the district-heating system--without the adjustment the buildings will simply be overheated. Second, building-level savings may not be transmitted to central heating

[21] Although designed as constant-flow systems, systems appear to operate at constant pressures, with some variation in flow rates due to system hydraulics. The Ryazan, Russia metering work (see Annex 3) has indicated that flow rates may vary by as much as 20 to 30 percent.

[22] A heat plant’s ability to lower the output temperature regime faces the further constraint that district-heating systems in FSU countries are designed to operate according to technical standards in which the return temperature is not supposed to fall below a certain standard value (usually 70°C).

> plants because of barriers in the distribution network. Finally, the central heating plant may be unable to provide fuel savings in response to lower heating requirements. (p.176)

Another impact of energy efficiency improvements on district-heating system operation and economics can come from changes in average versus peak system demand. Energy demand reductions may cause average demand to decrease more than peak demand. In particular, demand in spring and fall may decline significantly (and even the calendar dates of the beginning and end of the heating season may change with better insulated buildings), but winter peak demand may not decline by that much. On the coldest days, households will still demand as much heat as possible. These effects have been seen in district-heating systems in Sweden and Denmark.

In conclusion, determining the degree to which energy savings in buildings are translated into fuel savings at heat production sources depends on a careful analysis of several factors. These factors are: the technical characteristics of the district-heat distribution system, the technical characteristics of the cogeneration and heat-only boiler plants supplying the district-heat network, the institutional structure of heat-supply markets, and issues of surplus heat and/or electric power capacity. In most situations, fuel savings in heat-only boilers or cogeneration plants will correspond with energy savings in buildings, although appropriate technical adjustments to district-heating systems (including reductions in distribution losses) may be required to optimize these savings.

CHAPTER 4
LINKAGES BETWEEN ENERGY EFFICIENCY AND THE HOUSING PROBLEM

The "housing problem" reviewed in Chapter 2 can be viewed as a problem of how to achieve transitions in housing and utility ownership, management, and financing. Four types of transitions are occurring: (a) transitions in property rights and responsibility, such as enterprise housing divestiture and privatization of apartments (sections 2.3 and 2.4); (b) shifts in financial flows among municipal governments, households, utilities and enterprises, such as increasing recovery of actual housing and utility costs from households (sections 2.5 and 2.7); (c) formation of new management structures, such as homeowner associations and private housing-maintenance organizations (sections 2.3 and 2.6); and (d) new emerging markets, such as for real-estate and building-materials (sections 2.6 and 2.8). This chapter first examines briefly how energy efficiency investments can affect the speed and extent of these transitions. The rest of the chapter examines how these transitions enable and constrain energy efficiency investments. This examination is organized according to investment incentives, transaction barriers, returns from investments, social constraints related to low-income households, and heat-supply markets and regulation.

4.1 The Influence of Energy Efficiency on Housing-Sector Transitions

Energy efficiency investments can have a large impact on housing-sector transitions in at least four important ways. Energy efficiency investments can: (a) increase the willingness of municipal governments to accept divested housing from enterprises, (b) enhance the viability of greater recovery of actual housing and utility costs from households; (c) stimulate the formation and operation of homeowner associations and private-sector responsibility and financing for housing; (d) enhance utility cost-accountability and transitions in utility management.

Energy-efficiency investments reduce the operating costs of buildings and can delay or eliminate the need for further investments in energy-supply infrastructure. Municipal governments may be more willing to accept divested housing from enterprises if the operating and associated capital costs of the housing are reduced. In other words, energy efficiency investments are one component of an integrated strategy to achieve housing-divestiture policy objectives (see section 5.3). Reduced operating costs and avoided supply-side investments also enhance the possibilities for greater recovery of actual housing and utility costs from households. If the actual costs are reduced, cost-recovery can be accelerated without adversely affecting households. In fact, in some countries it may be difficult to achieve 100 percent cost recovery without accompanying reductions in energy costs because of basic social affordability questions (see sections 2.7 and 4.7).

Housing transitions are also affected by consumption-based metering and billing. In conjunction with investments in heat, hot-water, and gas meters, consumption-based metering and billing creates incentives for households to reduce energy consumption. Households faced with consumption-based energy bills have greater incentive to make behavioral changes and energy efficiency investments. Yet the largest opportunities to reduce energy costs require collective decision-making and action among all households in a building, so consumption-based metering and billing encourages the formation and operation of homeowner associations. This stimulus is important because the formation and operation of homeowner associations is proving difficult, yet is an important transition to greater private-sector financing and responsibility for housing.

In addition, consumption-based metering and billing shifts the actual costs of district-heating-system distribution losses (as opposed to the lower, theoretical costs; see section 4.8) from consumers to district-heating supply companies. This shift places both incentives and responsibility for distribution losses with the same agent--the district-heating company. The changes in energy payments and cost-accountability for distribution systems resulting from consumption-based metering and billing can support transitions in utility management and finance including greater separation of utility company finances from municipal budgets.

4.2 The Influence of Housing-Sector Transitions on Energy Efficiency Investments

Transitions in the housing sector have a large influence on the incentives, transaction barriers, and returns related to energy efficiency investments. For example, as cost-recovery from households increases, households face higher costs and greater incentives to reduce consumption. Also, changes in utility regulation can create new incentives for district-heating companies to invest in energy efficiency. Table 6 summarizes key factors associated with housing-sector transitions and conditions that influence energy efficiency investments. These factors are grouped in Table 6 by whether they primarily influence incentives for investing in energy efficiency, the transaction barriers to investments, or the character and extent of returns possible from investments. Although it is somewhat artificial to separate incentives, transactions barriers, and returns in this manner (i.e., factors which affect returns clearly also affect incentives, and transaction barriers affect both incentives and returns), Table 6 has been constructed to help with the organization of the analyses and explanations in this chapter.

Factors in Table 6 are further grouped by whether a potential investor in energy efficiency is a national or municipal government or private enterprise, or is a collective of households organized through a homeowner association.[23] In general, the number of factors is

[23] The term "potential investor" as employed in this chapter is usually the same as the "building owner," but could be different because of the complexities and ambiguities in the term "building owner" (see also Chapter 2). Although apartment privatization bestows legal ownership of individual apartments on households, the ownership of common areas of buildings and unprivatized apartments is more complex and varies by country. Also, ownership and responsibility do not necessarily go hand in hand. For example, in the Russian Federation, housing that is "on the balance" of an enterprise legally belongs to the federal government, although the enterprise is responsible for operating and maintaining that housing (the enterprise is a "defacto owner"). When such housing is divested to a municipal government, the municipal government becomes the "defacto owner" and assumes those responsibilities--but the housing still legally belongs to the federal government. Upon formation and registration of a homeowner association, defacto ownership of the common areas of the building is transferred to the association, while defacto ownership of unprivatized apartments remains with the municipal government. In the case of Lithuania, apartment privatization has transferred legal ownership of the common areas of buildings from the government to households, but until a homeowner association forms, the municipal government remains responsible for operating and maintaining the building (often, in reality, no entity appears responsible).

greater for households as collective investors than for single-entity investors like governments or private enterprises, partly because of the problems of collective management and decision-making, partly because of the limited capabilities of homeowner associations, and partly because of unique incentive problems related to free-riders and metering and billing.

The factors in Table 6 and their influence on energy efficiency investments are further explained in the next three sections.

4.3 Incentives for Investing in Energy Efficiency

Incentives for Federal or Municipal Governments or Private Enterprises. Incentives naturally exist for government or private-enterprise investments in residential buildings if the government or enterprise budget is affected by household energy consumption. Budgets can be affected by subsidies for heat and hot water, the level and structure of energy tariffs, avoided new investments in energy-supply capacity, targeted housing allowances to low-income groups for housing and energy services, and higher housing asset values. If housing and utility services are undersupplied, governments may also have political reasons for improving the housing conditions for their constituents; similarly, enterprises may want to improve housing conditions for their workers (although in most cases not all occupants of enterprise housing work for the enterprise that provides the housing). Municipal governments may also wish to reduce local dependence on external suppliers of heat, such as regionally or nationally owned combined-heat-and-power plants. If municipal governments are required to accept divested residential buildings from enterprises, the extra budgetary burden of maintaining and supplying energy to these buildings creates an incentive for the governments to invest in energy efficiency.

Expected future building-ownership transfers can also influence incentives. If a government makes an investment in a building that is expected to become the property of households (or a homeowner association) before investment costs are fully recovered, then there must be viable mechanisms for the government to recover investment costs from the future owners; otherwise, the government is not likely to invest. If housing has been part of the social assets of an enterprise, there is little incentive to spend financial and management resources on the housing stock because the enterprise anticipates ultimately divesting this stock to municipal governments or to private entities. This lack of incentive is clearly evidenced by the deteriorating condition of much enterprise-maintained housing, due to deferred maintenance and lack of capital repair. If enterprises anticipate keeping their housing, incentives should be much stronger.

Table 6. Factors that Influence Energy Efficiency Investments

<table>
<tr><th>Influence of factors</th><th>Factors if a national government, municipal government, or private enterprise is a potential investor</th><th>Factors if households organized collectively are a potential investor</th></tr>
<tr><td>Influence incentives for investing in energy efficiency (section 4.3)</td><td>• Energy tariffs paid by investor to energy suppliers
• Level of cost recovery from households
• Expected future building-ownership transfers (legal or defacto)
• Degree of unprivatized apartments remaining</td><td>• Energy tariffs paid by households (after any subsidies received)
• Degree of apartment privatization
• Consumption-based metering and billing vs. fixed payments for energy
• Building-level vs. apartment-level heat and hot-water metering
• Targeted housing allowances for low-income households
• Social perception of existing housing and energy services</td></tr>
<tr><td>Influence transaction barriers to energy efficiency investments (section 4.4)</td><td>• Information about costs, energy savings, financial returns, technical measures
• Managerial and technical capabilities of municipal government
• Availability of long-term financing for housing improvements
• Credit worthiness of municipal government
• Availability of design and construction firms</td><td>• Formation of homeowner associations
• Information about costs, energy savings, financial returns, technical measures
• Managerial and technical capabilities of homeowner associations
• Ability of households to collectively reach investment decisions
• Wide variation in income among households in the same building (section 4.7)
• Availability of long-term financing for housing improvements
• Credit worthiness of households and/or homeowner association
• Collateral mechanisms
• Availability of design and construction firms</td></tr>
<tr><td>Influence returns from energy efficiency investments (section 4.5)</td><td colspan="2">• Energy prices and investment costs
• Building characteristics
• Existing level of energy delivery and services
• Heat-supply markets and institutions
• District-heating system technical characteristics
• Heat-supply power-plant characteristics
• Energy policy and regulation
• Real-estate markets and marketability of building
• Operation and maintenance practices at the building</td></tr>
</table>

Household Incentives. Incentives for households to invest collectively in their building are influenced by a large number of factors, including of course energy tariffs and apartment ownership. Incentives may also be influenced by enforcement mechanisms that insure households pay their utility bills and the extent of the so-called “non-payments” crisis (section 2.5). Two social factors have a large influence on household incentives and transaction barriers--allowances to low-income households and the wide variation in income and socio-economic status of households within the same building; these factors are discussed separately in section 4.7. Below, the importance of consumption-based metering and billing for creating household incentives is discussed. Metering at both the building-level and at the apartment-level is important. Building-level metering is straightforward and inexpensive but apartment-level metering is more difficult and costly.

As cost-recovery and monthly energy bills increase, incentives for households to improve the energy efficiency of their building should likewise be increasing. But even with increased energy costs, if no gas, heat, and/or hot-water meters exist, households have no incentive to improve the energy efficiency of their buildings or to reduce their gas, space heat, and hot-water consumption. Without meters, households do not pay for consumption according to their actual use, but rather pay a fixed monthly amount based on the size of their dwelling (measured in either square-meters or cubic-meters), the number of registered inhabitants, and the type of appliances present (i.e., stove, water heater, and bath). Thus households face zero marginal-cost for their heat, hot water, and gas consumption.

Metering for gas, space heat, and hot water is an initial investment necessary to create incentives for further energy efficiency investments like insulation and controls. Once energy bills are based on metered readings, households have incentives to individually and collectively reduce heat consumption. These incentives increase as government cost-recovery increases. Investments in passive-technical measures (see Chapter 3) can then reduce energy consumption while maintaining or increasing the level of energy services (i.e., increased comfort). With investments in appropriate controls, households and homeowner associations can individually or collectively determine how much heat to use at what times of the day, week, or season of the year, and reduce heat consumption accordingly. (Technical measures for proper heat balancing within buildings are important for collective decisions about heating, so that intrinsically colder apartments, such as those on corners, the ground floor, or windy sides of the building, remain equally heated even when heating is throttled back.)

Recent Lithuanian experience, if valid, illustrates the impact of building-level metering. The Vilnius district-heating company claimed that average consumption of heat in the residential sector decreased by 20 percent in the Fall of 1995 compared with the previous year's consumption although the basis of comparison has not been reported (Kazakevicius et al. 1996). The company claimed that the decrease resulted from heat metering at the building level. A number of households also implemented simple measures to save energy. Anecdotal evidence from heat meter installation in Lithuania suggests that meters have led to increased consumer awareness and in some cases direct intervention by building occupants to control building substation valves manually, reducing the inflow of heat from the district-heating system.

Social surveys from the Russian Federation and Lithuania support the incentive effects of heat meters (see Annex D). Households generally believe they would reduce energy consumption with consumption-based metering and billing. For example, half of Lithuanian households surveyed would like an apartment-level heat meter and believe this would cause them to consume less and pay less (Arpaillange 1995b). Fifty-five to eighty-five percent of Russian households surveyed would prefer to pay for their actual, metered space heat and hot-water consumption rather than make the fixed payments they are charged now (Guzanova and Diachenko 1995a and 1995b). There is a perception that it is only fair to pay for what is consumed, and that with meters, bills would be reduced because inadequate amounts of heat are being delivered currently. Most Russian households (80 to 90 percent) would like regulators on radiators so that they can control their own heat consumption. About half of Russian households also recognized that controls would allow them to lower temperatures at night to save energy; 25 to 50 percent of households would lower temperatures at night if they had radiator valves. Some Russian households even responded that they would reduce consumption of hot and cold water during dish washing, manual clothes washing, and teeth brushing if they were motivated to save water by paying according to metered consumption.

Although building-level metering is necessary, it does not create the full range of possible incentives for households. The “free-rider” problem means that households won't conserve energy to the same extent if they are paying a fixed share of a collective energy bill than if they are paying only for their own consumption. Without apartment-level metering, this fixed share is likely based on apartment size, and individual household decisions about energy consumption have less influence on their energy bills. Thus apartment-level meters are important for apportioning the total heating costs of a building to individual households. Apartment-level controls are also needed so that households can regulate their individual consumption (see section 3.2).

The “free-rider” problem and the need for apartment-level metering in FSU countries is not unique. The issue of how to charge households for heat from collective systems has vexed Western analysts and governments for years (Energiberedskapsutredningen 1975; Vaermemaettningsutredning 1983; Wilhite et al. 1993). But it seems clear that apartment-level metering leads to a greater reduction in energy use than building-level metering alone. In Western European countries such as Denmark, Germany, and France, occupants with independent heating in each apartment tend to use less heat per square-meter than occupants of apartments served by centralized systems without individual apartment-level meters; this is true even though the centralized systems in unmetered buildings are larger and should be more efficient and use less energy overall (Schipper and Meyers 1993). Sweden, however, has very little individual metering of new apartments. But good insulation and controls in Swedish buildings, combined with interest from households through their homeowner associations, have resulted in heat consumption below levels in other countries where apartments have individual meters but poorer thermal properties (Schipper 1984; Schipper et al. 1985).

Sweden has mandated apartment-level metering for all new dwellings starting in 1997; one important concern that has previously prevented individual metering in Sweden is that apartment-level metering gives each household an incentive to lower its heat consumption and “steal” from surrounding apartments (i.e., permit neighbors’ heat to leak through the walls).

Where significant differences in indoor temperatures exist, this effect can be appreciable--perhaps 10 to 20 percent of one apartment's heat can leak to a colder neighbor. One solution is to provide each apartment with heat up to a temperature of approximately 15°C from the collective source and let each apartment provide supplemental heat from an autonomous source billed to each apartment. Another concern with apartment-level metering is that if meter readings are not corrected for any differences among apartments in heat loss from outside walls, roofs or basements, then some households, such as those with corner or top-floor apartments, will be unfairly penalized.

Apartment-level metering of space heat consumption poses special difficulties in buildings in FSU countries because of the physical design of piping arrangements within buildings. Heat distribution within multifamily 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. Nevertheless, small, inexpensive, stick-on, evaporative-type heat meters ("heat allocators") on each radiator are possible (see section 3.2), and can be used to allocate total building consumption across all apartments. Heat allocators need to be read and replaced once each year, adding somewhat to transaction costs, and special care must be taken to detect tampering by households.

Recent experience with metering in similar types of district-heating systems in Poland is instructive (Battelle 1996e). In these systems, heating services are billed to households on a combination fixed and variable basis. In 1996, 40 percent of heating bills was a fixed cost, and 60 percent was a variable cost based on metered heat consumption (the ratio started at 90 percent fixed/10 percent variable when meters were first installed). A 1996 national law mandated that the fixed portion be no more than 40 percent. These systems use the heat allocators mentioned above for apartment-level metering. A domestic Polish company was producing heat allocators for $4 each (one per radiator required) and charging $2/meter for annual service (meter reading, recharging the evaporative fluid, and resealing to prevent tampering). The heat meter manufacturer uses a sophisticated computer program to allocate heating costs across apartments and to account for the individual characteristics of each apartment. The manufacturer claims that the results are accurate to within 3 percent.

4.4 Transaction Barriers to Energy Efficiency Investments

Energy efficiency investments may not occur even if the financial returns are acceptable and the proper incentives are present because of transaction barriers. Transaction barriers can be categorized as the ***lack*** of some of the following conditions:

- Information about costs, energy savings, financial returns, and technical measures
- Managerial and technical capabilities (for specifying, contracting, and supervising)
- Ability of households to collectively reach decisions through homeowner associations
- Availability of long-term financing
- Regulatory capacities of municipal governments
- Collateral mechanisms and viable mechanisms for enforcement of lending agreements

Each of these conditions is described separately below.

Information about Costs, Energy Savings, Financial Returns, and Technical Measures

The lack of information about costs, energy savings, financial returns and technical measures can limit energy efficiency investments. Lacking adequate, credible information, potential investors may not know about the opportunities available or may overestimate the risks. Because few residential building renovations have taken place and few credible sources of information exist so far, many potential investors, especially households, doubt the validity of information they obtain. If potential investors contract for the services of energy consultants, the investors bear the risk if information supplied by the consultants is not valid. Consultant certification or other means of establishing legitimacy can reduce the risk. Information from consultants who do not have a direct stake in renovation contracting or equipment sales may be the most credible. Information disseminated from credible noncommercial sources could also reduce this risk and provide large public benefits.

To minimize information risk, potential investors may prefer to obtain information from a firm that also installs the retrofits and takes responsibility for their performance (such as an energy service company that offers performance contracting). But estimation of energy savings in residential buildings for purposes of performance contracts between households and energy-service companies is probably not feasible in the short term. Private third-party firms may not be able to properly conduct energy efficiency improvements on a performance basis because there are no consumption baselines for comparing performance where no heat meters exist (see section 3.5). If there are no historical heat consumption data with which to create a baseline to project or measure future energy savings, savings must be calculated using design standards or norms to estimate the “before” consumption. Case studies have shown that “before” estimates based on design standards or norms can be misleading, producing great uncertainty in the actual energy savings achieved.

Managerial and Technical Capabilities (for Specifying, Contracting, and Supervising)

In general, market-oriented managerial capabilities for specifying, contracting, and supervising renovation work are weak for all categories of potential investors--national governments, municipal governments, enterprises, and households. Lack of experience with competitive procurement and cost minimization in particular is a remnant of the former Soviet planned economy, because competitive procurement was not required and incentives did not encourage cost-minimization (Martinot 1995b). Households and homeowner associations are especially unlikely to have managerial, technical design, financial evaluation, and procurement experience and capabilities. The social survey results from Lithuania (see Annex D) provide further insight into the capabilities of homeowner associations. These results show that homeowner associations are very heterogeneous. Some appear quite able to manage and execute building rehabilitation and to manage loan repayment, while others have neither technical capability nor cohesion among their members. Thus governments, enterprises, and homeowner associations alike may choose to contract with private engineering firms to specify, manage, and supervise any renovation work. But even the specification and management of such a "turn-key" contract may be beyond the capabilities of many homeowner associations.

Ability of Households to Collectively Reach Decisions through Homeowner Associations

The formation of a homeowner association is a prerequisite for households to invest collectively in energy efficiency (see section 2.3 for the problems of homeowner association formation). Households can make some improvements themselves to their own dwelling (probably on a cash rather than credit basis), but most energy efficiency improvements in multifamily buildings must be made to the entire building and require a collective decision among all the households in a building. Although households may be collective owners, there may be no institutional mechanism through which to express their collective ownership. If no association exists, previously existing contracts with municipal building maintenance enterprises may remain intact, which represents an implicit decision to maintain the status quo and provides no opportunity for investment; these municipal building-maintenance enterprises typically do not engage in renovation investments.

Even if a homeowner association exists, it may not yet be making collective decisions about building maintenance and renovation. Collectively planned building improvements in particular still face a variety of social obstacles. Social surveys (see Annex D) have confirmed three of the main reasons for household reluctance to undertake such activities: (a) households would need to learn to "take charge" and undertake improvements by themselves rather than rely on the municipality or some state agency; (b) households would have to build trust in each other and learn to organize collective decision-making; and (c) households lack reliable information on housing maintenance and financing and have become risk-averse because of misunderstanding or misinterpretation of existing information. Social surveys also show that owners have very real fears about losing their apartments if they fail to repay a loan, and are unsure what government can do to help if they repayment problems. The ability of a homeowner association to make effective decisions is also affected by the quality of its chairperson, including his or her management and leaderships skills and time commitment to the position. The chairperson needs to be able to motivate and convince fellow homeowners of the need for collective action. Finally, in situations where housing allowances provide a "cap" on energy costs for low-income households, thereby reducing their incentive to make investments, these households may be able to block homeowner association decisions; or low-income households that can't afford investments may also attempt to block association decisions desired by more affluent occupants (both of these factors are further discussed in section 4.7).

Availability of Credit, Credit Worthiness of Borrower, and Collateral Mechanisms

Potential investors lack access to financing for energy efficiency investments even when such investments provide clear positive financial returns. Commercial banks are generally not willing to lend for housing rehabilitation or energy efficiency because they have little experience with these types of loans and see borrower default, contract enforcement, and/or investment performance as prohibitive risks (see section 2.6). In addition, banks in FSU countries are so far providing only short-term loans because of the macroeconomic environment. For example, maximum commercial loan terms in Estonia in 1996 were typically three years, and in Lithuania were two years. Short-term loans only support the very highest-return, shortest-payback-time renovations. Investments must be affordable to households (based on the full costs of investments including interest rate and taxation effects), and sufficiently long-term financing is required to make monthly payments within the reach of households.

Municipal governments may not be able to issue bonds to raise capital because of poor credit worthiness; they may also lack assets to use as collateral or may be forbidden by law from mortgaging their property (these constraints vary significantly from country to country). Thus the only mechanism through which a municipal government may be able to borrow is through regional or national government guarantees. Municipal government borrowing is aided by one factor: so far, municipal governments have little outstanding long-term debt.

Enterprises may borrow if they have clear assets that can be used as collateral. But enterprise credit-worthiness may be difficult to determine because of poor audit regulations or requirements. Because of economic restructuring and a lack of effective bankruptcy laws, many operating enterprises are technically bankrupt. But it is difficult for an outside agent to determine the extent of an enterprise's indebtedness and to unravel the chain of debts through other enterprises because of the “non-payments crisis” that continues to plague post-Soviet economies.

Homeowner associations face special problems with viable collateral mechanisms for commercial bank borrowing. Titles of individual apartments can be used as collateral, but apartments are individual property while the association is a collective entity with no collective property. Social surveys and interviews have shown that it is impossible to get each and every household in a building to agree to sign a loan mortgaging their apartments as collateral. The homeowner association needs to have the legal right to sign a loan without unanimous agreement among its members, using the first right in all apartments in the building as collateral. In other words, these first rights must be assigned to the association by law and not by individual mortgaging.

Recent policy experience in Lithuania is illustrative of a potentially viable collateral mechanism for homeowner associations. A 1995 Homeowners Association Law gives associations the right to levy charges on all households in the building, whether households are members of the association or not, for the purpose of financing maintenance, repair, and renovation. Investment decisions must be approved by a majority of association members (for details see World Bank 1996b). Under this law, if households do not uphold their share of collectively incurred loan obligations, the association has the legal right to take them to court to either get payment or to foreclose on the apartment and evict them (in which case the loan obligation would follow the apartment to the next owner).

The credit-worthiness of homeowner associations may be enhanced if there is commercial space in a residential building (such as first-floor retail storefronts). In this case, the association has access to a reliable source of income that can be used to repay loans.

Energy efficiency investments involving only removable equipment are a special case that could make the collateral problem easier for homeowner associations. For example, in Lithuania, district-heating companies have offered to sell and install meters, building substations and other heating equipment for greater energy efficiency to homeowner associations. The district-heating company would grant its own financing and allow repayments through heating bills. The installed equipment serves as collateral, to be repossessed if the loan is not repaid. This arrangement also overcomes some information and capability barriers because the district-heating company performs the design and installation. However, some equipment, such as substations, may benefit the district-heating company more than households, so sales by district-heating companies must be viewed in light of potential self-interest.

4.5 Returns from Energy Efficiency Investments

The degree and type of returns that result from energy efficiency investments in residential buildings are influenced by many of the housing-sector transitions that were mentioned at the beginning of this chapter. This section explains these influences and discusses several types of possible returns from energy efficiency investments. Most of these returns are financial and can accrue to households, municipal governments, national governments, and/or enterprises in the form of reduced utility bills, avoided investment costs of new energy-supply capacity, increased real-estate asset values, and reduced future maintenance and repair costs. Increases in indoor comfort, such as changes in indoor temperatures, are another type of return, especially for underheated or poorly balanced buildings. Reduced air pollution from fuel combustion is a third type of return. An indirect return at the macroeconomic level is that balance-of-payments can improve from reductions in energy imports, increasing investment ratios. These returns are interrelated and rarely can the returns on investment be isolated to just one of them. Rather, any investment project will impact all of them to varying degrees.

Utility Bills and Costs. Financial returns in the form of lower utility bills depend on the level and structure of utility tariffs and may also depend on the structure of heat-supply markets (see section 4.8). For example, if building-level metering and consumption-based billing are instituted in conjunction with other energy efficiency investments, total financial returns to consumers (i.e., households or municipal governments) may exceed economic returns as district-heating companies are forced to absorb additional costs associated with distribution-system losses. As another example, if the district-heating company can sell the avoided heat consumption in residential buildings to an industrial consumer at a higher tariff than the residential tariff (but less than the industrial consumer's own cost of production), then both the district-heating company and the industrial consumer also receive financial returns. Finally, two other regulatory mechanisms have important effects on financial returns: (1) regulations that give district-heating companies financial incentives (returns on capital investment) to invest in energy efficiency on either the distribution or demand side, and (2) regulations that ensure that the highest-cost heat production plants are closed as demand falls, rather than making across-the-board supply reductions from all plants (utilities may otherwise be reluctant to close plants). From this discussion it is clear that both economic and financial returns are partially dependent on transitions in utility regulation and management.

Heat Supply Capacity. If district-heat supply curtailments exist because of heat-supply capacity shortages, then the returns from investments may include the avoided capital costs of constructing new capacity. For potential municipal government investments in residential buildings and new heat-supply capacity, energy efficiency investments represent a viable alternative to address capacity shortages. Similarly, if less-efficient or obsolete heat sources still operate because of capacity shortages (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 (the sunk capital costs of district-heating systems in FSU countries are zero). For potential collective household investments in energy efficiency, some type of regulatory/tariff mechanism would be required to give households additional financial incentives, based on the avoided capacity requirements. Such mechanisms have not yet been used in practice in FSU countries for residential consumption, but could include, for example, differentiating heat tariffs into capacity and energy charges.

Housing Asset Values. In Western countries, home energy efficiency rating systems provide home buyers and mortgage lenders with an objective measure of a building's future utility costs; as a result, homes with higher ratings are worth more in the marketplace. Western mortgage lenders recognize that the variable costs associated with an energy-efficient building are less than with other buildings, so borrowers can obtain larger mortgages for energy-efficient buildings. In the emerging but primitive real-estate markets of FSU countries (see section 2.6), it is not yet clear (neither to professional real-estate agents nor to owners) how much building renovations increase asset value. Therefore, investments in energy efficiency may save utility costs, but their full value, including increased asset values, is not yet visible in the marketplace and so can't be captured by homeowners (at least in the short term). Thus the powerful incentive of increasing a building's market value with energy efficiency improvements is not yet present in FSU countries. This problem is particularly important in the context of the "takeback" effect discussed below. If a large portion of investment returns are increased comfort rather than utility bill savings, the main financial returns may occur in the form of increased asset values.

Building Maintenance and Repair Costs. Energy efficiency investments may reduce building operating and maintenance costs, such as costs for roof maintenance. However, some costs associated with energy efficiency improvements may not reduce energy consumption and thus do not generate financial returns (see sections 3.2 and 3.3). For example, serious structural problems with roofs and wall panels may require that roof reconstruction and joint/crack repairs occur in conjunction with energy efficiency improvements to roofs and wall panels. These required improvements can reduce the overall financial returns from the integrated retrofit package. Because of the serious deficiencies in building maintenance during the Soviet era (see section 2.1), many buildings are in poor condition. Few detailed surveys have been made of overall building conditions, so there is considerable uncertainty on a building-by-building basis about the total costs of specific energy efficiency renovation measures. Building repair costs for a specific building will not become apparent until a detailed building audit is conducted. Conversely, if energy efficiency improvements are undertaken in parallel with non-energy-related renovations that would happen anyway, then the energy efficiency improvements can yield higher financial returns than normal because of cost-sharing with the other renovations (so some energy efficiency measures, such as exterior wall insulation, become more attractive financially).

Indoor Comfort. Where existing indoor building temperatures are lower than comfortable or desirable during certain periods of the heating season because of district-heat supply curtailments, energy efficiency improvements may improve indoor comfort rather than reduce energy consumption during these periods--the so-called "takeback" effect.[24] The degree of "takeback" depends on many factors, including how underheated the building was before renovation, who controls the building's heat supply, what social interactions exist among households in a building, and what municipal political interests are involved. For collective household investments in energy efficiency, households will have to collectively decide how much to heat their building after renovation, and will collectively make the trade-off between increased comfort and financial savings. Otherwise, this decision is likely to be made by the municipal government (especially in the case of municipal government investments), which could elect to continue to undersupply heat to buildings. In this case energy efficiency investments result in utility bill savings and no changes in comfort (although some energy efficiency measures like improved building heat-balancing result in both increased comfort and bill savings). However, political considerations made it unlikely that a municipal government will be able to undertake renovations to underheated buildings without allowing some increase in comfort for the occupants. This political consideration may moderate utility bill savings from energy efficiency improvements for buildings that were underheated before renovations. But the opposite is also true: for buildings that were overheated before the renovations, comfort may improve (decreased indoor temperatures) at the same time that utility bill savings are achieved.

Air Quality and Emissions Charges. As discussed in section 3.8, the magnitude of fuel savings from energy efficiency improvements depend on institutional arrangements, district-heating system characteristics, and the structure of heat-supply markets. Further, the location (heat source) where those fuel savings occur may also vary, affecting the type of fuel that is saved--whether coal, oil, or gas. No matter which type of fuel is saved, the environmental benefits of reduced fuel consumption can include significant reductions in local air pollution and carbon-dioxide emissions. If coal-fired or high-sulfur-oil-fired heating boilers are operated, acid rain may also be reduced. Although few environmental regulations that assess financial penalties or taxes on air emissions exist or are enforced in FSU countries, such regulations may

[24] Energy efficiency "takeback" refers to the effect of higher energy efficiency on levels of energy consumption. By lowering the cost of energy services, higher energy efficiency can lead to greater demand for those energy services, depending upon the elasticity of demand. The only significant takeback related to residential energy consumption occurs in the demand for space heating, hot water, and air conditioning (Scott 1980). In the West, among all but the lowest income groups, the demand for these energy services appears to be inelastic with respect to price, with a short-term elasticity of 0.1 to 0.3. Among lower-income groups or in low-income countries, "takeback" can be more significant. Similarly, in times of rapid development when household energy use is growing more rapidly than household income, takeback can be significant. Heating and hot-water are the services most affected by takeback because virtually all other household energy services have other costs, both in terms of the time needed to use the service (e.g., washing) or aspects of wear and tear (e.g., light bulbs wearing out). For electrical appliances the effects are also smaller (Khazzoom 1980; Henly et al. 1988). The effect of takeback in residential energy consumption in FSU countries is not clear because the price elasticities of residential heat and hot-water demand are unknown. Where buildings are undersupplied with heat, takeback may be significant, but high relative energy costs will moderate the takeback. Similarly, given low existing levels of indoor lighting, takeback from greater electricity efficiency for indoor lighting may result in significantly greater lighting demand.

be enacted (and enforced) in the future, creating additional financial returns from reduced fuel consumption.

Economic Returns. Economic returns depend on the actual fuel savings achieved through energy efficiency measures, plus any savings in operating, maintenance, and avoided-capacity costs. Institutional arrangements, district-heating system characteristics, and the structure of heat-supply markets determine how energy savings at the building-level translate into actual fuel savings (see section 3.8). For a small group of buildings served by one heat production source, the economic returns are clearly identified with that source. But for larger systems, the fuel displacement may occur at different heat sources, thus affecting economic returns. For larger systems, one of the lessons of World Bank project preparation activities shows that the greatest economic savings will occur when there is close and willing cooperation between the end-user and the heat supplier (World Bank 1996a).

4.6 Households' Willingness to Pay for Energy Efficiency Investments

There is little question that basic energy efficiency investments are affordable to most households. For example, in Lithuania, the Ministry of Construction and Urban Development conducted a test activity in order to understand the needs and capabilities of homeowner associations, particularly within the context of improving energy efficiency in their buildings (World Bank 1996b). One of the findings of this activity was that even very poor households can afford to borrow for energy efficiency improvements if the size of investments is kept moderate. But are households willing to pay for energy efficiency investments themselves? Social survey results are mixed; some suggest that even if energy efficiency investments are affordable, households may still be unwilling to pay for them. In fact, some surveys suggest an alternative view by occupants: that the government should pay for building renovations.

The desire for greater energy efficiency and comfort is clear from occupant actions. In 1995 Russian social surveys (see Annex D), almost all Russian households reported resorting to makeshift weatherization and insulation, including windows, balconies, and front doors. In a 1995 Estonian survey, about half of all Estonian households in cooperatives or buildings with homeowner associations had weatherized their windows since 1992. Further, 17 percent of households had improved the hot-water system, installed a hot-water meter, and installed a heat meter since 1992 (Arpaillange 1995a). In a 1995 Lithuanian survey, nearly three-quarters of respondents reported wanting to better insulate their dwellings.

But willingness to pay for energy efficiency measures appears mixed. In the Russian surveys, no more than 15 percent of households were willing to pay for measures like replacement of radiators, temperature regulators on radiators, insulation of windows, insulation of doors, and caulking of cracks and cavities in the walls (at costs such as $\$4/m^2$ for window insulation, \$30 for window triple-glazing, and \$32 for temperature regulators). When Russian households were asked if they would be willing to borrow money to improve their homes, 13 to 22 percent responded positively, but their priorities were first apartment redecoration, followed by "equipment making the apartment more comfortable," and then followed by energy efficiency measures in third place. In another city, only 6 percent of Russians were willing to borrow the equivalent of $520 with a monthly payment of $8. Only 1 percent were willing to borrow $1,050 with a monthly payment of $17.

Estonians appeared more willing to finance renovations to their buildings, perhaps because of greater public information and greater prevalence of homeowner associations. In the Estonian survey, 75 percent of households said they would be willing to invest in housing by taking out a loan, and more than half of these respondents would use the loan to renovate their existing building. Frequently mentioned renovations included roof repairs, followed by improvements to heating systems and better building insulation. Loan amounts varied by income in the Estonian survey. Those with average monthly incomes from $90 to $200 were willing to pay average monthly amounts from $20 to $30 per month for a loan while those with very high monthly incomes (above $400) were willing to pay more than $100 per month.

4.7 Social Transitions and Low-Income Households

Besides the problems of homeowner formation and collective decision-making discussed in section 4.4, other social factors can affect the incentives and transaction barriers associated with energy efficiency investments. Two key social factors are discussed in this section: targeted housing allowances to low-income households for housing and utility costs, and the variation in socio-economic status among households living in the same building.

Targeted housing allowances to low-income households, depending on how the allowances are structured (see section 2.7), can limit incentives for these households to approve or participate in energy efficiency investments because the allowances effectively put a cap on total monthly heat and hot-water payments regardless of consumption. For example, in Lithuania, targeted housing allowances limit maximum housing and utility payments from qualifying households to 15 percent of household income. If a qualifying household is above this limit, it has no incentive to invest in energy efficiency because its utility bills would not change. Partial incentives may exist if payments are close to the subsidy threshold and reduced energy consumption would lower payments below the threshold. For example, if bills are 16 percent of household income and the subsidy threshold is 15 percent, energy efficiency improvements that reduced bills to 13 percent would mean the household would save 2 percent of its income. In cases where only a “portion” of a dwelling is eligible for subsidies (because of dwelling-size limitations on subsidization), partial incentives also will exist based on utility payments for the unsubsidized “portion” of the dwelling. In contrast, subsidies in the form of direct payments to low-income households, rather than threshold-based subsidies, would restore full incentives for energy efficiency investments to these low-income households.

A second key social issue has perhaps the greatest impact on the viability of collective household investments in energy efficiency: the variation in socio-economic status and household income among households in the same building. In the Soviet era, building occupancy was generally assigned without regard to the socio-economic status or income of households. When space opened up, the next family on the waiting list was assigned to it. Consequently, buildings now house an essentially random mixture of socio-economic groups. The emergence of real-estate markets and the differentiation of housing values based on location, amenities, and building quality is beginning to change this situation. Wealthier households are "trading up" to more desirable apartments and poorer households are "trading down" to more affordable apartments. But this is a long-term process and in the meantime, the variation of income within residential buildings will remain significant, with professionals who earn $2,000 per month living next to pensioners who may receive only $50 per month.

Homeowner-association laws are emerging that allow less than a 100 percent consensus among households in order to undertake building renovations. If the required majority of households in a homeowner association collectively decides to invest in energy efficiency, lower-income households in the same building will be forced to pay their share of the renovation costs. If they are unable or unwilling to pay, then the other households may end up either subsidizing or trying to evict these low-income households, producing a difficult social situation. From an allocative-efficiency perspective, it makes sense for low-income households to move to lower-cost dwellings and use the difference in asset value to reduce the burden of housing and utility costs--perhaps even to invest in energy efficiency improvements in the lower-cost dwelling. But primitive real-estate markets mean that such transitions will be very slow. Policies that encourage resettlement to more affordable housing, to the degree that they create more income equality within buildings, could improve the ability of households in these buildings to undertake energy efficiency investments. In fact, such policies could have a large long-term impact on aggregate investments in energy efficiency by households.

4.8 Heat-Supply Markets, Management, and Regulation in Transition

As reviewed in section 2.5, transitions in post-Soviet economies have hastened in new structures for utility ownership, management and regulation. The linkages between many of these transitions and the incentives, transactions, and returns of energy efficiency investments have been seen throughout this chapter. The linkages with evolving heat-supply markets and transitions in utility management and regulation are further discussed in this section, for several key issues:

Incentive to Reduce District-heat Distribution Losses. District-heating companies have had no incentive to invest in improving the energy efficiency of the distribution network (which has substantial losses; see section 3.6) because they have charged the municipal government or enterprises 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. Tariffs for building heat consumption have been calculated based on design or theoretical norms of consumption and include a fixed allowance for distribution losses, so that tariffs are supposed to correspond to heat consumed at the building. Typical norms for distribution losses are 5 to 15 percent although actual losses often approach 30 percent (Martinot 1995b; Cooper et al. 1992). Thus consumers are paying for distribution losses above the norms, while responsibility for reducing these losses rests with the district-heating company. If heat meters were installed in buildings and payments made for the actual heat supplied at the building entrance, the incentives for reducing distribution losses would properly shift to heat-supply companies. Installation of heat meters at the building-level without any changes in tariffs or consumption results in lower average heating bills because the extra distribution losses above the norms are not included in current tariffs.

Also, if a building is underheated, it's actual consumption will be less than norms. Typical differences in actual consumption compared with normative consumption can be 10 to 20 percent or even up to 40 percent, based on analyses of actual heating bills vs. normative consumption in Estonia and Lithuania (Martinot 1994; Association of Local Authorities of Lithuania et al. 1996; see also Annex A). On the margin, assuming no regulations that give offsetting incentives for the district-heating company, this reduction in heating bills means a financial loss for the district-heating company. Building-level meter installation on a large scale will push district-heating companies to reduce costs and/or to try to convince regulators to raise tariffs to keep revenues constant.

Heat Meter Ownership, Installation and Maintenance. The institutional question of who purchases, owns, and maintains building-level heat meters is not resolved in some FSU countries. In Lithuania, the district-heating company has financed and installed many meter installations and included meter costs in heat tariffs (World Bank 1996b). The experience from similar district-heating systems in Poland is quite relevant (Battelle 1996e). At the beginning, many Polish homeowner associations installed meters themselves. This situation quickly became a problem for the utility because there were too many different metering approaches and meter types, making it difficult to understand and approve the systems. So heating companies started to take control of the situation. They developed exact specifications for acceptable customer-installed meters (including specific qualifying manufacturers) and they installed meters at their own expense at distribution and building substations that they owned (and are responsible for maintaining those meters). In at least one region of Poland, the district-heating company has assumed ownership of all heat meters. Although the advent of heat meters has had a significant downward effect on company revenues, the company was still vigorously installing meters because it recognized the inevitability of 100 percent metering and decided that it should at least control the process.

Heat-Supply Markets and Autonomous Sources of Heat Supply. As competitive markets for heat supply evolve on a local level, one potentially attractive option is building-level autonomous heating boilers (see section 3.7). An autonomous boiler that supplies both heat and hot water for a building would allow that building to be disconnected from the centralized district-heating network. If gas distribution infrastructure is available, the economic cost-effectiveness of such installations could be high. The future feasibility and spread of autonomous sources of heat supply will affect investment decisions about building renovations for energy efficiency. In turn, the future spread of autonomous heat sources depends on the evolution and regulation of competitive heat-supply markets. Increased household incentives to reduce energy costs, through investments in meters and controls, could hasten the evolution of heat-supply markets as household demand for the cheapest energy-supply alternatives intensifies. But the institutional issues of ownership, operation, and maintenance of these installations require further policy attention and market experience. In the long term, household incentives to reduce energy costs, which could in turn drive investments in autonomous sources of heat supply, will have a growing impact on the viability of some existing district-heating infrastructure.

District-Heating Demand Displaced by Electric and Gas Heating. In both the Russian Federation and Lithuania, one out of four households supplement the district-heating supply with other heat sources frequently or constantly during the winter; up to half of all households use supplemental sources of heating at least sometimes (based on social surveys and also initial results from gas metering in Ryazan; see Annexes C and D). The primary sources of supplemental heat are gas cooking stoves and electric heaters. This situation has several implications. Residential consumption of gas remains unmetered for most buildings. If households begin to pay metered bills for heat and hot water but gas remains unmetered, consumption should shift to gas as households operate their gas stoves instead of consuming metered district heat. Increased gas consumption could strain gas distribution systems, requiring greater amounts of cross-subsidies of residential gas consumption by industry. In some countries, electric heating can be cheaper to purchase than district-heating. In this situation, not only will electric heating displace district-heat consumption if apartment-level metering and billing of heat is implemented, but new and retrofitted buildings may elect to disconnect from the district-heating system entirely and use only electric heating, if allowed by law, a process which has already begun in Estonia. From a social point of view this is economically inefficient because the artificially low electric power rates do not reflect actual costs. Electric heating on a large scale will strain electric distribution networks and require future electric power capacity investments sooner than they would otherwise be needed.

Least-Cost Planning for Heat Supply and Consumption. In theory, it should be possible to integrate the supply and demand sides of district-heating infrastructure, including energy efficiency investments in residential buildings, to develop least-cost, integrated-resources-planning type solutions to municipal heat supply. But in practice, management and ownership of district-heating systems are often institutionally complex and fragmented even though the systems themselves are technically integrated. Different organizations may be responsible for heat production, primary distribution, secondary distribution, heating equipment in buildings, and billing. Industrial enterprises may provide heat to a common network along with separate municipal heat enterprises and regional electric power utilities. Smaller-scale local systems for providing heat to just a few or several buildings may exist alongside larger district-heating networks, with the smaller systems maintained by separate organizations. Regulations or policies that attempt to provide least-cost solutions for these systems must confront this institutional fragmentation and support the necessary cooperation and incentives among different organizations.

CHAPTER 5
ENERGY EFFICIENCY INVESTMENT PROJECT DESIGN AND IMPLEMENTATION

This chapter examines project design and implementation for energy efficiency investments. First, energy-related policies and capacity-building requirements and strategies that should accompany energy efficiency investments are identified. Then, two examples of different approaches to lending for energy efficiency improvements are provided. Both examples are considered demonstrations of the institutional, financial, and implementation capacities needed to achieve energy efficiency investments in a transitional setting. Finally, the chapter discusses project monitoring and evaluation: technical monitoring to measure investment returns, and social and institutional monitoring to assess long-term impacts and learn from the experimental aspects of projects.

Energy efficiency projects must allow for the transitions occurring in conditions, institutions, capabilities, and policies in FSU countries. In the longer term, the role of governments in ownership and management of residential buildings will be replaced partly or wholly by the private-sector. However, the private sector is still emerging, and many of the laws, institutions, and other conditions needed for private-sector activities are not yet developed. Government will likely have some transitional role, and a clear challenge for project design is defining that role. Neither of the two project examples discussed in sections 5.3 and 5.4 are intended to create permanent mechanisms or conditions; both reflect designs based on the different levels of reform in the Russian Federation and Lithuania and different decisions about the transitional role of governments.

5.1 Policy Objectives: Housing Versus Energy Efficiency

As discussed in Chapter 2, a number of different housing-related policies can facilitate housing-sector transitions. These housing-related policy objectives may include social asset divestiture, increased cost recovery, privatization of housing maintenance, privatization of dwellings, formation of homeowner associations, strengthening of the commercial banking sector and real-estate/mortgage financing, or provision of targeted housing allowances for low-income households. Chapter 4 shows that these policy objectives are closely linked to the opportunities for energy efficiency investments that are described in Chapter 3. In fact, energy efficiency investments and housing-related policy objectives are both integral components of solutions to the “housing problem.”

In the context of development-based investments, an energy efficiency investment project whose objectives include assisting housing-sector transitions may be designed starting with a housing-sector policy objective. Different conditions and priorities in different countries will determine which housing-related policy objectives merit the most attention. A definition of the appropriate form of government intervention to achieve the objectives leads to a specific project design. Within that project design, the appropriate role and forms of energy efficiency investments that will support the objectives must be specified. In other words, the design should specify how the returns from energy efficiency investments (described in section 4.5) will help accomplish the specific housing-sector goals of the project.

The next stage of project design is to specify how to achieve the desired returns from energy efficiency investments. This is an important question. Achieving the benefits from energy efficiency may require that specific *energy-related* policies and capacity building need to be incorporated into the project's design. These energy-related policies and capacity building are discussed in the next section.

5.2 Energy-Related Policies and Capacity Building for Energy Efficiency Investments

The technical-economic opportunities for energy efficiency discussed in Chapter 3 and the returns discussed in Chapter 4 can be realized when proper incentives exist and when transaction barriers are surmountable. These conditions may or may not already exist, depending on the nature of the project. Thus the primary concerns of energy-related policies and capacity building within a development-oriented investment project are those discussed in Chapter 4:

- How to create incentives for investments in energy efficiency?
- How to overcome transaction barriers to investments and reduce transaction costs?
- How to ensure that desired returns are achieved?

Underlying the energy-related policies and capacity building in this section is a long-term theme: a transition to sustainable and functioning markets for energy efficiency products and services. This transition will occur when the necessary and sufficient information, capabilities, incentives, institutional capacities, legal frameworks, and price signals exist among market participants. These participants include consumers, materials and equipment producers, architecture and engineering firms, construction firms, consultants, commercial banks, regulators, and policy makers. The market should provide ways for consumers to answer fundamental questions like: Does it work? Where can I buy it? How much does it cost? Does it pay? Who will install it for me? Where and how can I borrow money to pay for it? Sustainable and functioning markets will provide greater benefits to households and governments, and contribute more to the housing problem, than simply one-of-a-kind projects. But such markets are slow to develop, and one-of-a-kind projects are important stimuli and demonstrations of technical, policy, regulatory, institutional, and social dimensions of energy efficiency improvements.

Consumption-Based Metering and Billing Systems

Almost any energy efficiency investment in residential buildings, in conjunction with investments in heat, hot water, and/or gas meters, requires some type of consumption-based metering and billing to enable reduced energy payments to utilities. But the required complexity of the metering and billing can vary substantially, as can the policies and capabilities that are needed to develop metering and billing "systems." Metering and billing systems may require an array of new regulatory, institutional, administrative and technical functions and capacities.

Metering and billing systems can be of three fundamental types: metering of distribution substations, of individual buildings, and of individual apartments. The simplest type is metering and billing of distribution substations. This type is adequate for municipally financed investments if households continue to pay for utilities on a fixed-cost basis and the energy efficiency returns accrue to the municipal government. Metering and billing of distribution substations allows simple determination of the aggregate quantities of energy supplied to residential buildings and paid for by the municipal government (with partial cost-recovery from households). Metering of individual buildings (without billing of individual buildings) can also provide a measurement of energy demand for the purpose of determining aggregate payments to heat suppliers.

The second type of consumption-based metering and billing is at the building-level, with households each paying a share of total building-level consumption. In this case, building-level consumption must be apportioned among all households according to some fixed formula, usually based on dwelling size or number of occupants. The third type of metering and billing is apartment-level metering. For space heating, a building-level meter is still required, with building-level consumption apportioned among households according to heat-allocation meters in individual apartments (see sections 3.2 and 4.3). For gas and hot water, individual apartment-level meters can be installed and do not require building-level metering.

With any of these approaches to metering, new contractual arrangements must be made between heat suppliers and consumers (most likely either municipal governments or homeowner associations). New regulations that establish residential tariffs based on actual consumption rather than normative consumption may be required. These regulations may be possible at a municipal level, or may require authority at a higher regulatory level. And metering of distribution substations may require participation of the district-heating company, a further subject of regulation.

With building-level or apartment-level metering, a database of building characteristics must be created in order to allocate building-level heat meter readings across all households within a building. This database will need to include individual apartment characteristics. An agency must be created, equipped, and trained to read the heat meters and calculate heat payments on a monthly or annual basis. New administrative mechanisms must be created for incorporating calculated payments into household bills that may be produced by a different agency. If apartment-level metering uses heat allocators, these meters must be read annually, the indicator in each meter must be replaced annually, and total building consumption must be apportioned among households according to the readings.

The transition to consumption-based metering and billing will require new regulations by municipal governments giving appropriate authority and budgets to new or existing agencies. Even more important, the new regulations will need to specify a system of consumption-based energy tariffs that correspond to equivalent levels of existing cost recovery, so that average household heat payments remain the same (otherwise cost recovery is implicitly altered). Regulations must also address the issue of payments on the basis of metered consumption right at the building, rather than on the basis of heat production at the power plant with fixed distribution-system losses built-in (see section 4.8). This new system of tariffs may need to be approved by a regional or national government. In the Russian Federation, for example, there is debate as to whether regional energy commissions would need to approve the transformation of residential heating tariffs from a per-square-meter to a per-gigacalorie basis. Since this has not happened in the Russian Federation yet, the issue has never been tested.

Building-level or apartment-level metering may result in other institutional and administrative requirements because households are used to making identical monthly payments year-round; consumption-based billing will result in varying heat bills from month-to-month and season-to-season. A method of averaging payments may be needed. Households could, for example, pay an estimated amount every month with a reconciliation at the end of the heating season that would result in a credit or an additional payment (which could be paid in installments).

Other Heat-Supply Sector Regulations

As discussed in section 3.8, technical changes in the district-heating system may be required so that energy demand reductions in residential buildings are translated into maximum fuel savings at power plants. Required technical changes depend on the characteristics of the buildings, district-heating system, and heat-supply markets. Heat-supply contractual changes may also be necessary with other district-heating customers. The most appropriate response of district-heating producers--selling their "surplus" heat to other customers if residential demand decreases--may require new regulatory provisions or approaches. These regulatory changes may be needed at municipal, regional, or national levels, depending on who the heat producers are. New regulatory provisions may also be needed if net revenues to district-heating companies decline because building-level metering forces district-heating companies to absorb more of the costs of distribution losses (see section 4.8). New regulatory mechanisms could provide incentives for district-heating companies to reduce costs (such as regulations that provide special profit incentives for reducing distribution losses) and forestall the need for increased tariffs.

Formation and Operation of Homeowner Associations

The formation and operation of homeowner associations is a prerequisite to collective energy efficiency investments by households. There is an emerging body of literature on homeowner association formation in FSU countries (Gardner 1995). Studies point out that existing or potential homeowner associations need access to organizational, legal, financial, and informational advice relevant to forming and operating functional associations. Public advisory centers are one possibility. Formal or informal channels through which homeowners associations can share knowledge and help each other learn from their experiences and articulate their needs can also be encouraged; an association of homeowner associations has been created in Lithuania, for example. There is also a need for policies that contain specific procedures and details about the operation and formation of associations. As Gardner notes:

> As time-consuming and painstaking as the process can be, cities are better served to address the concerns of homeowners, the gaps in legislation and other unresolved issues before they move forward with promoting widespread association registration. Approaching the process by passing broad based resolutions that promote association formation but provide few details on how the process is to be accomplished create an instantaneous result, but progress quickly halts because it gets bogged down in the unresolved details. (p.9)

Although social resistance and lack of knowledge mean that widespread registration of homeowner associations will take a long time no matter what type of legislation is passed or how specific such legislation is, the process is likely to be smoother if details are resolved and clarified in legislation or through the sharing of experiences of "pioneer" associations. Gardner notes several items to consider in the forming and operating of homeowner associations, including commercial-space ownership and leasing, utility subsidies, land boundaries and use, maintenance and utility service responsibilities, association membership and enforcement of member obligations, association charter and bylaws, municipal government participation in the association, and tax status and financial record keeping.

Household Information, Education, and Training Aimed at Encouraging Private Initiative

Even with functioning homeowner associations, one key to residential energy efficiency will be to encourage households to actively assume greater responsibility for their building. At the first stage, basic experience from the day-to-day operation of a homeowner association--bookkeeping, maintenance contracts and decisions, etc.--is an important prerequisite to increased responsibility and initiative.

Once this basic experience exists, access to credit and technical assistance and appropriate incentives can all encourage private initiative for residential energy efficiency improvements. But this assistance will only be useful if households sufficiently understand the technologies, costs, and benefits; if they trust the sources of information; and if they believe the information applies to them. Thus it is essential to produce and disseminate clear, simple, and complete information to homeowners associations and households regarding technical options for energy efficiency and the specific procedures and means for obtaining both advice and credit. To gain the confidence of households, information programs and procedures for obtaining advice and credit must be simple, transparent and fair. Programs must provide open access to information and resources without favoritism, bureaucratic hindrances, or exaggerated expectations.

The importance of engendering households' confidence cannot be underestimated. Households in FSU countries have little reason or inclination to trust government authorities. Even though households need protection from "opportunists" of questionable quality and motivation, they are unlikely to trust government authorities' endorsements. Households' fears of losing their apartments if they take out mortgages need to be addressed. Confidence in the banking system needs to be established. Independent, credible organizations designed to provide this information and confidence will play an important role.

In the Lithuania Housing/Energy Efficiency Project (see section 5.4), the Lithuanian Ministry of Construction and Urban Development conducted a test activity to understand the needs and capabilities of homeowner associations, particularly within the context of improving energy efficiency in their buildings (World Bank 1996b). This test activity found the most important qualities of homeowner associations to be: prior organizational experience (such as with former cooperatives), strong leadership that encourages households to participate in decision making, financial resources, and good information. Several other important lessons emerged from the test activity:

- Homeowner associations face large transaction costs in their attempts to improve energy efficiency under current conditions.

- Homeowners associations vary greatly in the strength, function, experience, and openness of their members and leaders.

- Households have considerable interest in improving energy efficiency but know little about technical options, costs, credit, and credit conditions.

- Despite the huge need, associations have little access to information about renovation and maintenance.

- Many households are anxious about indebtedness and credit. Although some of the anxiety may be dispelled by access to good information, positive experience will also be necessary.

- Households and associations are dependent on authorities and contractors for information yet mistrustful of these sources. There is considerable demand for independent advice.

Project Management, Procurement, Contracting, and Supervision

Because most energy efficiency investment projects require careful design and involve many different types of materials, equipment, and installation expertise, project management and procurement expertise can be the make-or-break factor in implementing energy efficiency investments. Projects should give careful consideration to the need for technical assistance, consulting, training, and other inputs to support project management, procurement, contracting, and supervision. This support will vary in form and character depending on whether the recipient is a municipal government, homeowner association, or another entity.

In the Lithuania Housing/Energy Efficiency Project test activity mentioned above, the Ministry of Construction and Urban Development and its consultants helped four homeowner associations go through a process of borrowing from commercial banks and implementing energy efficiency measures. Direct assistance was provided to the associations at each step in the process, including: (a) inviting associations to take the loan, (b) obtaining a mandate from association members, (c) gathering technical and procedural information, (d) preparing a proposal that identified options and their respective costs and benefits, (e) choosing a course of action and inviting bids from contractors, (f) selecting a bid, (g) negotiating with contractors, (h) negotiating with commercial banks, and (i) overseeing construction and installation. The activities in this project illustrate the kinds of support homeowner associations are likely to require.

Homeowner associations may also benefit from technical assistance or training to support energy efficiency improvements after installation. For example, one person within the building could be trained and supported as a building energy manager. This person could monitor energy consumption, identify energy waste and new opportunities to reduce energy consumption, and continue to refine the homeowner association's methods of fairly allocating utility costs across all households.

Commercial Banks

Commercial banks may need assistance that enables them to understand and appraise the technical and financial merits of energy efficiency projects and to create appropriate financing mechanisms and procedures. Banks also need to understand households as prospective clients and how to evaluate their credit-worthiness. Experience from pilot projects is needed to identify the arrangements necessary for commercial credit facilities that offer long-term lending to homeowner associations. Some type of government guarantee mechanism, at least in the earlier stages of lending, may be required.

Architect/Engineering, Consulting, and Energy-Service-Company Industries

The use of local architect/engineer, consulting, and energy-service companies will provide lower project costs and higher returns than if foreign firms are involved. However, local firms need assistance to understand the technologies, economics, and financing involved. They need to understand the needs and constraints of potential customers, such as homeowner associations and municipalities. They particularly need basic business training; the legacy of the planned Soviet economy has left managers ill-equipped to understanding basic business, management, marketing, and financing concepts. Design and contracting costs may be reduced by the development of systematized approaches to project design (“packaged technologies”) or contracting (“packaged transactions”). Development of a functioning market for these services may also include licensing and certification requirements for consultants, contractors, and energy-service companies. Establishment of “standard practice” and codes of conduct for particular industries may reduce legal and other transaction costs. Policies that promote joint ventures and technology transfers with foreign firms are an excellent way to build domestic industries while allowing domestic firms to benefit from the technical, financial, managerial, and marketing expertise of foreign firms. The development of these industries may also include the development of new building codes and standards; these codes and standards should be realistic under current conditions--that is, they should not be so strict so as to make any renovation unaffordable.

Domestic Building-Materials and Equipment Industries

The same considerations that apply architect/engineering firms apply to building-materials and equipment industries. The use of local materials and equipment in energy efficiency rehabilitation projects will result in lower project costs and higher returns. But domestic materials and equipment suppliers may not understand the needs and characteristics of the residential market, nor the technical requirements for residential buildings. Thus technical and market-related assistance can improve the ability of these firms to compete effectively in these markets. Training in economic and financial analysis of energy efficiency investments can improve firms' interactions with customers. Development of a functioning market may also include materials certifications and equipment standards.

Public Information Programs

The scope and scale of the transitions discussed throughout this report create a heavy demand for public information and education programs. The energy-related policies and capacity building described in this section may require accompanying public education programs. For example, the legislation necessary to implement consumption-based metering and billing may potentially stir up fears among households that energy bills will increase. These potential concerns must be addressed through public information so that households understand the design and benefits of such programs. One way to educate the public in this case would be to disseminate the results of pilot or demonstration projects (such as a pilot-scale consumption-based metering and billing system applied to a small group of buildings) from other cities or ideally from within the same city. Dissemination could even involve radio or television interviews with households from the pilot buildings.

Autonomous Heating Boilers

Public-sector projects for energy efficiency investments in residential buildings should consider demonstrations of autonomous heating boilers because of their importance to the housing sector (see section 3.7). Autonomous heating boilers offer a long-term option for restructuring district-heating systems, which may be favored by households once the proper incentives are in place. Yet the information gaps and uncertainties associated with autonomous heating boilers will seriously hinder private-sector initiatives. Research and demonstrations are needed to help provide information, reduce uncertainties, and give a basis for effective investment decisions related to autonomous heating boilers. In particular, the question of how the spread of autonomous heat supplies is linked to the development of gas-distribution systems requires study. Until these information and experience barriers are overcome, private-sector actors will be reluctant to invest in autonomous heat supplies because of the uncertain returns and viability.

5.3 Project Example: The Russian Federation Enterprise Housing Divestiture Project

Accelerated and sustainable divestiture of enterprise housing is the primary objective of the Russian Federation Enterprise Housing Divestiture Project (World Bank 1996a). Divestiture of residential buildings from enterprises to municipal governments, which puts municipal governments into the position of defacto owner/operators of these buildings, is a transitional mechanism toward ultimate private ownership and responsibility. In the longer-term, the project is designed to push the ownership, financing, and management of the housing stock toward the private sector. As a transitional strategy, municipal governments must accept responsibility for operating and maintaining this housing. As stated in Chapter 4, energy efficiency renovations are an essential component of an integrated strategy to reduce building utility costs and thus encourage municipal governments' willingness to accept these responsibilities. This project includes $300 million in World Bank financing for basic energy efficiency measures in an estimated 3,500 divested multifamily residential buildings in six cities. In conjunction with these investments, policy reforms at the municipal level are also designed to reduce maintenance and utility costs; these reforms include dwelling privatization, formation of homeowner associations, increased cost-recovery, targeted housing allowances, and competitive bidding for housing maintenance services.

In this project, municipal governments borrow capital, manage the design and implementation of energy efficiency retrofits, and repay the loan from the general municipal budget. Municipal governments recover their loan costs through the resulting lower payments for heat and other utilities for residential buildings. As household cost-recovery for utility services is phased in, municipal governments will continue to recover their retrofit investment costs in this manner. Household utility bills will include amounts for loan repayment, but total bills will be lower than if the investments had not been made. Because of the need for the greatest positive impact on municipal and household budgets in the short-term, financing covers only high-return packages of energy efficiency measures with payback periods of five years or less. The main constraint on the total size of investment for each city is not the availability of cost-effective retrofit opportunities but the credit-worthiness of municipal governments (and the related constraint of the need to secure guarantees for loans from regional and national governments).

Although transitional in nature, the project was conceived as a demonstration project; an explicit objective of the project is to demonstrate that a mix of policy measures and investments can accelerate and make sustainable the process of divesting housing from enterprises. If successful, this project could be replicated in other cities in the Russian Federation to enable them to negotiate the transition as well.

5.4 Project Example: The Lithuania Energy Efficiency/Housing Pilot Project

Two objectives of the Lithuania Energy Efficiency/Housing Pilot Project are: (a) to support private initiative in improving residential energy efficiency, and (b) to support the implementation of Lithuanian government policies for sustaining the privatization of housing and enabling increased private initiative in housing maintenance in general (World Bank 1996b).[25] The project makes almost $15 million available to approximately 200 to 300

[25] A further objective is to support public initiatives in improving energy efficiency in schools.

homeowner associations, through commercial banks, for energy efficiency investments. The project encourages formation of homeowner associations and develops their technical and managerial capacity to undertake such investments. The project also introduces commercial banks to the concept of long-term lending for housing and housing improvements. Finally, the project supports the development of private markets for energy consulting and housing renovation services.

One model for energy efficiency improvements under this project could be the following: A homeowner association commissions a consulting firm to conduct an engineering evaluation of potential energy efficiency improvements, to provide economic-cost and financial-return estimates, and to develop an investment proposal that meets the collective needs of the building's households. The homeowner association then borrows capital from a commercial bank based on this proposal. The loan is secured by the right of the homeowner association to levy charges on all households (a right granted by the 1995 Lithuanian Homeowners Association Law; see section 4.3). The same consultant then prepares a technical specification for the work, and the homeowner association bids the work to construction contractors with assistance from the consultant. The consultant supervises the renovation work and certifies its acceptability and performance. In addition, the commercial bank may have an inspection and certification requirement. The homeowner association pays the contractors with the bank loan and bears the investment risk. Households pay lower energy bills and repay the loan in monthly installments using their monthly energy-bill savings. While all retrofit measures do not have to be strictly related to energy efficiency, the overall financial returns must be high enough to justify the loan and ensure credit-worthiness (within the parameters of available credit). Investments per building are expected to range from $20,000 to $150,000 (which amounts to $100 to $3,000 per dwelling).

Households in buildings with existing meters for heat and hot-water and with functioning homeowner associations probably have the greatest incentive and ability to participate in the project although new homeowner associations can form expressly to participate in the project. The following types of technical assistance and institutional development are provided by the project to support participants and other stakeholders:

- Advice to households on how to form and operate homeowner associations will be provided through local advisory centers (run by the Lithuanian Association of Homeowners' Associations). In addition, formation of homeowner associations may be facilitated by eliminating unfavorable legislation or by available government assistance programs.

- Advice will be provided to households and homeowner associations on technical, financial, legal, and social aspects of energy efficiency improvements to their buildings. This assistance includes assessment of the scope for energy efficiency improvements, preparation of investment proposals acceptable to commercial banks, procurement of materials and services, and supervision of retrofit installations.

- Public information and education programs will help homeowner associations understand the technologies, costs, benefits, and financing of energy efficiency improvements and help them understand how to seek bank credit for these improvements.

- Loan appraisal support and training will be given to help commercial banks understand the technologies, costs, and benefits of energy efficiency improvements.

- Technical, financial analysis, contracting, and marketing training will be provided to energy consultants and building-rehabilitation contractors.

- Studies will be done on housing maintenance organizations and on government assistance programs to the housing sector (including existing homeowner association programs and renovation and heating subsidy programs).

Like the Enterprise Housing Divestiture Project, this project can be considered a demonstration project, because it is still unclear which financial and institutional mechanisms will prove most successful in its objectives. In particular, the willingness and ability of homeowner associations to take responsibility for maintenance and renovation of their buildings requires further understanding, including the specific needs for technical and managerial assistance, training, and public information. Collateral and repayment enforcement mechanisms involved in lending to homeowner associations need to be tested. Technical demonstrations of the specific energy efficiency investment packages that produce the highest returns under specific Lithuanian conditions are also important. Finally, legal and financial arrangements necessary for long-term commercial bank lending to homeowner associations need to be tested.

It is also uncertain how willing homeowner associations will be in practice to borrow capital and assume the risks of such loans. Social survey results are mixed on this point; some households have indicated on surveys that they are willing to borrow for energy efficiency improvements, but this willingness appears to decline if a loan puts title to their dwelling at risk (see Annex D). Through privatization, a dwelling may be the first real property that residents have ever owned, so they will be understandably reluctant to put this property at risk.

It is clear that an extensive learning process will be required to produce changes in the behavior of households and homeowner associations necessary for successful housing-sector reform. Given the widespread public mistrust of available information in FSU countries, working examples and models will be more effective learning tools than abstract information. This project will generate those examples, providing a base of reliable and credible information on technical measures, financial mechanisms, and institutional models.

5.5 Project Monitoring and Evaluation

Building renovations to improve energy efficiency in FSU countries will continue to have an experimental character until much greater technical, institutional, policy, and legal experience is accumulated. Even though models of project finance and implementation may be conceptually well thought out and designed, real implementation will offer the first test of their validity. Implementation will be a key source of new information and insights that can be used to refine or reject project concepts and generate new, more appropriate ones. In this context, monitoring projects for learning is even more important than monitoring for assessment.

In addition to monitoring and evaluation of a given project's targeted results, the project's impact n the broad market for energy efficiency renovations can also be evaluated. There are several measures of market impacts: (a) dissemination of information, ideas, and skills; (b) the sustainability of new institutions, legal frameworks, and knowledge bases; (c) the replication of project activities in other geographical locations and among groups not directly related to the original project; and (d) broader "market responses" in terms of the evolution of market institutions related to information, consulting, financing, construction, and contracting.

Two categories of monitoring and evaluation are discussed below: (a) technical monitoring and evaluation of retrofits and energy savings, and (b) social and institutional monitoring and evaluation.

Technical Monitoring and Evaluation

Technical monitoring and evaluation help determine financial returns, increases in occupant comfort, and fuel savings achieved in a specific project. Although it is called "technical" monitoring, this type of monitoring also includes social surveys for two reasons: (a) perceptions of occupants are important indicators of increased comfort (supplementing more technical indicators), and (b) actions (or potential actions) of occupants are important determinants of the energy savings and financial returns achieved from certain types of energy efficiency measures.

Sources of data for technical monitoring may include:

- Heat, hot-water, and gas meter readings
- Historical and current heating consumption and payments from household bills
- Climate data--daily average temperatures and daily and seasonal variations
- District-heating system actual supply temperatures and operating regime temperatures
- Building thermal characteristics
- Building heating equipment characteristics
- Indoor temperature and humidity measurements
- Building air-infiltration-rate measurements
- Household surveys

Technical monitoring involving metering that goes beyond a building-level commercial heat meter can be quite expensive. Nevertheless, for larger experimental projects, technical monitoring can be quite cost-effective because the design of later investments can benefit from the results of earlier investments.

For social surveys, baseline information should be gathered early in a project to allow comparison with data reflecting the outcome of the investments. Thus prior to any building retrofit activity, initial occupant surveys should identify: (a) what is important to the occupants and (b) how existing occupant behavior is likely to impact the effectiveness of different retrofit technologies. Follow-up surveys immediately after installation of retrofits should determine if there are ways to reduce the disruption to occupants. Also, surveys should be planned approximately one heating season following the first retrofits to determine to what extent occupants have found the retrofit measures acceptable. Information from these surveys will present an overall evaluation from the occupant perspective. The information also will identify any issues about occupant behavior that could defeat the effectiveness of the retrofits.

There are two important aspects of technical/economic evaluation of the retrofit installation process and the retrofit performance--actual costs and actual energy savings. The actual costs of the retrofit installation should be evaluated, and if forecasted total installed costs differ dramatically from actual costs, then forecasted investment returns need to be corrected. In addition, operation and maintenance costs of the retrofits should continue to be monitored and evaluated for their impact on project returns.

The second aspect of technical/economic evaluation involves the actual measurement of energy savings using metered energy-consumption data and the other data described above. Ideally, metered consumption data should be collected for one full heating season prior to retrofits to establish a baseline. After retrofits are completed, metered data should be collected during another full heating season. Then, a comparison of energy consumption can be made, adjusting for weather differences between the two years (and differences in district-heating supply). Software programs exist for this type of comparison; for example, the Enterprise Housing Divestiture Project will use a model called RusFEDS, a model calibrated against 24 different Russian multifamily building types. RusFEDS will be used to determine what the energy consumption would have been in the retrofitted buildings had no energy efficiency retrofits been made. The difference between actual building consumption with retrofits and projected building consumption without retrofits, using the same weather data, will quantify the effect of the retrofits during the first year following installation. Using this information and weather data reflecting the long-term averages for each city, RusFEDS can be used to adjust previous forecast performance and financial savings over the life of the retrofits. Gas metering in conjunction with household surveys is also important to establish whether gas consumption for heating, with gas kitchen stoves, has changed from the baseline. Gas-metering results will affect the overall evaluation of economic, energy, and fuel savings.

For large retrofit projects carried out over several years, early assessment results can be used to improve the performance of later retrofits phases. A large project in many buildings might be carried out by a municipal government, for example. In this type of project, baseline data should be collected as quickly and as early as possible, technical and economic performance should be evaluated against the baseline, and corrective actions taken for later retrofits to improve investment returns of the remainder of the project. For collective household investments in energy efficiency, a central clearinghouse or monitoring and evaluation service (public or private) can make results from completed retrofits available to associations and designers undertaking similar retrofits in similar buildings nearby. Ideally, project results should be kept in the public domain, which argues for public funding of some monitoring and evaluation activities.

Social and Institutional Monitoring and Evaluation

Because energy efficiency projects in residential buildings in FSU countries are social, financial and institutional experiments more so than they are technical ones, the social and institutional lessons of these projects are the most important. Therefore, careful social and institutional monitoring and evaluation offers the greatest opportunity to learn from such projects and to apply the lessons to a wider context. Social and institutional monitoring is also critical for long-term project impact assessment. These impacts must be measured not only as energy saved and of specific project objectives accomplished, but also in how incentives evolve over time, how regulatory and policy measures are working in practice, how sustainable markets for energy efficiency equipment and services are evolving, how transaction barriers are being reduced, how new financing sources and mechanisms are emerging, and, in more general terms, how new learning is taking place among all stakeholders in the housing problem.

There are three goals of social and institutional monitoring, each with different indicators (Table 7). The first goal is to determine the effectiveness and success of the energy-related policies and capacity building strategies that were outlined in section 5.2. The second goal of monitoring is to evaluate how markets are responding over time to the policies and capacity buildings--whether investments are actually occurring. Finally, the third goal monitoring is to consider the long-term impacts of the market responses--what long-term impacts in the housing sector are occurring as a result of the investments. Specific energy efficiency investment projects can incorporate some degree of the first two goals, while the third goal is best done at a higher level of aggregation, perhaps by a public agency with long-term responsibility for transitions in the housing-sector. A variety of techniques can be used to monitor and evaluate each indicator shown in Table 7. These techniques include household socio-economic surveys, participant-observation, statistical data collection, simple record-keeping by project participants, market surveys, and interviews with officials and key private-sector agents.

Table 7. Sample Indicators for Social and Institutional Monitoring

Goal of monitoring	*Sample indicators*
Effectiveness of energy-related policies and capacity building	**Consumption-based metering and billing systems** • Number of households paying according to actual consumption **Homeowner association formation and operation** • Structure and functional characteristics of homeowner associations • Management capabilities of homeowner associations • Membership in homeowner associations • Homeowner association financial accounts / indebtedness **Information dissemination** • Increased investor access to technical information • Households and homeowner associations familiarity with technical opportunities, financial returns, etc. **Project management, procurement, contracting, and supervision** • Number of homeowner associations managing their own building renovations • Number of energy-service companies offering "turn-key" services • Existence of training or public-financed resources to develop these skills **Architect/engineering, consulting, equipment, and building-materials industries** • Number of firms offering building-renovation design and engineering services • Number of firms marketing equipment and materials for energy efficiency rehabilitation
Market responses to policies and capacity building	• Investment volumes in residential buildings by households and governments • Investment volumes in network rehabilitation by district-heating companies • Volume of commercial-bank lending for energy efficiency in buildings
Long-term assessment of the impacts of market responses	• Household satisfaction with housing and utility services and comfort • Affordability of utility costs to households • Speed of housing-sector transitions relative to other regions/cities (privatization, cost recovery, private housing maintenance firms, etc.)

5.6 Comprehensive Building Rehabilitation Projects

As mentioned in Chapter 2, the quality and energy efficiency of existing multifamily buildings in FSU countries is poor. In the long-term, most existing residential buildings will need renovation to remain habitable. In addition, energy and maintenance costs will eventually give way to comfort, amenities, building conditions, and market value as dominant housing concerns. However, because the cost of simply maintaining and operating the existing housing stock at a habitable level remains the most pressing issue, projects for comprehensive building rehabilitation are likely to be rare. Experience with extensive renovations of similar multifamily buildings in Eastern Europe, such in the former East Germany, gives some indication of the substantial costs of such retrofits (Weidleplan 1995). These more-extensive renovations are well beyond the financial means of households and governments in FSU countries today.

Nevertheless, to the degree that more-extensive building renovations are carried out, energy efficiency improvements can be carried out at the same time at lower cost and with greater returns than if the energy efficiency improvements were undertaken by themselves (see section 3.2). Danish studies clearly indicate that measures applied to a building’s outer shell (i.e., insulation and improved windows) or within the walls (i.e., new hot-water pipes and ventilation) are much more cost-effective when undertaken during overall building rehabilitation. Thus any residential building rehabilitation project in FSU countries should include an energy efficiency component. There are different ways to accomplish this goal. Building codes and standards that dictate increased energy performance levels from rehabilitation are one common method. In Sweden, for example, improved thermal performance from rehabilitation is a formal requirement for securing a rehabilitation loan, similar to other standards for electrical wiring, plumbing, and fire safety. In the process, the increased asset value of a more energy-efficient building should increase credit-worthiness for such loans.

CHAPTER 6
CONCLUSIONS

This report concludes that large opportunities exist for energy efficiency improvements with attractive financial returns in multifamily residential buildings. Achieving these returns is technically well understood and straightforward (given good building-audit data). The key challenges are financial, social and institutional. These challenges include, for example, forming homeowner associations; developing consumption-based metering and billing for heat, hot water, and gas; creating utility regulations that encourage energy efficiency investments on the supply side and that allow maximum financial returns from investments on the demand-side; fostering managerial capabilities and collective decision-making within homeowner associations (complicated by wide variations in income among households in the same building); providing long-term financing and collateral mechanisms; and increasing the capabilities and number of local design and construction firms.

These challenges demand flexibility in energy efficiency investment projects. Projects must encourage learning, include controlled experimentation, and accommodate failure. Some learning will be related to the cost and performance of energy efficiency technologies themselves, but most learning will be related to the process of establishing new institutions, incentives, regulatory regimes, and capabilities for investment decision-making and project implementation. The optimal policies and capacity-building strategies will emerge in the medium and long terms, but important approaches are already apparent, as discussed in Chapter 5. And as officials, households, and private firms learn and develop increased confidence to tackle these problems, the rate of energy efficiency improvements will accelerate.

The Housing Problem and Energy Efficiency

A variety of important transitions in the housing sector in FSU countries--the "housing problem"--have emerged as a high development priority since the demise of the Soviet centrally planned economy in 1991 (see Chapter 2). These transitions are made much more difficult by the high costs of housing and utility services relative to household incomes and municipal budget revenues. Infrastructure dominated by multifamily buildings and large district-heating systems is costly to operate and maintain because of poorly insulated buildings, poorly controlled district-heating distribution systems, inadequate or inappropriate utility management and regulation, and lack of competitive housing maintenance. Many national and municipal governments must subsidize housing and utility costs and provide targeted housing allowances. Governments face political difficulties in recovering the full costs of housing and utility services from households because many households cannot afford the full costs. Apartment privatization has not given households the incentives or means to reduce costs themselves for three reasons: (a) fixed-cost payments for heat, hot water, and gas, due to lack of meters, do not provide effective incentives for households to make energy efficiency investments; (b) a lack of heat controls prevents households from reducing energy consumption in response to higher prices; and (c) collective decision making by homeowner associations, necessary for most energy efficiency improvements, has been slow to emerge.

Technical studies and project experience from several FSU countries demonstrate that packages of energy efficiency measures in multifamily residential buildings offer technical opportunities to reduce energy consumption by up to 25 to 30 percent at attractive economic and financial rates of return, while maintaining existing indoor comfort levels or simultaneously improving comfort (see Chapter 3). Basic packages of technical measures in most buildings can be designed with payback periods of 5 years or less. Payback periods of 5 to 10 years are common for more inclusive packages of measures. Energy consumption reductions of up to 50 percent are possible with extensive retrofit packages although payback periods are significantly longer, extending to more than 20 years in some cases. A basic package of measures can cost from $300 to $900 per apartment, a more inclusive package can cost from $600 to $1,300 per apartment, and an extensive renovation can cost from $1,500 to $3,000 or more per apartment.

Technical measures can be grouped into three categories: (a) passive-technology measures such as insulation, ventilation improvements, improved heat balancing and other heating-system improvements, and low-flow shower heads, which all reduce the energy required to produce given levels of comfort and service without any occupant intervention; (b) behavior-related measures such as valves and controllers, which allow occupants to regulate and control energy consumption to desired levels of comfort and service; and (c) meters, which alter the way heat payments are calculated and create incentives for energy efficiency investments and energy consumption reductions. Most technical measures must be applied to the building as a whole rather than to individual apartments. The largest and most cost-effective opportunities for energy efficiency are related to heating and hot water, although improved efficiency of electric and gas appliances, such as stoves, refrigerators, and lights, is also possible.

The linkages between energy efficiency investments and the housing problem mean that energy efficiency improvements are an important compliment to policy reforms in accelerating transitions in the housing sector in at least three important ways (see Chapter 4). First, technical measures to reduce energy consumption also reduce the operating costs of buildings and can delay or eliminate the need for future investments in energy-supply infrastructure. Reduced operating costs and delayed investment requirements can improve the willingness of municipal governments and eventually tenants to accept divested housing from enterprises. Reduced operating costs and delayed investments can also allow greater and/or more accelerated cost-recovery from households because the full costs become more affordable. Second, heat and hot-water metering, coupled with consumption-based billing, create incentives for households to reduce energy consumption and invest in energy efficiency measures. The need to collectively reduce energy consumption in buildings can, in turn, stimulate the formation and operation of homeowner associations, which is an important step toward greater private responsibility for housing. Third, building-level metering, coupled with consumption-based billing, shifts the full costs of district-heating distribution losses from consumers to district-heating companies. This shift places both incentives and responsibility for distribution losses with the same agent--the district-heating company--and can support transitions in utility management and supply-side cost reductions.

Conversely, transitions in the housing sector have a large influence on the incentives for, transaction barriers to, and returns possible from energy efficiency investments. Incentives and transaction barriers are influenced differently depending on the potential investor--whether a single entity like a municipal government or a private enterprise, or a collective entity like a group of households making decisions through a homeowner association. The influences of housing-sector conditions on energy efficiency investment incentives, transaction barriers, and returns are outlined below:

Incentives (section 4.3). Federal or municipal government incentives to invest in energy efficiency can depend on a number of conditions, including: (a) subsidies for heat and hot water (level of cost recovery); (b) energy regulation that affects the actual costs of utilities to the government; (c) the possibility of avoided investments on the supply-side; and (d) the costs of targeted housing allowances to low-income households for utility payments. Likewise, household incentives to invest collectively in energy efficiency are affected by a number of conditions: (a) the energy tariffs they pay; (b) the extent to which their apartments are privatized; (c) whether their energy payments are fixed or based on actual consumption; (d) whether energy is metered at the building-level or at the apartment-level; (e) the size of their household income and affordability of investments; and (f) their views of existing comfort.

Transaction Barriers (section 4.4). Energy efficiency investments may not occur even if the financial returns are acceptable and the proper incentives are present because of transaction barriers. Overcoming transaction barriers means providing or enhancing some combination of: (a) information about technical opportunities and their associated costs, energy savings, and financial returns; (b) managerial and technical capabilities of homeowner associations, municipal governments, and/or third-party intermediaries (for specifying, contracting, and supervising); (c) the ability of households to reach investment decisions collectively through homeowner associations; (d) the availability of long-term credit; (e) adequate collateral and/or guarantee mechanisms for loans; (f) regulations and institutions for consumption-based heat and hot-water metering and billing; and (h) the capabilities and number of design and construction firms.

Returns (section 4.5). Energy efficiency investments offer a number of different types of returns. Some returns are financial, such as reduced utility bills, reduced building maintenance and repair costs, avoided investment costs of new energy supply capacity, and increased housing asset values. Other types of returns include: (a) increases in indoor comfort (changes in indoor temperatures and other comfort parameters), especially in the case of underheated or poorly balanced buildings; (b) reduced air pollution from fuel combustion; and (c) improvements in macroeconomic balance-of-payments (and increased investment ratios) from reductions in energy imports. The degree and distribution of these returns depends on several factors, including: (a) energy prices and investment costs; (b) subsidies and expenditure-sharing arrangements; (c) building characteristics; (d) existing level of energy delivery and services; (e) heat-supply markets and institutional structures; (f) district-heating system technical characteristics; (g) characteristics of power plants or heating boilers; (h) energy policies and regulations and the capabilities of regulatory authorities; (i) the level of development of real-estate markets and the marketability of buildings; and (j) the volume of energy imports and domestic energy production.

Energy efficiency investments are further constrained by two significant conditions: (a) the structure of targeted housing allowances to lower-income households for housing and utility costs; and (b) the variation in socio-economic status and household income among households living in the same building (section 4.7). Targeted housing allowances limit incentives of low-income households to invest in energy efficiency because the allowances effectively put a cap on total monthly heat and hot-water payments regardless of consumption (provided total payments are above the subsidy threshold). The wide variation in income among households living in the same building results in wide variations in affordability of housing costs and investments, and can affect the ability of homeowner associations to reach collective investment decisions. While differentiation of housing occupancy based on income is starting to happen as real-estate markets emerge, this will be a very slow process, and the social issues involved are not easy to address.

Investment-Project Design and Implementation

A development-oriented investment project that incorporates energy efficiency can begin with the specific needs and objectives of housing-sector transitions and an analysis of how energy efficiency investments can support those needs and objectives (see Chapter 5). The project design must then specify how to accomplish the desired energy efficiency improvements. Various combinations of energy-related policy development, institutional capacity building, and technical assistance may be necessary in conjunction with the investments themselves. Examples of policy development and capacity building that are important in the context of energy efficiency investments include (see section 5.2):

- Provide technical assistance to municipal governments for design, specification, procurement, construction supervision, certification, and project management of energy efficiency improvements;

- Provide technical assistance to municipal governments in the areas of energy tariff regulation, registration of homeowner associations, planning for full recovery of utility and housing costs, establishment of housing allowance programs, and competitive bidding of housing maintenance services;

- In conjunction with investments in heat, hot-water, and/or gas meters, support the necessary administrative, technical, and regulatory capabilities and institutions for consumption-based metering and billing systems;

- Support development of the necessary regulations and provide technical assistance to district- heating companies to address any necessary technical, legal, and/or marketing changes that must accompany reduced residential energy consumption, and to allow district-heating companies to respond to new incentives to reduce distribution-system losses;

- Encourage the formation and operation of homeowner associations, and provide assistance and/or models that address important issues, such as maintenance and utility services responsibilities, association membership and obligations, charter and bylaws, and taxes and financial records;

- Provide information, education, training, and technical assistance to homeowner associations to encourage private initiative in energy efficiency improvements, and to build capacities for effective collective decision making, project design, contracting, and project management;

- Provide assistance to commercial banks to help them understand and appraise the technical and financial merits of energy efficiency projects in residential buildings;

- Support functioning markets for architect/engineering firms, consulting firms, and energy-service companies, by helping these firms to understand the technologies, economics and financing involved, and to understand the needs and constraints of potential customers;

- Support the development of domestic building-materials and equipment industries to supply the residential market for building rehabilitation;

- Provide public information and education programs to address household concerns related to many of the above issues.

The Russian Federation Enterprise Housing Divestiture Project and the Lithuania Energy Efficiency/Housing Pilot Project are good examples of project design, for two very different policy objectives (see sections 5.3-5.4). In the Russian project, municipal government investments in energy efficiency reduce the costs of operating residential buildings in conjunction with other housing-sector policy measures that are also designed to reduce operating costs; together the investments and policy measures support the divestiture of enterprise housing. In the Lithuanian project, energy efficiency investments by homeowner associations with commercial bank financing support domestic policies to sustain the privatization of housing and the development of commercial lending in the housing sector. Because transitions in the housing sector are ongoing, these two projects have a transitional and pilot/experimental nature. The experience from these two projects should be carefully monitored and disseminated because it will prove valuable to future projects.

New information and experience during the next several years will provide additional knowledge and insight into the most effective ways to address the housing problem and improve the affordability and comfort of residential buildings in FSU countries. In the future, publicly funded technical demonstrations should give way to commercially funded retrofits. Actual utility bills and loan performance for these “commercial” retrofits will give new insights into costs, returns, and affordability. Municipal regulations will develop that address the multitude of regulatory and institutional issues discussed throughout this report. Social understanding of energy efficiency and the problems of housing costs, services, responsibility and decision making will grow. Functioning private markets will develop for energy efficiency services and products.

As experience expands it should be captured and understood through proper monitoring and evaluation (see section 5.5). Technical monitoring and evaluation will help to determine whether anticipated financial, comfort, and fuel-savings returns from specific projects were achieved. But more important than technical monitoring and evaluation is social and institutional monitoring and evaluation. This monitoring should capture the changing incentives and willingness to invest in energy efficiency, innovative institutional and regulatory approaches, the reduction of transaction barriers, the evolution of markets for energy efficiency products and services, the investment volumes occurring as a result of targeted policy and capacity-building interventions, and ultimately the aggregate social and economic benefits of energy efficiency investments.

District-Heating Systems: The Systemic View

In conjunction with energy efficiency investments in residential buildings, improvements in district-heating systems are also important (see section 3.6). Improvements to district-heating systems typically fall into one of three categories: more efficient heat production in boilers, improved regulation and control of heat flows within distribution systems, and improved insulation of distribution system pipelines. In general, the debate about the relative merits and timing of improvements on the supply-side versus the demand-side of district-heating systems has not produced clear consensus. Rather, this debate has indicated that both supply-side and demand-side improvements should be addressed simultaneously in ways that make short-term economic sense while at the same time confronting the long-term issues. Short-payback-time improvements in district-heating systems in conjunction with renovations to the buildings they supply are important. In general, the district-heating and building energy efficiency problem lends itself well to concepts of least-cost, integrated-resources planning concepts when looked at from a system viewpoint.

Autonomous sources of heat are a technology that should be considered carefully in the context of both supply-side and demand-side improvements to district-heating systems (see section 3.7). There is no question that Soviet-era district-heating systems will undergo long-term technical and institutional restructuring (and are doing so already). A key element of that restructuring will be the transition to much greater use of autonomous heating boilers serving individual buildings and greater use of apartment-level heaters. Although experts in both FSU and Western countries recognize that well-maintained district-heating systems with cogeneration are usually more efficient than autonomous heat sources, these experts also conclude that greater economic and technical efficiency can be achieved with autonomous heat sources in the appropriate geographical and technical circumstances in FSU countries. In the longer-term, increased household incentives to reduce energy costs, through improvements like metering and controls, coupled with competitive heat-supply markets, may hasten the spread of autonomous heat sources.

This report advocates concurrent investments on both the supply and demand sides, and concludes that energy-related policies and capacity building should also address both the supply and demand sides of district-heating systems. As discussed in sections 3.8 and 4.5, the actual fuel savings (and thus economic and air-quality returns) from energy efficiency investments in buildings depend on the technical and institutional characteristics of district-heating supply systems and heat-supply markets. Energy-related policies and capacity building that integrate the supply and demand sides are especially important in the context of three other heat-supply-market issues (see section 4.8): (a) incentives to reduce district-heat distribution losses once building-level heat meters are installed; (b) heat meter ownership, installation, and maintenance;

and (c) district-heating demand that is displaced (and/or supplemented) by electric and gas heating. The important question is not whether to start on the supply-side or on the demand-side, but what are the financial, institutional, social, and policy approaches that will produce the most cost-effective solutions.

Opitz (1994) echoes these conclusions in explaining the importance of a "systemic view" of district-heating systems:

> The systemic view was found to be important throughout the analysis, as indoor climate conditions, heating system efficiency, and potential energy savings were determined not only by building characteristics and the action taken by building occupants, but also by the characteristics of the district-heating system and the behavior of central heat station operators. Thus future efforts at institutional reform in the urban housing sector should account for all major causes of space-heating energy efficiency. In other words, programs providing economic incentives for building occupants to improve energy efficiency may be ineffective if the programs focus only on improving building envelopes--such programs should include incentives for improving control of heating systems, parts of which are beyond the control of building residents. (p.171)

This systemic view is not always easy to achieve operationally. Corporations, governments, and multilateral agencies tend to be organized by sector, so energy in buildings is either viewed as an "energy sector problem" or as a "housing sector problem," but not both. For example, there are separate organizational units within the World Bank to address the energy and housing sectors. Such divisions require special managerial emphasis and attention to cooperation, coordination and integration in order to achieve this systemic view.

Future Research and Project Preparation Activities

To support future projects, research and project-preparation activities should focus in several key areas:

Technology Choice. Research should aim to understand and evaluate the choices that households and municipal governments are likely to make in selecting technologies for energy efficiency, and the implications of those choices for the housing and energy-supply sectors. Very little data exists about occupant reactions to recent demonstration projects in FSU countries and the technologies employed. Research should identify the technologies that will provide the highest returns in the future--not just in terms of reduced expenditures on energy, but in terms of increased housing asset value, reduced investment costs for energy-supply capacity increases, improved indoor comfort, increased environmental benefits, and improved macroeconomic balance of payments.

Affordability and Social Decision Making. Affordability and social decision making are key to any energy efficiency project. Far too little is known about how much households are willing to invest in energy efficiency, what sorts of returns they require, how real or perceived risks can be reduced, how fast households will respond to new incentives, and what sorts of collective decisions about energy consumption and energy efficiency investments can be reached in collectively owned buildings where rich and poor households live side by side and must share the burden of energy and investment costs.

Consumer Education and Capacity Building. What information and education strategies are most effective in reaching households and municipal governments to educate them about the opportunities for energy efficiency and the ways in which they can take initiative themselves? What specific capabilities are needed by homeowner associations, financial institutions, municipal governments, district-heating companies, and private-sector firms to enable them to initiate and implement energy efficiency improvements? What are appropriate vehicles for providing that increased capability? Pilot projects should provide valuable information about the financial, institutional, and social aspects of energy efficiency investments; these projects should help identify the specific needs for assistance, training, and public information.

Collateral Mechanisms. More experience is needed with regulations that create collateral and repayment enforcement mechanisms for private-sector lending to homeowner associations. And further analysis and recommendations are needed on the potential role of national and municipal governments in reducing investment risk, especially during the early years when energy efficiency investments in residential buildings remain relatively rare.

Heat-Supply Markets, Municipal Energy Policy, and Regulation. How should consumption-based heat and hot-water metering and billing be implemented? What types of legal, administrative, and regulatory structures are most effective to support this metering and billing? How should district-heating companies be regulated and encouraged to respond to changes in residential heat demand and to make energy efficiency improvements to distribution systems? What types of policies and regulations will promote an integrated least-cost heat supply approach encompassing both supply and demand sides?

Autonomous Heating Boilers. Research should investigate and reduce the information gaps and the technical, legal, and institutional uncertainties associated with the spread of autonomous heating boilers. Research should also address questions of ownership and maintenance, the role of these boilers in evolving heat-supply markets, and the implications for future development of gas-distribution and district-heating systems of the spread of these boilers.

The Role of Development Institutions

This report has made clear the role for the World Bank and other development-oriented institutions in making residential energy efficiency improvements in FSU countries. Financing for energy efficiency improvements, in conjunction with energy-related policy development and institutional capacity-building, will support housing-sector development goals. Eventually, private long-term financing should become available. In the meantime, development institutions can provide financing and technical assistance to create institutional, regulatory, technical, and social models and capabilities that will support such investments. Without such involvement, homeowner associations and municipal governments will have to surmount transaction barriers on their own; they will be forced to invest in energy efficiency based on accumulated savings rather than credit financing; and as a result they will respond to increased incentives only slowly. Energy efficiency retrofits will be possible, but the pace of such improvements will be much slower than if development-oriented financing and technical assistance are provided, and if resources are devoted to learning from social and institutional experiments and to disseminating lessons learned. Because housing and utility costs are high relative to what households and governments can afford, partly due to serious energy inefficiencies in buildings and district-heating systems, housing and utility costs will remain a serious problem unless development assistance is provided. Unless housing and utility services are more affordable, there is a serious risk of housing stock deterioration. Without development assistance for energy efficiency improvements, housing-sector transitions will occur much more slowly. Slower transitions will retard growth in living standards and social development. Thus the investment strategies for energy efficiency suggested by this report can have a profound impact on future economic and social development in FSU countries.

ANNEX A
CASE STUDIES OF ENERGY EFFICIENCY RETROFIT PROJECTS IN ESTONIA, LITHUANIA, THE RUSSIAN FEDERATION, AND UKRAINE

This annex describes several case studies of actual building-retrofit projects. An extensive retrofit and metering project in the city of Ryazan in the Russian Federation is described separately in Annex C. The primary literature reference for each case study is given in each subheading. The information from these references is supplemented by case study descriptions by Martinot (1995a and 1995b) and Schipper et al. (1994), which contain primary field research data and other unpublished reports obtained through field research. The case studies described in this annex are summarized in Table 4 in Chapter 3.

In almost all of these case studies, there is considerable uncertainty about the estimated energy savings and payback periods, for reasons discussed in section 3.5. None of the case studies except for one (Rolén et al. 1994) contained a truly scientific "before and after" analysis of the impact of retrofits on energy efficiency, according to the methodology recommended in section 5.5 (and used in the Ryazan metering and retrofit demonstrations--see Annex C). The majority of the projects rely on proxies for a comparison reference, usually a nearby identical building that has not been previously calibrated to the retrofitted building, and/or analytical estimation of the "before" consumption. Other projects, such as the Haljala, Estonia experiment with thermostat radiator valves, make no attempt at a sophisticated estimation, but simply compare aggregate (town-level) energy consumption before retrofits to aggregate energy consumption after retrofits.

The project costs and estimated payback periods given for these case studies include only the direct costs of materials, equipment, and installation (plus value-added taxes). They do not include the indirect costs of project management, auditing, insurance, and procurement administration unless noted. In general, most economic and financial analyses in the literature (see also Annex B) do not include these indirect costs. In many projects the indirect costs are not provided or clearly defined. In other projects these costs are given but vary widely--from 10% to 100% of the direct costs--because of the one-of-a-kind, demonstration, and experimental nature of many of these projects. Experimental projects may require institution building, and technical design, analysis, and evaluation that would not ordinarily be conducted. The actual indirect costs during a non-demonstration project will vary greatly depending on the project size, prior information and experience, and participants' contracting and administrative requirements and capabilities.

Unless noted, a heat price of $20/Gcal is used for all payback-time calculations.

Case Study 1: Tallinn, Estonia (Aro 1995; Axovaatio 1996)

A renovation experiment in one typical concrete-panel, five-story, 60-apartment building (3,500 m^2) was completed in the Õismäe district of Tallinn in 1994. This project was financed by grants from the Estonian State Energy Department, the Finnish Ministry of Environment, and the Finnish

Ministry of Trade and Industry. The Finnish contribution paid for a Finnish consulting company to do the design, procurement, and construction supervision work, plus the Finnish equipment and materials used for the project. The Estonian government's contribution paid for Estonian construction labor and materials purchased in Estonia. The contract was signed in August 1994, and installation was completed by November 1994.

Technical Measures: Improvements included roof insulation (15mm), weather-stripping of windows and balcony doors, additional insulation of balcony doors, exterior wall insulation along the eaves under the roof on facade walls (100mm), exterior wall insulation on the two gable (windowless) sides of the building (50mm), new substation with heat regulation and heat exchangers for both heating and hot water, new radiators and radiator thermostat valves, riser balancing valves, a hot-water circulation pump, active roof ventilation fans and renovation of the ventilation systems in each of the four entrance subsections of the building, replacement of the hot and cold water pipes in the building, conversion from a one-pipe system to a two-pipe system for heating, replacement of all hot and cold water taps in kitchens and bathrooms, new mastic applied to inter-panel exterior joints, sandblasting and painting of the exterior walls, and renovation of balconies.

Total Cost: Total cost was 4.4 million EEK ($370,000), including 430,000 EEK ($36,000) for consulting, supervision, transport, and insurance. If non-energy efficiency work is excluded (wall sand blasting and painting, staircase and balcony renovation), indirect costs are excluded, and domestic water pipes and taps and ventilation fans are excluded (their energy-efficiency value was questionable), the cost is 2.0 million EEK ($170,000).

Energy Savings: Energy savings were originally estimated at 40% to 55%. This included a space-heating reduction of 30% to 40% (including 20% from exterior insulation and 10% to 20% from better heating control and ventilation), and 10% to 15% from decreasing (tap) hot-water consumption by 30% to 50%. Follow-up metering during the 1995-96 heating season compared energy consumption with an identical neighboring building (although the buildings were not calibrated before the comparison, so the results are somewhat uncertain--see section 3.5). The results of this metering showed that heating consumption was 25% to 30% less than in the reference building, which is somewhat less than the 30% to 40% estimated originally for space-heating reductions. Hot-water consumption comparisons were not available because the hot-water meter was stolen during the experiment.

Simple Payback Period: The payback period is 14 years assuming a “curtailed” heating supply regime (250 to 300 kWh/m^2/yr), an estimated energy savings of 45% (35% heating and 10% hot water), and the reduced project cost of 2.0 million EEK. This payback period becomes 11 years if estimated savings in building maintenance costs (45,000 EEK/yr) are included in the analysis. Payback period becomes 7 years assuming a “normal” heating supply regime (500 kWh/m^2/yr).

Case Study 2: Tallinn, Estonia (Rolén et al. 1994)

A demonstration project of residential energy efficiency measures took place in the Mustamäe district of Tallinn during 1991-93. The project was financed by the Swedish aid agency BITS. The project was a combination of before-and-after comparison and side-by-side measurements involving a retrofitted building and a reference building. Technical measures included roof insulation, weather-stripping, a new substation, building-level heat control, additional window panes on the top floor, and heat meters.

Two typical nine-story, 72-apartment (5050 m²) neighboring buildings were selected, one as the renovated building, and the other as the reference building. Initial energy inspections and measurements were made, followed by renovations in the fall of 1992. During the winter of 1992-93, energy consumption and indoor temperatures were monitored and recorded. The indoor climate was also studied using a questionnaire given to residents.

Potential energy savings from this project were initially estimated at 28%. Actual energy savings of 15% compared with the reference building were obtained during measurements in the 1992-93 heating season, after appropriate analytical adjustments. The researchers noted that because of lower than normal heat supply during this period, the 15% savings is less than it would be under normal heating conditions. The energy signature of the retrofitted building showed that the building's energy consumption was much better adjusted to the outdoor temperature than was the reference building. Residents in the retrofitted building also obtained a more reliable supply of hot water and experienced an improvement in air quality.

During project preparation, thermostat valves for radiators were considered but excluded from the design. Balancing valves on each riser were considered sufficient. The indoor temperature variation among apartments was not great, and with additional window panes on the top floor to keep top floor apartments warmer, the building-level controls and balancing valves were deemed sufficient.

The project design also considered repairing panel joints, but concluded that panel joints were tight (based on pressure tests) and not an obvious energy efficiency problem.

Technical Measures: Improvements included roof insulation, window weather-stripping, a new substation with heat exchangers for both heat and hot water and building-level heat control, riser balancing valves, insulation of heating and hot-water pipes in the basement, additional window panes on the top floor, and heat meters.

Total Cost: Total cost was 680,000 EEK ($60,000), at 1993 price levels, using primarily Swedish equipment and materials including some discounts from vendors.

Energy savings: Energy savings were 15%, as measured during February through April 1993, based on prior-year calibration of target building and a reference building, comparison of target and reference building in year the savings were measured, and adjustment for degree days and indoor room temperatures.

Payback Period: Actual payback period is 14 years based on 15% energy savings. The payback period originally given in the project report for a speculative future project using all Estonian materials is 8 years, based on a $17/Gcal heat price, estimates of project costs supplied by Estonians (which have been proven too low), and a calculation error in the project report. If the calculation error is corrected, the original estimated payback period becomes 10 years. A payback period of 6 years can be expected if the full 28% energy savings originally estimated is achieved (the report states 4 to 5 years, which must be corrected for the calculation error noted above).

Note: prior to retrofit, energy savings were estimated at 28%, costs were estimated at 550,000 EEK ($45,000), and payback period was calculated as 6.5 years. The reasons given for the discrepancy between these estimates and the actual results achieved are several: a higher ventilation rate, lower district-heat supply temperatures, incomplete window retrofits on the top floor, and suboptimal adjustment of the heating system within the building.

Case Study 3: Tallinn, Estonia (Danish Building Research Institute & COWIconsult 1995a)

In 1994, the Estonian Ministry of Environment, the Estonian Building Department, and the Danish Ministry of Energy supported a retrofit demonstration in one five-story building in Tallinn, Estonia (40 apartments, 2630 m²). This project involved several different energy efficiency measures, including insulation, heating controls, building energy management, consumption-based payments by individual households for heat and hot water, and investigation of changes in indoor humidity from window weather-stripping.

Significantly, this project attempted to analyze the effects of consumption-based billing of each household, which was based on building-level heat meter readings allocated among all apartments. Allocation was done on the basis of evaporative heat meters on each radiator. Very few experiments of this type have been conducted (for one other, see Case Study 6 below). The project results showed that if actual apartment-level consumption were to be used as a basis for billing, individual household payments would vary from 50% to 125% of the fixed payments that households had been making. Thus if energy consumption were approximately 25% lower after retrofit, no household should pay more than it was paying before, and most households would pay significantly less. The distribution of payments is quite large, with the highest household payment equal to 250% of the lowest payment.

Unfortunately, this project did not provide a true “before and after” comparison of energy consumption. Instead, energy consumption in the retrofitted building during the 1994-95 heating season was compared with measured consumption in another nearby building selected as a reference building. This other building was not identical to the retrofitted building, so the comparison had to be corrected for the different sizes and characteristics of the buildings. Thus there is a degree of uncertainty in the energy savings estimates and payback periods of this project.

Technical Measures: Improvements included attic insulation (150 mm), building-level heat control with heat exchanger, riser balancing valves, insulation of heat and hot-water pipes in the basement and in the attic, radiator thermostat valves, new circulating hot-water system with storage tank, heat allocators on each radiator, and hot-water cost allocators on hot-water supply pipes to kitchens and bathrooms in all apartments. Window weather stripping was not selected because the poor quality of the window frames would have made renovations costly.

Total Costs: Total costs were 920,000 EEK ($80,000) for materials and installation. Approximately 510,000 EEK ($45,000) of this was directly related to energy efficiency, with the remainder for renovation of the hot and cold water systems in apartments.

Energy Savings: Heat consumption was reduced by 16%, estimated using actual measurements during the 1993-94 heating season, plus measurements of the reference building, adjusted for differences in building sizes. If adjustments are also included for differences in indoor temperatures between the reference and the retrofitted building (the reference building was colder by an average of 1.5°C), then the estimated heat savings become 24%. Hot-water energy savings were also estimated at 24% (because of reduced hot-water consumption from the new circulating hot-water system). Thus combined heat and hot-water energy savings were estimated at 24%.

Payback Period: Payback period is 15 years using the lower cost figure of $45,000.

Case Study 4: Tallinn, Estonia (Swedish National Board 1995)

In 1994, the Swedish government through the Swedish National Board for Industrial and Technical Development (NUTEK) made a loan to the Mustamäe district, guaranteed by the Tallinn City Council, for renovation of four buildings in 1994. These four buildings are five-story concrete panel buildings with 80 apartments (4,700 m² each building). The total loan for 1994 was 4.1 million EEK ($340,000), plus an additional 0.3 to 0.4 million EEK from the Mustamäe administration, so the total cost per building is about 1.1 million EEK ($90,000). The technical measures in this project were very similar to those for Case Study 3 with a few exceptions. In Case Study 3, ventilation was also included, additional window panes were installed on part of the top floor, pipes in the basement were insulated but not replaced, and the front entrance doors were not replaced. In one building of the four in this project, a sloping roof with attic was installed over the original flat roof, while the existing flat roof was repaired and insulated in the other three buildings.

Technical Measures: Improvements included roof insulation and repair, new entrance doors and awnings, new heat meter, new substation, weather stripping of windows and balcony doors, replacement of heat and hot-water pipes in the basement, riser balancing, and ventilation system renovation. In one building, a new attic and sloping tile roof was installed on a previously flat roof.

Total Costs: Total costs were 4.5 million EEK for four buildings, or 1.1 million EEK ($90,000) per building average.

Energy Savings: Energy savings are estimated at 15% under a "curtailed" heat supply regime, based on the experience with an earlier retrofit in Tallinn (Rolén et al. 1994), but no actual performance evaluations were conducted.

Payback Period: A payback period of 20 years is estimated, using estimated energy savings and heat consumption, and an energy price of \$20/Gcal. Some of the measures included in the project did not reduce energy consumption, and if these are excluded from the calculation, the payback period is closer to 15 years.

Case Study 5: Tartu, Estonia (Fjärrvärmebyran 1994)

In conjunction with the World Bank's district-heating rehabilitation loan in Tartu, a monitoring, metering, and retrofit project was conducted in 1994 to determine the needs and cost-effectiveness of different building energy efficiency measures. Twelve buildings in all were included in the study, in four groups of three buildings each. The three buildings in each group were of different sizes, and each group of three buildings received identical technical measures. The first group was a reference group, the second had weather stripping applied, the third had weather stripping and automatic building-level heat supply control (based on outdoor temperature), and the fourth group had weather stripping, heat control, and also heat-riser balancing-valves. Using actual measurements, energy consumption was calculated for all buildings, these calculations were used to determine the energy savings associated with different specific measures, and payback periods were calculated. Payback periods for all measures were less than two years.

Three groups of four similar buildings each were involved, for a total of twelve buildings:
Group 1: 5 stories, 60 apartments, 4,500 to 5,000 m²
Group 2: 9 stories, 36 apartments, 3,000 m²
Group 3: 3 stories, 15 to 30 apartments, 1,500 to 2,500 m²

Technical Measures: each group of four similar buildings was retrofitted as follows:
Type 0: heat meter only
Type 1: heat meter, weather stripping of windows and balcony doors
Type 2: heat meter, weather stripping plus building-level heat control
Type 3: Type 2, plus riser balancing valves and hot-water heat exchanger

Total costs: For all building sizes and types, the costs of weather stripping were consistently about 4 EEK/m² (\$0.33/m²). The costs of building-level controls were consistently about 38,000 EEK (\$3,200) per building, which made their cost vary from 8 to 25 EEK/m² (\$0.66/m² to \$2.00/m²). Costs for the riser balancing valves were consistently about 3 to 4 EEK/m², or \$0.25/m² to \$0.33/m², across all building sizes. Costs for the hot-water heat exchanger were consistently about 43,000 EEK (\$3,600), which made its cost vary from 10 to 30 EEK/m² (\$0.85/m² to \$2.50/m²). Total costs for buildings with each of the four types of installations were:
Type 0: 25,000 (\$2,000)
Type 1: 34,000 to 44,000 EEK (\$2,800 to \$3,600)
Type 2: 72,000 to 85,000 EEK (\$6,000 to \$7,000)
Type 3: 120,000 to 150,000 EEK (\$10,000 to \$12,500)

Energy Savings: Comparisons with reference buildings across all three building groups showed 6% to 20% reductions for weather stripping, an additional 0% to 22% reduction for building-level heat control, and an additional -11% to +11% for riser balancing. For a "normal" heat supply regime, Fjärrvärmebyran estimates 10% savings for Type 1 retrofits, 25% for Type 2, and 26% for Type 3, compared to the theoretical (design) consumption of the buildings. The main problem with these estimates is that actual pre-retrofit measurements of building consumption are not available, so estimates must come from comparisons with design consumption or similar but uncalibrated reference buildings. During measurements, indoor temperatures were higher in Type 2 and 3 buildings because the injector pumps in Type 0 and 1 buildings combined with a curtailed heat supply regime produced below-design temperatures while the heat exchangers in Type 2 and 3 buildings resulted in design indoor temperatures. Taking the actual average comparative difference between buildings of Type 0 and 3 gives an energy savings of 20% for Type 3.

Payback Periods: The project report gives 0.9 years for weather stripping only, 1.6 years for weather stripping plus building-level heat control, and 1.8 years for weather-stripping, building-level heat control, and riser balancing valves. These payback periods calculations exclude the costs of the building-level heat meters, which in Type 1 retrofits was a substantial portion of the total costs. Payback periods are based on the design energy savings figures (10%, 25%, and 26%). These figures are suspect because of the problems of correctly estimating energy savings. For Type 3 retrofits, assuming 20% energy savings, the payback period is 2 to 3 years across all buildings.

Case Study 6: Haljala, Estonia (Virudan 1993, Martinot 1995a)

In early 1992 officials in the Viru district of Estonia contacted a Danish engineering firm for assistance in improving the energy efficiency of buildings in that region. The Danish company successfully obtained financing for this project from the Danish government for both auditing and equipment installation. Two towns were involved: Toila, population 1,200, and Haljala, population 3,300. The primary measures involved were radiator thermostat valves and building-level heat regulation systems. In fact, this was one of the few case studies with radiator thermostat valves installed on such a wide scale. In Haljala, 2,170 radiator valves were installed on individual radiators in six apartment buildings and nine public buildings (schools, offices, etc.). In addition, each building had heat meters and pressure regulators installed in the main boiler room in the basement. Evaporative-type heat meters were installed on radiators in six of the apartment buildings, and households were billed according to actual consumption--which proved to be a novel but failed social experiment (see below). In Toila, the project was begun in April 1993 and was completed and handed over to the municipality in June 1993. In Haljala, the project was begun in March 1993 and completed and handed over to the municipality in September 1993.

Most dwellings in these towns are served by a central district-heating plant although some single-family houses have their own boilers or electrical heating. The boiler plant in Toila has a capacity of about 30 MW. The distribution pipes are above ground, which, combined with poor insulation, results in approximately 20% loses of total energy production. Each of the buildings connected to the network has its own boiler room with pipe heat exchangers for hot water, and all radiator systems are direct with mixing loop. The boiler rooms have no energy or water meters; all billing is based on apartment size.

The three main phases of the projects were (1) to analyze the existing heating facilities; (2) to install energy meters, evaporation meters, and radiator thermostat values in apartments and municipal buildings to provide control and measurement of actual energy savings and to learn about equipment installation requirements; and (3) to establish Estonian-Danish joint ventures for commercial development of energy efficiency equipment. The project lasted from March 1993 to September 1993.

Retrofits in Haljala took place in six three-story buildings with 18 to 24 apartments each (1,100 to 2,100 m² each building).

Technical Measures: Improvements included radiator thermostat valves on all radiators, heat allocators on radiators, pressure regulators, and heat meters.

Total costs: about 1.5 million EEK for the entire project in Haljala (2,170 thermostat valves in 15 buildings), including nonresidential buildings. For the six buildings, reported costs were about 2,500 to 3,000 EEK ($200 to $250) per apartment, plus 200 EEK ($17) per year to operate heat allocators. There was some uncertainty about cost allocation in the project, and according to the author's estimates, the total cost per apartment appears closer to $250 to $300. Of this total cost, 65% was used for equipment, 20% for engineering and wages, 10% for freight, tools and training, and 5% for administration and miscellaneous costs. The labor in Toila was slightly more than one man-hour to install one radiator valve.

Energy Savings: An initial test installation in one pilot apartment led the project to anticipate energy savings of approximately 30% in individual apartments with existing heating plant operation. After the project was completed, a project estimate of the energy savings from the thermostat valves was based on a very rudimentary comparison of fuel cost savings between the periods January to April 1993 and January to April 1994 for the Haljala boilerhouse. The total fuel costs for the Haljala boilerhouse were 27% lower in the four-month period in 1994 than in 1993, even though average outdoor temperatures were considerably lower in the 1994 period. This analysis neglects several factors: (1) the different relative prices per unit of energy for the two boilerhouse fuels used (gas and oil); (2) the change in consumption by industrial consumers connected to the same boilerhouse from one year to the next; (3) the change in heating system supply temperatures from the first year to the second because of the change in outdoor temperatures or because of changes in operating regimes. Correcting for differences in fuel costs, calculations by Martinot (1995a) show that total heat production was probably about 40% less in the 1994 period than in the 1993 period. But the reduction could be partly attributed to reduced industrial consumption or lowered heat plant output during certain periods rather than reductions from operation of the thermostat valves. Because there is no “before” picture of energy consumption, estimation of actual energy savings is difficult. The variation in energy consumption of individual apartments with thermostat valves relative to design consumption was -50% to +20%, with many apartments consuming 15% to 20% less than design consumption.

Payback Period: Assuming energy savings of 15%, payback period should be 6 to 7 years. For households that choose to reduce comfort to economize on heat costs, payback periods should be shorter.

Radiator Heat Allocators: A Social Experiment with Apartment-Level Consumption-Based Metering and Billing

The social experiment with apartment-level consumption-based metering and billing in this project was unique among the available case studies. Residents in the six buildings with heat allocators on the radiators were charged for heat according to these meters for the first heating season, 1993-94. Monthly bills to residents during the heating season reflected per-m² charges, but at the end of the heating season residents received an additional bill or credit based on the actual consumption as measured by the heat allocators. Some residents paid significantly less than the per-m² basis, up to 1,500 EEK ($125) less, while others were billed more, up to 600 EEK ($50) more. Most of the residents who were billed an additional amount refused to pay it. Total heating bills for the heating season averaged 3,000 EEK/apartment ($250), so these figures represent -50% and +20% respectively of total heat consumption. The average monthly wage in Haljala in 1994 was 1,000 to 1,500 EEK/household ($85 to $125), so these figures represent 100% and 40% of the average monthly wage, respectively. More typical savings appeared to be in the 300 to 600 EEK/household ($25 to $50) range, or 10% to 20% of total heating costs.

In 1993-94, the retrofitted school building paid 40% less for heat than in the previous year, which is attributed to the installation of the thermostat valves and night setback controls in the substation. Measured consumption for the school in 1993-94 was 995 MWh (150 kWh/m²).

Before the second heating season (1994-95), a town meeting was convened and residents in five out of six of these buildings voted not to reinstall the heat allocators but instead to pay for heat on a per-square-meter basis. One reason for this sentiment, cited by an official of the Haljala municipality, was that residents didn't want to pay the 50 EEK ($4) charge per year per meter, which covered a new measurement element, royalties to the heat-allocator manufacturer, and measurement and analysis of the reading at the end of the heating season. A typical four-room apartment would have to pay 200 EEK per heating season, which represented about 7% of the total heating bill of 3,000 EEK/yr ($250/yr) which is the typical heat payment for a 50 m² flat. A second reason given was that those residents who had paid more in 1993-94 than they would have if billing was on a per-square-meter basis were naturally interested in reverting to the old system. A third reason was that some residents simply didn't understand the meters well enough or didn't think it was fair that different apartments should pay different amounts for heat.

As a result, in 1994-95, residents in five out of the six buildings were controlling their heat consumption according to their thermostat valves with an incentive only to maintain proper comfort and not to reduce total expenditure on heat for the entire heating season. The total heat savings in 1994-95 should thus have been less than in 1993-94 but probably still more than in years prior to the retrofits (this could be a subject of further evaluation).

Heat consumption for the six buildings (147 apartments total and 428 residents total, concrete-block construction, three stories) was monitored during the 1993-94 heating season and also during January 1995. The data for the 1993-94 heating season included the size of each apartment, the measured heat consumption for that apartment from the heat allocators, and the total heat consumption for the building. Most residents consumed heat during the 1993-94 heating season according to individual regulation of thermostat valves in each apartment while in January

1995 only one building had heat measured according to the heat allocators. Actual measured consumption of these buildings during the 1993-1994 heating season (9/1/93 through 5/1/94), is shown in Table A-1.

Table A-1. Actual Apartment-Level Heat Consumption in Six Buildings in Haljala

Address	*Bldg. size (m^2)*	*No. of apts.*	*Bldg. heat (MWh)*[a]	*Bldg. heat (kWh/m^2)*[b]	*Apt. heat, min. (kWh/m^2)*[b]	*Apt. heat, max (kWh/m^2)*[b]	*Ratio of max./ min. (%)*
Pollu 8	2127	36	649	305	195	465	240
Rakvere 6 (*)	1105	18	211	190	140	260	185
Rakvere 8 (*)	1282	27	264	205	130	325	250
Tallinna 6 (*)	1251	24	250	200	145	250	170
Tallinna 10	1113	18	295	265	185	290	160
Tallinna 16	1430	24	429	300	165	440	260

Note: The apartments consuming the minimum amount of heat were all located on the first floor of their respective buildings, except for one on the third floor, while those consuming the maximum amounts were located 50% on the first floors and 50% on the third (top) floors. All minimum and maximum apartments were those outfitted with heat allocators.

a. Total heat consumption is based on building-level heat meters. Heating includes both space heat and hot water except for those buildings marked with an (*), which only include space heat. An estimate was made in project documentation of the ratio of hot water to heating as 80%/20%, but there was no specific basis given for this estimate.

b. The average heat in kWh/m^2 is for the entire apartment building. The minimum and maximum values represent the total heating season consumption for the one apartment receiving the most heat and the one apartment receiving the least heat in that building. The metered consumption for individual apartments with heat allocators is based on the meter readings. Several apartments in each building did not have the heat allocators, and their consumption was calculated based on the total building consumption minus the metered apartments' consumption, distributed in proportion to the size of the unmetered apartments.

Source: Martinot 1995a

Case Study 7: Vilnius, Lithuania (Danish Building Research Institute and COWIconsult 1995b)

In 1994, the Lithuanian Ministry of Construction and Urban Development decided to conduct a demonstration project in one 16-story building in Vilnius (65 apartments, 7600 m^2). The project was also supported by the Danish Ministry of Energy. The project included a similar reference building for side-by-side comparisons. Technical measures included building-level heat control with heat exchanger, heating-system balancing, installation of radiator thermostat valves and apartment-level heat-allocators, and insulation of heating and hot-water pipes within the building. The apartment-level heat-allocators allowed the project to conduct an experiment with consumption-based metering and billing. After retrofits, heat consumption in the retrofitted building was still roughly equal to that of the reference building, but average indoor temperatures were 3.2°C higher than in the reference building (both were underheated); thus some of the returns from investment occurred in the form of increased comfort. Hot water consumption in the retrofitted building was 18% less than in the reference building. The project estimated that if the difference in indoor temperature were corrected for in the analysis, the retrofitted building would consume 20% less heat for space heating than the reference building.

The project reports that heat and hot water bills were 33% lower in the retrofitted building as a result of the retrofits. Investment cost was approximately $45,000.

Case Study 8: Petrozavodsk, Russian Federation (Finnish Energy Conservation Group 1996)

Heating equipment retrofits in residential buildings were demonstrated in one project in the city of Petrozavodsk in the Russian Federation with financing from the Finnish Ministry of Trade and Industry, the administration of Petrozavodsk, and private Finnish firms. Four identical 5-story, 60-apartment buildings were selected in the south-western part of the city. During the winter of 1994-95 these buildings were instrumented and metered for both building-level energy consumption and indoor air temperatures. In 1995 retrofits were made to three of the four buildings, with the fourth building serving as a reference building. Heat exchangers for domestic hot-water (closed system) were installed in three of the four buildings. In one of these three, the existing heat injector was left intact. In the second building a building-level heat controller with circulation pump was installed. In the third building a full heat-exchanger system for heating was installed. Energy savings were evaluated after measurements during the winter of 1995-96. Measurement of energy savings for space heating was compromised by the fact that heat supply was severely curtailed in Petrozavodsk during these periods; therefore data on actual energy savings was not available. Costs for the retrofits varied from approximately $15,000 for the first building to $25,000 for the third building. Based upon estimated energy savings of 23% for the second and third buildings under "normal" district-heating system conditions, a payback period of three years was estimated for these installations using a heat price of $27/Gcal.

Case Study 9: Kiev, Ukraine (Sogelerg 1995)

A demonstration project for building retrofits was under way in 1995-97 in Kiev with financing from the French government. The project was undertaken in six separate sections of one multifamily building. Two sections were retrofitted, one with heat controls only and one with heat controls and exterior insulation. The project also included installation of an autonomous heating boiler to provide heat to a third section (that was disconnected from the district-heat supply). Three unretrofitted sections were instrumented as reference sections. Measurements of the retrofitted and reference sections were under way during the 1996/97 heating season, and analysis of these measurements was planned for 1997.

ANNEX B
ANALYTICAL STUDIES OF RESIDENTIAL BUILDING ENERGY EFFICIENCY FOR ESTONIA, LATVIA, LITHUANIA, AND THE RUSSIAN FEDERATION

This annex reviews several analytical studies that supplement the actual project experience from the case studies described in Annex A. Several of these studies were associated with World Bank project-preparation activities and with the UNDP/World Bank Energy Sector Management Assistance Program (World Bank 1996a and 1996b; BCEOM 1995; SWECO 1995 and 1996; Rolén 1994; Martinot 1995a). Others were the result of EU PHARE assistance to Estonia (EXERGIA et al 1995 and 1996) and Danish bilateral assistance to Latvia and Estonia (Danish Building Research Institute and COWIconsult 1993a, 1993b, 1994, 1995a, and 1995b).

The range of energy savings estimates and payback periods found in these studies and demonstrations reflects several types of variation: (a) different assumptions about future district-heat service levels, (b) future heat costs (some project analyses used heat prices found in Western European countries that were far higher than those expected in the country where the demonstration was conducted), (c) inclusion or exclusion of renovation costs not related directly to energy efficiency improvements, and (d) uncertainties about performance estimates of renovation measures. Other variations in payback period may result from the difference in costs between imported and domestically purchased materials and equipment.

Unless noted, a heat price of $20/Gcal is used in all analyses.

Costs, Energy Savings, and Payback of Individual Measures

Table B-1 gives an indication of the costs, energy savings, and payback periods of individual measures. This table has been synthesized from the case studies in Annex A and from the analytical studies reviewed in this annex. There is a wide variety of estimates about energy savings and payback periods associated with different measures, which reflects uncertainty, variation in assumptions and heat supply conditions, variations in materials costs, and different building types in differing states of disrepair. Nevertheless, there are enough commonalties and consistencies in these studies to generate approximate ranges of values for Table B-1.

Building Heat and Hot Water Consumption

The case studies and analytical studies also give a variety of indications of building heat and hot water consumption. This energy consumption varies by building type, individual building characteristics, district-heat supply (whether supplied according to design norms, or whether curtailed to levels below these norms), and weather conditions. The figures below from various sources can be compared with typical building heat and hot-water consumption in Nordic countries. In older Swedish buildings, this consumption can be 190 kWh/m²/yr while in newer Swedish buildings this consumption can be 130 kWh/m²/yr (Rolén 1994).

Table B-1. Indicative Costs, Energy Savings, and Payback Periods of Individual Energy Efficiency Measures (for a Typical 5-Story, 60-Apartment Building)

Measure	*Cost per apartment*	*Typical energy savings*[a]	*Payback periods*[b]
Weather-stripping for windows	$30 to $100	5% to 15%	short
Refurbishment of windows	$300	10% to 20%	medium
New windows	$1,000 to $1,500	10% to 20%	long
Third window panes	$100 to $300	varies	short to medium
Building-level heat meter[c]	$15 to $30	n.a.	n.a.
Building-level heat control[d]	$20 to $60	0% to 15%	short
Substation w/building-level control and heat exchanger[d]	$100 to $300	5% to 15%	medium to long
Balancing valves /risers	$10 to $80	1% to 5%	short to medium
Manual radiator valves	$100 to $150	0% to 20%	short
Thermostat radiator valves[e]	$100 to $300	0% to 20%	medium to long
Ventilation roof fans & ducts	$300 to $700	---	long
Insulate all pipes in basement	$20 to $50	1% to 5%	short
Roof insulation--flat roof[f]	$300 to $1,000	5% to 10%	medium to long
Attic floor insulation	$100 to $200	5% to 10%	short
Insulation of gable walls	$150 to $500	---	long
Panel joint repair with new mastic	$200 to $500	---	---
Insulation of basement ceiling	$30 to $200	1% to 5%	long
New entry-door closer	$10 to $20	1% to 2%	short
Apartment heat allocators[c]	$15 to $50	n.a.	n.a.

--- Not available.
n.a. Not applicable.
Note: Data given are for indicative purposes only and should not be used for cost-estimation in feasibility studies or project preparation.
a. Energy savings from individual measures do not reflect the savings possible when combined with other measures, only the savings from one specific measure in isolation.
b. Payback periods are generally classified as short (5 years or less), medium (5 to 10 years) and long (more than 10 years).
c. No payback or energy savings is directly associated with heat meters (see section 3.2).
d. Estimates of energy savings from building-level heat control depend greatly on assumptions about building overheating and the heat supply regime used in practice (if curtailed or not) as well as the degree of imbalance between different parts of a building and whether balancing valves exist. The energy savings from building-level heat control also depend on whether radiator thermostatic valves exist. Savings and payback period for substations are generally lumped together with heat control.
e. Radiator thermostat valves are one of the most complicated measures to analyze because of the confounding variations from many variables. Estimates of energy savings from these valves depend on the degree of building overheating or underheating, whether building-level heat controls exist, whether balancing controls exist, and the type of billing system (building-level or apartment-level with apartment-level heat meters).
f. Estimates of payback period for roofs depend on whether or not repair work is required, and whether the repair cost is included in the payback analysis. If lower roof maintenance costs are included, payback periods may be reduced.
Source: Data compiled from the case studies reviewed in Annex A and the analytical studies reviewed in Annex B.

In Tallinn, Estonia (Axovaatio 1996) heat consumption was calculated (using design data) at 400 to 650 kWh/m²/yr in a "normal" year in which district heat is produced according to design parameters. Heat consumption was calculated at 230 to 300 kWh/m²/yr in a "curtailed" year in which district-heat production and temperatures are reduced for economic or fuel availability reasons. These estimates were based on total district-heating system production, assumed building losses, and interviews with residents prior to retrofit, which showed that indoor temperatures during a "normal" year typically exceed 24°C while in a curtailed year they range from 15°C to 22°C. Based on empirical heat consumption data from another similar building plus calculations and estimations, total heat consumption for the retrofitted building during the 1993-94 heating season (prior to retrofit) was estimated at 1000 MWh/yr, or 280 kWh/m²/yr.

For Lithuanian and Estonian buildings, Rolén (1994) and Rolén et al. (1994) estimated typical heat and hot-water consumption at 300 kWh/m²/year. The Swedish National Board for Industrial and Technical Development (1995) estimated heat consumption at 280 kWh/m²/year (1,330 MWh/year for the whole building) for an Estonian five-story concrete panel building. In three-story buildings in Estonia (Virudan 1993), buildings without metered hot-water consumed about 200 kWh/m²/yr for heating only while those with hot water included in the meter readings consumed about 300 kWh/m²/yr. Heat and hot-water consumption for three Lithuanian buildings, based on measurements normalized to a normal heat-supply regime, were estimated at 160 to 220 kWh/m²/yr (SWECO 1995).

The Danish Building Research Institute and COWIconsult (1995a) measured two different buildings prior to retrofitting one of them. These measurements showed 240 kWh/m²/yr and 285 kWh/m²/yr adjusted to an "average" year according to degree-day data (consumption in the measured year was 20% lower than these figures because the winter was warm).

In six Russian buildings (Battelle 1996b), annual heating energy delivered by the district-heating system was estimated at between 114 and 187 kWh/m² in 1995/96 although district-heat supply during this period was curtailed. In addition, Battelle estimated that hot-water systems within the buildings provided significant space-heating energy; this "supplemental" space heat was estimated to be as much as 25% to 40% of the space-heating energy supplied to the building by the district-heating system.

For the Tallinn, Estonia retrofit, Axovaatio (1996) estimates that hot water represents 25% of total building energy consumption. Rolén (1994) and Rolén et al. (1994) estimate this share at 33% for Lithuanian and Estonian buildings. Virudan (1993) estimated that 20% of the total heat energy for each building went to hot water, but actual heat consumption measurements suggest this share is closer to 30%. The Danish Building Research Institute and COWIconsult (1995a) measured hot water as 40% of total heat and hot-water consumption in a five-story building. EXERGIA et al. (1995) measured hot water as 33% of total heat consumption in one demonstration building in Tallinn, Estonia.

Analyses of Integrated Energy Efficiency Retrofit Packages

Four significant analytical studies of integrated energy efficiency retrofit packages were sponsored by the World Bank in 1995-1996 as part of project-preparation activities in Lithuania and the Russian Federation and the UNDP/World Bank ESMAP project. Several other analyses of energy efficiency retrofit packages have also been conducted in recent years. A summary of these studies is presented here. The results are also presented in Table 5 in Chapter 3.

Lithuania (BCEOM 1995)

As part of a UNDP/World Bank ESMAP study and as preparation for a proposed World Bank loan, a study of energy efficiency in residential buildings in Lithuania was conducted in 1995. Six actual buildings were examined representing three types of construction: brick, cast on-site concrete, and prefabricated concrete panels. Buildings ranged in size from 12 to 100 apartments and from three to ten stories. All buildings were supplied from district-heating systems through a distribution substation and had vertical one-pipe heating systems. Annual calculated energy consumption in these buildings varied from 225 kWh/m² to 265 kWh/m².

For each building, two to four different packages of measures were analyzed. The full package included roof insulation, replacement of all windows in apartments, exterior wall insulation, building-level heat controls, replacement of outside-doors including door closers, weather-stripping of windows in entryways and repair of broken panes, basement ceiling insulation, insulation of hot-water pipes, and heating system balancing. Partial packages were also analyzed. One partial package consisted of the full package minus wall insulation. Another partial package consisted of the full package minus window replacement (refurbishment instead of repair). Total costs for the full package ranged from $1,450 to $4,300 per apartment, with energy savings in the range of 40% to 53%, and payback periods from 9 to 17 years. The higher costs were associated with the smaller buildings, and the lowest costs were for the largest building. All three large buildings (60 or more apartments) cost less than $2,000 per apartment. The partial package costs ranged from $430 to $2,200 per apartment, with energy savings in the range of 26% to 42% and payback periods from 4 to 11 years. All three large buildings had costs less than $900 per apartment. The study considered mostly the use of domestic Lithuanian materials at prices lower than imported materials.

The study also analyzed packages from the perspective of “energy efficiency” versus “building improvement” investments. In these analyses, some portion of the roof insulation, window replacement, and wall insulation costs were considered “building improvement” costs and subtracted from the energy efficiency investment analyses. Using this approach, the cost of the full package for the five-story, 60-apartment building decreased from a total of $2,050 per apartment to only $1,300 per apartment accounting for the “energy efficiency” costs only, and the payback period decreased from 9 years to 6 years. Similarly analyzing the partial package (no window replacement) for the same building, costs decreased from $870 to $670 per apartment and the payback period decreased from 5 to 4 years. For consistency of comparison with other projects, the full investment costs are reflected in Table 5, rather than just the “energy efficiency” portion of these costs.

Lithuania (SWECO 1995 and 1996)

As part of project-preparation activities for the Lithuania Energy Efficiency / Housing Pilot Project, eight typical multifamily buildings in Lithuania were audited and analyzed for energy efficiency retrofit measures. The buildings were mostly five-story or nine-story prefabricated panel construction except for two five-story brick buildings and one 13-story panel building. The buildings ranged in size from 20 apartments to 100 apartments. A variety of technical measures were considered for each building individually, and metered energy consumption data were obtained for each building. Two packages were analyzed for each building. A basic package typically included refurbishment of windows, new doors, building-level heating control, a circulating pump for the heating system, new heat exchanger, balancing valves, and roof renovation. Thermostatic radiator valves and conversion to a two-pipe system were part of the basic package in some buildings. The optional packages also included new roofs with additional insulation in the place of roof renovation.

Total costs for the basic package ranged from \$600 to \$1,600 per apartment, with energy savings in the range of 40% to 64% and payback periods from 8 to 20 years. Packages for the three medium-size buildings (60 to 100 apartments) all cost less than \$1,000 per apartment. Total costs for the optional package ranged from \$1,300 to \$2,900 per apartment, with energy savings in the range of 45% to 73%, and payback periods from 10 to 26 years. Costs for the optional package in the three medium-size buildings (60 to 100 apartments) were less than \$1,800 per apartment.

For most buildings two sets of analyses were done--one assuming “normal” heat supply conditions and indoor temperatures of 18°C and the other assuming indoor temperatures of 13°C. The analyses for 18°C are included in Table 5.

Lithuania (World Bank 1996b)

As part of project-preparation activities for the Lithuania Energy Efficiency/Housing Project, the World Bank conducted an analysis of energy efficiency retrofit packages based on the findings of BCEOM (1995), SWECO (1995), and Masso (1995). This analysis considered two building types--a large 100-apartment building and a small 32-apartment building--and considered three different packages of measures, their costs, and their energy savings and financial returns. Local costs of materials and equipment were used where possible. The estimated costs, energy savings, and economic payback periods of these three packages for the two different building types are shown in Table B-2. In the small building, the basic package consisted of a heat meter, building-level temperature controller, heat system balancing, and a heat exchanger. The medium-size package added new doors and window improvement to the basic package. The extensive package consisted of a prefabricated substation (including heat meter, heat exchanger, and building-level temperature control), thermostatic radiator valves, and roof renovation. In the large building, the basic package consisted of a heat meter, building-level temperature controller, heat system balancing, staircase improvement, and pipe insulation. The medium package added basement insulation and window improvement to the basic package. The extensive package added basement insulation, roof insulation, and new windows to the basic package.

Table B-2. World Bank Estimates of Typical Energy Efficiency Packages for Lithuania

Building type	*Retrofit package*	*Cost per apartment (US$)*	*Energy savings (percent)*	*Payback period[a] (years)*
Small Building	basic	250	17	6
	medium	750	44	7
	extensive	1,400	42	13
Large Building	basic	100	22	2
	medium	400	34	5
	extensive	1,500	45	15

a. Payback period based on estimated financial returns.
Source: World Bank 1996b.

Russian Federation (World Bank 1996a)

Project-preparation analyses for the Russian Federation Enterprise Housing Divestiture Project considered 10 different generic building types that represent virtually all multifamily residential buildings in the six selected project cities, differentiated according to the following parameters:

- building height
- building footprint
- attic/no attic
- bypass/no-bypass radiators
- closed/open hot water
- natural gas available
- panel, brick, wood construction

The analysis further categorized buildings as "small" (two- to four-story), "medium" (five- to eight-story) and "large" (nine- to 14-story). This grouping is important because different size buildings exhibit different thermal characteristics and per-apartment retrofit costs, so financial returns are quite different across the different size categories. For example, the analysis indicated that natural draft ventilation controls should be cost-effective in the "large" buildings but not so in the "small" buildings.

The analysis considered 40 different retrofit measures for two different climate categories (representing climates typical of the northern and central European parts of the Russian Federation). The analysis showed that packages of measures with payback periods of 3 to 4 years were possible with costs ranging from $750 per apartment in large buildings to $1,100 per apartment in small buildings. Most of the measures considered fell into eight categories: insulation, weather stripping, caulking, heating controls, improvements in the water system, ventilation, envelope replacements, and improvements to electrical systems.

Estonia (EXERGIA et al. 1995 and 1996)

A study of energy efficiency in housing in Estonia began in 1995 under the Ministry of Economy of Estonia and supported by the EU PHARE program. The study began by surveying existing technical and economic conditions associated with housing and utility services in Estonian residential buildings, as well as social views of housing problems, existing construction standards, and an overview of the capability and perspectives of the construction and building material sectors. In the second phase of the study, a list of energy efficiency measures was compiled along with detailed costs and energy savings estimates. This list was prioritized, and economic and financial analyses were conducted. The study found ten high-priority measures for multifamily buildings. These measures were selected according to what was considered absolutely necessary, what provided a good economic and financial return, and what offered a less favorable economic return but improved occupant comfort. The measures are:

- Building-level heat and hot-water meters
- Building-level heat controls
- Radiator thermostat valves
- Heating balancing valves
- New building substations
- Heat and hot-water pipe insulation in basements
- New low-flow hot and cold water taps
- Micro-exhaust air fans at ventilation grilles in each apartment
- Window weather stripping
- Insulation on basement ceilings.

Financial and economic analyses were conducted on these individual measures for different fuel supply scenarios and building types, including net present value, discounted payback, and internal rate of return. However, no analyses were conducted on integrated packages of measures in that phase of the study. A wide range of rates of return were estimated, from 5% to almost 500%, with many measures offering rates of return from 20% to 80%.

Estonia (Danish Building Research Institute and COWIconsult 1993a and 1995a)

In one of the earliest studies, grants from the Danish and Estonian governments supported detailed energy audits of three multifamily buildings in 1993 in Tallinn, Estonia. Based on the audits, consultants developed a catalogue of energy efficiency measures for these buildings and estimated energy savings and payback periods (calculated using Danish equipment and materials and Danish heat prices, which at the time were $40/Gcal, 2-1/2 times higher than Estonian heat prices). Payback periods were less than 10 years for a variety of short-term and longer-term measures, including window tightening, insulation of hot water and heat pipes in apartments and in basements, building-level heat control, manual radiator valves, additional insulation of pitched roofs, and hot-water temperature control. Other measures, including exterior insulation, heat system balancing, and basement insulation, were seen to have longer payback periods, from 11 to 48 years.

Integrated energy retrofit packages also were analyzed for the three buildings. These packages were uniform and included radiator thermostat valves, building energy management, window weather stripping, roof insulation, basement floor insulation, building-level heat control, and heat system balancing. For purposes of analysis in this report, the thermostat radiator valves, building energy management, and exterior wall insulation are removed from the packages, and the effect of the building-level heat controller is correspondingly increased (in the original analysis, the buildings were assumed to be 15% overheated, but this situation is no longer a reasonable basis for analysis). With these modifications, the total costs of these packages become \$36,000, \$72,000 and \$165,000, respectively for an "old block building" (four-story, 32 apartments), a "new panel building" (five-story, 45 apartments) and a "city building" (seven-story, 144 apartments). The estimated energy savings are 30%, 25%, and 20%, respectively. The payback periods using a \$20/Gcal heat price are 15 years, 18 years, and 13 years, respectively. These payback periods are likely higher than they would be for an actual renovation because they are based entirely on the costs of imported materials and equipment.

Russian Federation (Gabrielsson 1995)

An initial analysis of one multifamily building (114 apartments) in St. Petersburg was conducted by a consortium of Finnish and Russian private companies. Two different integrated energy efficiency retrofit packages were considered. The first package included window weather-stripping, thermostat radiator valves, apartment-level and building-level heat meters, a building substation, balancing valves, new domestic hot-water pipes, roof insulation, joint caulking between exterior wall panels, and new external doors. The second package was similar to the first but added radiator replacement and new water-saving faucets. The cost of the first package was estimated at \$266,000 while that of the second package was estimated at \$390,000. Estimated energy savings for the first package were 33%. At a heat price of \$20/Gcal, the payback period for this package would be about 15 years.

Russian Federation (Stork Comprimo 1996)

A UNDP/World Bank ESMAP district-heating study conducted for the city of Orenburg in the Russian Federation also analyzed demand-side energy efficiency retrofit packages for comparison with supply-side options. Various demand-side measures were considered and analyzed based on internal rate of return. The economic analysis was based strictly on fuel savings at the power plant and the measures' influence on electricity consumption. The analysis included measures with a 10% or greater internal rate of return; five measures met this test: building-level heat meters, building heat controls, pipe insulation (unspecified), staircase refurbishment (unspecified, but most likely window and door weather-stripping and repair), and window refurbishment (weather stripping and repair). For a hypothetical 100-apartment, five-story building, the costs of this basic package were estimated at \$410 per apartment with associated energy savings of 28%.

ANNEX C
RUSSIAN GOVERNMENT METERING AND BUILDING RETROFITS IN THE CITY OF RYAZAN

In 1996, the Russian government contracted with two different Western European engineering firms for the retrofit of four (two nine-story and two five-story) demonstration buildings in the city of Ryazan, as part of the Enterprise Housing Divestiture Project (Battelle 1996c and 1996d). The focus of the retrofit activities was to reduce energy and water consumption and overall maintenance expenses, and to improve living conditions for the occupants. Extensive metering and monitoring of all four buildings plus two unretrofitted reference buildings took place during the 1995-96 heating season (Battelle 1996b), and post-retrofit monitoring of all six buildings took place again during the 1996-97 heating season. The results of the post-retrofit monitoring and evaluations of retrofit performance were planned to be available in 1997.

There were two primary objectives of the Ryazan demonstration project. The first was to gain project experience in retrofitting Russian multifamily buildings and in the logistic and contractual efforts necessary to support the retrofit process. The second was to begin developing an accurate data base on the costs and energy savings of retrofits. These cost and performance data can guide future retrofit decisions.

Technical Measures for the Five-Story Buildings

Original project plans called for one building to be retrofitted for the most effective five-year payback package and the second building to be used as a test building for promising new technologies. During the technical negotiations, this approach was changed, and the decision was made that one building (Zubkova 22-1) would have its heating system completely retrofit to "European standards," and the second building (Zubkova 24-2) would have its envelope extensively retrofit to reduce heat losses. The hydroelevators in 24-2 were retrofitted and recalibrated to ensure that they provided energy appropriate for the newly tightened building. This approach was designed so that the pre- and post-retrofit energy consumption data would provide information on the relative value of tightening the building envelope versus upgrading the heating system.

Below, the technical measures considered (based on building audits) are reviewed for the five-story buildings, together with the reasons for final inclusion or exclusion of each measure in the retrofit packages that were ultimately applied to the buildings.

Basement Ceiling and Wall Insulation. The audit report recommended that a 50-mm layer of mineral wool be glued to the basement walls and ceiling. The ceiling retrofit would serve as an insulation layer to keep the first floor apartments warm, and also serve as a vapor barrier to prevent further moisture damage to the apartment floors above. It was not clear that insulating the basement walls would provide much additional benefit over insulating the ceiling--especially given all of the openings in the basement walls to the outside--and so that retrofit was eliminated on cost-effectiveness grounds. Later, during the final contract negotiations, the basement ceiling insulation was eliminated as well, in order to bring the contract cost underneath the overall Ryazan demonstration project financial cap. There is some expectation that effective pipe insulation in the basements will significantly lower basement temperatures, leading to cold floors in the first level, because the basement ceiling is not insulated. Post-retrofit surveys should investigate this situation in both buildings.

Exterior Wall Insulation. The audit report recommended that the facades, gable walls, kitchen corners, and balcony floors be insulated with 75mm of mineral wool with weather protection of metal, plaster, or wood. Further calculations demonstrated that these retrofits would not meet the five-year payback criterion, so they were largely eliminated. The decision was made, however, to insulate the gable walls in order to gain experience with, and cost information on, external insulation, and to improve comfort in end apartments. (Implemented in Zubkova 24-2.)

Attic Floor Insulation and Vent Stack Exhaust to Outside. The audit report recommended a layer of 100-mm insulation boards on the attic floor, with a vapor barrier. It also recommended that the stacks that deliver air from the kitchens and bathrooms in each apartment be vented through the roof to the outside in order to eliminate any chance of moisture damage. Further analysis indicated that this ventilation of the apartments into the "warm attic" serves a useful purpose of providing a warm buffer zone between the top-floor apartments and the outside, negating the need for attic insulation. These measures were entirely eliminated from the ultimate retrofit package. Mid-winter measurements demonstrated that attic temperatures were within a few degrees of apartment temperatures even during the coldest weather, and there do not appear to be any moisture problems because of the warm temperatures.

Radiator Reflectors. The proposal to back each radiator with a reflector (25-mm mineral wool with a reflective surface) was accepted as highly cost-effective. (Implemented in Zubkova 24-2.)

Exterior Panel Sealing. The proposal to seal the joints between exterior wall panels was accepted, both as an energy-savings measure and as a maintenance strategy, to prevent moisture from penetrating the building and causing deterioration of the panels. (Implemented in Zubkova 24-2.)

Repair of Staircase Windows. The proposal to repair broken window panes in the staircases was accepted. The repair material is a tough plastic, rather than glass, to help prevent future breakages. (Implemented in Zubkova 24-2.)

Weather-Stripping and Caulking of Windows and Doors. The audit report called for weather-stripping and caulking of windows and doors leading to the balconies. (Implemented in Zubkova 24-2.)

Upgrade Entry Doors. The audit report called for replacement of all four entrance doors with solid hardwood doors with automatic closers. (Implemented in Zubkova 24-2.)

Toilet Water Savings Devices. The audit report did not call for renovation of toilets, but this measure was added to the specification because of its substantial conservation potential.

The specific measure implemented was a weight addition to the flushing mechanism that causes the flush duration and water use to be reduced. (Implemented in Zubkova 24-2.)

Low Flow Showerheads. The audit report did not call for the installation of low-flow showerheads as energy and water saving devices, however these were added to the specifications as highly cost-effective retrofits. (Implemented in Zubkova 24-2.)

Pipe Insulation. The audit report called for anti-corrosion painting and insulation of the major heating, DHW and cold water pipes in the building. The pipes were insulated in both buildings because this retrofit is highly cost-effective.

Heating Retrofits. The audit report provided four alternatives for consideration:

(a) As Designed: retrofit of the existing heating system so that it would meet the original construction specifications for the building. This would entail installation of bypasses and valves on each radiator (optionally including a thermostatic control valve) and rehabilitation of the hydroelevators to effect the appropriate mixing rate.

(b) Automatic Controls: replacement of the hydroelevators with weather compensating mixing loops, with bypasses and valves installed on each radiator.

(c) Building Substation: Installation of a heat exchanger in the building to effect a separate secondary loop that is controlled by a weather compensating controller. This measure was combined with modification of the building to a two-pipe system, installation of an expansion tank, and installation of thermostatic radiator controls on each radiator.

(d) Stand-Alone Building Boiler: Disconnection of the building from the district-heating system and installation of a gas-fired boiler to provide both heat and hot water to meet the entire building's needs.

Different heating-system solutions were selected for each of the buildings. In Zubkova 22-1, the full "European" solution of heat exchanger, controller, two-pipe system, and radiator thermostatic controllers was accepted. Additionally, the retrofit rehabilitated existing radiators and resized them, as appropriate. Finally, evaporative heat allocators were installed on each of the radiators, and an actual-use billing system was developed for use by the city. In Zubkova 24-2 (the "tightened" building), the initial decision was to rehabilitate the existing hydroelevators to determine how effective the less-costly combination of tightening and rehabilitate hydroelevator would be in reducing energy costs. However, during design it was determined that there was not enough pressure difference between the supply and return loops for effective hydroelevator operation, so the decision was made to replace the hydroelevators with mixing loops controlled by outdoor-temperature sensors (separate sensors/loops for each section).

Compact Fluorescent Lamps. The audit report did not recommend any electrical system retrofits. Although the installation of compact fluorescent lamps is clearly cost-effective for some applications in the buildings, this retrofit was not selected because of cost considerations and because the project was already gaining experience with this retrofit through the nine-story building retrofits.

Technical Measures in the Nine-Story Buildings

Below, the technical measures considered (based on building audits) are reviewed for the nine-story buildings, together with the reasons for final inclusion or exclusion of each measure into the retrofit package that were ultimately applied to each building.

Basement Ceiling Insulation. The audit report recommended that a layer of rockwool covered by a plaster layer be installed across the entire basement ceiling. The retrofit would serve as an insulation layer to keep the first floor apartments warm (since the basement pipes were to be insulated, cooling the basement significantly), and serving as a vapor barrier to prevent further moisture damage to the apartment floors above. A recommendation for the use of spray-on polyurethane foam as a tougher, cheaper way of insulating and sealing the basement ceiling was contained in the specification issued to the potential contractors. Unfortunately, however, the Ryazan fire marshall would not approve the use of polyurethane inside the building, and so the contractor reverted to a mineral wool insulation layer. The plaster layer was not installed, however, because of costs. The vapor barrier is provided by an aluminum foil facing on the mineral wool whose seams have been carefully taped. This should provide a reasonable vapor barrier if it is adequately maintained.

Exterior Wall Insulation. The audit report recommended insulating the exterior walls with mineral wool with a hard-cover layer of plaster or paneling. Since the installation was to be done in winter, the only solution would have been a metal or wood panel covering. The cost for such insulation proved prohibitive despite the contractor's focused attempts to reduce cost, and so no external insulation of the walls was contained in the contractor specification.

Archway Insulation. The residents living over and adjacent to the archway complained of extreme cold because of the poor insulating quality of the archway walls and ceiling. Hence, the decision was made to provide external insulation as a comfort measure even though the expected payback did not meet the five-year criterion. (However, the overall retrofit package meets the five-year payback criterion since other retrofits have much shorter payback periods.) The retrofit that was implemented was mineral wool insulation covered by painted metal panels. The retrofit specification contained an allowance for protecting the bottom portions of the walls with brickwork.

Attic Floor Insulation. The audit report recommended a layer of insulation on the attic floor, covered by a plaster layer. Analyses indicated that because the buildings were of "warm attic" construction (i.e., the ventilation ducts empty into the attic), the attics would be too warm to warrant any insulation on the floor layer. So this retrofit was not included in the contractor specifications. Later temperature measurements showed that attic temperatures were within a few degrees of apartment temperatures even during the coldest weather.

Radiator Reflectors. This measure was not included in the audit recommendations (because it would not be needed with external insulation), but was added later to reduce heat loss to the exterior walls in back of radiators. The retrofit is a thin insulating layer covered with foil that is glued to the wall behind each radiator in the building that is located against an exterior wall.

Exterior Panel Grouting. This measure was not included in the audit report since it was not needed with the recommended external insulation. When external insulation was found to be too expensive, this retrofit became important and was included in the contractor specifications. This retrofit measure was one of the most difficult to install during extreme cold winter weather for two reasons: the extreme cold hindered the installers and because the crevice-filling and crack sealing materials would not cure appropriately; materials were wasted as a result. In the future, more cold-tolerant technologies need to be employed or else this retrofit needs to be scheduled for warmer times of the year.

Reinstallation of Windows. The audit report suggested that windows be reinstalled with new hardware. This was found to be too expensive. However, any windows in extremely poor condition were repaired.

Weather-Stripping and Caulking of Windows and Doors. The audit report called for weather-stripping and caulking of windows and doors, which was done. There were implementation problems because many residents did not want their windows opened during extremely cold periods for the retrofitting. But revisits during warmer weather resulted in a good adoption rate for this retrofit. In 14 of the apartments, however, the residents refused to let the contractors do the weather-stripping insulation. Instead, they accepted the materials to install on their own at a later date.

Replace the Fortochka with a Louvered Metal Panel. The audit report recommended replacing the small ventilation window (Fortochka) in window assemblies with an adjustable louvered panel to better control ventilation during cold weather. The recommendation was not implemented because the overall thermal integrity of the window assembly would have been reduced and because the residents were quite happy with the existing configuration and would not accept change--especially changing a window for an opaque panel.

Upgrade Entry Doors. The audit report called for replacement of all four entrance doors with solid hardwood doors with automatic closers. This recommendation was enhanced in the specifications to include the addition of a vestibule buffer zone established by the construction of a small inner wall and attached additional door.

Install Balcony Windows. The audit report called for installing double-glazed windows on the balcony outside parapet. This recommendation was rejected because of its high cost and because it would encourage the wintertime use of the balcony area as part of the living space, thereby increasing energy use rather than reducing it.

Toilet Repair. The audit report did not call for renovation of toilets but this measure was added to the specification because of its substantial conservation potential. The retrofit specification estimated that 25% of the toilets (36) would need repair. According to the water conservation subcontractor, all toilets were inspected and only 32 needed to be repaired. The mechanics of 20 toilets were replace in their entirety, and 12 toilets required only limited repairs.

Low Flow Showerheads. The audit report recommended the installation of low-flow showerheads as energy and water saving devices. The goal was to install high-quality units that would prove satisfactory to the residents and would be easy to keep clean and working. No suitable showerheads were apparently available on the Russian market, so simple water flow restrictors were substituted by the water efficiency subcontractor. The flow restrictors were installed only on floors 1 through 6, because water pressure was too low on the top three floors to warrant their use.

Kitchen Aerators. The audit report recommended the installation of faucet aerators on both kitchen and bathroom faucets. However, since the bathroom faucets serve both the sinks and bathtubs, it was felt that aerators would be unacceptable in the bathroom (because they would substantially increase the amount of time it takes to fill the bathtub), so aerators were installed only in kitchens.

Riser Replacement. Many domestic hot-water risers were in need of replacement because scaling had reduced flow to a trickle in some apartments. The audit report estimated that 120 meters of pipe would need to be replaced. Actually, 200 meters were replaced.

Building-Level Filters for Domestic Hot-Water and Cold Water. Water filters were not specified in the audit report but were added to the retrofit package in order to prolong the life of the water saving measures installed in the apartments.

Pipe Insulation. The audit report called for insulation of the major DHW and heating transit pipes in the building and also for insulation of the heating riser system. In the specifications, the insulation of the riser system was eliminated for cost reasons and to ensure that the basement remained warm enough to prevent freezing problems.

Heating Substation. The audit report suggested a number of ways that the heating system could be reconfigured for better temperature control and energy savings, including installation of a heating substation (controller plus heat exchanger), a direct mixing system, and a stand-alone gas boiler. The heating substation was selected as most cost-effective. The expected cost savings were attributed to reduction in building pipe maintenance as well as heating energy savings. As part of the heating upgrade, balance valves were added to the riser systems, and the flow through the risers was balanced to make the building as evenly heated as possible.

Compact Fluorescent Lamps. The audit report did not recommend any electrical system retrofits. It was decided to give each resident one compact fluorescent light to install in the highest-use light fixture, and to install lamps (behind wire protectors) on each of the floor landings. The resident use is clearly cost-effective. The landing installations would have been very cost-effective as a replacement for incandescent lighting. However, because 90% of the former lighting installations proved to be inoperable, the expectation was that energy use would actually increase after installation. Nonetheless, the retrofit was included as a means of gaining occupant approval for the overall retrofit process.

Cost and Performance Experience

The actual performance of the retrofits was to be determined after the 1996-97 heating season, when post-retrofit energy and water consumption was to be contrasted with weather-adjusted pre-retrofit consumption measured during the 1995-96 heating season. Even before performance results are available, the demonstration has provided concrete information on the cost of retrofits.

The original estimated costs for equipment, materials and installation for Zubkova 22-1 and Zubkova 24-2 were about $115,000. Including VAT ($16,000) and transport ($10,000), the total estimated costs for both buildings were about $140,000. The actual cost of installed equipment and materials for the two buildings was about $91,000, which together with VAT ($11,000) and transport ($11,000) comes to about $113,000 for the two buildings.

The original estimated costs for equipment, materials and installation for Novoselov 30 and Novoselov 32 were about $200,000, including VAT and transport. The actual cost of equipment, materials, and installation for the two buildings was about 5% greater than the estimated budget. Although the overall budget was close to projections, the individual cost elements varied widely from original estimates for various reasons. A few comments on these cost variances are provided below:

- Insulation retrofits ranged between 21% and 42% above the predicted costs both for unit and total retrofit costs. But weather-stripping was only about half as costly as projected.

- Exterior window and door grouting was 59% more expensive than projected. Some of this overrun can be attributed to slow productivity during extremely cold weather and to materials wasted during these cold periods. Some cost can also be attributed to the need for a crane-with-bucket ("cherrypicker") that was needed to apply the grouting. The installation cost may be lower for shorter buildings that do not require a crane.

- The vestibule and entry doors were more than four times as expensive as projected. The specifications did not provide for a brick inner partition to establish a vestibule zone, and the specification called for wooden doors, whereas metal doors were provided. Finally, there were problems with the automatic closing devices initially installed, which were not strong enough; these were replaced with heavier units.

- The unit cost of toilet repair appears to be about half of what was projected even though materials were procured on a low-volume basis in local stores.

- The cost for showerhead flow reduction was less than 20% of the projected cost. This difference reflects a technology switch, as it in-line flow restrictors were substituted for high quality adjustable low-flow showerheads. If flow-restrictors are acceptable to residents, then this retrofit will be extremely cost-effective.

- Riser replacement costs were significantly higher than projected on a unit basis (almost three times more expensive) and on a total basis (more than five times more expensive). Balancing of the risers was, however, significantly less expensive (44%) than projected.

- The attic ventilation fans cost over 3 times the expected amount. This finding would tend to eliminate attic-level active ventilation control as a cost-effective retrofit measure unless a much less expensive configuration can be designed.

Implementation Experience

Substantial experience in project implementation, including the logistical and contractual efforts necessary to support a retrofit process, resulted from this demonstration project. The retrofit process was a continuous learning experience full of surprises and difficulties. Some of these difficulties were similar in all buildings while others were unique to either the five-story or nine-story buildings. The demonstration provided insights into the requirements for managing building retrofit activities and for developing the necessary managerial expertise. Many important lessons were learned from the demonstration project:

- Contracting processes can be lengthy and there is a need for efficient contracting procedures.

- Foreign contractors should have a good working knowledge of Russian value-added-tax (VAT) and customs requirements, as well as local regulations and what these requirements mean with respect to equipment availability and cost, and project delays.

- In contracting with firms that will install retrofits but not design the specific technical measures, it is important that contracts specifically define the cost of individual retrofits on an easily extensible basis. Then, once an audit determines which technical measures are necessary in a particular building, the determination of contractual retrofit costs will be a straightforward mathematical exercise.

- Foreign firms need guidance on what types of formal registration are required, if any, for conducting different types of business in the Russian Federation, and how to register. Although foreign firms should be able to learn about these requirements on their own, Russian regulations are complex and uncertain, and smaller firms especially may need outside support in understanding these requirements.

- Western and Russian equipment and materials suppliers need to become more educated about the potential future demand for their products related to energy efficiency in residential buildings, the need for product certification, and the need to establish effective distribution networks.

- Few Russian apartment buildings have accurate, up-to-date as-built construction documents. Heating and other systems may not function as designed and may not even be repairable due to shortcomings of the district-heating systems (as was the case with Zubkova 24-2). In addition, residents often retrofit heating systems themselves, adding or increasing the size of radiators, which leads to a building with a totally unbalanced heating system. Thus heating companies that serve the buildings being retrofitted need to be intimately involved in the retrofit decision process so that they can provide information on the status of the system (including future plans), and so retrofits of the buildings can be designed and implemented to enhance (or at least not degrade) district-heating system performance.

- Local housing maintenance organizations lack sufficient equipment and experience to perform building audits themselves, but, with support and the proper tools, they could perform these functions. Tools could include, for example, audit protocols and worksheets, measurement equipment, and training in the use of that equipment.

- There is a need to make a clear distinction in the project design and contract between repairs and upgrades that are the responsibility of the retrofit contractor and those that are the responsibility of the building owner and housing maintenance organization. Some repairs, such as repair of leaking pipes, radiator cleaning, repair of stairwell windows, etc., may be more cost-effective when done prior to building retrofits by the contractor.

- Prices for equipment, materials, and labor vary widely among vendors, over time, and in different regions. Thus research to obtain better information on retrofit costs is important. Given the uncertainty in costs, the retrofit procurement process should be structured so that final retrofit decisions are only made after the contractor has submitted firm prices for unit retrofit activities and the payback has been calculated using those prices.

- Russian subcontractors need to develop more experience with these types of construction projects. In the five-story building retrofits, two Bulgarian firms were subcontractors, and shared with a Russian energy efficiency institute the responsibility for on-site oversight. The Bulgarian firms were more familiar with common construction projects than were the Russian subcontractors for the nine-story building retrofits, resulting in lower project costs.

- Russian subcontractors may need extensive training in bid preparation and access to cost data bases to allow them to participate meaningfully in a competitive bid process. Some Russian subcontractors were unable to conduct detailed cost analyses because they had little experience in this field, because they had no reasonable cost data from which to develop a bid, and because they did not have the general business expertise for Western-style competition.

- Bid documents need to be very explicit about the level of detail and quality of work. In addition, continuous training and demonstration of work approaches that yield higher quality may be necessary. In Western cultures, technical documents are often short and to the point, relying on good workmanship standards of the contractor, normally accepted industry standards, and on-site construction management. However the subcontractors in this project were not familiar with this type of work and did not automatically meet quality standards; they were unable to perform some retrofits without technical training. In addition, contractual issues of all types differ between Western and Russian cultures, including insurance coverage and worker safety issues.

- Advance payment to Russian subcontractors may be required, but payment mechanisms are needed that provide firms with adequate working capital without surrendering the leverage needed to ensure prompt quality performance. Russian subcontractors are typically not well capitalized and there appear to be no effective bank guarantees in the Russian commercial sector. As a result, the standard Western expectation that payment will be made only after inspection and acceptance of retrofits did not work very well for this project. The contractor often had problems purchasing retrofit materials and paying employees because of cash flow problems, and retrofit progress suffered as a result.

- In communicating with households in the demonstration buildings, the project employed many standard approaches, including building-level meetings, flyers, one-on-one meetings, and radio/television/press coverage, but these communications were generally not very effective. Meetings were poorly attended, and it was unclear whether anyone read the flyers. An effective communication strategy should enlist one or more key opinion leaders in each building to serve as coordinators. These coordinators could facilitate communications, schedule apartment retrofits with households, and identify general problems and propose solutions. The coordinators should also be members of any retrofit inspection/acceptance team.

- Household interest in and acceptance of building retrofits can be enhanced by having residents of new retrofit projects inspect the works on earlier projects and talk to residents affected by those earlier successes.

- Some residents did not want retrofits in their apartments for aesthetic reasons. For instance, the window caulking all had to be done to the outside frames since the residents didn't want to risk damage to interior decorations (wallpaper). Some residents who had upgraded initial fixtures did not want to replace existing quality fixtures (shower heads, weather-stripping, etc.) with inferior (or perceived inferior) materials.

- A formal acceptance committee should be established. This committee should be trained to interpret the formal retrofit specifications so that the committee can make quality judgments against those specifications and not be deceived by either retrofit omissions or technology substitutions.

- Several promising retrofits (polyurethane foam insulation and stand-alone gas-fired boilers, for instance) were identified as candidates for the demonstration program but were not used because of building code issues and uncertain cost information. There appears to be considerable cost-effective energy savings potential in technologies that are currently not widely used in the Russian Federation. There is a need to more clearly identify these technologies, to obtain more reliable cost and performance information on them, to develop technology certification where necessary, and to change regulations where necessary to allow these technologies to be used.

- Given the high labor cost associated with weather-stripping and caulking, it may be more cost-effective to provide training and issue supplies and lend tools so residents in a building can do their own weather-stripping. Installation service can be provide only to those unable to do their own retrofits. This would be a good approach for a single-building test/demonstration that could result in substantial financial benefits if the approach proves feasible.

- Some retrofit equipment is more sophisticated than the equipment it replaces, requiring adequate training in maintenance and operation for appropriate personnel and organizations. It is unlikely that one or two formal training programs will be adequate to ensure effective operation, maintenance, and repair; rather, ongoing training support is important.

Experience was also gained in terms of the time required to implement these types of retrofit activities. Each of the three major project activities--contracting after bid award, audits and analysis of technical measures, and installing the retrofits--took about four times longer than had been programmed under a highly ambitious schedule that required very tight timing and coordination. (This ambitious schedule was designed to provide the maximum experience for the Enterprise Housing Divestiture Project by 1996.)

The difference between planned and actual schedules can be partly explained by such factors as subcontracting difficulties (resulting in part from foreign subcontractor inexperience in working in the Russian Federation, and the geographical separation between contractor and subcontractors), delays while imported equipment cleared customs, difficulties in finding suitable retrofit materials in the Russian Federation, the impact of especially cold winter weather on retrofit activities (some activities cannot be conducted in severely cold weather, such as panel sealing and application of external spray-on foam insulation), unfamiliarity of subcontractors with some types of retrofit measures (which resulted in re-work), and difficulties in gaining access to apartments and agreement with residents.

Metering Activity Findings

The objectives of the metering activities during the 1995-96 heating season were to measure all of the energy and water flows into the six pilot buildings described above, including heating water, domestic hot water, cold water, electricity, and natural gas; to document the buildings' physical characteristics; to measure key building operating characteristics in order to understand the level of service and the quality of life in the buildings; and to collect a full suite of meteorological information to facilitate analysis of the consumption data.

Extensive apartment-level temperature monitoring revealed that two of the buildings were underheated, on average, at least some of the time, and that the remaining four buildings were overheated, on average, all of the time. Some apartments failed to meet minimum temperature requirements (18°C) in all of the buildings. Daily swings in temperature brought more apartments below the 18°C norm for short periods of time.

Metered heating energy consumption for the six demonstration buildings showed a dramatic difference in consumption among identical five-story buildings, with one consuming only about 60% of the heat that its two siblings consumed. This low consumption was a result of dramatically reduced flow of district-heating water into the building as well as a 10°C lower temperature for the heating water that was delivered. On a per-floor-area basis, heating energy consumption in the nine-story buildings was closer to that of the severely underheated five-story building than to the other two buildings. Based on the 39-day pre-retrofit measurement period, the annual heating energy delivered by the district-heating system was between 114 and 187 kWh/m²/year for the six buildings. Additionally, the domestic hot-water systems supplied significant space heating energy, estimated at 25% to 40% of that provided by the district-heating system. Electric and gas systems also provided heat to the buildings, though a lesser amount. There was not a clean, linear relationship between heating energy consumption and outdoor temperature. Heat consumption rose with decreasing outdoor temperature, but there was a significant, explainable, amount of scatter.

The consumption of domestic hot water was fairly uniform (except in one building), averaging about 150 liters/person/day, with peak consumption occurring on the weekends. This agrees with a generally accepted norm for consumption of 150 to 170 liters/person/day. There was evidence of extensive leakage in the building that significantly exceeded the norm.

The consumption of cold water was also fairly uniform (except in the building with extensive leakage), averaging about 175 liters/person/day, with peak consumption again occurring on the weekends. (Hot and cold water consumption was highly correlated.) This is less than a generally accepted norm for consumption of 190 to 210 liters/person/day.

An evaluation of temporal patterns in the data suggested that electricity and gas (stoves) were being used to supplement the heating system in the severely underheated five-story building. Significantly more gas was used in that building when it was cold outside than when it was warm outside. Electricity consumption seems to mirror this natural gas consumption pattern in the building, although to a smaller degree, indicating that there also may have been some electrical resistance units used to help heat the apartments. There was no such pattern in hot water, however, leading to the conclusion that the occupants were not filling sinks and tubs with hot water to extract the heat.

Examination of the daily consumption profiles for these buildings provided a reasonable feel for the consumption habits of the building occupants. There were no surprises and the consumption patterns were easily explained by the occupant' daily and weekly patterns of activity.

ANNEX D
SOCIAL SURVEY RESULTS FROM BELORUS, ESTONIA, THE KYRGYZ REPUBLIC, LITHUANIA AND THE RUSSIAN FEDERATION

Social surveys of households in multifamily apartment buildings in Belorus, Estonia, Lithuania, the Kyrgyz Republic, and the Russian Federation were conducted in 1994 and 1995 as part of World Bank project-preparation activities and the UNDP/World Bank Energy Sector Management Assistance Program (ESMAP). These surveys were the first of their kind in these countries directed at households and addressing energy efficiency, housing maintenance, and utility services. The purpose of these surveys was to determine housing conditions, and the needs, perceptions, and attitudes of households about housing maintenance and potential energy efficiency improvements.

The surveys all varied somewhat because of the different project designs and objectives for which the surveys were intended. For example, the Lithuania survey needed to assess the level of potential demand for commercially available credit for energy efficiency improvements, to determine impacts on project beneficiaries, and to understand the roles of potential stakeholders, especially homeowner associations. In contrast, the Russian surveys focused more on occupants' perceptions of housing maintenance and utility services and to better understanding of the most significant technical problems and opportunities for reducing utility costs. The sample unit in all surveys was the household.

In Belorus, surveys were conducted among a statistically representative sample of 3,000 households to understand energy consumption patterns, consumer attitudes toward energy efficiency, and basic affordability issues.

In Estonia, one survey included 1,497 households in 675 buildings in principal Estonian cities (Arpaillange 1995a). The respondents were randomly selected and interviewed with a questionnaire containing 215 questions. In another survey, a representative (not random) group of 150 households was interviewed to provide insights into the willingness to invest in housing rehabilitation (Larson 1995).

In the Kyrgyz Republic, a statistically representative sample of 686 households was surveyed. The sample consisted of 380 urban and 306 rural households, distributed among the six regional capital cities, seven secondary towns, and twenty-six villages.

In Lithuania, surveys were conducted in the two largest cities, Vilnius and Kaunas, as part of the Lithuania Energy Efficiency/Housing Pilot Project (Arpaillange 1995b). Households were selected randomly; one initial address was chosen and a "random walk" procedure selected from there. This procedure was especially designed for Lithuanian building-stock characteristics. A total of 2007 households in 607 buildings were selected. For each household, one member was interviewed with a questionnaire containing 700 questions. The survey investigated energy consumption patterns, living standards, attitudes toward housing and maintenance, and the organizational capabilities of homeowner associations.

In the Russian Federation, surveys were conducted in three cities (Guzanova and Diachenko 1995a and 1995b). The cities were Ryazan (population 540,000), Vladimir (population 360,000), and Volkhov (population 50,000). Random households were selected: 455 households in Ryazan, 508 households in Vladimir, and 300 households in Volkhov. For each household, one adult member was interviewed with a questionnaire containing more than 300 questions.

The survey findings most relevant to energy efficiency are summarized in the following sections.

Social Views of Existing Comfort and Housing Services

Overall dissatisfaction with housing and energy services is prevalent. In all Russian surveys, a majority of households were dissatisfied with overall communal services. Principal causes of dissatisfaction were reported as high rent and utility payments, inadequate heating and hot-water supply, and problems with sewerage. In two surveys (Vladimir and Volkhov), a majority of Russian households reported that in winter their apartments were frequently or always either "rather cold" or "very cold" while in a third Russian survey (Ryazan), one-third of households reported "rather cold" or "very cold" conditions in wintertime (the frequency of these conditions in Ryazan was unspecified). Conversely, 20% of households in one survey (Ryazan) reported their dwellings were too hot in the winter at least sometimes. Other areas of dissatisfaction included humidity, ventilation (cold drafts from windows or apartment doors), and cold water supply.

Almost half (44%) of Estonian households were dissatisfied with the cost of renting or maintaining their home. More than one-third (38%) of Estonian households said their apartments were too cold in wintertime. Energy-related problems reported as "severe" by 15% to 22% of Estonian households included leaking roofs, roof insulation, hot-water availability, and windows. These same problems were reported at a lesser level than "severe" by an additional 27% to 36% of households.

Almost half (43%) of Lithuanian households were dissatisfied with their heating system and considered their apartments cold during the 1994/95 winter. But far fewer (20%) Lithuanian households connected to centralized district-heating systems were very satisfied with their heating system, compared with 56% of households that used apartment-level gas heaters and were very satisfied with their heating systems. About one-quarter of all Lithuanian households were very discontented with their heating systems.

Two-thirds of Kyrgyz households were dissatisfied with their district-heating system. Seventy-three percent felt their dwellings were too cold. Energy prices for district-heating and electricity were already considered unaffordable, and most respondents (86%) stated that they would not be able to pay more for energy. Households not connected to district-heating systems were reducing their consumption of coal for heating, hot water, and cooking, because it was too expensive.

The reliability of heat and hot water supplies was an issue. Russian households reported that hot-water is only available in most apartments when the district-heating system is operating (except for some 10% to 15% of apartments with individual hot-water heaters). In two surveys, 13% to 15% of households reported no hot water for periods of 90 days or longer each year; in another survey, 65% of households had no hot water for 45 to 90 days each year. On average, hot water is shut off for 30 to 45 days during the summer months. In addition, emergency interruptions occur six to seven times per year, sometimes for periods lasting up to four days. The time that hot-water taps must be left running in order for hot water to reach an apartment through hot water pipes varies greatly, from immediately to more than five minutes, and depends on the time of day or night. Between 10% to 25% of households have to wait more than five minutes at night for hot water once taps are opened. Central heating system shutdowns during the heating season were reported by 46% of Lithuanian households, and hot-water shutdowns during the off-season were reported by 92% of households.

Some households use supplemental heating sources when their dwellings become too cold. About one-quarter of Lithuanian households reported using electricity as a supplementary heating source. In wintertime, 20% to 30% of Russian households in two surveys (Vladimir and Volkhov) use supplementary sources of heat either frequently or constantly. Another 30% do so occasionally. In a third Russian survey (Ryazan), 30% of households use supplemental heating at least sometimes during the winter, and 40% of households use supplemental heating during the fall and spring before and after the heating season. The two most common sources of supplemental heating are plug-in electric heaters and gas kitchen stoves, with respondents split equally between which they used. Wealthier households appear to use electric heaters, which are metered, more often while the poorer households use gas stoves, which are not metered, more often.

Social Views of the Energy Efficiency Problem

There appears to be general understanding of energy efficiency measures that are needed. In the Russian survey, technical measures seen as especially important were replacement of radiators, installation of temperature regulators on radiators, insulation of windows, insulation of doors, and caulking of cracks and cavities in the walls. In the Estonian survey, measures seen as necessary by a majority or close to a majority of households included window weatherization, installation of new windows, and installation of hot-water and heat meters. One-third of Estonian households felt that heating systems needed to be repaired and ventilation systems needed to be improved. Three-quarters of Lithuanian households believed that insulation would reduce their energy bills and would like to insulate their dwellings and buildings. The desire to insulate appeared strongly related to household financial problems with paying energy bills. Most Kyrgyz households (80%) agreed that energy efficiency would reduce their energy bills, but most (60%) also felt that energy efficiency improvements were not affordable for them.

Most households have already taken steps to improve their comfort and reduce energy losses from their apartments. In the three Russian surveys, 75% to 90% of households reported resorting to makeshift weatherization and insulation, including improvements to windows, balconies, and front doors. (Locations of colder apartments as reported by households tend to correlate with the expected colder locations in buildings, such as corner apartments and first-floor apartments, indicating that better heat balancing could improve distribution of comfort within buildings.) About half (53%) of all Estonian households in cooperatives or buildings with homeowner associations had weatherized their windows since 1992. Improvements to the hot-water system, installation of a hot-water meter, and installation of a heat meter had been done by 17% of these households since 1992. Six percent of these had made improvements to ventilation systems. The corresponding figures for households in buildings without homeowner associations were 36% for window weatherization, 6% for improvement in hot-water system and installation of a heat meter, 3% for installation of a hot-water meter, and 4% for ventilation system improvement. Thus it is clear that households in organized buildings in Estonia have made much more progress in energy efficiency improvements than those in buildings without organized homeowner associations. Lithuanian households commonly reported having carried out winter insulation; window insulation was most common (75% of households), followed by door insulation (50%), and balcony glazing (25%).

Most households already engage in some form of energy conservation. For example, 90% of Lithuanian households reportedly turn off lights in unoccupied rooms. But 80% of Lithuanian households also believed that their energy consumption had already reached a minimum and that additional reductions in consumption would represent a hardship (however, this result should be interpreted cautiously because even households that are satisfied with their heating responded this way).

Households believe they would reduce energy consumption with marginal-consumption billing. Half of Lithuanian households would like an apartment-level heat meter and believe this would cause them to consume less and pay less. Seventy-five to eighty-five percent of Russian households would prefer to pay for their space heat and hot-water consumption on a marginal basis according to meters rather than on the fixed basis in place now. There is a perception that it is only fair to pay for what is consumed, and that bills will be reduced because inadequate amounts of heat are being delivered. Most Russian and Kyrgyz households (80% to 90%) would like heat regulators on their radiators so they can control their own heat consumption. About half of the households also recognized the economy possible by keeping apartments cooler at night and would employ this strategy if controls and metering were available. Some Russian households would reduce consumption of hot and cold water during dish washing, manual clothes washing, and teeth brushing if they were motivated to save water by paying according to metered consumption. For example, two surveys reported that only 3% to 8% of households now turn off the water while washing dishes. Few households would significantly reduce the length of their showers or take fewer baths or showers. The majority of Russian households responded that they would welcome low-flow showerheads and faucet caps to reduce hot and cold water consumption if they had to pay for water according to metered consumption.

Affordability and Willingness to Pay

Energy costs represent a significant portion of household income. Average payments for communal services (housing maintenance and utilities) by Russian households were about 10% of total household income in both Vladimir and Volkhov. Households eligible for housing subsidies, that is, households paying more than 15% of total household income for communal services, represented 30% to 40% of respondents.[26] The poorest households had communal services bills up to 20% to 25% of total household income. Similarly, Lithuanian households reported that they spend an average 11% of their monthly income on energy (electricity, heating, hot water, gas, etc.), which increases to 15% in the winter. Low-income households bear a relatively higher burden than any other income groups; energy bills absorb at least 20% of their monthly income (and up to 26% in the winter). A majority of Lithuanian households (73%) state they have problems paying for energy. In 1994, Belorussians were still paying less for housing services than households in other FSU countries; the lowest-income groups reported that housing and utility costs were 10% of their monthly income while the highest-income groups reported this share as 2.5%.

If energy prices were higher, about half of Lithuanian households agree they would consume less energy although most households felt they could not pay more for energy than they currently do (a general opinion that should be treated with caution since even the richest households made this statement). No data were collected on the willingness of Lithuanian households to pay for energy efficiency improvements.

Willingness to pay for energy efficiency measures generally still appears low in the Russian Federation. In two surveys, no more than 15% of Russian households were willing to pay for measures like replacement of radiators, temperature regulators on radiators, insulation of windows, insulation of doors, and caulking of cracks and cavities in the walls; the exception was that 20% in Vladimir were willing to pay for radiator temperature regulators. Interestingly, Russian households were willing to accept retrofits or improvements done free of charge only if they felt these were necessary; in other words, households are wary of experiments and do not want equipment or changes they do not think they need. When Russian households were asked if they would be willing to borrow money to improve their homes, 13% to 22% responded positively, but most of these respondents favored using loans to improve apartment or building appearance and safety, with increased apartment comfort and reduced utility bills as only second and third priorities, respectively. In one Russian survey in 1995 that mentioned specific loan amounts on questionnaires, only 6% were willing to borrow $520 with a monthly payment of $8, and only 1% were willing to borrow $1,053 with a monthly payment of $17.

Results from two different surveys in Estonia in 1995 were quite different. In one survey, only 4% of Estonian households were seriously interested in borrowing to improve their dwellings if it meant mortgaging or pledging their dwellings. Interest in housing loans even without the mortgage requirement was still low: only 20% of apartment owners and 15% of single-family-home owners. About 20% of Estonian households had no desire to improve their dwellings. Yet in another survey, 75% of households said they would be willing to invest in

[26] These figures are estimates based upon official income data, which does not include substantial amounts of unreported (unofficial) income. Despite the high percentage of households eligible for subsidies, statistics for Vladimir at the time of the survey showed that only 9 percent of households city-wide were receiving housing subsidies.

housing by taking a loan, and more than half of these would use the loan to renovate their existing building (as opposed to buying or building a new home). Among the motivations cited in this survey for investing were: keeping apartments in good shape for one's descendants, feeling responsible for one's property, controlling one's environment, and taking pride in one's home. Respondents were also willing to borrow to be able to move into their own single-family home. Among the factors that negatively influenced willingness to invest were lack of a social safety net, uncertainty about maintenance costs, high interest rates, and lack of sufficient legislation on homeowners associations.

Aside from the information gathered in these social surveys, little other information exists regarding affordability of energy efficiency. Official income data do not provide the full picture of resources available to households, and there are no established "rules of thumb" about what fraction of household income constitutes an affordable expenditure for housing and utilities. An affordability analysis conducted by the World Bank (1996b) showed that even very poor households are able to afford modest packages, and most households can afford many basic types of packages.

Ownership and Privatization

Privatization is more advanced in Estonia and Lithuania than in the Russian Federation or Ukraine. By 1995 almost two-thirds of Estonian households had privatized their dwellings and another 20% had not yet received their property titles although they had applied for private ownership. A majority (60%) of Estonian homeowners and privatization applicants think that they are better off after privatization and think that privatization is a guarantee that they will not lose their homes. However, as owners have started to realize that ownership brings certain responsibilities, like maintenance, their positive attitudes toward privatization have diminished. A majority (60%) of the existing Estonian renters wanted to privatize their apartments but were unable to. Most of these were unable to privatize because their apartments were already owned by someone prior to the privatization process, or the apartment was returned to an owner under the country's restitution policy. A small number (11%) were unable to privatize because the privatization vouchers they had received were not sufficient to pay for their apartments or they had outstanding utility bills. Ninety-four percent of Lithuanian households reported owning their homes. Even Lithuanian households living in dormitories reported similar rates of privatization. In one Russian survey of multifamily building households, 20% had privatized their apartments, but only 25% felt that privatization was worthwhile. Fifty percent of the Russian households thought privatization was not worthwhile because they thought they would then have to pay property taxes.

Formation of Homeowner Associations

Most households in Lithuania and Estonia favor formation of homeowner associations (this issue was not addressed in the Russian survey). More than half of all Lithuanian households strongly believe that a homeowners' association would be useful, a statement with which only 7%

"strongly disagree." Likewise in Estonia, of those households who do not live in buildings with a homeowner association, most would welcome the creation of an association (80% of existing apartment owners and 64% of applicants for ownership). In Lithuania, attitudes toward the importance of homeowners' associations appear to be only slightly influenced by respondent's level of education and income. Gender or age appear not to influence attitudes toward associations. Homeowners' associations or cooperatives were reported to exist in the buildings of 12% of the surveyed households in Lithuania (and 13% in the Estonia survey); two-thirds of these associations were created after 1991. The incidence of associations is highest among households living in apartments owned by a private landlord and among households owning their homes (this is less true in municipal owned buildings). In nearly all cases where a homeowners' association exists, housing maintenance is also organized by the association, and a majority of homeowner associations are responsible for building cleaning, central heating maintenance, building repairs, and payment of heating bills. Although some associations had tried to obtain a grant (5%) or loan (4%), only 1% had been able to obtain a loan and only 2% had been able to obtain a grant.

Needs and Capabilities of Homeowner Associations

The Lithuania survey showed that a majority of homeowner association presidents (chairpeople) thought that assistance in building maintenance and finance would be useful but most did not think that assistance in the area of management would be useful.

In the Lithuania Housing/Energy Efficiency Project, the Lithuanian Ministry of Construction and Urban Development conducted a test activity in order to understand the needs and capabilities of homeowner associations, particularly within the context of improving energy efficiency in their buildings. The Ministry and its consultants helped four associations go through a process of borrowing money from banks to implement energy efficiency measures. Direct assistance to the associations was provided at each step in the process, including: (i) inviting associations to take the loan; (ii) obtaining a mandate from association members; (iii) gathering technical and procedural information; (iv) preparing a proposal that identified options and their respective costs and benefits; (v) choosing a course of action and inviting bids from contractors; (vi) selecting a bid; (vii) negotiating with contractors; (viii) negotiating with commercial banks; and (ix) overseeing the construction and installation of measures.

As a result of this test activity, the most important qualities of homeowner associations were deemed to be: prior organizational experience (such as with former cooperatives), leadership that encourages households to participate in decision making, financial resources, and good information. Several important lessons emerged from the test activity:

- There are tremendous transaction costs to homeowner associations in their attempts to improve energy efficiency under current conditions.

- Homeowners associations vary greatly in the strength, function, experience, and openness of their members and leaders.

- Homeowners have considerable interest in improving energy efficiency, but they know little about technical options, costs, borrowing, and loan conditions.

- Despite the huge need, homeowners' association have little access to information about renovation and maintenance.

- Many homeowners are anxious about indebtedness and credit; although some of the anxiety may be dispelled by access to good information, positive experience will also be necessary.

- Although the concept of interest rates in general appears well understood, there is consensus that interest rates of 15% in a government program were "outrageously high" yet just about the maximum affordable.

- Individual homeowners and homeowners' association are dependent on authorities and contractors for information, yet mistrustful of them. Thus there is considerable demand for independent advice.

- Even very poor households can afford to borrow for energy efficiency improvements if the size of the investments is moderate.

ANNEX E
CHARACTERIZATION OF THE BUILDING STOCK

There are several types of multifamily residential building construction common to most FSU countries (characteristics are described in Opitz 1994; Matrosov et al. 1994; EXERGIA et al. 1995; BCEOM 1995; Rolén 1994; Schipper et al. 1994; Kazakevicius et al. 1996):

- *Brick*. These were mostly constructed from 1950 to 1975, with 4 to 12 stories, and have radiators for the heating system. In 1989, these buildings represented about 30% of the total floor area of multifamily buildings in the Soviet Union.

- *Large block*. These were mostly constructed from 1955 to 1970, with 4 to 12 stories, and have radiators for the heating system. In 1989, these buildings represented about 7% of the total floor area of multifamily buildings in the Soviet Union.

- *Prefabricated concrete panel*. These have been constructed from 1960 to the present using both one-layer and three-layer panels. Building sizes range from 5 to 22 stories. Heating systems in older buildings of 5 and 9 stories used radiators while most 12-story buildings that emerged in the 1970s used heated wall panels; convectors were used in modern 17-story and 22-story buildings. In 1989, these buildings represented almost two-thirds of the total floor area of multifamily buildings in the Soviet Union.

- *Wood*. These are single-family houses and multifamily buildings of 2 to 4 stories.

Multifamily buildings provide the majority of total dwellings: 73% in Estonia, 50% in Lithuania, and approximately 80% in the Russian Federation, for example (Schipper et al. 1994; Kazakevicius et al. 1996). These multifamily buildings share similar characteristics:

- Joints between panels consist of rubber molding and cement mortar (there is usually air leakage through these joints).
- Buildings have mainly flat concrete roofs; in many buildings there is no roof insulation.
- Windows are usually double-pane, with wooden frames (there is typically a lot of air leakage).
- Most buildings do not have heat exchangers in substations.
- District-heating system hot water is mixed with the return flow from building radiators through an ejector pump. The mixing ratio is fixed, so the temperature of the water through radiators is dependent on the district-heating supply temperature.
- Radiator systems are either one-pipe or two-pipe systems (one-pipe systems are most common). Most radiators do not have valves, or if they do, the valves have usually become broken or non-functional.
- Heat distribution risers in buildings typically do not have balancing valves.
- Ventilation is typically natural draft, with vents in kitchens and bathrooms leading to chimneys that vent through the roof.

- A typical U-value for external walls in a climate like Lithuania is 1.0 $W/m^2/°C$ (approximately six times higher than the corresponding U-value for a new Swedish building) although lower U-values were being introduced in more recent norms for new construction.

With respect to energy efficiency improvements, the building stock in FSU countries can be characterized based on differences in design and construction that influence both the current energy consumption and the cost and effectiveness of various retrofit measures. There are six main dimensions to this characterization:

Building size (typically the number of stories). The building size affects a number of parameters that influence current energy consumption and choice of retrofit measures. These parameters include air infiltration, surface-to-volume ratio, presence or absence of elevator shafts, and the presence of fire/security doors off common spaces. In addition, the building size has a large impact on the costs per apartment of retrofit measures that apply once to each building (like building-level heat control).

Wall construction. Walls can be made of concrete panels, concrete blocks, brick, or wood. The type of wall affects infiltration and conduction and the types of wall insulation that are possible in a retrofit.

Attic. Some buildings have attics while others have the roof directly over the top-floor apartments. Attics can be "warm" or "cold." In a warm attic the ventilation shafts from apartments exit into the attic while in a cold attic the ventilation shafts exit into the outside air. The existence and type of attic influences the heat loss through the roof and whether the ceiling on the top floor of apartments is warm or cold. It also affects the type and placement of insulation--whether insulation can be placed in the attic (much cheaper), or whether it must be added to the roof (more expensive).

Heating System. The heating system can be direct district heating (water from the power plant circulates through radiators), indirect district heating (a heat exchanger creates a secondary loop circulating through radiators), or non-district heating (with individual apartment-level heaters or a building-level boiler serving one or a few buildings). The heating system determines the types of heating retrofit measures and heating control strategies that are possible.

Domestic Hot-water (DHW) Supply. Domestic hot-water can come from district-heating systems with configurations that are either open (hot water from power plant flow out hot-water tap) or closed (a heat exchanger with a secondary loop supplies hot-water taps). Hot water can also be produced from individual gas or electric water heaters in each apartment. The type of DHW system impacts the cost of delivered hot water, the amount of heat supplied to the building from the DHW system, and the cost-effectiveness of hot-water retrofits.

Appliances. The types of appliances in a building (such as refrigerator, gas or electric stove) affect the potential for energy efficiency and also affect current or anticipated fuel substitution, such as supplemental heating with gas stoves.

No Soviet statistics on the detailed characteristics of the building stock existed on an all-union level, yet a picture can be established from post-Soviet studies of individual countries.

Available data on the building stock varies from one country to another. Some countries, particularly the smaller ones, have the entire building stock characterized on a national level. Other countries, such as the Russian Federation, require data collection on a city-by-city basis, as no national-level statistics exist on the detailed characteristics of the building stock. Some data on the building stock in the Russian Federation, Lithuania, and Estonia are reviewed below.

Russian Federation. One source of data is the Russian Federation Enterprise Housing Divestiture Project, which collected detailed data on the building stock in six cities (Table E-1). This data was grouped into 29 different building categories.

Lithuania. Although the majority of residential buildings in Lithuania are single-family houses made of wood or bricks, close to 50% of all dwellings are in multifamily buildings (Kazakevicius et al. 1996). About 60% of these multifamily buildings are concrete panel types with flat roofs and 5 to 9 stories. Another 30% are buildings with walls of silicate or baked clay bricks, flat roofs, and 4, 5, 9, and 12 stories.

Estonia. In Estonia, there are four main categories of buildings and heating, as shown in Table E-2 (EXERGIA et al. 1996). In total, there are about 610,000 dwellings for Estonia's 1.6 million population, one of the lowest levels of inhabitants per dwelling (2.6) of any FSU country. Total floor area in Estonia is split roughly evenly--one-third wood, one-third brick, and one-third concrete panel. In rural areas, the percentage of wooden construction is much higher; about half of all rural buildings are wood.

Data Collection and Building Audits

In the Russian Federation, under the Enterprise Housing Divestiture Project, detailed information was collected during 1995-97 for a sample of 40 buildings distributed across the six cities. Data collection was done to determine the optimal package of retrofits for each building category by city. The information is of 4 types, each discussed separately below. The collected information provides calibration of a building simulation tool that is modified specifically for Russian multifamily housing (Dirks et al. 1996).

Detailed Audit Data. Detailed audit data to be collected during the 1997-98 heating season are listed in Table E-3. This data fully describes the physical characteristics of the sample buildings for modeling purposes.

Table E-1. Building Stock in Six Russian Cities (percent)

Building type	*Share of total building stock*	*Share with district-heat for space heating*	*Share with district-heat for hot water*	*Share with attic*
1- to 2-family house, wood/brick	4	51	28	---
2- to 4-story, wood	22	100	55	100
2- to 4-story, brick	21	98	74	87
5-story, brick	10	100	83	49
5-story, panel	25	100	89	47
6- to 8-story, brick	1	100	100	95
9-story, brick	5	100	100	39
9-story, panel	11	100	100	27
10- to 13-story, brick	1	100	100	92
10- to 13-story, panel	1	100	100	68
14-story, brick	less than 1	100	100	16
14-story, panel	less than 1	100	100	0
higher than 14-story, brick	less than 1	100	100	0
higher than 14-story, panel	less than 1	100	100	33

--- Not available.

Source: Battelle 1996a, based on data covering 19,714 buildings.

Blower-Door Test Data. Blower door tests were conducted on the sample buildings to determine the primary sources of infiltration and exfiltration as well as intra-building air movement. These tests are used to develop equivalent leakage areas (ELAs) for each envelope component. Based on these data, an infiltration model is developed for the multifamily buildings that takes into account the building height, component ELAs, wind speed, and difference between inside and outside temperatures (Armstrong et al. 1996). This infiltration model is integrated into the previously mentioned building simulation tool. The integrated model assesses the performance of envelope weatherization measures intended to reduce infiltration.

Envelope U-Value Measurement Data. U-value measurements of building envelopes were also made for the sample buildings. Because of the relative high U-value (>2 W/m²-K) the conductive loss through the walls represents a significant portion (about one-third)of the building heat loss. Differences in construction practices, as well as material type (e.g., brick or panel), material composition (sand, gravel, clay), and material density can be expected to produce significant variation in envelope U-values. Accurate estimates of actual U-values is necessary for model calibration and for determination of envelope retrofit cost-effectiveness.

Metered Data. At the heart of the model calibration and retrofit verification exercises is the actual energy consumption within buildings. In the sample buildings, meters were provided with pulse output to facilitate the collection of hourly data. In addition to the revenue meters, other temperature and weather information must be collected. Table E-4 lists metered data for collection on a hourly basis over one heating season.

Table E-2. Building Characteristics in Estonia

Building type	*Share of dwellings*	*Heating system type*	*Hot-water system type*
Older, mainly wooden, single-family houses, 1- to 2-stories	9%	80% solid-fuel stoves 20% boiler & radiators	60% solid-fuel stoves 20% boiler 20% electric water heater
Newer single-family houses, 1- to 2-stories	22%	60% solid-fuel stoves 40% boiler & radiators	40% solid-fuel stoves 40% boiler 20% electric water heater
Multifamily apartment buildings, 5-, 6- or 9-stories, with 15 to 144 apartments, either concrete panel or brick walls	35%	100% district heating	100% district heating
Multifamily apartment buildings, 1 to 4 stories, 6 to 36 apartments, concrete block or silicate brick walls	34%	58% district heating 29% solid-fuel stoves 13% building-level boiler	71% apartment-level gas-fired water heaters 20% apartment-level electric water heaters 9% solid-fuel stoves

Source: EXERGIA et al. 1996

Table E-3. Detailed Building Audit Data (under the Enterprise Housing Divestiture Project)

<u>Construction:</u>
Year of Construction
Building Floor Area, apartments (m²)
Building Floor Area, common space (m²)
Building Air Volume (m^3)
Building Footprint (m²)
Floor-to-Floor Height (m)
Floor-to-Ceiling Height (m)
Floor Thickness (concrete, floor boards) (m)
Ceiling Thickness (m)
North Side Length (m)
East Side Length (m)
Number of Floors
Number of Sections
Total Number of Flats
Number of 1-Bedroom Flats
Number of 2-Bedroom Flats
Number of 3-Bedroom Flats
Number of 4-Bedroom Flats
Number of Occupants
Estimated Current Average Inside Temperature Over the Heating Season

Annual Heat Consumption Design Value (G-Cal)
Annual Hot-water Consumption Design Value (G-Cal)

Plans:
Roof plan
1st floor plan
Other floor plans (if different)
East, West, North, and South elevation of typical end section
East and West or North and South elevation of typical core section
Ventilation riser diagram and unique code for each unique riser
Mark code for each riser on floor plan
Show location (or potential location) of security halls and doors
Show gas, electric, and roof drain risers and branches
Show location of basement, roof, and attic access doors

Radiator:
Building heating supply water temperature function (e.g., of outside temperature)--temperature supplied to the risers
Building heating return water temperature function (e.g., of outside temperature)--temperature returned from radiators
Radiator Type (0=no bypass, 1=w/bypass, 2=two pipe)
Radiator Valve Present (0=no, 1=yes)
Average Projected Wall Area per Radiator (m^2)
Number of Radiators (in common space, in flats, on outside walls for common space and on outside walls for flats)
Number of risers
Riser Balancing Valves Present (yes/no)
Radiator supply method (e.g., top-to-bottom)

Exterior Wall:
Wall Thickness (m)
Wall Construction Type (wood, brick, block, panel)
Wall Design U Value w/o air films ($W/m^2 \cdot °K$)
Gross North wall area (including windows and doors) (m^2)
Gross East wall area (including windows and doors) (m^2)
Gross South wall area (including windows and doors) (m^2)
Gross West wall area (including windows and doors) (m^2)
If Panel: Panel width (m)
Panel height (m)
Joint length per m^2 of Wall Area (m)
Portion of Joints Currently Sealed (%)
If Block: Joint length per m^2 of Wall Area (m)
Portion of Joints Currently Sealed (%)
If insulation is present: Insulation Location: Building Interior/Wall Interior/Wall Exterior
Insulation Thickness (cm)
Insulation Type (e.g., rockwool)
Estimate Insulation R-value ($m^2 \cdot °K/W$)

Interior Wall:
Wall Thickness (m)
Wall Construction Type (wood, brick, block, panel)
Gross wall area separating front and back apartments (m^2)
Gross wall area separating front apartments from common space (m^2)
Gross wall area separating back apartments from common space (m^2)
If Panel: Panel width (m)
Panel height (m)
Joint length per m^2 of Wall Area (m)
Portion of Joints Currently Sealed (%)

If Block: Joint length per m² of Wall Area (m)
Portion of Joints Currently Sealed (%)

Bottom Floor:
Floor Construction Type (slab-on-grade, cold/well ventilated crawl space, warm/poorly ventilated crawl space)
Floor Design U Value w/o air films (W/m².°K)
Floor cavity thickness--(bottom flat to crawl space) (m)
If insulation is present: Insulation Location: Floor Interior/Crawl space ceiling/perimeter for slab-on-grade
Insulation Thickness (cm)
Insulation Type (e.g., rockwool)
Estimate Insulation R-value (m² · °K/W)
Is there a vapor barrier (yes/no)?

Roof:
Roof type (flat, flat w/ cold air attic, flat w/ warm air attic, peaked)
Roof Design U Value w/o air films (W/m².°K)
Roof thickness--(top flat to attic or outside) (m)
If insulation is present: Insulation Location: Roof Interior or Attic Floor
Insulation Thickness (cm)
Insulation Type (e.g., expanded clay)
Estimate Insulation R-value (m² · °K/W)
Is there a vapor barrier (yes/no)

SHW:
SHW supply temperature function (e.g., same as heating water, as a function of outside temperature, etc.)
SHW return water temperature function (e.g. of outside temperature)--temperature returned from the recirculation
Estimated percentage of total hot water use for sinks (%)
Estimated percentage of total hot water use for showers (%)
Estimated percentage of total hot water use for other (%)
Average full-flow rate for existing faucet (1st floor and top floor) (liters/minute)
Average full-flow rate for existing shower head (1st floor and top floor) (liters/minute)
Percentage of faucets with existing aerators (%)
Percentage of faucets that will accept aerators (Flow reduction ok) (%)
Percentage of faucets that cannot accept aerators (Flow reduction ok) (%)
Percentage of bathroom sinks that serve both sink and tub (%)
Percentage of showers with low-flow shower heads (%)
Number of faucets
Number of Shower Heads
Type of hot-water service (district hot water or gas)
If district hot water: Recirculation (constant, none, time clock--if time clock then what is the schedule)
Total length of recirculating pipe excluding attic and crawl space (m)
Pipe diameter (mm)

Window:
For each window type [apt. non-balcony (more than one type possible), apt. balcony, glassed-in balcony, common space]: Area per window (area of the window hole) (m²)
Perimeter length per window (perimeter of window hole) (m)
Glass area (m)
Percentage of window perimeter sealed (%)
Sash length per window (sash is perimeter of movable window) (m)
Estimated U-value (W/m² · °K)
Shading Coefficient of the glass
Number of panes
Balcony window area (m)
Number of windows of this type facing North

Number of windows of this type facing East
Number of windows of this type facing South
Number of windows of this type facing West

Ventilation and Air Leaks:
Number of exhaust vents per flat that connect directly to the vertical channel (i.e., room-to-room vents should not be included)
Free area of direct exhaust grilles found in each size of apartment (m^2)
Percentage of exhaust vents that are covered permanently (%)
Percentage of exhaust vents that have manual controls (%)
Number of exhaust stack groups per building (count at top-floor ceiling level)
Cross-sectional area of each channel at top-floor ceiling level (m)
Height from roof to top of exhaust collector stack (m)
Quantity and cross-sectional area (m^2) of each roof exhaust stack type
Height of technical attic (m)
Number of potential security hall locations with no door (also as %)
Number and average area of smoke exhaust damper leaks (m^2)
Description & aggregate area (m^2) of attic (top-floor ceiling) penetrations
Description & aggregate area (m^2) of basement (first-floor) penetrations

Door:
Number of exterior doors (excluding balcony doors)
Percentage of exterior doors that are in satisfactory condition and close (i.e., close automatically and remain closed)
Percentage of exterior doors that are in satisfactory condition and do not close (i.e., these doors are often/always ajar)
Percentage of exterior doors that are in unsatisfactory condition and do not close (i.e., these doors are often/always ajar)
For each door type (apt., security hall, fire escape, building entrance)
Area per door (area of doorway) (m^2)
Perimeter length per door (perimeter of doorway) (m)
Percentage of door perimeter sealed (%)
Sash length per door (perimeter of doorway) (m)
Threshold clearance (m)

Lights:
Number of fixtures per kitchen
Number of lamps per kitchen fixture
Watts/kitchen lamp (W)
Number of fixtures per living room
Number of lamps per living room fixture
Watts/living room lamp (W)
Total number of common space fixtures
Number of lamps per common space fixture
Watts/common space lamp (W)

Technical Attic and Basement/Crawl Space:
Floor joint length per m^2 (m) (joint is where concrete panels come together)
Smoke exhaust duct area (m^2 per section)
Basement ceiling (1st floor deck) joint length per m^2 (m)
Is technical attic warm or cold?

Table E-4. Types of Metered Data for Building Measurements (under the Enterprise Housing Divestiture Project)

Average building inside temperature

All weather data (hourly dry bulb temp, absolute humidity, solar insolation, wind velocity)
Electricity consumption or design value if metered not available (kWh)
Gas consumption or design value if metered not available (MJ)
Cold water consumption (m^3)
SHW consumption (m^3)
SHW supply temperature (°C)
SHW return temperature (°C)
SHW energy delivered to the building Q_{SHW} (MJ)
Heating water supply temperature (°C)
Heating water return temperature (°C)
Heating energy delivered to the building Q_{heat} (MJ)

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