PNNL-11644
UC-350

Kyiv Institutional Buildings Sector Energy Efficiency Program: Technical Assessment

August 1997

Global
Studies
Program
Pacific Northwest National Laboratory
Advanced International Studies Unit

PNNL-11644
UC-350

Kyiv Institutional Buildings Sector Energy Efficiency Program: Technical Assessment

T. J. Secrest
S. L. Freeman
A. Popelka[(a)]
P. A. Shestopal[(b)]
E. V. Gagurin[(b)]

August 1997

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest National Laboratory
Richland, Washington 99352

(a) Tysak Engineering.
(b) Agency for Rational Energy Use and Ecology.

Summary

The government of Ukraine, through the State Committee of Energy Conservation (State Committee), is considering the implementation of energy efficiency measures in state and municipal institutional buildings in the city of Kyiv. The State Committee entered into an agreement with the U.S. Department of Energy to assess the efficiency potential of the institutional buildings sector in Kyiv. Results of this assessment would support a loan by the World Bank for implementing an institutional buildings sector efficiency improvement program in Kyiv.

This report documents the assessment of the institutional buildings sector efficiency resource conducted by Pacific Northwest National Laboratory (PNNL) and its subcontractors, Tysak Engineering and the Agency for Rational Energy Use and Ecology (ARENO-ECO). The assessment consists of three primary tasks: evaluation of the institutional sector building stock in Kyiv, estimation of heat energy consumption in this building stock, and assessment of the cost-effective energy efficiency potential through retrofits to the buildings.

Buildings suitable for inclusion in a potential loan program were identified by means of a survey of owning organizations. Of the 1,678 buildings identified by the survey, education buildings make up the largest category with 1,296 buildings and a total of 6 million square meters of floorspace. There are an estimated 339 healthcare buildings having about 1 million square meters of floorspace. Forty three cultural buildings were also included in the survey with a total of 113 thousand square meters of floorspace. Total floorspace included in the survey for the institutional sector is 7.2 million square meters.

Of 17.7 Gcal of heat energy supplied to the buildings sector in the form of hot water for space heating and domestic hot water purposes, the share by sector is estimated as follows: residential sector 68%, institutional sector 16%, and commercial sector 16%. Although a literature review and professional experience indicate these estimates to be reasonable, uncertainty is high for these estimates. Of the institutional buildings included in this assessment, the educational category was estimated to represent about 84% of the total energy consumption.

Building types were analyzed by size and age subcategories to determine the cost-effective energy efficiency potential. Measures to improve energy efficiency were selected and applied to each subcategory to reduce space heating and domestic hot water energy use. Measures were selected based on the economic criterion of a 5-year or less simple payback. The measures include insulation (exterior, roof, attic, and pipe), weatherstripping, storm windows, radiator reflectors, controls (building and radiator level), low-flow showerheads, and faucet aerators. After measures were selected, the performance of the measure package was evaluated based on simple payback, internal rate of return, and net present value.

The estimated efficiency potential ranges from 20% of baseline energy use for art galleries and museums to 29% for theaters, or a weighted average efficiency potential of 26% for all buildings. The investment levels associated with the efficiency improvements range from $3.47 per square meter for schools to $6.21 per square meter for hospital administration buildings, or a weighted average investment of $4.31 per square meter. The total cost to install the efficiency measures is $31.1 million.

As a result of energy efficiency improvements, a reduction in energy bills of $1.7 million is estimated in the first year, increasing to over $9 million annually when the installation of efficiency measures is completed in the fifth year of the program. In addition to energy use reductions, annual emissions are expected to be reduced as follows: 332 metric tons of NO_x, 232 metric tons of SO_x, and 85,427 metric tons of CO_2. None of the measures considered are expected to have negative health impacts or other environmental impacts.

Abbreviations and Acronyms

A/C	air conditioning
AISU	Advanced International Studies Unit
ARENA-ECO	Agency for Rational Energy Use and Ecology
ASEAM5	A Simplified Energy Analysis Method, Version 5
ASHRAE	American Society for Heating, Refrigeration, and Air Conditioning Engineers
CFC	chlorofluorocarbon
CHP	combined heat and power
CO_2	carbon dioxide
dm^3	cubic decimeters
DOE	U.S. Department of Energy
DWH	domestic water heating
ECOs	energy conservation opportunities
EHDP	Enterprise Housing Divestiture Project
FLEOH	full load equivalent operating hours
Gcal	gigacalories
GJ	gigajoules
GWh	gigawatt-hours
IEA	International Energy Agency
IRR	internal rate of return
K	degrees Kelvin
kcal	kilocalories
KGTKE	Kyiv Municipal District Heat Company
km	kilometer
KRB	Hryvna
kWh	kilowatt-hours
m	meter
MJ	megajoule
NO_x	oxides of nitrogen
NPV	net present value
O&M	operations and maintenance
ODS	ozone depleting substances
PNNL	Pacific Northwest National Laboratory
R-Value	resistance to heat flow, defined as thickness/thermal conductivity
RRR	required rate of return
SCEC	State Committee for Energy Conservation
SO_x	oxides of sulfur
TETS	combined heat and power station

TMY	typical meteorological year
U-Value	overall heat transfer coefficient
VAT	value added tax
W	watt

Conversion Factors

1 Gcal	=	1163 kWh
1 Gcal	=	4.186 GJ
1 GJ	=	278 kWh

Acknowledgments

This assessment was made possible by funding provided by the U.S. Department of Energy (DOE) under a Memorandum of Cooperation between the DOE and the Ukrainian State Committee for Energy Conservation (SCEC). Recognition is provided to Brian Castelli and Elizabeth Arner of DOE's Office of Energy Conservation and Renewable Energy for their perseverance and leadership in this effort. Appreciation is extended to Carolyn Gochenour and Pentti Aro of the World Bank and Tord Holmstrom of Energi Planerarna AB for their coaching and many suggestions and comments. Appreciation is extended to Mykhailo Kovalko, Nikolai Raptsoun, and Georgy Panchenko of the SCEC for their in-country leadership to facilitate data collection and agreements with Ukrainian participants.

Contents

Summary iii

Abbreviations and Acronyms v

Conversion Factors vi

Acknowledgments vii

1.0 Introduction 1.1

1.1 Scope and Approach 1.1

1.2 Report Organization 1.2

1.3 Study Participants 1.2

2.0 Energy Use Baseline Assessment 2.1

2.1 Sector and Subsector Definitions 2.1

2.1.1 Institutional Sector 2.1

2.1.2 Residential Sector 2.4

2.2 District Heat System Overview 2.5

2.3 Thermal Energy Consumption Baseline 2.7

2.3.1 Building Sector Heat and Hot Water Consumption 2.13

3.0 Efficiency Assessment 3.1

3.1 Efficiency Measures 3.1

3.1.1 Efficiency Measures Considered 3.1

3.1.2 Efficiency Measures Not Considered 3.22

3.1.3 Summary of Efficiency Measures Considered 3.26

3.2 Analysis Approach 3.26

3.2.1 Technical Analysis Method 3.27

3.2.2 Economic Analysis Method 3.29

3.3 Efficiency Potential Assessment 3.31

3.3.1 Institutional Sector Efficiency Potential 3.32

3.3.2 Residential Sector 3.33

3.4 Sensitivity Analysis 3.34

3.5 Investment Requirements 3.35

4.0 Impacts Assessment 4.1

4.1 Economic Impacts 4.1

4.2 Environmental Impact 4.3

4.2.1 Emissions Impacts 4.4

4.2.2 Health and Safety 4.6

4.2.3 Indoor Air Quality 4.6

4.2.4 Soil Contamination 4.7

4.2.5 Ozone Depleting Substances 4.7

5.0 Conclusions 5.1

6.0 References 6.1

Appendix A - Institutional Building Stock Survey and Data Collection A.1

Appendix B - Baseline Energy Consumption B.1

Appendix C - Efficiency Measure Cost Data C.1

Appendix D - Efficiency Measure Performance Analysis D.1

Appendix E - Investment Requirements E.1

Appendix F - Review of Literature F.1

Figures

2.1 District Heating Regions in Kyiv 2.6

2.2 Estimated Energy Flow of Kyiv District Heating System, 1995..... 2.12

Tables

2.1 Number and Floorspace of Institutional Buildings by Type and Subsector, 1996 ..... 2.4

2.2 Residential Buildings and Floorspace 2.4

2.3 Hot Water Capacity of the Kyiv District Heating System..... 2.6

2.4 Estimated Fuel Consumption by District Heat Suppliers in Kyiv, 1995 ..... 2.9

2.5 Estimated Heat and Electricity Supply to the District Heating System in Kyiv, 1995..... 2.10

2.6 Estimated Heat and Electricity Consumption from the District Heating System in Kyiv, 1995..... 2.11

2.7 Institutional Sector Baseline Heat and Hot Water Energy Consumption Supplied by District Heat..... 2.14

2.8 Residential Sector Baseline Heat and Hot Water Energy Consumption Supplied by District Heat..... 2.15

3.1 Efficiency Measures Considered and Installed Cost Per Unit 3.26

3.2 Institutional Sector Efficiency Potential 3.33

3.3 Residential Sector Efficiency Potential 3.34

3.4 Internal Rate of Return Switching Valve for Energy Savings and Installed Costs - Institutional Buildings 3.34

3.5 Internal Rate of Return Switching Valve for Energy Savings and Installed Costs - Residential Buildings 3.35

3.6 Investment Requirements for the Institutional Buildings Sector 3.36

3.7 Investment Requirements for the Residential Buildings Sector..... 3.36

4.1 Secondary Impacts 4.2

4.2 Boiler Plant Permissible Air Pollutant Emission Levels 4.4

4.3 Maximum Permissible Concentration of Air Pollutants 4.5

4.4 Emissions Estimate Assumptions 4.5

1.0 Introduction

The government of Ukraine, through the State Committee of Energy Conservation (State Committee), is considering the implementation of energy efficiency measures in state and municipal institutional buildings in the city of Kyiv. The State Committee entered into an agreement with the U.S. Department of Energy to assess the efficiency potential of the institutional buildings sector in Kyiv. Results of this assessment would support a loan by the World Bank for implementing an institutional buildings sector efficiency improvement program in Kyiv.

This report documents the assessment of the institutional buildings sector efficiency resource conducted by the Pacific Northwest National Laboratory (PNNL) and its subcontractors, Tysak Engineering, a U.S.-based engineering consultancy; and the Agency for Rational Energy Use and Ecology (ARENA-ECO), a Ukrainian nongovernmental organization that specializes in energy efficiency assessments. Companion assessments of the central district heat supply resources (combined heat and power plants) and distribution system (distributed heat generation plants and thermal distribution system) were conducted by Joseph Technology Corporation (JTC 1996) and Ekono Energy (1996), respectively.

1.1 Scope and Approach

The purpose of this assessment is to characterize the economic energy efficiency potential and investment requirements for space heating and hot water provided by district heat in the stock of state and municipal institutional buildings in the city of Kyiv. The assessment involves three activities. The first is a survey of state and municipal institutions to characterize the stock of institutional buildings. The second is to develop an estimate of the cost-effective efficiency potential. The third is to estimate the investment requirements to acquire the efficiency resource.

Institutional buildings are defined as nonresidential buildings owned and occupied by state and municipal organizations. General categories of institutional buildings are education, healthcare, and cultural. The characterization activity provides information about the number of buildings, building floorspace, and consumption of space heating and hot water energy provided by the district system.

Because of the desire to limit the potential loan program to a small number of owing organizations, this assessment focused on those organizations expected to have large numbers of buildings and floorspace under their subordination. These organizations include the Municipal Department of Health, the Ministry of Health, the Municipal Department of Education, the Ministry of Education, and the Municipal Department of Culture. The building stock data are thus most complete for the categories of healthcare, education, and cultural buildings. Data were not collected for building types, such as office buildings, that are widely distributed among state and municipal organizations.

The analysis adopts simple payback as the primary metric for determining the suitability of efficiency measures for the loan program. This reflects the desire for the project savings to pay back the loan in a short timeframe. The basic economic requirement is for the installed cost of the energy efficiency measures to have a simple payback of 5 years or less. The economic analysis also examines the costs from net present value (NPV) and internal rate of return (IRR) standpoints. The efficiency potential is developed to provide estimates of the reduction in total annual energy consumption. The sensitivity of the investment is also examined with respect to costs of efficiency measures and energy savings.

Although other buildings served by the district heating system in Kyiv are not the focus of a planned investment program, an estimate of the efficiency potential and cost is also developed for the residential sector.

1.2 Report Organization

The efficiency assessment is presented in the following four chapters:

- Chapter 2 provides a characterization of the building sector and the baseline heat and hot water energy supplied by the district heating system.

- Chapter 3 presents the energy conservation opportunities (ECOs) and the estimated economic efficiency resource along with investment requirements. This includes an analysis of the sensitivity of the cost-effectiveness of the investment to key factors.

- Chapter 4 presents the estimated secondary economic and environmental impacts analysis of the efficiency resource. Secondary economic impacts include employment, balance of payments, and potential domestic manufacture of equipment and materials. Environmental impacts include reductions in emissions and worker exposure to hazardous materials.

- Chapter 5 contains a summary and conclusions.

Appendix A describes the stock of institutional buildings and the data collection methodology. Appendix B describes baseline energy consumption. Appendix C contains the efficiency measure cost data. Appendix D describes the efficiency measure performance analysis. Appendix E describes investment requirements. Appendix F is a review of the literature. These appendices are referenced in the applicable chapters.

1.3 Study Participants

PNNL, one of DOE's five multiprogram research laboratories, conducts a significant number of programs in the area of energy efficiency and integrated resource planning. PNNL's Advanced Inter-

national Studies Unit (AISU) conducts research on global climate change and manages cooperative programs to transfer energy efficiency practices and technologies to other countries. PNNL provided technical and management oversight for this effort and contributed to the analysis.

PNNL/AISU contracted with Tysak Engineering and ARENA-ECO to support the assessment activities. Tysak Engineering specializes in buildings efficiency assessments and implementation projects, with substantial experience in Central and Eastern Europe. Tysak provided direct oversight for and was directly responsible for the conduct of the majority of the analysis.

ARENA-ECO is a Ukrainian nongovernmental, nonprofit organization dedicated to improving economic development and the environment through energy efficiency. ARENA-ECO provided the in-country coordination for the assessment and contributed to all aspects of the analysis.

2.0 Energy Use Baseline Assessment

This chapter presents a baseline assessment of the consumption of district heat energy by building sector. Although the focus of this assessment is the institutional buildings sector, the baseline is also provided for the residential sector. Section 2.1 describes the building sectors defined for this assessment and characterizes the sectors by number of buildings and square meters of floorspace. Information on institutional buildings in this section is based on a survey carried out for the project, which is described in detail in Appendix A. Section 2.2 describes the district heating system in Kyiv. Section 2.3 provides estimates of the baseline space heat and hot water energy provided to each building sector by the district heating system.

2.1 Sector and Subsector Definitions

Three building sectors were defined in this analysis: institutional, residential, and commercial. Of these three sectors, residential buildings are the most precisely characterized in the literature. Little information exists on the number, size, and types of buildings in the institutional and commercial sectors. Characterization of the institutional buildings sector, the primary focus of this study, was carried out by means of a survey, which is described in detail in Appendix A. This survey was not comprehensive, but instead was intended to identify and characterize those categories of buildings (by type and ownership) most suitable for the potential loan program. No building stock information was available for the commercial sector.

The primary descriptors used to characterize institutional buildings are function, age, and size (number of floors), each of which has an impact on thermal performance. The building age categories used are buildings constructed prior to 1958, those constructed from 1958 to 1980, and those constructed after 1980. These age groups conform roughly to periods with particular architectural styles and building codes that impact the thermal performance and applicability of energy efficiency measures (e.g., roof construction impacts the choice of roof or attic insulation as an efficiency measure). Building size categories were selected based on the available data. For institutional buildings these are 1 to 2 story buildings, 3 to 4 story buildings, and buildings 5 stories and greater. For residential buildings the categories are 1 to 4 story buildings, 5 to 9 story buildings, and buildings 10 stories and greater. The institutional and residential building sectors are described in more detail below.

2.1.1 Institutional Sector

The characterization of the institutional buildings sector was developed by surveying the state and municipal organizations that own and occupy buildings in this sector. More detailed information on the state and municipal organizations surveyed for the information in this section is presented in Appendix A.

Institutional buildings are defined as nonresidential buildings owned and occupied by state and municipal government organizations. There are three types (subsectors) of institutional buildings: healthcare, education, and cultural. Each of these types is described below.

Healthcare

Healthcare buildings include only those buildings under the direction of the Municipal Department of Health and the Ministry of Health. There are a number of healthcare facilities under the direction of other organizations. The majority of buildings in the survey are owned by the Municipal Department of Health.

The healthcare subsector is divided into four building types as follows:

- *Hospitals*. Hospitals provide in-patient care and medical services. In-patient hospitals are widely distributed by size with about one-third of the 160 buildings being 1 to 2 stories, 3 to 4 stories, and greater than 4 stories. In terms of floorspace, however, about two-thirds is in the >4 stories category, about half of which was built between 1958 and 1980, the other half after 1980. Hospitals are the largest subsector of healthcare buildings.

- *Polyclinics*. Polyclinics provide out-patient medical services. Polyclinics are widely distributed by both age and size. More than 45% of polyclinic floorspace is in the size category >4 stories and of post-1980 construction. About 35% of floorspace is in the categories of 3 to 4 story polyclinics built between 1958 to 1980 and after 1980. There are a total of 110 buildings in this category.

- *Hospital Administration and Support Buildings*. The healthcare sector includes a number of buildings that serve exclusively for administration and support activities. Though about 50% of the 69 hospital administration buildings are 1 to 2 story buildings and pre-1958 construction, the largest concentration of floorspace (44%) is found in newer (post-1958) buildings >4 stories.

- *Other Healthcare Buildings*. Though there are a large number of "other" healthcare-related buildings (136), they represent only 6% of the total healthcare floorspace. In addition, 64 buildings that are not primarily dedicated to healthcare have some floorspace used for healthcare activities. Again, this floorspace represents a small fraction of total floorspace in healthcare facilities. These buildings were not included in the analysis.

Education

The education subsector is divided into four building types. Kindergartens and schools are under the direction of the Municipal Department of Education. Higher education facilities and student hostels are under the direction of the Ministry of Education. A number of additional education buildings not included in this analysis are under the direction of several other organizations. A description of the four building types follows.

- *Kindergartens*. Public kindergartens serve a broader function in Ukraine and many other Eastern European countries than in the United States. After childbirth, mothers are allowed paid leave (currently 3 years, previously 1.5 years) to care for their child. An additional unpaid leave of the same duration is also available if they choose to remain in the home, with a guarantee of their old job when they return. Kindergartens thus serve a preschool/daycare function for children anywhere from 1.5 to 6 years of age. The kindergartens are generally small, with about 100-200 students, and are dispersed throughout the residential districts. In total there are approximately 600 state-owned kindergartens in Kyiv, all of them less than 5 stories high. More than half of the buildings and floorspace were built between 1958 and 1980 and are 1 to 2 stories high. The bulk of the remainder are also 1 to 2 stories and were built since 1980.

- *Schools*. Primary schools are also of small size and are distributed throughout the residential districts. The 389 school buildings are also less than 5 stories, with the majority (94%) being 3 to 4 stories high. About half of the buildings were constructed between 1958 and 1980. Along with buildings constructed since 1980, there is also a sizable population of pre-1958 buildings. Schools are the largest single institutional building category in the survey, by area, comprising about 2.8 million square meters of floorspace.

- *Higher Education*. This building type includes technical institutes and universities. Of the 174 higher education buildings, more than 50% of buildings and floorspace were constructed in the period 1958-1980. About 25% of the floorspace is in the post-1980 category. This floorspace is accounted for by 19% of the buildings, reflecting a trend toward larger buildings in this period.

- *Hostels*. The Ministry of Education also operates a significant number of residential buildings for students. As with other higher education buildings, most hostels are greater than 5 stories, accounting for nearly 90% of total floorspace for hostels. About three quarters of this floorspace was built from 1958 to 1980.

Cultural

The cultural buildings included in the survey are owned by the Municipal Department of Culture. The cultural buildings category is divided into two building types as follows:

- *Theaters*. Most of the 12 theaters included in the survey are of pre-1958 construction and have 3 to 4 stories. Pre-1958 buildings also make up 85% of floorspace.

- *Art Galleries/Museums*. Information was collected for 31 art galleries and museums. About 84% of these (26) are of pre-1958 construction.

The estimated number of institutional buildings and floorspace by building category and ownership is shown in Table 2.1. A more detailed listing is provided in Appendix A.

Table 2.1. Number and Floorspace of Institutional Buildings by Type and Subsector, 1996

Institutional Buildings		Number of Buildings	Floorspace (m^2)
Subsector	**Type**		
Healthcare	Hospitals	160	637,125
	Polyclinics	110	293,867
	Administration	69	92,245
Education	Kindergartens	600	1,312,326
	Schools	389	2,804,268
	Higher Education	174	1,228,765
	Hostels	133	730,614
Cultural	Theaters	12	48,043
	Art Galleries/Museums	31	65,358
Total		1,678	7,212,611

2.1.2 Residential Sector

The characterization of the residential sector building stock in Kyiv is derived primarily from a report on building sector efficiency potential in Kyiv (TACIS 1994) and the more recent studies by Joseph Technologies and Ekono Energy (JTC 1996; Ekono Energy 1996). These reports are reviewed in detail in Appendix F. Total estimates of residential floorspace for the past 16 years are presented in Table 2.2.

Table 2.2. Residential Buildings and Floorspace[(a)]

Year	Number Dwellings	Average Area (m^2)	Floorspace (million m^2)
1980	620,400	53.4	33.1
1985	701,300	54.4	38.1
1990	807,300	54.0	43.6
1991	(b)	(b)	44.5
1992	(b)	(b)	45.5
1993	(b)	(b)	46.3
1994	(b)	(b)	47.2
1995	(b)	(b)	48.1
1996	889,400	55.1	49.0

(a) Estimates for 1980-1990 are from TACIS (1994). Total floorspace estimates from 1991-1996 are from Ekono Energy (1996). Number of dwellings in 1996 is from JTC (1996). Average area in 1996 is estimated from the total floorspace and number of dwellings and is consistent with the trend toward larger apartments.

(b) No data available.

In 1990, 99.7% of buildings used for public housing were connected to the district heating network, and public-owned buildings made up 95.5% of total dwellings (TACIS 1994). Hence, descriptions of the residential housing sector describe, to a large degree, the residential sector demand on the district heating system.

The stock of residential buildings is divided into age categories depending on location either in the city center or the periphery as follows (TACIS 1994):

- Residential buildings located in the city center compose less than 5% of the floorspace. Of these, the distribution by construction time period is:

constructed before 1917	61%
constructed from 1917-1961	34%
constructed after 1961	5%

- Residential buildings located on the periphery compose more than 95% of the floorspace. Of these, the distribution by construction time period is:

constructed before 1961	0%
constructed from 1961-1975	31%
constructed after 1975	69%

Multifamily residential buildings can also be described according to the number of building stories, which has a strong correlation with thermal performance. In Kyiv the housing floorspace is divided as 8.3% in buildings 1 to 4 stories, 67.9% in buildings 5 to 9 stories, and 23.8% in buildings over 9 stories (Ekono Energy 1996). While a more precise description of the building size categories would be useful, this characterization will suffice for a first order approximation of the residential buildings efficiency resource because it is not the focus of this assessment.

2.2 District Heat System Overview

The district heating system in Kyiv consists of six heating regions, with the addition of two heating regions planned. Heating regions 1, 2, and 3 are located on the west side of the Dnieper River, and regions 4, 5, and 6 on the east side of the river. The layout of the six heating regions is shown in Figure 2.1. The two planned regions are to the south of region 6.

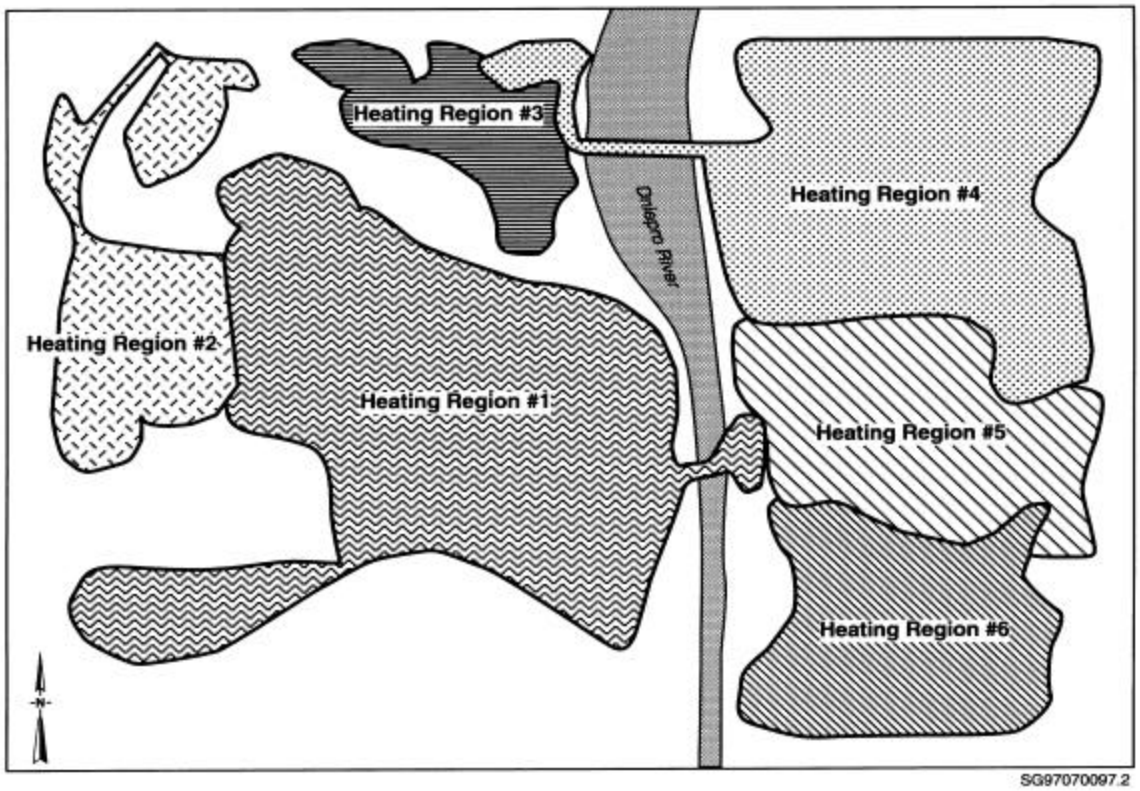

Figure 2.1. District Heating Regions in Kyiv

Hot water is supplied from a number of sources with capacities shown in Table 2.3.

Table 2.3. Hot Water Capacity of the Kyiv District Heating System

Source	Gcal/Hr	MW	%
Kievenergo	5,667	6,591	60.1
Kyiv Municipal District Heating Company	511	594	5.4
Akademteploenergo	250	291	2.7
Industrial Boilers	2,221	2,583	23.5
Other Boilers	783	911	8.3
Total Capacity	9,432	10,969	100

Kievenergo owns and operates two combined heat and power (CHP) plants, purchases heat from a CHP supplier, and owns and operates nine large heat-only boiler plants. The Kyiv Municipal District Heat Company (KGTKE) owns and operates 112 heat-only boiler plants, Akademteploenergo owns and operates two heat-only boiler plants, and industrial sources provide heat from about 350 plants. Industrial boiler capacity also includes 1,601 Gcal steam/hour, which is consumed primarily for process uses.

The primary heat transmission network (transmission system) is about 1,000 km in length, about 768 km of which Kievenergo owns and maintains. The KGTKE is responsible for about 232 km. KGTKE also owns and maintains 2,206 substations and an estimated 662 km of secondary network (distribution system) [estimated assuming 300 m per substation]. The other heat suppliers also own and maintain sections of piping and substations.

Hot water is supplied to the network in a constant flow configuration, with heat delivery regulated by hot water supply temperatures having a design temperature of 150°C. Hot water for space heat is supplied directly to most buildings through a hydroelevator system located in the basement. In this system, entering water is cooled to appropriate levels by mixing with the return water in a venturi nozzle.

Buildings operators purchase heat from the system based on estimated consumption rather than actual consumption. Because of the lack of heat metering in buildings, there is no way to verify that charges match consumption, and hence there is no incentive to conserve energy. Buildings also lack functional controls, so temperature regulation is carried out by opening windows. Though radiators are sometimes equipped with shut-off valves, the poor quality of the valves recommends against their use. In normal conditions, significant overheating occurs early and late in the heating season and during warm periods in the middle of the winter. In recent years, however, fuel supply and capacity constraints have reduced service levels, resulting more commonly in under-heating than over-heating. Lack of effective controls also results in poor heat distribution, so that some rooms, zones, or buildings may be under-heated while others are adequately or over-heated.

2.3 Thermal Energy Consumption Baseline

In this study, the energy efficiency potential is estimated from baseline energy consumption estimates, which are developed from a combination of simulation modeling estimates, actual system performance data, and design performance estimates. Efficiency potential is expressed as a percentage of this baseline. Because of this, the magnitude of the baseline energy consumption plays a critical role in the estimation of the cost-effective resource potential. Lacking a significant amount of metered data, these baseline energy consumption estimates are at best approximate. Though a wide variety of sources exist, the information contained in these sources is not always consistent. For some parameters, such as transmission and distribution system performance, the actual efficiency is only an educated estimate. Baseline energy consumption estimates are presented below.

This section presents estimates of the consumption of energy in the district heating system in the city of Kyiv for 1995 and estimates of the consumption of heat and hot water in the buildings sector by building category. Because of the poor economic situation in Ukraine in 1995, the district heat energy production was depressed relative to normal conditions due to fuel shortages and capacity constraints. The 1995 energy flow estimates are used primarily to illustrate the relative importance of the various heat supply sources and heat consuming sectors. The efficiency resource assessment is based on design

heat consumption estimates and modeled performance in normal heat supply conditions. Hence, the building sector level heat consumption estimates used in assessing the efficiency potential will differ from the 1995 heat consumption estimates.

Estimates of energy flows in the district heating system are largely based upon the reports prepared by Joseph Technologies and Ekono Energy for the rehabilitation of the heat generation and distribution components of the Kyiv District Heating System (JTC 1996; Ekono Energy 1996). The baseline and forecast heat consumption estimates in these reports are based primarily on a master plan developed by Ukrenergoprom in 1995 in close cooperation with Kievenergo, Energoproject, and Kievproject (Ukrenergoprom 1995).

In addition, the Joseph Technologies report contains detailed operations and accounting information for Kievenergo and KGTKE both for the year 1995 and, in the case of Kievenergo, for estimated 1996 operations. The Ekono Energy report also contains fuel energy use data for Kievenergo and KGTKE.

Estimates of building sector level energy flows in the district heating system are difficult to make because of the lack of metered energy consumption data for the system and for Kyiv buildings. Estimates of the distribution of heat energy consumption are generally derived in terms of capacity demand data (usually given as Gcal/hour). Though some limited metering has been done to calibrate building energy demand models (e.g., TACIS 1994), estimates of specific energy consumption in buildings must often be developed from rough estimates of system performance, and rough descriptions of the supply system connections to buildings' floorspace. A more detailed evaluation of the various specific energy consumption estimates found in the literature is presented by building sector in Appendix B.

City-level heat and energy flow estimates for 1995 are presented in Tables 2.4 through 2.6, and are summarized in Figure 2.2. Values used to generate Figure 2.2 are shaded in the respective tables.

Fuel consumption (Table 2.4) is presented only as the city-level total, and is assumed to be split as 85% natural gas and 15% mazut. This estimate is based on Kievenergo accounting data (JTC 1996) and is consistent with the dominant use of natural gas for boiler fuel in Kyiv.

Heat and electricity production are presented by supplier in Figure 2.2. These values can be found by supplier in the bottom two rows of Table 2.5. In Figure 2.2, the category "other" includes heat produced by heat-only boiler plants and individual heat generators.

Heat and electricity consumption estimates in Figure 2.2 are from the right-hand column of Table 2.6. The public sector total (4.2 million Gcal) is split into commercial and institutional sectors in Figure 2.2. Because there is no actual data on energy consumption in public buildings, this value is split evenly between the two sectors. The estimated energy consumption of 1.1 Gcal for education, cultural, and healthcare buildings suggests that this assumption is reasonable. Energy flows for Kievenergo and KGTKE are based on actual 1995 fuel consumption and heat production data reported in Ekono Energy

Table 2.4. Estimated Fuel Consumption (thousand Gcal) by District Heat Suppliers in Kyiv, 1995

Consumer Groups		Estimated Fuel Consumption By Heat Suppliers													
		TETS[a]	Heat-Only Boiler Plants										Industrial Boiler Plants and Secondary Energy Resources (SER)	Individual Heat Generators	Total for All Suppliers
			Kievenergo			Akademteploenergo			Kievzhilteplokommunenergo			Heat-Only Boiler Plants of Other Owners	Total for Heat-Only Boiler Plants		
		TETS[a]	District Boiler Plants	Total	District Boiler Plants	Other Boiler Plants	Total	District Boiler Plants	Other Boiler Plants	Total					
1		2	3	4	5	6	7	8	9	10	11	12	13	14	15
Residential and Public Sector	Total incl.:	8,845	4,576	13,422	266	153	419	105	1,360	1,465	2,142	17,447	382	784	18,613
	Residential	6,115	3,164	9,279	167	87	254	87	773	860	1,177	11,570	284	763	12,617
	Public	2,730	1,412	4,142	98	66	165	17	587	604	965	5,876	98	21	5,995
Industry	Water	2,075	1,073	3,148	151	2	153	-	20	20	31	3,353	5,991	-	9,344
	Steam	602	-	602	-	-	-	-	-	-	-	-	6,267	-	6,869
Total for Electricity		7,471	-	7,471	-	-	-	-	-	-	-	-	-	-	7,471
Total for Heat		11,522	5,650	17,172	417	156	572	105	1,380	1,485	2,173	20,800	12,640	784	34,827
Total for All Consumers		18,993	5,650	24,643	417	156	572	105	1,380	1,485	2,173	20,800	12,640	784	42,298

(a) TETS refers to combined heat and power plants.

Total fuel use estimates for Kievenergo and Kievzhilteplokommunenergo from Ekono Energy (1996). Sector splits for Kievenergo from Ekono Energy (1996) and for Kievzhilteplokommunenergo from capacity demand splits from Ukrenergoprom data. Fuel use estimates for other boiler owners estimated from heat production estimates based on an estimated average boiler efficiency of 88%. Fuel use for electricity estimated from electricity supply data and Kievenergo estimates of 1996 heat rate (JTC 1996).

Table 2.5. Estimated Heat and Electricity Supply (thousand Gcal) to the District Heating System in Kyiv, 1995

Consumer Groups		Estimated Heat and Electricity Supply by Heat Suppliers													
		TETS[a]	Heat-Only Boiler Plants										Industrial Boiler Plants and Secondary Energy Resources (SER)	Individual Heat Generators	Total for All Suppliers
			Kievenergo		Akademteploenergo			Kievzhilteplokommunenergo			Heat-Only Boiler Plants of Other Owners	Total for Heat-Only Boiler Plants			
		TETS[a]	District Boiler Plants	Total	District Boiler Plants	Other Boiler Plants	Total	District Boiler Plants	Other Boiler Plants	Total					
1		2	3	4	5	6	7	8	9	10	11	12	13	14	15
Residential and Public Sector	Total incl.:	7,804	4,038	11,842	234	135	370	89	1,154	1,243	1,890	15,344	337	692	16,373
	Residential	5,395	2,791	8,187	147	77	224	74	656	730	1,039	10,180	251	673	11,103
	Public	2,409	1,246	3,655	87	59	145	15	498	513	851	5,164	86	19	5,269
Industry	Hot Water	1,831	947	2,778	133	2	135	0	17	17	27	2,958	5,286	0	8,244
	Steam	512	-	512	-	-	-	-	-	-	-	-	5,327	-	5,839
Total Electricity (Gwh)		5,049	-	5,049	-	-	-	-	-	-	-	-	-	-	5,049
Total El. (thousand Gcal)		4,341	-	4,341	-	-	-	-	-	-	-	-	-	-	4,341
Total Heat (thousand Gcal)		10,147	4,985	15,132	368	137	505	89	1,171	1,260	1,917	18,302	10,950	692	30,456

(a) TETS refers to combined heat and power plants.

Heat production for Kievenergo and Kievzhilteplokommunenergo estimated from energy use data and boiler performance estimates (Ekono Energy 1996). Total heat production for heat-only boiler plants, industrial boilers and secondary sources, and individual heat generators from Ekono Energy (1996), allocated by sector based on heat demand estimates (Gcal/hour) from Ukrenergoprom. Electricity production from Kievenergo data (JTC 1996).

Table 2.6. Estimated Heat and Electricity Consumption (thousand Gcal) from the District Heating System in Kyiv, 1995

Consumer Groups		Estimated Heat and Electricity Consumption													
		TETS[a]	Heat-Only Boiler Plants										Industrial Boiler Plants and Secondary Energy Resources (SER)	Individual Heat Generators	Total for All Suppliers
			Kievenergo		Akademteploenergo			Kievzhilteplokommunenergo			Heat-Only Boiler Plants of Other Owners	Total for Heat-Only Boiler Plants			
		TETS[a]	District Boiler Plants	Total	District Boiler Plants	Other Boiler Plants	Total	District Boiler Plants	Other Boiler Plants	Total					
1		2	3	4	5	6	7	8	9	10	11	12	13	14	15
Residential and Public Sector	Total incl.:	6,243	3,230	9,473	187	108	296	71	923	994	1,512	12,275	269	554	13,098
	Residential	4,316	2,233	6,550	118	61	179	59	525	584	831	8,144	201	538	8,883
	Public	1,927	997	2,924	69	47	116	12	398	410	681	4,131	69	15	4,215
Industry	Hot Water	1,464	758	2,222	107	2	108	-	14	14	22	2,366	4,229	-	6,595
	Steam	410	-	410	-	-	-	-	-	-	-	-	-	-	5,053
Total Electricity (Gwh)		4,628	-	4,628	-	-	-	-	-	-	-	-	-	-	4,628
Total El. (thousand Gcal)		3,979	-	3,979	-	-	-	-	-	-	-	-	-	-	3,979
Total Heat (thousand Gcal)		8,117	3,988	12,105	294	110	404	71	937	1,008	1,534	14,641	4,498	554	24,746

(a) TETS refers to combined heat and power plants.

Heat supply estimated from heat production assuming 20% losses of heat and steam in the transmission and distribution system (Ekonon Energy 1996), and assuming electricity transmission losses of 8.3% based on Kievenergo data (JTC 1996).

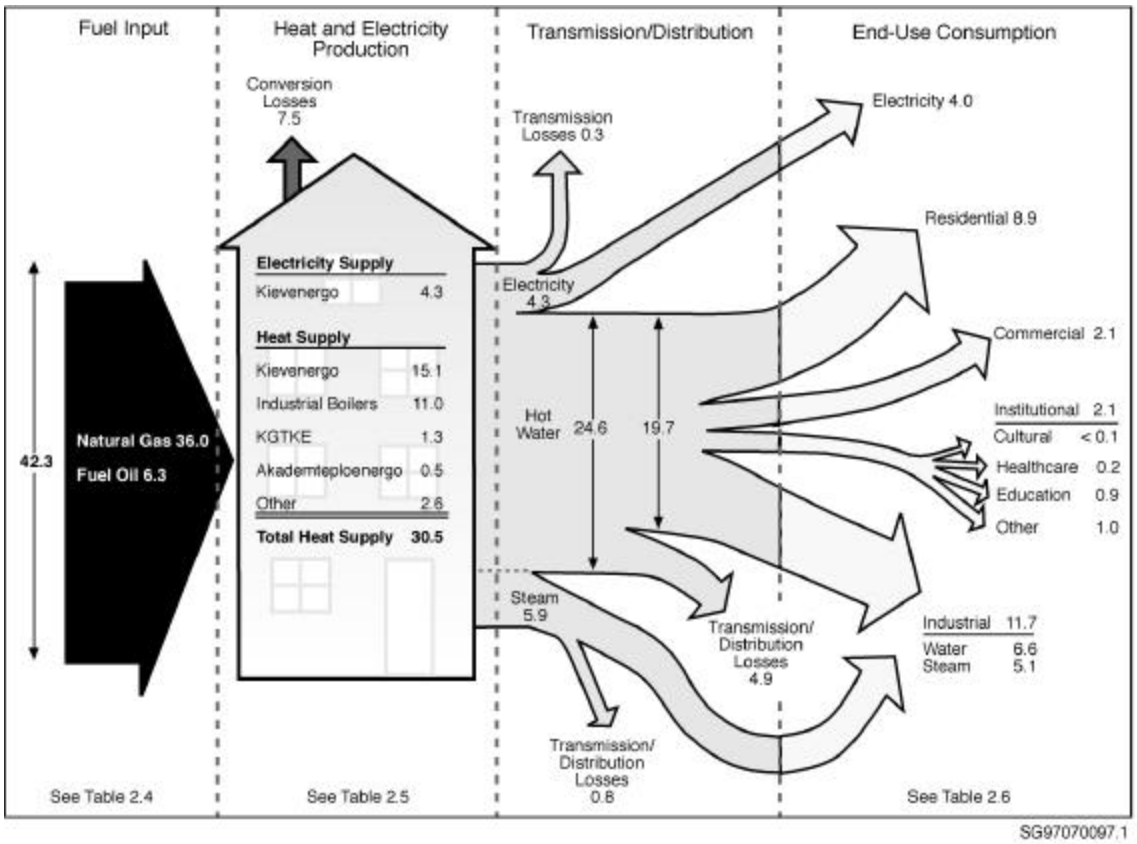

Figure 2.2. Estimated Energy Flow of Kyiv District Heating System (million Gcal), 1995

(1996). Energy flows for Kievenergo are distributed by building sector according to building sector shares given in Ekono Energy (1996), and are consistent with Ukrenergoprom estimates. Energy flow shares by building sector for KGTKE are taken from capacity demand shares from Ukrenergoprom. Energy flow estimates for other heat suppliers are taken from annual heat production estimates in Ekono Energy (1996) distributed by building sector using Ukrenergoprom capacity demand shares. Energy use for these suppliers is back-calculated based on an estimated boiler performance of 88%, the approximate value for Kievenergo boilers (Ekono Energy 1996; JTC 1996).

Heat supply to buildings is estimated from heat production by assuming an average of 20% transmission and distribution system losses, taken from Ekono Energy (1996). This value is higher than both the Joseph Technology estimate (12%) and the annual average values in Kievenergo documents[(a)] (13%) presented in Joseph Technologies (JTC 1996). These values appear low considering the poor condition of the transmission and distribution system. This is illustrated by the high level of water leakage from the system, estimated at from 5 to 45 times system volume annually depending on the network (Ekono Energy

(a) Kievenergo loss estimates vary by quarter from 10% (first quarter) to 33% (third quarter) for annual average losses of 13%.

1996). By comparison, Ekono Energy cites normal replacement volumes for a well-maintained system of 1 to 2 times system volume per year.

The energy flow diagram (Figure 2.2) also shows fuel use in the production of electricity by combined heat and power plants. Fuel-use estimates are taken from Kievenergo accounting data presented in Joseph Technologies (JTC 1996). Power production is estimated using a heat rate of 1,480 kcal/kWh, which is derived from detailed power generation estimates for Kievenergo in 1996 (JTC 1996), and includes power purchases by Kievenergo. Net electricity supply is estimated assuming 8.3% transmission losses, also from the same source.

Annual energy-flow estimates shown in Figure 2.2 are based on actual conditions in 1995, and hence cannot be compared directly with annual energy-flow estimates from Ukrenergoprom and Ekono Energy, which are based on estimated energy flow in normal fuel supply and capacity conditions. It is estimated, however, that in 1995 the heat supply was about 74% of the expected supply in normal conditions (Ekono Energy 1996). Using this ratio, the total residential sector heat supply (1995 actual) of 8,883 Gcal (Table 2.6) leads to an estimated 12,084 Gcal in normal supply conditions. This value can be compared to the Ekono Energy and Ukrenergoprom estimates of 11,314 and 15,080 Gcal, respectively. By comparison, estimated heat consumption based on design data and residential floorspace data is 11,685 Gcal (see Table 2.6 and Appendix B for derivation of this estimate).

Including energy used in the production of electricity, Kievenergo accounts for 58% of the total 42.3 million Gcal of fuel consumption. After conversion losses, this amounts to a production of 24.6 million Gcal of hot water, 5.9 million Gcal of steam, and 4.3 million Gcal (5049 GWh) of electricity. Total supply of heat energy after transmission and distribution losses is 24.8 million Gcal, of which 47% is for industry (including hot water and steam), 36% for residential buildings, and 17% for institutional and commercial buildings. The residential sector is estimated to account for over two-thirds of building sector heat consumption, with the remaining one-third split about equally between the institutional and commercial sectors.

2.3.1 Building Sector Heat and Hot Water Consumption

Heat and hot water energy consumption provided by district heat is estimated in this section for each of the three building categories discussed in Section 2.1. As noted above, these estimates are based on the assumption of normal heat supply, and hence cannot be compared directly to the building level heat supply values in Figure 2.2, which are estimated to be about 74% (based on 1995 data) of normal supply conditions. Heat consumption for other building sectors can be estimated by dividing the values in Figure 2.2 by 0.74.

Institutional Sector

The heat consumption estimates for the institutional sector were based on floorspace data from the survey discussed in Section 2.1, design heat consumption estimates for representative buildings in each subsector, and a sample of metered information taken in December of 1996. Additional detail on the estimation of institutional sector heat and hot water consumption is provided in Appendix B.

The estimates of institutional sector heat and hot water consumption are shown in Table 2.7 by building type and subsector. Institutional sector energy use is dominated by education, which has the largest amount of floorspace.

Table 2.7. Institutional Sector Baseline Heat and Hot Water Energy Consumption Supplied by District Heat

Institutional Buildings		Baseline Energy Use (thousand Gcal)
Subsector	**Type**	
Healthcare	Hospitals	157
	Polyclinics	59
	Administration	16
Education	Kindergartens	329
	Schools	470
	Higher Education	240
	Hostels	154
Cultural	Theaters	10
	Art Galleries/Museums	12
Total		1,446

Residential Sector

The baseline heat consumption estimates for the residential sector are based in part on analysis conducted for a recent World Bank report (World Bank 1996) and in part on a recent study conducted in the Czech Republic (PNNL 1996). Additional detail for the residential sector baseline is located in Appendix B.

The estimates of residential sector heat and hot water consumption are shown by building type in Table 2.8. The total energy use estimate closely approximates the value of 8.9 Gcal as shown in Figure 2.2 adjusted by the factor 0.74. Residential sector energy use is largest in the 5 and 9 story building types, which dominate total floorspace. Five story buildings also have a relatively high estimated specific energy use.

Commercial Sector

No attempt was made to characterize the commercial sector building stock. Baseline energy consumption by this sector is estimated to be 2.8 million Gcal annually based on the values in Figure 2.2 and the adjustment factor of 0.74.

Table 2.8. Residential Sector Baseline Heat and Hot Water Energy Consumption Supplied by District Heat

Building Type	Baseline Energy Use (thousand Gcal/year)
2-story	2,569
5-story	3,545
9-story	3,545
14-story	2,026
Total	11,685

3.0 Efficiency Assessment

The estimated cost-effective efficiency resource and corresponding level of investment required to obtain the resource is presented in this chapter. Section 3.1 describes the measures considered for application in Kyiv, as well as those not considered applicable to this project. The technical and economic analysis approaches employed to estimate the efficiency resource are described in Section 3.2. The building sector efficiency resource is discussed in Sections 3.3, 3.4, and 3.5.

The efficiency resource and investment levels are developed with attention to the institutional buildings sector. The efficiency resource and investment levels are also estimated for the residential sector using existing information.

3.1 Efficiency Measures

Forty six energy conservation opportunities (ECOs) were evaluated for improving building sector energy efficiency. Of these, 20 were determined to be applicable to one or more building types and were analyzed with respect to energy efficiency potential, cost, and availability on the Ukrainian market.

A brief discussion of the ECOs evaluated follows. Measures considered applicable to Kyiv buildings within the scope of this project are presented in Section 3.1.1; measures not considered applicable are located in Section 3.1.2; and a summary of the applicable measures is located in Section 3.1.3.

3.1.1 Efficiency Measures Considered

The 20 efficiency measures considered applicable to buildings in Kyiv are presented by category of application: building envelope measures, air handling measures, domestic water heating measures, and heating system measures. The description of each measure includes the building type application, installation cost, and availability. Efficiency measure cost data are presented in more detail in Appendix C.

Building Envelope Measures

1. **Insulate Exterior Side Walls** - Insulation installed on the exterior walls of the building improves the R-value, or thermal retention, of the building shell, and therefore decreases heat loss through the walls. Depending on the method used and the material thickness, the R-value of the walls may be increased by 0.8 to 1.4 m^2 K/W. Exterior insulation also results in increasing the temperature in zones adjacent to exterior walls by as much as 3 to 5°C, thus indirectly reducing overheating of the building core space when building temperatures are properly adjusted and building temperature controls are available. An additional positive effect is the elimination of moisture condensation on the interior side of the external walls in cold weather.

The insulation of exterior walls with a large window-to-wall ratio is typically labor intensive and costly. Only insulation of walls without windows or with a relatively small number of windows was considered. Practically, this means that only two sides are insulated for most buildings.

Building Type Application

- This measure was considered applicable to most building types. Exceptions include buildings constructed prior to 1958, mainly because these buildings have thick brick walls with complex external surfaces which make it very difficult and inefficient to install any external insulation. In addition, some cultural buildings are not suitable for external insulation because of changes that would occur to the external appearance.

Considerations

- Although this ECO is widely used, poor workmanship can cause the energy savings to be less than expected in many installations.

- This ECO generally has a high installation cost and is therefore not cost-effective in most applications. In particular, one study in Kyiv found exterior insulation difficult to justify economically, with payback periods ranging from 7 to 26 years (TACIS 1994). New spray-on-type foam insulation is much cheaper and has been used in some projects for this ECO; however, this method has not been widely demonstrated and is not considered here.

- Positive impact on comfort, elimination of condensation problems in coldest rooms, and elimination of health problems (due to fungus growth on wet wall surfaces) supports selection of this ECO.

- Although this ECO is passive, its effectiveness relies upon active measures to control heat input to prevent overheating.

- Heat controls require operational oversight and maintenance.

- Change in building exterior appearance must be considered.

Cost

- Material costs vary widely depending on the type of insulation used. For this project, material costs are estimated to be \$10.50/m^2.

- Labor time to install the measure is estimated to be 1.1 hours/m^2, with a labor cost of \$14.66/m^2.

Availability

- Insulation materials are readily available domestically.

- Materials may be a source of domestic manufacture. One manufacturing operation in Kyiv has developed an external insulation product that includes fastening and facing materials; however, the product is not currently in production and may not be cost-effective.

2. **Insulate Roof** - The top floor ceiling in many building types is poorly insulated, which results in substantial heat loss from the top floor. Higher space heat to compensate for this often causes overheating of the building core space. Insulating the top floor ceiling from the interior side sometimes causes moisture condensation in the corners and on the upper portion of vertical walls due to thermal bridging of walls/ceiling. Roof insulation installed from the outside must be covered by a new layer of roofing material. This technology is applicable to buildings with a flat roof and single-roof-panel construction (without a ventilation space). Roofs of buildings with ventilation space (between the ceiling and the roof panels) can be insulated by applying the insulation between the ceiling and roof panel. The roof insulation increases the R-value by 2.1 to 3.0 m^2 K/W.

Building Type Application

- This measure is applicable to all buildings with a flat roof (without attic). For this study, all institutional buildings constructed after 1958 are assumed to have a flat roof. Some buildings constructed earlier also have flat roofs; however, peaked roofs are more common. For these buildings attic insulation is considered (measure 3 described below).

Considerations

- Application of the insulation to the exterior roof surface requires installation of a water membrane.

- Insulation installed in the ventilation space between the roof and ceiling panels must be well ventilated to prevent condensation and deterioration of the insulation material.

- Ukrainian fire codes restrict the use of synthetic insulation in buildings.

- Although this measure is passive, its effectiveness relies on active measures to control heat input to prevent overheating.

Costs

- Material costs are estimated to be \$23.41/m^2.

- Labor time to install the measure is estimated to be 0.34 hours/m^2 with a labor cost of \$4.54/m^2.

Availability

- Roof insulation and roofing materials are readily available.

- Foreign-made insulation and roofing materials are available from local outlets of foreign suppliers.

3. **Insulate Attic** - Insulating the attic is a widely used method of reducing heat losses in buildings that have an attic space. The insulation may be installed in many different ways (e.g., blown into the attic, laid on top of the ceiling, or poured in as a foam/liquid). Fiberglass blankets or boards or Styrofoam boards are most commonly used. Depending on the method used, the R-value can be increased by as much as 3.5 m^2 K/W.

Building Type Application

- This ECO is applicable to all buildings with a pitched roof and an attic space. All buildings constructed prior to 1958 are assumed to have an attic space suitable for installing the insulation; however, the ECO may be more cost-effective in some building types than others. Information indicates that buildings constructed after 1958 typically do not have a pitched roof, and attic insulation is not applicable to these buildings.

Considerations

- Insulation in attics accessible as storage space must be protected in walkways and in areas used as storage or for any other purposes.

- The cost of protection material and its installation must be considered.

- Ukrainian fire codes restrict the use of synthetic insulation in buildings.

Costs

- Material costs are estimated to be \$6.45/m^2.

- Labor time to install the measure is estimated to be 0.37 hours/m^2, with a labor cost of \$4.93/m^2.

Availability

- Attic insulation materials are readily available in all forms (hard boards, spray, fiberglass) from local sources.

4. **Insulate Floor Above Basement** - Insulating the floor above a cold basement, crawl space, or concrete slab improves the floor R-value as well as the comfort of occupants, which typically results in a lower thermostat setting. Many floor covering materials with good thermal insulation are available. For floors with an air cavity, blown-in cellulose-based insulation is also available.

Building Type Application

- Floor insulation is applicable to all buildings considered in the study.

Considerations

- Insulation installed on the floor must be designed to sustain required traffic or must be protected by walk-on materials. Many flooring materials having the required insulation characteristics can be used.

- Ukrainian fire codes restrict the use of synthetic insulation in buildings.

- Floor insulation increases the comfort level for occupants by lowering the room's vertical air temperature stratification.

- Although this measure is passive, its effectiveness relies on active measures to control heat input to prevent overheating.

- Balancing the heating system (radiator control) in the space with insulated floors may be necessary.

- Basement below the insulated floor will be colder, and in some instances it may be necessary to heat the basement to prevent frost damage to plumbing.

- Buildings with a basement may also be insulated from the bottom (basement ceiling).

Costs

- Material costs are estimated to be \$6/m^2.

- Labor time to install the measure is estimated to be 0.12 hours/m^2, with a labor cost of \$1.60/m^2.

Availability

- Limited types of floor insulation materials and basement ceiling insulation materials are available from domestic manufacturers. Decorative floor materials are available from local outlets of foreign suppliers.

5. **Weatherstrip Windows and Doors** - Sealing cracks around windows and doors is a simple way to reduce infiltration to occupied and unoccupied spaces and thus reduce the energy required to heat ambient air entering the heated space and reduce the heat losses to unheated spaces. Windows, especially in older buildings, fit poorly, resulting in significant levels of unnecessary infiltration. To be functional, seals have to be properly installed and maintained.

Building Type Application

- Weatherstripping of windows and doors is applicable to all buildings in which the windows were not recently replaced with new tight-construction, high-performance windows. It is assumed that such upgrades have been done in only a small number of buildings in the city of Kyiv.

Considerations

- Weatherstripping improves comfort levels in the space by eliminating drafts close to windows.

- Some spaces indirectly rely on fresh air supply by uncontrolled infiltration through the windows. Proper sealing of window gaps may cause lower indoor air quality. Spaces with high requirements for fresh air must be provided with forced ventilation with heat recovery.

- In buildings that suffer from periodic or chronic under-heating, building occupants may have previously adopted some type of weatherstripping or sealing measures to reduce infiltration. Commonly found measures include the use of foam-type material in areas of poor window sealing, and taping window frames closed during winter months when ventilation requirements are small. In many cases, these measures appear to be quite effective; however, in the absence of under-heating, maintenance of these measures may be limited. In addition, as with most measures, weatherstripping will be effective only if active measures are taken to control space temperatures.

- Seals have to be inspected and properly maintained. The life of a typical seal is approximately 5 years; then it has to be replaced.

Costs

- Material costs are estimated to be $0.9/m.

- Labor time to install the measure is estimated to be 0.1 hours/m, with a labor cost of $1.05/m.

Availability

- Good quality window seals currently must be imported or purchased from local outlets of foreign manufacturers, but could be a source of domestic manufacture. Good quality seal materials are crucial to attaining savings.

6. **Install Storm Windows and Weatherstripping** - The fenestration area of buildings in Ukraine can be a significant fraction of the building envelope area. The U-value, or rate of heat loss, of the windows is 2.7 to 4.2 times greater than for the walls. Consequently, heat losses through windows are significant. Installation of a third pane on existing windows provides improved R-value for the fenestration area and reduces heat losses through the glass. The U-value of a window with a third glass (storm window) is typically 1.9 to 2.1 W/m^2K, whereas the common two-pane window has a U-value of 2.6 to 2.8 W/m^2K. It is also assumed that new storm windows will provide a tighter fit resulting in lower infiltration. Installation of weatherstripping on existing windows is assumed to be done at the same time.

Building Type Application

- This measure is assumed to be applicable to all buildings.

Considerations

- The storm window is installed in its own light frame attached to the exterior side of the existing window frame (typically wood frame). The storm window frame can easily be used as an insect screen during the summer.

- On some windows designed to open to the outside, the third glass may be installed on the external side of the openable window frame.

- A storm window will reduce uncontrolled infiltration, and spaces relying on such sources of fresh air may need to be ventilated via controlled ventilation (with heat recovery).

Costs

- Material costs are estimated to be $60 per window.

- Labor time to install the measure is estimated to be 5 hours per window, with a labor cost of $66.67 per window.

Availability

- Storm windows may be manufactured by local window/door manufacturers or purchased from local outlets of foreign suppliers.

- This product may be a source of local manufacture.

7. **Install High-Performance Glass and Weatherstripping** - Depending on the ratio between the external wall area and the fenestration area, up to 30% of the heat loss by the building envelope is through the glass. Existing windows have regular potassium-based glass with thickness in the range of 2.5 to 3 mm. Such windows have U-values of approximately 2.7 to 3.07 W/m^2K. It is typically not economical to replace the entire window including the fixed frame. Instead, only the glass or window wings are replaced. Window glass available on the market today is highly heat reflective and has greater thermal resistance resulting in lower U-values in the range of 1.5 to 1.8 W/m^2K.

   Installation of weatherstripping on existing windows is assumed to be done at the same time.

   Building Type Application

   - This measure is assumed to be applicable only to cultural buildings.

   Considerations

   - When the frame of the window glass is structurally acceptable, only the glass pane is replaced; however, sometimes, especially in very old windows, the window must be retrofitted by replacing the entire movable part.

   - High-performance glass is highly reflective and provides a thermal shield during the summer time, especially in windows exposed to direct sunshine. Should air conditioning be used in the space, energy savings during the cooling season are significant.

   - It is usually sufficient to replace only one (external) pane in a double-glassed window.

   Costs

   - The material costs for this measure are estimated at $24.50/m^2$.

   - Labor time to install this measure is estimated at 1.4 hours/m^2, with a labor cost of $18.66/$m^2$.

Availability

- High-performance glass is available from local outlets of foreign manufacturers and suppliers.

8. **Install Third Window Pane** - One of the commonly used methods of increasing the thermal resistance of windows is to install a third pane into the existing window frame. This is accomplished by modifying the existing window frame holding the glass pane and inserting an additional high-performance pane. The most appropriate way is to install the new high-performance glass to the outside. Practically, it is easier to install it between the existing panes. Sometime, a UV-resistant plastic foil with thickness of 0.04 mm is installed between the frames and sufficiently stretched to avoid light/view distortion. However, the life of plastic foil is substantially shorter (3-5 years) and overall life cycle costs may be greater.

   Installation of weatherstripping on existing windows is assumed to be done at the same time.

   Building Type Application

   - This measure is assumed for all building categories, except where the appearance of the window is critical (historical buildings).

   Considerations

   - It may not be feasible to install a third pane in windows with poor frames or in windows that have complex shapes.

   - It is necessary to ensure that the third pane is removable for window cleaning.

   - Assembly must be airtight to prevent dust and moisture entering the space between the panes.

   Costs

   - The material costs for this measure are estimated at $13.00/m^2.

   - Labor time to install this measure is estimated at 1.33 hours/m^2, with a labor cost of $17.69/m^2.

   Availability

   - High-performance glass is available from local outlets of foreign manufacturers and suppliers.

   - Window foil is available from local suppliers.

9. **Install Heat Reflectors Behind Each Radiator** - Heat reflectors deflect the radiant portion of the heat otherwise absorbed by the wall (in most cases an exterior wall) into the heated space. The wall temperature behind the radiator is lowered and the R-value of the part of the wall covered by the reflector is increased, thus reducing the heat losses. This is in many cases a "do-it-yourself" inexpensive measure.

Building Type Application

- All buildings are heated by hot water (or steam) radiators, and this measure is applicable to all buildings.

Considerations

- Some radiator types in Kyiv may be installed too close to the wall and may require some additional work during the installation of the reflecting material. Removal of the radiator or its disconnection from pipes was not considered to be necessary. Such cases are assumed to be minimal.

- Reflectors improve thermal comfort in the room, sometimes resulting in a lower temperature setting of the thermostat (where available).

- Reflecting material with thermal insulation was assumed for the application.

- Self-adhesive materials can be used in easy-to-access places; adhesive tape should be used for places with difficult access behind radiators.

Costs

- Material costs are estimated to be $5.16 per radiator.

- Labor time to install the measure is estimated to be 0.37 hours, with a labor cost of $3.90 per radiator.

Availability

- This material will have to be imported or purchased from local outlets of foreign manufacturers.

Air Handling Measures

10. **Install Ventilation Heat Recovery** - Buildings designed to hold gatherings or large crowds require substantial fresh air supply. Hot air ventilation is typically installed only in buildings constructed after 1958. In older buildings the fresh air is delivered via opened windows, doors, or with assistance of

exhaust fans. When fresh air is not delivered, the space can become uncomfortable within less than 30 minutes, depending on space size and number of people occupying the space. Such ventilation causes uncontrolled infiltration and thus substantial heat loss. Installation of an air make-up unit with a heat recovery system allows controlled ventilation during heavy load in the wintertime and, if air conditioning (A/C) is available, also during the summer. Existing total heat recovery systems achieve up to 80% efficiency.

Building Type Application

- This measure applies to cultural buildings only.

Considerations

- Economy of the heat recovery installation is strongly dependent on the total number of operating hours and typically is applied to systems operating 24 hours a day.

- Air heat recovery can only be used when it is technically possible to install supply and exhaust air ducts close to each other.

- Application of heat recovery in air handling systems with cooling is typically economical due to year-round savings.

Cost

- Material costs are estimated to be \$2.20/m^3/hour.

- Labor time to install the measure is estimated to be 0.04 hours/m^3/hour, with a labor cost of \$0.41/m^3/hour.

Availability

- Good quality heat recovery heat exchangers with efficiency of more than 75% are available only from several foreign suppliers.

11. **Install Ceiling Fans** - Halls accommodating large numbers of people are typically designed with excessively high ceilings to provide sufficient air supply. High open spaces cause room temperatures to stratify. As a result, the temperature difference between the floor and the ceiling may be as high as 10°C, which results in discomfort and space overheating mainly during low and medium occupancy load. De-stratification of temperatures in high ceiling spaces is accomplished by application of large-diameter, slow-speed ceiling fans. The use of ceiling fans eliminates the air temperature stratification

and reduces temperature losses caused by overheating. In the cooling mode, ceiling fans produce a slight air draft and delay the use of A/C during low cooling demand periods.

Building Type Application

- This measure applies to cultural buildings only.

Considerations

- In some buildings, such as those with chandeliers or decorative art on the ceiling, the installation of ceiling fans may not be desirable.

- In some spaces with interior decorative walls, it may be difficult to install required electrical wiring.

Cost

- Material costs are estimated to be $163 per fan.

- Labor time to install the measure is estimated to be 3.0 hours per fan, with a labor cost of $40.00 per fan.

Availability

- Certain types of ceiling fans are available locally. Decorative fans are available from foreign manufacturers and may have to be imported.

Domestic Water Heating Measures

Domestic water heating (DWH) systems in institutional buildings utilize mostly shell-and-tube instantaneous heat exchangers located either in the substations or directly in the buildings. Except for some small number of newer substations, DWH systems are insufficient, inoperative, or completely lack temperature controls. Pipes and heat exchangers are generally poorly insulated or not insulated at all. DWH heat exchangers are instantaneous, through-flow types without a hot water storage tank and, as such, are designed for maximum flow. During off-peak periods, domestic water is overheated and heating water is returned back to the return pipe at much higher temperature, typically mixing with the space heating return water. Because the heating water flow is constant, this occurs permanently and increases heat loses in the return pipe. And, because the heat supply is not metered, credit for higher return temperature cannot be taken by the user.

Heat exchangers located in the substations require separate DWH piping between the building and the substation, resulting in additional losses. In addition, Ukrainian law requires that heat metering for space heating and domestic hot water be carried out via a common meter (Cabinet of Ministers of Ukraine 1995). This is not possible in systems with hot water heat exchangers located in substations, which represent approximately 80% of the institutional building stock. In such cases, it is necessary to disconnect the existing DWH connections and install the DWH heat exchanger in each building.

12. **Install Hot Water Heat Exchanger** - The equipment required for the DWH system upgrade is composed of a heat exchanger, necessary piping and plumbing components, and a thermostatic control.

    Energy savings by this measure are accomplished by introducing the ability to control the required domestic water temperature by preventing unnecessary losses in the DWH pipes; by eliminating the unnecessary return of hot heating water back to the return line; by insulating the internal pipes; and, in some installations, by eliminating losses in the external pipes (between the substation and the building).

    Building Type Application

    - This measure is considered for all building types, but is assumed to apply to only 80% of buildings, or that fraction which currently operates on a four-pipe system. The measure is probably not appropriate for buildings with low hot water demands such as hospital administration and cultural buildings. For simplicity, it is applied across all buildings.

    Considerations

    - Utilization of compact, package-type pre-assembled DWH systems is highly recommended, because they reduce the number of field-installation-related problems and are more reliable.

    - Installation of water treatment, such as filters and softeners is desirable, especially in hospitals and schools. This will also increase the life of the system.

    - This measure is considered necessary to comply with Ukrainian regulations.

Costs

- Material costs associated with retrofit of a domestic water heating system are a function of the installed water heater capacity and range from $11 to $25 per kW of installed capacity, with smaller systems bearing larger per unit costs.[(a)]

- Labor time to install the measure is estimated to be 50 hours for every 100 kW of installed capacity. In monetary terms the labor cost represents an average cost of $7.62 per kW of installed capacity.

- Periodic inspection and O&M is necessary, and its cost should be included in the operational budget of the building owner/occupant.

Availability

- Domestic water heating systems and components are available from local sources and from several foreign companies having representation (sales offices) in Ukraine.

13. **Install Tank-Type Storage Water Heating System** - The equipment required for the DWH system upgrade is composed of a heat exchanger, necessary piping and plumbing components, thermostatic control, and an appropriately sized domestic water storage tank. The use of a properly insulated storage tank will enhance temperature control (prevent overheating) and will also enhance the availability of hot water to occupants.

    Energy savings by this measure are accomplished by introducing the ability to control the required domestic water temperature by preventing unnecessary losses in the DWH pipes; by eliminating the unnecessary return of hot heating water back to the return line; by insulating the internal pipes; and, in some installations, by eliminating losses in the external pipes (between the substation and the building). Enhanced by a simple timer, the control system is capable of lowering the domestic water temperature in the tank during unoccupied periods.

    Building Type Application

    - This measure is considered for all buildings with considerable domestic hot water consumption, such as hospitals and schools. It was not considered for administration and cultural buildings, in

---

(a) Costs are estimated from the cost per unit capacity for heat system retrofits and estimated hot water demand. This method may underestimate costs for systems with low demand, for which this measure is probably inappropriate.

which the volume of water consumption and consequent energy savings would not justify the required investment.

Considerations

- Installation of the storage tank will require availability of floorspace.

- Water storage tank cleaning should be done periodically (at least every 5th year).

- Utilization of compact, package-type pre-assembled DWH systems is highly recommended, because they reduce the number of field-installation-related problems and are more reliable.

- Installation of water treatment, such as filters and softeners is desirable, especially in hospitals and schools. This will also increase the life of the system.

- This measure is usually considered as a substantial capital improvement of the building and bears a relatively high cost.

Costs

- Material costs associated with retrofit of a domestic water heating system are a function of the installed water heater capacity and range from $24 to $32 per kW of installed capacity, smaller systems bearing larger per unit costs.

- Labor time to install the measure is estimated to be 62 hours for every 100 kW of installed capacity. In monetary terms the labor cost represents an average cost of $9.45 per kW of installed capacity.

- Periodic inspection and O&M is necessary and its cost should be included in the operational budget of the building owner/occupant.

Availability

- Domestic water heating systems and components are available from local sources and also from several foreign companies having representation (sales offices) in Ukraine.

14. **Install Low-Flow Showerheads** - Low-flow showerheads available on the market can reduce the required water flow through the shower by 40 to 50% without sacrificing user comfort. These showerheads create the same “massaging” effect as high-flow models. Showerheads are easy to install and do not require plumbing changes.

Building Type Application

- Showerhead installation is assumed in hospitals having in-patient facilities. Polyclinics, schools, kindergartens, and offices are assumed to have insufficient hot water use in shower facilities to substantially influence the hot water consumption.

Considerations

- Installation of showerheads requires that the existing pipe connections be in reasonable condition.

- Savings from low-flow showerheads are dependent on reducing average flow rates of showers. The effectiveness of this ECO is often overestimated because of overestimates of existing showerhead flow rates.

Costs

- Material costs are estimated to be $7.69 per showerhead.

- Labor time to install the measure is estimated to be 0.25 hours, with a labor cost of $2.64 per showerhead.

Availability

- Showerheads are locally available from outlets of foreign suppliers, and could be a source of domestic manufacture.

15. **Install Aerators in Faucets** - Aerators reduce the flow of water in bathrooms and utility room faucets for bathing, dish washing, etc. Installing aerators is simple and inexpensive and can be done by the occupant or as a maintenance procedure. The water consumption can be reduced by up to 30 to 50% of the faucet flow for a "running water" usage.

Building Type Application

- This measure is assumed to be applicable in hospitals, schools, and residential buildings. In other building types water usage is not considered large enough to result in significant energy savings.

Considerations

- Aerators are effective only when a "running water" usage is assumed. For faucets used to fill containers or tubs, aerators should not be used as they do not reduce energy use and increase the filling time in such cases. Also, some faucets may not be amenable to adding an aerator.

Costs

- Material costs are estimated to be $3 per aerator.

- Labor time to install the measure is estimated to be 0.15 hours, with a labor cost of $1.59 per aerator.

Availability

- This material is available from local sources. Some good quality models can also be obtained from local outlets of foreign suppliers and could be a source of domestic manufacture.

16. **Install Hot Water Meters** - Metering does not itself directly impact hot water use. Instead, it provides building occupants with an incentive to reduce hot water consumption and thus leads to reductions in hot water use. In institutional buildings, heat consumption for hot water would be measured at a single point of heat supply because heat costs are paid at the building level. For residential buildings, unlike heat metering, which is difficult to implement because of the one-pipe heating systems, hot water metering would be relatively straight forward by installing meters at the single point of supply to each apartment. Studies have shown that hot water metering can have a dramatic impact on hot water use. Not only are hot water costs a significant portion of energy costs for a typical family in Kyiv (more than $9 per month according to IEA [1996]), hot-water-related energy use for residential customers is also a large component of total heat consumption in Kyiv.

Building Type Application

- This measure is applicable in residential buildings.

Considerations

- Metering imposes an additional burden of reading meters and billing. While these costs are expected to be passed on to the consumers, no attempt is made to quantify them here.

Costs

- Meter costs are estimated to be $95 per meter.

- Labor time to install the measure is estimated to be 3 hours, with a labor cost of $40.00 per meter.

Availability

- This material is available from local sources.

17. **Insulate Hot Water Pipes in Unheated Spaces** - Hot water pipes are generally insulated from the point of heating to the bottom of riser shafts, but not in the unheated shafts themselves (Ekono Energy 1996). In addition, old insulation may be insufficient, damaged, or otherwise not functional. Additional new insulation and/or repair of damaged parts of insulation lowers the hot water heat losses. Insulation in heated spaces is not considered economical, since the heat is "utilized" for space heating during the heating season.

Building Type Application

- All buildings are considered for this measure.

Considerations

- If existing pipe insulation contains asbestos fibers, the disturbance of the old insulation may create hazardous conditions and require additional measures to control and dispose of the asbestos. Asbestos is not known to be used for building insulation in Ukraine, however.
- Good insulation decreases heat loss, which helps maintain the water temperature and reduces the recirculation pump capacity.

Costs

- Material costs are estimated to be $3.30/m.

- Labor time to install the measure is estimated to be 0.2 hours/m with a labor cost of $2.72/m.

Availability

- Insulation materials based on mineral wool, closed cell foams, or fiberglass are readily available.

Heating System Measures

An important characteristic of heating systems found in most institutional (and residential) buildings in Ukraine is the single-pipe design, either with or without bypasses on the radiators. Without costly plumbing changes, this design does not allow zoning or control of the heating by a single zone valve for a building section. Heat metering for individual apartments in residential buildings is also difficult for the same reason. Multiple zone valves on each segment and multiple heat allocation devices would have to be used to meter the occupants' heat consumption.

Except for a small number of large buildings with more than 10 stories and some other important buildings, virtually all buildings in the city of Kyiv supplied by the district heating system utilize hydro-elevators (venturi nozzles) for circulation of heating water inside the buildings. Buildings greater than 10 stories use a heat exchanger and circulation pump system. In a hydroelevator system, the temperature of the circulating water in the building heating system is reduced in the hydroelevator by mixing with return water. Such building heating systems directly circulate the district heating water and require (and assume) constant pressure in the district heating system pipes. Control of hydroelevator systems is very difficult; however, most of the systems were designed without controls, and the mixing ratio is driven only by the system pressure. At high-supply water temperatures, buildings will be overheated, and during low-supply temperature (which is currently the case) the relatively low-supply water temperature (65 to 75°C) is uncontrollably mixed with the return water, which reduces the water temperature entering the building system to almost unusable temperature levels of 40 to 45°C.

Hydroelevator systems are quite outdated and are very inefficient. Without the ability to control building temperature, virtually no energy efficiency improvements could be effective (produce savings) without implementing a building heating control system upgrade. Based on available options, it is apparent that the building control system upgrade will require the installation of substations with water-to-water heat exchangers, and all necessary plumbing such as pipes, control and shutoff valves, liquid filters, circulating pumps, etc. In other words, to be able to improve energy efficiency of buildings, the hydroelevator system in each building must be replaced by a heat-exchanger-based substation. It is important to understand that even weatherization of a building envelope (e.g., by insulating the walls) will not produce savings without control of heat input to the space. Lack of such controls will result in space overheating, which leads to the use of windows to control temperatures.

The substation controller retrofit includes the substation with outdoor temperature reset control, equalizing (balancing) valves for the heat system branches throughout the building, and a control system utilizing occupied/unoccupied period setback when applicable.

The energy conservation effort must, in general, include two parts: the party responsible for energy bills must 1) be able to control the energy consumption and 2) must have an incentive to actually save energy. Installing temperature controls alone would likely not produce sufficient and sustainable energy savings as the occupants would not be rewarded for efforts to save energy. Therefore, metering energy consumption is very important, and energy meters must be installed for each user and are assumed to be part of every energy conservation measure considered in this study. Some Eastern European countries, such as the Czech and Slovak Republics, mandated metering by legislative order supported by financial incentives for metered consumption (leading to temporarily better rates).

Ukraine's building code requires all new buildings be equipped with a heat metering device (Cabinet of Ministers of Ukraine 1995). In addition, the Decree ratified a program for installing heat and water meters in existing residential buildings within the period of 1996 to 2000. The implementation process is

coordinated by the State Committee on Housing and Communal Services, and regional state administrations are responsible for the implementation.

The main objective of the metering program is to minimize demand on energy resources by reducing heat and water consumption. For the existing building stock, in the first stage, building-level metering is to be introduced in high-rise (5-story and more) buildings and then in low-rise buildings. In the second stage, apartment-level metering will be introduced.

Installation of meters is to be financed from the special-purpose funds created by regional administrations. The program is oriented mainly to domestically manufactured meters and temperature controls. New production facilities are to be created for equipment not currently available in Ukraine.

18. **Install Building Heat Meters** - As described above, building heat meters are considered an integral part of the energy-efficiency retrofits in all buildings. Building heat meters, because they allow for payment based on actual service, not calculated service, provide an incentive for building occupants to minimize heat consumption. This can have a substantial impact on the operations and maintenance of energy savings measures. It also allows for the verification of energy savings.

    Building Type Application

    - This measure is included for all buildings.

    Considerations

    - Metered service results in additional meter reading and billing requirements. Though it is assumed that these costs will be passed on to the consumer, no attempt is made to quantify them here.

    Costs

    - Material costs are estimated to be $2,800 per meter.

    - Labor time to install the measure is estimated to be 12 hours per meter, with a labor cost of $160 per meter.

Availability

- High-quality meters are available from local sales outlets of foreign suppliers and from local manufacturers.

19. **Retrofit Heating System** - Considering the existing design and poor condition of the building heating systems, the overall retrofit of the heating substations in institutional buildings was deemed to be the

most appropriate. The retrofit assumes the replacement of the existing hydroelevator-based systems with new, heat-exchanger-based substations; installation of balancing valves and proper balancing of individual loops (risers); and utilization of outdoor temperature reset controls with unoccupied setback (night, weekends). Balancing valves installed on each riser will allow more accurate distribution of heat throughout the building sections.

Energy savings by this measure are accomplished by the ability to control the required heat input to the building during the occupied and unoccupied periods, and to provide sufficient heat to difficult-to-heat spaces (such as building corner rooms) without severely overheating the building core space.

Building Type Application

- This measure is considered for all buildings currently equipped with hydroelevator-type heating systems without temperature control and without proper heating system balancing. In some buildings, such as inpatient hospital facilities, unoccupied setback cannot be utilized due to permanent occupation of the space.

Considerations

- This measure does not provide for temperature control in individual zones/rooms.

- Balancing should be done periodically (at least every 5th year).
- Utilization of compact, package type pre-assembled heat substations is recommended, because they are highly reliable and reduce the number of field-installation-related problems.

- A building-side pipe cleaning procedure prior to installation of the new substation is necessary. Failure to clean the pipes may result in severe operational problems.

- This measure is usually considered a substantial capital improvement of the building and bears a substantial cost.

- Installation of heat exchangers in a large portion of buildings on a single district heating loop may change operating conditions in other buildings on the loop that continue to use a hydroelevator system. If the system is not adjusted to account for these changes, overheating of the buildings with hydroelevators may occur. In such cases, it may be necessary to balance the district heating loop.

Costs

- Material costs associated with retrofit of substations are a function of the installed substation capacity and range from $11 to $25 per kW of installed capacity, with smaller substations bearing larger unit costs.

- Labor time to install the measure is estimated to be 50 hours for every 100 kW of installed capacity (including the labor time for installation of balancing valves). In monetary terms the labor cost represents an average of $7.62 per kW of installed capacity.

- Substation seasonal inspection and O&M is necessary, and its cost should be included in the operational budget of a building owner/occupant.

Availability

- Packaged substations including all components are available from several western European companies having representation (sales offices) in Ukraine. The heating system retrofit assumes that field installation of individual components will utilize a majority of domestic parts and import items not individually available domestically (controls). Riser balancing valves are available domestically or from local sales outlets of major companies.

20. **Install Radiator Balancing Valves** - Temperature control is assumed to be provided by the outdoor temperature reset in the substation. Balancing valves installed on each radiator will allow more accurate distribution of heat throughout the building. This measure does not allow for temperature control; however, it can be used for permanent (or long-term) reduction of heat output by individual radiators. Energy savings are accomplished by the ability to provide sufficient heat to difficult-to-heat spaces (such as building corner rooms) and thus the ability to reduce unnecessary heat supply to the building core space.

Building Type Application

- This measure is considered for all buildings without proper heating system balancing, mainly in combination with temperature control systems. As a stand-alone measure, it is considered for buildings with permanent occupation, such as hospitals, where unoccupied setback cannot be utilized.

Considerations

- This measure does not provide for temperature control.

- Balancing should be done periodically (at least every 5th year).

- This measure is usually combined with temperature control installation.

Costs

- Material costs are estimated to be $14.25 per valve.

- Labor time to install the measure is estimated to be 1.0 hour for radiators not requiring a bypass and 1.5 hours for radiators requiring a bypass, for total labor costs of $13.34 and $20.00 per valve, respectively.

Availability

- Radiator balancing valves are available domestically or from local sales outlets of major companies.

3.1.2 Efficiency Measures Not Considered

A number of ECOs identified (26) were not considered for further evaluation because they did not offer an adequate level of efficiency improvement potential, they could only be addressed through a more focused data collection effort beyond the scope of this effort, they would address only a small part of the building stock, and/or they were applicable to the energy supply side. Applicable ECOs that were not considered are presented in this subsection by ECO category.

Building Envelope

1. *Revolving or Double Door in Building Vestibule*. Installation of revolving doors was not considered because most of the buildings either already have a second door or the installation is impractical or costly.

2. *Triple Pane Windows*. This measure was not considered due to its high cost. Windows are typically replaced as part of overall reconstruction of a building where the replacement is not based on investment payback from the energy savings.

3. *Storm Doors*. Storm doors are not practical on high-traffic entrance doors of institutional buildings.

4. *Add Internal Insulation in Walls*. This measure is expensive to implement, affects the appearance of the interior, and imposes a considerable burden on the occupant. Also it may potentially cause structural damage to the wall material. If installed improperly, with air access between the wall and the insulation, it may cause condensation and fungus growth.

5. *Insulate Exterior Walls of Historical Buildings and Buildings with Complex Exterior Appearance*. This was rejected as unacceptable for the historic buildings and too expensive for the other building groups.

6. *Insulate Building Exterior Walls Having Windows*. This was considered too expensive to do in a manner that would be acceptable from an appearance standpoint. Installation of insulation on walls with many windows has proved not to be cost-effective

7. *Insulate Internal Walls Between Heated and Unheated Spaces (stairways)*. This was not considered to provide sufficient efficiency improvement and would have required additional data collection and analysis to evaluate.

8. *Insulate Basement Perimeter Above the Ground*. This was not considered to provide sufficient efficiency improvement and would have required additional data collection and analysis to evaluate.

9. *Repair Leaking Roofs and Gutters*. Leaks in roofs and gutters cause wet roof and wall insulation to become ineffective. This was not considered to be a common measure and would have required additional data collection and analysis to evaluate. Also, such a measure is considered to be a necessary building maintenance issue.

Heating System

1. *Re-Work Building Heating System Plumbing*. Re-designing and re-working the building heating system from a single, not-zoned system to allow a single control and energy consumption measurement point for each occupant (tenant of an office building, or hospital budget center) was not considered cost-effective.

2. *Replace or Improve Existing Gas or Room Heaters*. This was not considered to be a common measure. Room heaters are mostly being used to supplement the main heating system during heat shortages. Because room heaters are primarily electric, and because electricity use is metered, building occupants have a disincentive to use them when the heat supply is adequate.

3. *Insulate Boilers and Water Heaters to Reduce Standby Losses*. This measure is not applicable due to a very low fraction of local boilers and water heaters. Insulation of domestic water heater tanks in substations is considered a supply-side measure.

4. *Switch Fuel*. This supply-related measure was beyond the scope of this analysis.

5. *Replace Circulating Pumps and Temperature and Flow Control Components with High-Performance Parts*. Replacement of standard motors (pumps, blowers, etc.) by high-efficiency units does not produce sufficient monetary savings and produces a long payback period. Pumps and other

motors are typically replaced for other than energy saving reasons, such as failure, need to increase capacity, etc.

6. *Insulate Conduits Between Boiler or Heat Exchanger and Building*. This measure is related to the supply side of the energy system and insufficient data exist to effectively evaluate it.

7. *Use Heat Pumps for Space and Water Heating*. High-performance heat pumps are not available locally, and foreign made heat pumps are too expensive to produce a reasonable payback period. The Ukraine climate would require a ground-source heat pump for efficient operation during the winter. Additional data collection and analysis of heat pump performance characteristics would have to be performed for local climatic conditions.

8. *Use of Thermal Storage*. Thermal storage is a load-shifting measure, not an energy-saving measure, and therefore was not considered.

9. *Implement Nonconventional Energy Sources, Such as Solar, Geothermal, Waste Heat From Local Industry, etc*. This was not considered to be a common measure and was assumed to be of an experimental nature, requiring longer-term data collection and analysis for local climatic conditions.

10. *Improve Maintenance (cleaning) of Heat Sources, Such as Local Boilers, Room Heaters, etc*. This would have required additional data collection and analysis to evaluate.

11. *Outdoor Temperature Reset Control System for the Substations Serving Multiple Buildings*. This was considered to be a supply-side measure, which will be included in the supply-side analysis and implementation.

Ventilation and Heat Recovery

1. *Install Indoor Air Quality Ventilation/Heat Recovery Units*. High-efficiency heat recovery ventilation units in rooms or building sections would introduce the required quantity of fresh air. Unless the use of ventilation systems is mandated by minimum air quality standards (such as ventilation standards for surgery rooms), this measure may actually increase energy consumption.

2. *Install Combustion Air Preheating for Local Heaters*. This supply-related measure was beyond the scope of this analysis.

3. *Install Heat Recovery Vent System in Basements*. Although this measure typically produces good savings in the residential sector, it was deemed not to be economical in institutional buildings, where basements are not used for storage and do not require ventilation.

4. *Install Waste Water Heat Recovery Heat Exchanger*. Application of heat recovery in the waste water system requires certain hot water usage patterns and quantities. Except for a small portion of hospital buildings with inpatients facilities, this measure would not be economical and was not recommended.

Domestic Water Heating

1. *Insulate Hot Water Pipes in Conditioned Space*. This was not considered to be a cost-effective measure. Heat lost from the hot water pipes is utilized for space heating and, from an energy conservation view, insulation of such pipes in heated space would not produce savings. Also, most of the hot water pipes are reasonably insulated.

2. *Lower Domestic Hot Water Temperatures.* Domestic water temperature is maintained at 55°C, and lowering the temperature may introduce a health hazard. Also, lowering the temperature of the water could, in some cases, cause a hot water capacity shortage.

3.1.3 Summary of Efficiency Measures Considered

Table 3.1 summarizes the 20 efficiency measures considered by installed cost per unit.

Table 3.1. Efficiency Measures Considered and Installed Cost Per Unit

Efficiency Measure	Unit	Cost ($)/Unit
Building Envelope		
Exterior Side Walls	m^2	25.17
Roof Insulation	m^2	27.94
Attic Insulation	m^2	11.38
Basement Floor Insulation	m^2	7.59
Weatherstripping	m	1.96
Storm Windows	each	127
High-performance Glass	m^2	43.17
Third Window Pane	m^2	30.68
Radiator Reflectors	each	9.07
Air Handling		
Ceiling Fans	per fan	203
Ventilation Heat Recovery	m^3/hr	2.60
Domestic Water Heating		
Hot Water Heat Exchanger (weighted average)	bldg.	2,190
Storage Water Heater	bldg.	3,147
Low-Flow Showerheads	each	10.32
Faucet Aerators	each	4.58
Hot Water Meters	each	135
Insulate Pipes	m	6.02
Heating System		
Building Heat Meters	each	2,960
Retrofit Heating System (weighted average)	bldg.	9,018
Radiator Balancing Valves	each	27.58

Different combinations of measures were installed depending on the performance of the measures in each building type. These combinations are discussed further in Section 3.3. Appendix C provides additional detail on the installed cost of the measures by building type.

3.2 Analysis Approach

The focus of the analysis was on the institutional buildings sector, so greater attention and more detailed analysis underlies the institutional sector estimates. Two subsections (3.2.1 and 3.2.2) describe the technical and economic analysis methods, respectively. Differences in the analysis approach for the institutional and residential sectors are noted in these two sections.

3.2.1 Technical Analysis Method

The technical analysis was based on the simulation of efficiency measure performance in prototype buildings chosen to reflect the mix of buildings found in Kyiv. The prototype building designs were developed based on site visits to buildings in Kyiv. A total of 33 prototypes were developed to model the Kyiv building stock. These prototypes are described in more detail in Appendix C.

Because the prototype buildings do not necessarily match the size of the average buildings in Kyiv for which they are used, all building level estimates are scaled to the average building area, by building category. The purpose of this scaling is two-fold: to allow for the estimation of per building costs and savings for average buildings in Kyiv, and to ensure that costs per building for measures, such as heat meters, accurately reflect the requirement that one heat meter be installed in each building.

Data presented on a per-building basis are consistent with per-unit floorspace estimates and total floorspace by building type. It should be noted, however, that there is not a one-to-one correspondence of building types to building prototypes. Hence, detailed level estimates, such as cost by ECO and building type, will not correspond exactly to the full set of building types (e.g., see Tables C.4 and E.1).

The analysis methodology, by measure type, is described below.

Analysis of Building Envelope Measures

The ASEAM5 (A Simplified Energy Analysis Method, Version 5) computer program was used in this analysis to model heat losses in buildings based on procedures recommended by the American Society for Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE). The program calculates the peak building energy demands and annual energy consumption based on weather conditions in a given location. This computer program utilizes a bin-type TMY (typical meteorological year) weather file created from hourly weather data collected over a long period. The output reports include effects of other factors on building heat loads, such as occupancy schedule, lighting, appliance usage, insulation, etc., which helps determine the most effective energy conservation measure for each building type.

Baseline and post-measure installation heat and hot water energy consumption were calculated for each measure and each building type, the difference being the efficiency improvement. The development

of the baseline building heating loads for each institutional building type required making several assumptions. The most important assumptions were infiltration rates, internal temperatures in different locations, and occupancy and equipment schedules. These assumptions were based on recommended values, previous experience, and information gathered during the energy audit of the representative buildings for each group.

In the modeling of each ECO, only the pertinent value describing the given ECO was changed in the model. Insulation of walls, ceilings, and floors was modeled by lowering U-values. Weatherstripping was modeled by lowering the infiltration rate. Modeling of triple-pane and storm windows was accomplished by lowering U-values.

Analysis of Water Heating Measures

Efficiency improvement calculations for low-flow showerheads and faucet aerators were based on statistical information regarding the use of hot water in Ukraine, statistical information on hot water use by purpose (dishwashing, shower, laundry, etc.), and manufacturers' performance information. Calculation of efficiency improvements obtainable by insulating the hot water pipes in unconditioned spaces is based on lowering heat losses through additional pipe insulation with improved R-value or replacement of existing insulation with high-performance materials. Because of the limited nature of this effort, exact length and sizes of pipes could not be determined, but rather were estimated for each building group based on typical plumbing designs.

Analysis of Building Heating System

All ECOs in this category provide improved energy management in the building and assume that outdoor temperature reset control is installed in each substation of the central district heating system.

Installation of temperature control devices in conjunction with installation of energy consumption metering provides building occupants/owners with an incentive to reduce energy consumption. The use of a programmable thermostat also improves the use of setback during unoccupied periods. The combination of better energy management and distribution within the building and the ability of motivated occupants to lower energy consumption results in two effects:

- Room temperature is kept at the lowest possible acceptable (comfortable) level.

- Windows are opened only to maintain acceptable indoor air quality and not for temperature control.

The computerized calculations used for the building heating system efficiency improvements were also derived from procedures recommended by ASHRAE. For each measure, the baseline and post-measure installation heat loss were both calculated. The difference between the two heat loss values is the energy-use reduction. For each ECO analyzed, the temperatures and infiltration rates were estimated based on

performance of the proposed equipment and expected occupant behavior. In general, more accurate equipment and motivated occupants will produce lower temperatures and lower infiltration rates. The temperatures were not assumed to drop below accepted comfort limits.

Analysis of Ventilation Heat Recovery Measures

Although none of the ventilation energy-efficiency measures were considered for application, evaluation of several measures was performed. The energy saving calculations developed for the heat recovery applications were again derived from procedures recommended by ASHRAE. Inputs to the calculations include properties and mass flow of media from which the waste heat is recovered and manufacturers' performance characteristics for the heat recovery equipment.

3.2.2 Economic Analysis Method

This section provides a discussion of the economic analysis metrics, the economic assumptions, and the approach employed to assess the economic performance of the efficiency measures.

Analysis Metrics

The ECOs described in the previous section were analyzed using a number of economic methods or "metrics" to evaluate the attractiveness of each option. A number of economic metrics commonly used to evaluate measure performance are simple payback, present and net present value (NPV), and internal rate of return (IRR). These metrics are described below.

Simple Payback. The most basic economic analysis metric is the simple payback period, which in its simplest form is calculated by dividing the installed cost of the ECO by the value of the annual energy savings. The simple payback period is the number of years required for the savings resulting from an investment in energy efficiency to offset the cost of the investment. The lower the payback period, the more attractive the investment.

In many analysis situations, this metric is too simplistic to be of much use. ECOs with future costs may be overvalued if these costs are not accounted for. Escalating fuel prices will also undervalue an ECO. Simple payback does not enable ready comparison for measures having different useful lifetimes. This method also does not account for the time value of money and may not be readily comparable with other investments using more sophisticated measures of value. Despite the many shortcomings of this method, it is frequently used along with first cost to evaluate the attractiveness of measures.

Present and Net Present Value. A Hryvna today is worth more than a Hryvna tomorrow for two principal reasons: general price inflation and the time value of money. Based on general price inflation, the purchasing power of a Hryvna declines over time, and because the true value of money lies in what it is capable of purchasing, inflation causes its value to decline. The time value of money refers to the fact

that even in the absence of general price inflation, money received sooner is preferred to money received later.

It is this preference for consuming sooner rather than later that leads to the existence of positive rates of interest, even in the absence of price-level inflation. Individuals and firms are willing to pay a premium to obtain goods and services sooner rather than later, and the premium they are willing to pay is the "real rate of interest." The market or "nominal" rate of interest is the real rate plus the rate of inflation (this is a slight simplification). As an example, 100 Hryvna received 2 years from today is worth 82.64 Hryvna today, assuming a 10% nominal rate of interest. Conversely, 82.64 Hryvna invested today at a 10% per annum annual nominal rate of interest yields 100 Hryvna 2 years later.

The costs and benefits of an efficiency investment occur at different periods in time, which must be accounted for in the analysis. A metric for reflecting this fact is net present value, where the present value of all the costs of an ECO is compared to the present value of all the benefits of the ECO. The difference between the two, NPV, is a measure of the cost-effectiveness of an ECO. A negative NPV means the costs of an ECO outweigh its benefits, while a positive NPV means that the benefits are greater than the costs. The higher the NPV, the better. The formula for calculating the NPV is:

$$NPV = \sum_{t=1}^{N} \frac{R_t}{(1+d)^t} - C$$

where: t = year
R = annual return
d = discount rate
C = capital outlay

Internal Rate of Return. The IRR is the interest rate that equates the present value of the expected future cash flows or receipts to the initial capital outlay. The formula for calculating the IRR is:

IRR = r such that:

$$\sum_{t+1}^{N} \frac{R_t}{(1+r)^t} - C = 0$$

where: t = year
R = annual return
r = interest rate
C = capital outlay

The difference between the NPV and IRR is the discount rate (d) and interest rate (r). In the case of IRR, the formula is solved for the interest rate (r) where the benefits minus the costs equals zero. The

IRR is often used to screen and rank alternative investments--in general, the higher the IRR, the better. In the case of this analysis, an IRR of 20% or greater is deemed acceptable before accounting for risks, and the minimum acceptable IRR after risks is the discount rate of 10%.

In this analysis the IRR is computed only for those ECOs where a conventional cash flow stream exists and where the NPV is positive. Other cases may lead to multiple solutions or no solution. Conventional cash flow is the net cash flow stream, which begins with a disbursement of funds followed by a stream of savings.

Economic Assumptions. Two types of economic analysis methods typically used are nominal and real. The main difference between the two is the presence or absence of inflation, respectively. In a nominal analysis, the value of energy savings in 1997 is expressed in 1997 Hryvna, the value of energy savings in 1998 is expressed in 1998 Hryvna, and so on. The nominal value of the energy savings continues to increase because of inflation and the general level of prices. A real analysis expresses all money values in constant terms by removing the effects of inflation. In the case of this analysis, all values are expressed in 1996 currency values.

The implication of using a real analysis is the need to calculate a real discount rate to reflect the time value of money, which is the "real" interest rate after the effects of inflation have been removed. For the purposes of this analysis, a simplification is used whereby the discount rate is calculated as the nominal interest rate minus the expected rate of inflation.

Basic economic assumptions are provided below.

- nominal discount rate - 16%
- inflation rate - 6%
- real discount rate - 10%
- analysis period - 15 years.

3.3 Efficiency Potential Assessment

This section provides the energy and economic assessment of the 20 energy efficiency measures (described in Section 3.1.1) considered for the analysis. The method employed to assess the efficiency potential for the institutional sector consisted of three steps:

1. Screen the individual measures by simple payback; measures having a simple payback of less than 5 years were retained for additional analysis.

2. Combine the measures to identify interactive effects to avoid double counting the efficiency potential and to deselect measures that reduced the payback of selected bundles for individual building types.

3. Evaluate the measure bundles and applicable individual measures for each building type to estimate efficiency potential.

The residential sector efficiency potential was based on a combination of previous assessments conducted in the Czech Republic (PNNL 1996), the Slovak Republic (PNL 1995), and in Russia (World Bank 1996). Residential sector prototypes constructed for an analysis in the Czech Republic were simulated using Kyiv weather data. The quantities of material for the residential building types were drawn from an analysis of residential sector efficiency potential in Russia. Cost data were specific to Ukraine and consistent with cost data used for the institutional sector assessment.

3.3.1 Institutional Sector Efficiency Potential

The following group of four space-heating measures having an interactive effect were selected for application:

- windows and door weatherstripping
- reflectors behind radiators
- ceiling fans
- substation-level controls.

Depending on building type, a subset of these items was selected based upon their combined performance.

The following three measures, which did not exhibit interactive effects, were also selected for application depending on their performance:

- hot water heat exchangers
- low-flow showerheads
- aerators on faucets.

In all cases building heat meters are included.

Table 3.2 shows the cost-effective institutional sector efficiency potential by building type. Additional detail is contained in Appendix D.

Table 3.2. Institutional Sector Efficiency Potential

Building Type	Baseline Energy Use (thousand Gcal)	Efficiency Potential (thousand Gcal)	Efficiency Improvement (%)	IRR (%)
Hospitals	157	40	25.8	27.8
Polyclinics	59	16	27.2	24.4
Administration	16	4	26.2	16.4
Kindergartens	329	86	26.2	31.7
Schools	470	129	27.4	29.1
Higher Education	240	64	26.5	31.6
Hostels	154	34	22.0	25.4
Theaters	10	3	28.7	26.8
Art Galleries/Museums	12	2	19.6	12.9
Total	1,446	378	26.2	29.2

3.3.2 Residential Sector

The assessment of building efficiency potential for the residential sector was based on previous analyses conducted for the Czech Republic (PNNL 1996) and for Russia (World Bank 1996), and was modified to account for differences in the size mix of the housing stock and differences in the thermal performance of residential buildings in Kyiv. Retrofit equipment cost data were taken primarily from the Russia study with modifications made in some cases based on data from the Czech study or from information developed specifically for the institutional buildings assessment in Kyiv. The following measures were selected for application:

- reflectors behind each radiator
- low-flow showerheads
- faucet aerators
- hot water flow meter in each apartment
- building-level heat meters
- substation-level temperature controllers.

The efficiency improvement attributed to this package of measures is presented in Table 3.3.

Table 3.3. Residential Sector Efficiency Potential

Building Type	Baseline Energy Use (thousand Gcal/year)	Efficiency Potential (thousand Gcal/year)	Percentage of Baseline (%)	Internal Rate of Return (%)
2-story	2,569	451	17.6	23.4
5-story	3,545	873	24.6	26.4
9-story	3,545	1,070	30.2	35.7
14-story	2,026	645	31.9	41.6
Total	11,685	3,039	26.0	32.4

3.4 Sensitivity Analysis

The sensitivity of the economic analysis to any particular input variable can be assessed by holding all other exogenous variables constant while the variable of interest is changed. In this fashion, the value of any particular variable at which the investment becomes unattractive (i.e., the IRR becomes less than 10%) can be determined. This value is referred to as the switching value.

The switching analysis was carried out with respect to two variables: energy savings and efficiency measure installed costs. The switching values, expressed as the percentage of the energy savings below the estimated value, or as the percentage of installed costs above the estimated value, for which IRR becomes less than 10%, are presented in Tables 3.4 and 3.5 for the institutional and residential building sectors.

Table 3.4. Internal Rate of Return Switching Value for Energy Savings and Installed Costs - Institutional Buildings

Type	Energy Savings (%)	Installed Costs (%)
Hospitals	40	240
Polyclinics	45	220
Hospital Admin.	70	160
Kindergartens	35	280
Schools	40	260
Higher Education	35	280
Hostels	45	220
Theaters	45	240
Art Galleries/Museums	80	120

Table 3.5. Internal Rate of Return Switching Value for Energy Savings and Installed Costs - Residential Buildings

Type	Energy Savings (%)	Installed Costs (%)
2-story	50	200
5-story	45	220
9-story	30	300
14-story	25	360

In the case of hospitals, the energy savings would have to fall to 40% of the estimated value for the IRR to drop below 10% (i.e., the energy savings would have to be 10.3% instead of 25.8% of baseline energy use), or the installed cost would have to increase by 240%. The institutional building types most sensitive to realized efficiency improvements or installed costs of efficiency measures are cultural buildings and hospital administration buildings. In the residential sector, the sensitivity to efficiency improved and the installed cost of the measures decreases as the building height increases.

3.5 Investment Requirements

This section discusses investment requirements for efficiency resources described in Section 3.3.

Investment levels are expressed both in terms of investment per building and investment per square meter of floorspace. The per-square-meter estimates are multiplied by the building stock estimates to provide an overall sector investment requirement. These values should be taken as an upper bound, as they are based on the assumption of 100% penetration of the efficiency measure packages into the building stock. In reality, not all existing buildings would be susceptible to retrofit.

The investment requirements for the institutional and residential building sectors are presented in Tables 3.6 and 3.7. Efficiency measure cost estimates are presented in Section 3.1. Other assumptions used in developing the investment requirements are presented in detail in Appendix E.

Table 3.6. Investment Requirements for the Institutional Buildings Sector

Building Type	Investment Requirements ($)		
	Per Building	Per m^2	Total
Hospitals	21,719	5.45	3,475,019
Polyclinics	14,143	5.29	1,555,709
Administration	8,309	6.21	573,290
Kindergartens	11,771	5.38	7,062,886
Schools	24,987	3.47	9,719,980
Higher Education	27,703	3.92	4,820,270
Hostels	23,994	4.37	3,191,160
Theaters	21,295	5.32	255,545
Art Galleries/Museums	12,809	6.08	397,093
Total	18,505	4.31	31,050,952

Table 3.7. Investment Requirements for the Residential Building Sector

	Investment Requirements ($)		
Building Type	Per Building	Per m^2	Total (millions $)
2-story	6,044	13.49	64.9
5-story	32,626	4.08	68.7
9-story	36,844	6.64	111.8
14-story	35,102	4.08	39.2
Total or Average	31,939	5.92	284.6

In the institutional buildings sector, the per square meter costs range from a low of $3.47 for primary/secondary schools to a high of about $6.08 for houses of culture. The single largest category for investment potential is schools at $9.7 million, followed by kindergartens at $7.1 million. The potential investment level for residential buildings is nearly $300 million compared to $31.1 million for the institutional buildings considered in this analysis.

4.0 Impacts Assessment

The buildings efficiency improvement program will have potential additional impacts, primarily in two categories: economic and environmental. These include impacts on employment, energy security, air pollutant emissions levels, worker health and safety during building renovation activities, and indoor air quality as a result of building renovations. In addition to the environmental aspects mentioned above, World Bank policies prohibit investment in sites with contaminated ground soil. In this chapter these issues are addressed with respect to the current situation in Kyiv. Existing environmental regulations pertaining to Kyiv, as well as World Bank operational directives, are reviewed.

4.1 Economic Impacts

The potential economic impacts are substantial for buildings efficiency programs in Kyiv and Ukraine. The estimated economic and employment impacts are presented in Table 4.1.

An efficiency program would have direct and positive employment impacts for retrofit installation work. This analysis assumes the ratio of Ukrainian to Western labor ranges from 5:1 to 8:1, depending on the efficiency measure. While it is not clear to what extent energy retrofit services exist in Kyiv, such capabilities are likely to develop. The resulting employment impacts are estimated at 64 full-time equivalents for the second through fifth years of the project. It is expected that domestic suppliers and manufacturers of equipment will also develop, but associated employment is not estimated.

The reduction in energy expenditures translates directly into reductions of state and municipal expenditures. Budgetary expenditures are projected to decrease by $9 million per year in the last year of the project. This is estimated to result in a redirection of $5.8 million in annual expenditures for fuel imports.

Although a residential sector program was not examined in detail, the burden of excessive fuel consumption is also felt by residential consumers. The International Energy Agency (IEA) estimates that a typical urban family of four pays as much as one-third of wage earnings for the energy bill (IEA 1996). Reductions in energy consumption that are translated into reductions in energy-related expenditures would have a substantial positive impact on disposable income. It is estimated that residential sector energy bills could be reduced by as much as 25%.

Table 4.1. Secondary Impacts

	1998	1999	2000	2001	2002	Annual
Budget Reductions						
Municipal Dept. of Health ($)	266,411	543,478	831,521	1,130,869	1,441,858	1,441,858
Municipal Dept. of Education ($)	945,421	1,928,658	2,950,847	4,013,152	5,116,769	5,116,769
Ministry of Education ($)	429,093	875,349	1,339,284	1,821,427	2,322,319	2,322,319
Municipal Dept. of Culture ($)	23,314	47,560	72,768	98,964	126,179	126,179
Total ($)	1,664,238	3,395,046	5,194,420	7,064,412	9,007,125	9,007,125
Emissions Reduction (tonnes)[(a)]						
NO_x	66	133	199	266	332	332
SO_x	46	93	139	185	232	232
CO_2	17,085	34,171	51,256	68,342	85,427	85,427
Domestic Employment (FTEs)[(b)]						
Direct (measure installation)	3	63	63	63	63	
Indirect (materials manufacture)	*	*	*	*	*	*
Fuel Import Reductions[(c)]						
Natural Gas (thousand m^3)	11,452	22,904	34,357	45,809	57,261	57,261
Mazut (tonnes)	16,118	32,236	48,354	64,472	80,590	80,590
Natural Gas ($)	950,531	1,901,062	2,851,593	3,802,123	4,752,654	4,752,654
Mazut ($)	218,744	437,489	656,233	874,978	1,093,722	1,093,722
Total Fuel ($)	1,169,275	2,338,551	3,507,826	4,677,101	5,846,376	5,846,376

(a) NO_x and SO_x emission factors from Ekono Energy (1996). CO_2 emission factors from DOE (1995).

(b) Full-time equivalents.

(c) Fuel import reductions estimated from energy savings using estimated transmission/distribution losses of 20%, and average boiler efficiency of 88%. Natural gas savings converted from Gcal to cubic meters using 7,975 kcal/m^3 (Kievenergo data) (JTC 1996), and mazut savings converted from Gcal to tonnes using 7,000 kcal/kg. Estimated price of natural gas, $83/thousand m^3. Estimated price of mazut, $95/tonne.

* Domestic manufacture of equipment and materials is expected, but an estimate of the types and quantities of materials and associated employment impacts has not been made.

4.2 Environmental Impacts

Assessment of the net environmental impacts associated with the potential investment program, particularly emissions impacts, requires an adequate characterization of an existing or baseline situation. As with the efficiency assessment baseline, this is somewhat problematic for the city of Kyiv. Currently, a capacity shortfall exists for district heating in some parts of the city. In addition, economic circumstances have led to the refusal of service by some building owners and/or occupants, depressing energy consumption at district heating plants to below-normal levels. As a result, current pollutant emissions are also below normal levels.

The actual environmental impact of the potential investment program at the building level is also highly dependent on the level of service received by any particular building. In buildings with adequate heating or overheating, an appropriately selected set of efficiency measures will result in reduced energy use, and hence reduced emissions. In buildings where heating service is inadequate, efficiency measures may improve the comfort level in the building, but not reduce energy use. While assessing impacts based on the existing (heat supply conditions in 1995) situation may accurately reflect actual short-term changes in emissions, the assessment will not capture the full expected impacts when service levels return to normal, which may be a more appropriate measure of environmental impacts.

Further complications to estimating environmental impacts also arise as a result of under utilization of district heating services, which in some cases is caused by electric space heaters, rather than natural gas, being used to provide supplemental heating. While the emissions impacts of this additional electricity use may or may not be local to Kyiv, they are in fact real impacts, and depending on the technology used to generate this additional electricity, may be much more dramatic than impacts due to changes in natural gas consumption at district heating plants. The complexity of this issue, however, is beyond the scope of the current effort to evaluate impacts associated with changes in electricity-related emissions.

Finally, emissions reductions related to energy savings depend on the performance of the heat production and distribution system, which are the subjects of a related improvement program. Direct emissions impacts as a result of these programs are estimated elsewhere (JTC 1996; Ekono Energy 1996). Explicit changes in average emissions factors as a result of these programs will not be estimated here. Instead, generic emission factors for boilers in Ukraine will be used, in conjunction with performance estimates of the existing heat production and distribution system. This method is transparent and provides a reasonably accurate assessment of emissions impacts associated with the potential investment program.

This assessment is driven both by World Bank and Ukrainian requirements for environmental assessments related to building efficiency improvement programs. The project requires a category “B” Environmental Mitigation Plan (EMP) as defined in the Bank’s Operational Directive on Environmental Assessment, O.D. 4.01 (World Bank 1991). The assessment has also been performed in accordance with the requirements of the Ukrainian Ministry of Environmental Protection and Nuclear Safety, 1991 Law of

Ukraine "On Protection of Natural Environment" (Law of Ukraine 1991) and 1992 Law "On Protection of Ambient Air" (Law of Ukraine 1992). Specific regulations are discussed by topic area below.

4.2.1 Emissions Impacts

Ukrainian law regulates both total emissions and stack concentrations from gas and mazut-fired boilers. Emissions limits exist for nitrogen and sulfur oxides and particulate. The emission limits are presented in Table 4.2.

Table 4.2. Boiler Plant Permissible Air Pollutant Emission Levels

		Permissible Levels of Air Pollutant Emissions									
		Total Exhaust, g/MJ [(a)]					**Concentration of Air Pollutants in Exhaust Gases (when a = 1.4), mg/m^3, at Normal Conditions**				
		Particulate			**Oxides**		**Particulate**			**Oxides**	
		Adjusted Amount of Ash in the Fuel, % kg/MJ					**Adjusted Amount of Ash in Fuel, % kg/MJ**				
Boiler Steam Capacity, t/hr Thermal Capacity, MWt	**Fuel**	**<0.6**	**0.6-2.5**	**>0.6**	**Sulfur**	**Nitrogen**	**<0.6**	**0.6-2.5**	**>0.6**	**Sulfur**	**Nitrogen**
420 t/hr and bigger, 300 MWt, (1,000 GJ/hr)	Gas					0.043 (1.25)					125
	Mazut	0.02 (0.586)			0.175 (5.13)	0.065 (1.9)	50			400	185
Less than 420 t/hr, 300 MWt, (1,000 GJ/hr)	Gas					0.086 (2.5)					250
	Mazut	0.06 (1.76)			0.25 (7.33)	0.1 (2.93)	150			600	290
(a) Numbers in parentheses are values in kilograms/tonnes standard fuel.											

Ukrainian law (Ministry of Environmental Protection and Nuclear Safety) also regulates maximum permissible concentrations of selected air pollutants for short-term and 24-hour average concentrations. The full list of regulated pollutants includes more than 800 items, of which the most important for this project are NO_X, SO_2, CO_2, and particulate. The maximum permissible concentrations of these pollutants are presented in Table 4.3.

Table 4.3. Maximum Permissible Concentration of Air Pollutants

Pollutant	Maximum Short-Term Concentration (ppm)	Average Concentration per 24 Hours
Nitrogen Dioxide	0.085	0.04
Nitrogen Monoxide	0.6	0.06
Sulfur Dioxide	0.5	0.05
Residential Oil Ash (recalculated to vanadium penoxide)	--	0.02
Nonorganic Particulates (silicon dioxide content above 70%)	0.15	0.05
Nonorganic Particulates (silicon dioxide content ranging from 20 to 70%)	0.3	0.1
Nonorganic Particulates (silicon dioxide content below 20%)	0.5	0.15
Note: ppm is parts per million.		

The potential investment program is expected to reduce heat demand in buildings, and hence energy consumption and emissions. The magnitude of the emissions reduction is a function of the heat demand reduction, the net heat production and distribution efficiency, and the emissions rates of the district heating boilers. As discussed above, precisely estimating the actual emissions reduction is difficult. However, a reasonable approximation can be made using estimated average emission factors and system performance. The assumptions used in this analysis are presented in Table 4.4.

Table 4.4. Emissions Estimate Assumptions

	Natural Gas	Mazut	Total or Average
Fuel Share	85%	15%	100%
Emission Factors (g/MJ)			
NO_x	0.21	0.21	0.21
SO_x	-	0.975	0.146
CO_2	50.3	74.7	54.0
Boiler Efficiency	88%	88%	88%
Transmission Efficiency	80%	80%	80%
Heat Use Reduction (Gcal)	321,501	56,735	378,236
Fuel Use Reduction (Gcal)	456,677	80,590	537,267
Fuel Use Reduction (MJ)	1,912	337	2,249

Total emissions reductions by year as a result of the project are presented in Table 4.1. It is projected that after the year 2002, NO_x emissions would be reduced by 332 tons, SO_x emissions would be reduced by 232 tons, and CO_2 emissions would be reduced by 85,427 tons annually.

4.2.2 Health and Safety

Both the World Bank and Ukraine have health and safety guidelines for construction activities. Of primary concern is the potential for exposure of workers and occupants to asbestos, which is sometimes used in building materials such as insulation. Exposure to airborne asbestos particles poses a known health risk. In Ukraine, asbestos is used primarily to produce asbestocement, which may be used as a material for different types of pipes and ducts, and for roofing tiles. Asbestocement air ducts may be used in ventilation exhaust systems. However, Ukrainian law (State Committee of Ukraine on Affairs of Urban Development and Architecture 1996, SNiP No. 2.04.05-91) prohibits the use of asbestocement air ducts in input ventilation systems. It has been determined that asbestos is not commonly used as an insulating material. The potential investment program does not contain components related to the ventilation system. Hence, the potential to encounter asbestos in renovation projects is negligible; however, it is recommended that the presence of asbestos and its potential disturbance be addressed in the audit of individual buildings.

An additional health issue that may be worthy of further consideration relates to the use of industrial waste materials in concrete used to manufacture prefabricated panels for high-rise apartment construction. Since the early 1960s, these panels were manufactured at industrial facilities along the Dnieper River. In some cases industrial residues from the Donets Basin were used as aggregate in these panels (TACIS 1994). The use of such residues is now prohibited due to the potential for high heavy metals content in the waste. However, little publicly available information has been located on the health hazards associated with the use of these panels in existing buildings.

Positive health impacts can be expected due to improved temperature control in buildings. The improved environment may reduce the number of occupant sick days and improve productivity; however, it would be extremely difficult to quantify such impacts, and no attempt to do so is made here.

4.2.3 Indoor Air Quality

Ukrainian sanitary norms regulate maximum permissible concentrations of harmful substances in ambient (outdoor) air. Under regulations of the Ministry of Health, maximum concentrations for indoor air of residential and institutional buildings must not exceed established maximum permissible concentrations for ambient air. To comply with these regulations, Ukrainian law (State Committee of Ukraine on Affairs of Urban Development and Architecture 1996, SNiP 2.04.05-91) requires that the building ventilation system be designed appropriately, and that the heating system design must account for heat losses due to the warming of ventilation air. These heat losses are normally calculated on the basis of one air change per hour, though some buildings may be designed for greater air change rates. The World Bank requires a minimum ventilation rate of 0.5 air changes per hour.

Actual existing ventilation rates in Ukraine are difficult to quantify. In institutional buildings, ventilation systems are often inoperable. Because of high infiltration rates, however, indoor air quality is generally not a problem. Because some efficiency measures are expected to reduce infiltration, it will be necessary to ensure that adequate ventilation is maintained.

The potential for insufficient ventilation will be addressed for individual buildings at the time of the building audit to determine applicable efficiency measures. In addition, the monitoring and verification activities should include a component to monitor air quality in selected buildings.

4.2.4 Soil Contamination

The potential investment program is not expected to have a significant impact on soil contamination. None of the materials expected to be used in the program are, or contain, contaminants. World Bank directives also prohibit investment in buildings with soil contamination.

Existing soil contamination may be of concern in Kyiv due to the location of past or present industrial activities near residential and commercial areas. In addition, Kyiv is located in an area affected by the 1986 Chornobyl nuclear power plant explosion, which spewed radioactive materials into the atmosphere. This contamination is no longer considered to pose a hazard, but it is recommended that the potential for disturbance of contaminated soil be addressed during the audit of individual buildings.

4.2.5 Ozone Depleting Substances

In compliance with the Montreal Protocol[(a)] (signed by Ukraine on February 18, 1988, and ratified by the Ukrainian Parliament on September 20, 1988), the Cabinet of Ministers of Ukraine issued decree #1274 (Cabinet of Ministers of Ukraine 1996) approving a program for stopping the production and use of ozone depleting substances (ODS) in Ukraine. While ODS regulated by the Montreal Protocol are not manufactured in Ukraine, they are used in almost every sector of the economy.

Ukraine will receive financial assistance, partly financed by a Global Environmental Facility (GEF) grant of $26.5 million, to implement projects on the conversion of ODS-using enterprises. The grant is conditioned on the implementation of licensing procedures for the import of ODS and ODS-containing equipment and materials, including foam insulation manufactured with chlorofluorocarbon (CFC) foaming agents such as HCFC-11. The total number of licenses will gradually be reduced as required by the London amendments to the Montreal Protocol.

(a) The 1997 Montreal Protocol on Substances that Deplete the Ozone Layer, as adjusted and amended by meetings in London in June 1990, in Copenhagen in November 1992, and in Vienna in December 1995; sponsored by the Ozone Secretariat, United Nations Environmental Program.

The World Bank also restricts the use of ODS in particular foam insulations manufactured with CFCs or their derivatives. To comply with these regulations, all tender documents for this project will stipulate that foam insulation materials shall not be manufactured using CFCs.

5.0 Conclusions

The government of Ukraine, through the State Committee of Energy Conservation (State Committee), is considering the implementation of energy efficiency measures in state and municipal institutional buildings in the city of Kyiv. The State Committee entered into an agreement with the U.S. Department of Energy to assess the efficiency potential of the institutional buildings sector in Kyiv. Results of this assessment would support a loan by the World Bank for implementing a buildings efficiency improvement program in Kyiv.

This report documents the assessment of the institutional buildings sector efficiency resource conducted by PNNL and its subcontractors, Tysak Engineering and the Agency for Rational Energy Use and Ecology (ARENO-ECO). The assessment consists of three primary tasks: evaluation of the institutional sector building stock in Kyiv, estimation of heat energy consumption in this building stock, and assessment of the cost-effective energy efficiency potential through retrofits to the buildings.

In conducting this assessment, because of limitations in quality and availability of existing data, uncertainty arose regarding the size, distribution, and energy consumption of the institutional sector building stock. This assessment focused on reducing the uncertainties associated with size and distribution data by directly surveying the owning institutions. The uncertainty associated with the baseline energy consumption could not be addressed as directly due to time and budget limitations. In place of direct measurement of energy use, information from the literature and professional experience were drawn upon to produce baseline estimates. The energy consumption information generated in this manner is therefore considered conservative.

Of the 1,678 buildings included in the survey, education buildings make up the largest category with 1,296 buildings and a total of 6 million square meters of floorspace. A total of 989 of these buildings are under the jurisdiction of the Municipal Department of Education, the remainder being under the jurisdiction of the Ministry of Education. The Municipal Department of Health is estimated to own 339 buildings having about 1 million square meters of floorspace. Forty three cultural buildings were also included in the survey with a total of 131 thousand square meters of floorspace. Total floorspace for the institutional sector included in the survey is 7.2 million square meters. By comparison, residential buildings include about 49 million square meters of floorspace.

Of energy supplied to the buildings sector in the form of hot water for space heating and domestic hot water purposes, the share by sector is estimated as follows: residential sector 45%, industrial sector 34%, institutional sector 11%, and commercial sector about 10%. Although the literature review and professional experience indicate these estimates to be reasonable, uncertainty is high for these estimates. Of the institutional buildings included in this assessment, the educational category was estimated to represent about 84% of the total energy consumption.

Building types were analyzed by size and age subcategories to determine the cost-effective energy efficiency potential. Measures to improve energy efficiency were selected and applied to each subcategory to reduce space heating and domestic hot water energy use. Measures were selected based on the economic criterion of a 5-year or less simple payback. The measures include insulation (exterior, roof, attic, and pipe), weatherstripping, storm windows, radiator reflectors, controls (building radiator level), low-flow showerheads, and faucet aerators. After measures were selected, the performance of the measure package was evaluated based on simple payback, IRR, and NPV.

The estimated averages for efficiency potential range from 20% of baseline energy use for art galleries and museums to 29% for theaters. For education buildings, cultural buildings, and hospital administration buildings, the bulk of the efficiency potential is achieved through the building heat substation retrofit, which enhances temperature control and allows for setback of temperatures during unoccupied periods. For inpatient hospital buildings, the efficiency potential due to enhanced building controls is reduced because of the 24-hour occupancy schedule; however, high hot water use levels result in additional efficiency potential from the hot water heat exchanger retrofit (see Table 3.2).

The investment levels associated with efficiency improvements range from $3.47 per square meter for schools to $6.08 per square meter for hospital administration buildings, or an average investment of $4.31 per square meter. These investment costs are primarily related to building size. The cost per unit capacity for building controls and hot water heat exchanger retrofits are higher for smaller units, and hence are higher for smaller buildings. In addition, heat meter costs are the same regardless of building, and hence cost more per unit floorspace for small buildings. The per square meter investment levels lead to a total investment of $31.1 million.

The performance of the efficiency measure package varies as a function of building size, age, and function. In general IRR is lower for small and older buildings. By function, IRR is lowest for hospital administration buildings (16%) and art galleries/museums (13%), and highest for kindergartens and higher education buildings (32%). The weighted average IRR is 29% (see Table D.4).

The sensitivity of the economic assessment with respect to efficiency measure performance and installed costs was also examined. The estimated values for efficiency measure performance and installed costs were either raised or lowered until the IRR fell to 10%, the minimum value for which the net present value is positive. For the value of the IRR to fall below 10%, at a heat price of $22/Gcal, the efficiency improvement would have to decrease between 35% and 80% of the estimated value. For example, the efficiency improvement of kindergartens would have to fall from 26% to 9.1% for the IRR to fall to 10%. The cost of materials would have to more than double for the IRR to fall below 10% in all but hospital administration buildings and art galleries/museums, for which the cost of materials would have to escalate by 20% to 60% (see Table 3.4).

As a result of energy efficiency improvements, a reduction of $1.7 million in energy bills is estimated in the first year, increasing to over $9 million annually when the installation of efficiency measures is completed in the fifth year of the program. The reduction in energy costs translates to additional funding available for redirection to other uses in the agencies or reductions in the state and municipal budgets. The reduced consumption of energy also translates to a decrease in the outflow of currency to purchase fuels. In addition to energy use reductions, emissions are expected to be reduced as follows: 332 metric tons of NO_x, 232 metric tons of SO_x, and 85,427 metric tons of CO_2 annually (see Table 4.1). None of the measures considered are expected to have significant health impacts or other negative environmental impacts.

6.0 References

Cabinet of Ministers of Ukraine. 1995. *On Program for Staged Equipping of Residential Building Stock with the Instruments for Metering and Regulation of Water and Heat Consumption in 1996-2000*, Decree #947 of November 27, 1995, Cabinet of Ministers of Ukraine, Kyiv, Ukraine.

Cabinet of Ministers of Ukraine. 1996. *On Program for Stopping the Production and Use of Ozone-Depleting Substances in Ukraine*, Decree #1274 of October 17, 1996, Cabinet of Ministers of Ukraine, Kyiv, Ukraine.

Ekono Energy. 1996. *Feasibility Study for Heat Supply and Energy Efficiency Project Kiev*. Ekono Energy, Espoo, Finland.

International Energy Agency (IEA). 1996. *Energy Policies of Ukraine: 1996 Survey, Organization for Economic Cooperation and Development.* International Energy Agency, Paris, France.

Joseph Technology Corporation (JTC). 1996. *Ukraine Kiev District Heating Project.* Joseph Technology Corporation, Woodcliff Lake, New Jersey.

Law of Ukraine. 1991. *On Protection of Natural Environment*, Decree #1268-12 of June 26, 1991, Parliament of Ukraine, Kyiv, Ukraine. With changes introduced by the Laws #3180-12 of May 5, 1993, and #81/96-BP of March 6, 1996, Parliament of Ukraine, Kyiv, Ukraine.

Law of Ukraine. 1992. *On Protection of Ambient Air*, Decree #2708-12 of October 16, 1992, Parliament of Ukraine, Kyiv, Ukraine. With changes introduced by the Law #75/95-BP of February 28, 1995, Parliament of Ukraine, Kyiv, Ukraine.

Pacific Northwest National Laboratory (PNNL). 1995. *An Assessment of the Building Sector Efficiency Resource for the Town of Handlova*. PNNL-10847. Pacific Northwest National Laboratory, Global Studies Program, Richland, Washington.

Pacific Northwest National Laboratory (PNNL). 1996. *Assessment of the Buildings Sector Efficiency Resource for the City of Plzen, Czech Republic*. PNNL-10898. Pacific Northwest National Laboratory, Richland, Washington.

State Committee of Ukraine on Affairs of Urban Development and Architecture. 1996. SNiP 2.04.05-91*U, *Heating, Ventilation and Air Conditioning*, Order #117 of June 27, 1996, State Committee of Ukraine on Affairs of Urban Development and Architecture, Kyiv, Ukraine.

TACIS. 1994. *Study of the Potential for Developing Actions to Improve the Overall Energy Efficiency in the Building Sector in Ukraine*. Commission of European Communities by Sogelberg Ingeniere, and TechInvest, Lisbon, Portugal.

Ukrenergoprom. 1995. *Draft Plan of the Kiev District Heating Development in the Period 2005 and Potentially until 2010*. Ukrenergoprom, Kyiv, Ukraine.

United States Department of Energy (DOE). 1995. *Emissions of Greenhouse Gases in the United States: 1987-1994*, DOE/EIA-0573(87-94), U.S. Department of Energy, Energy Information Administration, Washington, D.C.

World Bank. 1991. *Operational Directive 4.01: Environmental Assessment*, The World Bank Operational Manual, World Bank, Washington, D.C.

World Bank. 1996. *Staff Appraisal Report, Russian Federation, Enterprise Housing Divestiture Project*, Report No. 15112-RU, World Bank, Washington, D.C.

Appendix A

Institutional Building Stock Survey and Data Collection

Appendix A

Institutional Building Stock Survey and Data Collection

A.1 General Description

Kyiv, the capital of Ukraine, is situated on the banks of the Dnieper River and has a population of about 2.8 million. The city is divided into 14 districts and covers an area of about 80,000 hectares (200,000 acres). Overall the city contains about 50,000 buildings including residential, industrial, commercial, and public (institutional) buildings. There is a large industrial area along the Dnieper River, and a newly developed area, with primarily residential buildings, on the outskirts of the left (East) bank. Institutional buildings are spread throughout the city, but the majority are located on the right (West) bank in the older parts of the city.

Institutional buildings are a diverse category that includes buildings with various social functions, such as:

- healthcare (hospitals, polyclinics, medical research institutes, etc.)
- primary and secondary education (kindergartens, schools, boarding schools, children's centers, grammar schools, lyceums, etc.)
- professional and higher education (professional colleges, institutes, universities, academies, student hostels, etc.)
- social and cultural institutions (museums, theaters, concert halls, libraries, sport complexes, etc.)
- administration and office buildings (ministries, committees, city and district administrations, various municipal organizations, research and design institutes, etc.).

The goal of the project was to consider only those buildings with state or municipal (city and district) ownership. Until quite recently, the state was the nominal owner of almost all real-estate property. State and municipal institutions acted as actual owners who were responsible for accounting procedures and maintenance of buildings. In this capacity there are such major institutions as ministries, state committees, ministry-level organizations (e.g., National Agency for Reconstruction and Development, State Property Fund, etc.), and the city and district administrations. Ministries and state committees,

apart from their own buildings, may have in their subordination research, design, and educational institutes, research and development bureaus, etc. Although formally subordinated, these institutions act as separate legal entities with full rights of property disposal (except selling the property).

As a result of insufficient financing from the state and municipal budgets, these institutions are usually forced to rent their buildings to government or commercial organizations and to charge the tenants with the operation and maintenance expenses. The current ownership situation is further complicated because of ongoing processes of privatization and transformation of ownership: state-owned buildings are being transferred to municipal property, and public buildings are being sold to private owners. As a result, the institutional buildings stock is undergoing rapid changes and cannot be regarded as fixed.

A.1.1 Targeted Buildings

Because the purpose of this study is to provide an assessment of the institutional buildings sector efficiency potential and investment level for a potential World Bank loan, the focus was on institutional buildings with large populations administered by a single owner. It is more likely that such owners will consider a loan and that the loan and its repayment will be administered more easily. Also, the administrative process of issuing the loan (due diligence) is much simpler and less expensive for larger borrowers. In addition, the willingness of large owners to provide data and to cooperate during the survey phase was a positive sign of their interest in obtaining the potential loan.

The existing ownership structure was analyzed, and the owners with large building populations were selected. Preference was given to those buildings where ownership relations were simplest and building stock could be considered as sufficiently stable (i.e., buildings are not rented to various tenants and the privatization process did not complicate the situation). In this regard, the obvious categories to consider were healthcare and education. Preschool and secondary education buildings (kindergartens, schools, boarding schools, youth centers, etc.) are owned by the city. The majority of higher and professional education buildings are subordinated to the Ministry of Education, and some other ministries have their own educational establishments. Healthcare institutions (hospitals, polyclinics, etc.) are owned by the city and the Ministry of Health. There is a much smaller number of healthcare buildings with other owners: Cabinet of Ministers, Ministry of Internal Affairs, Ministry of Transport, etc. There are very few of these buildings and information on them was much more difficult to obtain. Thus, they were not included in the detailed assessment.

An additional argument in favor of evaluating healthcare and education buildings was their substantial energy-saving potential due to their occupancy schedule. In addition, there are important social aspects of improving the overall conditions and level of comfort in educational and medical institutions. Also, in these categories many buildings were constructed according to standard designs, which makes it possible to replicate approaches to energy conservation opportunities and will reduce required implementation costs. Institutional buildings in other categories were not built according to the same standard designs and would require an individual approach.

Another category with a large number of buildings is research and design institutes. Here the largest owner is the Ukrainian National Academy of Sciences. It has dozens of institutes in its structure, although each of them is regarded as a separate legal identity. The situation here is quite complicated, as the Academy is now in the process of restructuring, and the privatization process is under way. As a result, the current ownership structure is changing, and the prospects for these buildings are not yet clear. Other institutes are formally subordinated either to ministries or other state structures, or to the city. These also have separate legal identities and, under conditions of insufficient financing, are usually forced to rent their office space to various commercial structures or state organizations.

Tables A.1 and A.2 present summary information on the number of buildings and floorspace for 9 categories of buildings: hospitals, polyclinics, and hospital administration buildings; kindergartens, secondary schools, higher education buildings, and student hostels; and theaters and art galleries/ museums. Data for healthcare facilities primarily include information for buildings owned and operated by the Municipal Department of Health. Data on healthcare institutions with other owners (Cabinet of Ministers, Ministry of Defense, Ministry of Internal Affairs and the National Safety Service) are not available. Healthcare units not located in separate buildings were not assessed for efficiency potential, as well as those where the efficiency potential is relatively small and implementation of energy conservation opportunities does not make sense (pathologies, laundries, garages, warehouses, etc.).

A.1.2 Building Categorization

Information in Tables A.1 and A.2 is segregated by vintage and size (number of stories). The time periods used in the analysis are prior to 1958, 1958 to 1980, and after 1980; gradation by size is small (1 to 2 stories), medium (3 to 4 stories), and large (greater than 4 stories).

Prior to 1958, Russian building codes (abbreviated SNiP) did not exist. Construction practices were based on methods described in special literature and reference books. These methods were based on traditional practices for constructing buildings with thick brick walls, which provided satisfactory heat insulation levels. For these buildings, it is difficult to make an accurate estimate of thermal resistance values for the building envelope. However, available reference information allows indirect estimation of these values based on so-called “specific heat characteristics” of different buildings, which were used before 1957 for approximate calculation of heat losses.

In 1957 some SNiP chapters appeared, including standards regulating the level of thermal insulation for building envelopes. Under theses norms, which were valid until 1994, thermal resistance of building envelope elements (apart from windows) was determined by the maximum allowed by the norms as a function of the difference between the temperature of indoor air and internal surface of the building envelope. For example, for external walls this difference varied between 6 and 7°C for different types of public buildings. Practically all buildings were designed and constructed to minimize their cost, so the building envelope had the minimum possible thickness.

Table A.1. Number of Buildings by Vintage and Size

Institutional Building Owner and Category	Number of Buildings by Vintage and Size									
	Pre-1958			1958-1980			Post-1980			Total Number of Buildings
	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	
Municipal Dept. of Health										
Hospitals	41	26	5	12	22	30	3	2	19	160
Polyclinics	25	8	1	10	22	3	4	14	23	110
Administration	34	2	1	13	5	4	3	3	4	69
Subtotal	100	36	7	35	49	37	10	19	46	339
Municipal Dept. of Ed.										
Kindergartens	43	1	0	375	0	0	153	28	0	600
Schools	7	95	0	11	185	0	7	84	0	389
Subtotal	50	96	0	386	185	0	160	112	0	989
Ministry of Education										
Education Buildings	4	32	5	9	43	48	4	7	22	174
Hostels	2	6	7	2	5	97	0	0	14	133
Subtotal	6	38	12	11	48	145	4	7	36	307
Municipal Dept. of Culture										
Theaters	0	8	1	2	0	0	0	0	1	12
Art Galleries/Museums	17	8	1	0	0	1	3	1	0	31
Subtotal	17	16	2	2	0	1	3	1	1	43
Total										1,678

Table A.2. Floorspace of Buildings by Vintage and Size (m^2)

Institutional Building Owner and Category	Floorspace of Buildings by Vintage and Size (m^2)									
	Pre-1958			1958-1980			Post-1980			Floorspace of Buildings
	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	
Municipal Dept. of Health										
Hospitals	58,026	58,475	15,492	12,437	61,374	191,483	10,357	12,863	216,618	637,125
Polyclinics	24,340	9,775	1,300	6,715	50,886	12,757	2,876	51,462	133,756	293,867
Administration	19,219	2,487	3,100	9,189	8,735	16,022	2,420	6,261	24,812	92,245
Subtotal	101,585	70,737	19,892	28,341	120,995	220,262	15,653	70,586	375,186	1,023,237
Municipal Dept. of Ed.										
Kindergartens	47,867	1,427	0	732,806	0	0	431,920	98,306	0	1,312,326
Schools	12,792	531,414	0	19,409	1,419,251	0	19,987	801,415	0	2,804,268
Subtotal	60,659	532,841	0	752,215	1,419,251	0	451,907	899,721	0	4,116,594
Ministry of Education										
Education Buildings	18,648	182,982	26,924	19,965	236,144	430,404	11,664	51,559	250,475	1,228,765
Hostels	8,722	26,899	31,525	3,840	39,189	539,789			80,650	730,614
Subtotal	27,370	209,881	58,449	23,805	275,333	970,193	11,664	51,559	331,125	1,959,379
Municipal Dept. of Culture										
Theaters	0	38,470	2,700	3,453	0	0	0	0	3,420	48,043
Art Galleries/Museums	18,334	15,159	5,380	0	0	20,000	3,585	2,900	0	65,358
Subtotal	18,334	53,629	8,080	3,453	0	20,000	3,585	2,900	3,420	113,401
Total										7,212,611

After the 1970s energy crisis in the West, former norms and standards were supplemented by instructions to compare the thickness of thermal insulation for selected building envelopes against the economically justified value, but the suggested method of calculation was not used in practice because of its over-complexity. As a result, in 1980 standard adjustment factors to norms on thermal resistance values were introduced. They were required to be taken into account as a minimum addition in calculations of economically justified heat insulation thickness. It is these adjustment factors (between 1.1 and 2.0) that appeared in construction designs beginning in 1980, and their official introduction is the reason for some improvement of heat insulating properties in building envelopes.

Beginning in 1994, new guidelines appeared in Ukraine for the calculation of thermal resistance of building envelopes, with requirements for thermal insulation 2 to 2.5 times higher than previously required. But decreased volume of construction in recent years, and financial problems in the introduction of new norms, led to the situation where by the end of 1996, the new norms had not yet substantially influenced heat consumption in existing buildings.

In addition to factors connected with the age of buildings, their thermal characteristics are influenced by the number of floors (stories). All institutional building types considered in this analysis have been divided into groups characterized by the number of stories. The breakdown by stories was carried out according to principles that make a basis for normative tables of energy-use intensity values, where these values are similar for different groups of buildings.

A.1.3 Data Collection Methodology

To accelerate the process of project preparation, data collection activities were focused primarily on the owners who will probably retain the authority over the structures subordinated to them, and who could issue executive orders to provide the data (city/district administrations, Municipal Department of Health, Municipal Department of Education, Ministry of Education, Municipal Department of Culture). Energy savings potential for corresponding building categories (healthcare, education, cultural) appeared to be the most promising.

Obtaining the information from the owners directly was preferred to “anonymous” data collection, because the project is the basis for a potential loan to the owner. Also, obtaining data from the central city registry of buildings (Bureau of Technical Information) would have taken much time and effort and could not produce a comprehensive picture. The registry keeps technical data on each individual building whose owner contacted the registry sometime in the past. Information is not computerized and is identified only by the address of each building. The current owner and purpose of the building is not in the registry and must be determined by contacting each owner directly. Also, information on the building stock is not complete, because not all buildings have been included in the registry.

The State Committee for Energy Conservation coordinated data collection activities and made initial contacts that were necessary for successful implementation of the work. The State Committee on Energy

Conservation organized a meeting with representatives of important structures: the Ministry of Health, City Department of Education, Department of Health, Department of Finance, and the State Committee on Urban Development and Architecture. The objectives of the project were presented and cooperation in collecting necessary basic data was requested. Subsequent meetings were held within these organizations with representatives of subordinate district structures, and a questionnaire was explained and distributed among the participants.

Responses were obtained from Municipal Departments of Education who provided detailed data on pre-school and secondary education buildings (kindergartens, secondary schools, boarding schools, grammar schools, lyceums, youth clubs, etc.). The summary data are included in Tables A.1 and A.2.

In addition, a letter from the State Committee on Energy Conservation was forwarded to the Deputy Chairman of City State Administration. As mentioned above, there is not a central registry that could provide basic data on buildings in the form required for the project, so the city authorities gave instructions to a subordinate organization to provide help in collecting necessary data. This organization, Kievzhilspetsekspluatatsia, is responsible for servicing residential and nonresidential buildings in the city of Kyiv. It worked with district administrations to provide the required data on buildings. This work and the analysis of obtained data have shown that the process of privatization and renting the buildings is quickly changing the structure of ownership and financing. Pure municipal budget financing of office/ administration buildings is used only for buildings of city/district administrations (that is, 15 buildings) and a small number of other municipally owned buildings. The same is true for the ministries and other state structures. Pure budget financing is applicable almost exclusively to buildings where the headquarters of ministries, committees, etc. are located.

The information provided by district administrations is not always complete and must be supplemented by estimates and additional data. For example, some healthcare institutions, although owned and operated by the city, were not included in the submitted data. Information on healthcare buildings was obtained with the help of the Ministry of Health. There is a construction design institute that was formerly owned by the Ministry, but now has been transformed into the joint-stock company Medinvestproject. The Ministry recommended this company help in providing the required information. On a contract basis, Medinvestproject has prepared basic data on healthcare building stock and some additional information, such as indoor temperatures, for different buildings.

Another letter from the State Committee on Energy Conservation was forwarded to the Ministry of Education to request help in collecting data on their buildings (there are 19 institutions of higher education, such as universities, academies, and institutes; and 41 technical colleges). The Ministry prepared letters to subordinate institutions that provided the data.

Other state structures are too numerous to allow the collection of necessary information within the timeframe of the project. (There are 54 ministries and state committees, National Academy of Sciences,

etc.). Moreover, many of their subordinate organizations, such as research and design institutes, have already become independent stock companies, and others are now in the process of making this change.

Appendix B

Baseline Energy Consumption

Appendix B

Baseline Energy Consumption

This appendix presents the estimated baseline district heat energy consumption for each of the building types. Baseline energy consumption is estimated as the product of building floorspace and specific energy consumption per unit floorspace. The sources of floorspace data and specific energy consumption data are described in each subsection.

The baseline energy consumption estimates are referenced to a base year of 1995. The baseline estimates are premised on the delivery of design heat levels to all buildings (i.e., to maintain design temperatures of 18°C). In reality, in 1995 these design conditions were often not met due to adverse economic circumstances, which led to fuel supply constraints, and a capacity shortfall in the district heating system. Because this situation is expected to be temporary, the baseline estimates reflect normal service delivery. Sector level estimates are presented below.

B.1 Institutional Buildings Sector

Institutional building stock estimates and data collection are described in Appendix A. Because of difficulties in collecting data on the institutional buildings sector, these estimates are not comprehensive. Building stock estimates used in this analysis are also not comprehensive, but instead represent that fraction of the institutional buildings stock for which a large volume of buildings was subordinated to a single budget organization, and for which detailed building characteristic data were available. This stock was considered the most suitable for effective implementation of a buildings energy efficiency program.

Specific energy consumption estimates for the building types included in the assessment were derived from design data and other estimates. Design energy use in buildings can be divided into three components: space heating, water heating, and ventilation. Specific energy consumption estimates for space heating were derived from design data and were verified using simulation modeling of prototype buildings with Kyiv weather data. Because water heating energy use in institutional buildings is a function of factors such as occupancy, it was estimated generically on the basis of building function as a percentage of space heating energy use. Space and water heating energy intensity estimates are presented by building type in Table B.1.

Specific energy use for ventilation was not estimated. Mechanical ventilation is seldom used in Kyiv, and no ventilation energy conservation measures were considered, so no energy efficiency improvements are expected from ventilation changes.

Table B.1. Specific Energy Intensity by Vintage Size (space heat and hot water)

Institutional Building Owner and Category	Specific Energy Intensity by Vintage Size (Gcal/m^2)									Percentage of Energy Use for Space Heat
	Pre-1958			1958-1980			Post-1980			
	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	
Municipal Dept. of Health										
Hospitals	0.20	0.17	0.17	0.30	0.30	0.28	0.30	0.23	0.23	60
Polyclinics	0.16	0.16	0.16	0.24	0.24	0.20	0.24	0.20	0.19	75
Administration	0.14	0.14	0.14	0.24	0.19	0.19	0.24	0.19	0.16	90
Municipal Dept. of Ed.										
Kindergartens	0.15	0.15		0.27			0.23	0.23		80
Schools	0.12	0.12		0.19	0.19		0.16	0.16		80
Ministry of Education										
Education Buildings	0.15	0.15	0.15	0.27	0.27	0.19	0.23	0.23	0.16	80
Hostels	0.21	0.21	0.21	0.21	0.21	0.21			0.21	72
Municipal Dept. of Culture										
Theaters		0.20	0.20	0.31					0.23	95
Art Galleries/Museums	0.16	0.16	0.16			0.23	0.23	0.23		95

Baseline energy consumption can be estimated by building category by multiplying the specific energy intensity estimates in Table B.1 by the floorspace of each building category from Table A.2. Baseline energy consumption estimates are presented in Table B.2.

B.2 Residential Building Sector

Though the residential sector was not the primary focus of this study, a richer body of information exists with which to characterize the sector. Not only does this information complement the analysis of institutional buildings, but it also provides some basis for assessing the relative accuracy with which design estimates of building energy consumption conform with other estimates.

Estimates of floorspace for the residential building sector are found in a variety of references. Total residential floorspace estimates over the past 16 years are presented in Table B.3.

According to TACIS (1994), the vast majority of public buildings in Kyiv are connected to the district heating network. Hence, the residential stock supplied by district heating in 1995 is estimated at 48.1 million square meters. The residential building stock can also be broken out roughly by size as follows: 1 to 4 stories - 8.3%; 5 to 9 stories - 67.9%; 10 or more stories - 23.8% (Ekono 1996).

There are several sources of specific energy consumption estimates (energy use per unit floorspace); however, there appears to be little measured data. In addition, much of the available information on energy use in residential buildings is presented in terms of energy demand, not annual energy use. Some of the available estimates are discussed below.

Specific energy consumption estimates for residential buildings can be derived from design peak demands (SNiP 2.04.07-86) for existing buildings using estimates of the number of equivalent hours at full load. Design data, in watts per square meter, for standard efficiency buildings built prior to 1985 are presented in Table B.4 for outdoor design temperatures of -20°C and -25°C, as well as interpolated values for -22°C, the design condition for Kyiv.[a] The latter values are then converted to annual specific energy consumption using an assumed full load equivalent operating hours (FLEOH) of 2143. This value is derived from Kievenergo's method for estimating annual energy use for heating from demand values. Annual heat energy use is estimated from the equation:

$$Qa = \frac{24 \text{ hours/day} * Qd * HDD}{\Delta T}$$

(a) SNiP 2.04.07-86 also has standards for efficient buildings built prior to 1985 and for buildings built after 1985. Both of these building categories have lower energy consumption; however, the standard values used here are felt to more accurately represent the aging building stock.

Table B.2. Baseline Annual Energy Consumption (space heat and hot water)

Institutional Building Owner and Category	Baseline Energy Consumption of Buildings by Vintage and Size (Gcal)									Energy Consumption (Gcal)
	Pre-1958			1958-1980			Post-1980			
	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	
Municipal Dept. of Health										
Hospitals	11,783	9,778	2,591	3,763	18,572	53,368	3,134	3,022	50,886	156,896
Polyclinics	3,954	1,588	211	1,626	12,318	2,601	696	10,491	25,136	58,621
Administration	2,602	337	420	2,220	1,623	2,977	585	1,163	3,886	15,811
Subtotal	18,338	11,703	3,221	7,608	32,513	58,945	4,415	14,676	79,908	231,328
Municipal Dept. of Ed.										
Kindergartens	7,290	217	0	199,132	0	0	99,313	22,604	0	328,556
Schools	1,566	65,062	0	3,651	267,000	0	3,223	129,230	0	469,732
Subtotal	8,856	65,279	0	202,783	267,000	0	102,536	151,833	0	798,287
Ministry of Education										
Education Buildings	2,840	27,867	4,100	5,425	64,170	80,971	2,682	11,855	40,390	240,299
Hostels	1,837	5,665	6,639	809	8,253	113,672	0	0	16,984	153,857
Subtotal	4,677	33,532	10,739	6,234	72,422	194,643	2,682	11,855	57,373	394,157
Municipal Dept. of Culture										
Theaters	0	7,694	540	1,054	0	0	0	0	792	10,080
Art Galleries/Museums	2,895	2,394	849	0	0	4,632	830	672	0	12,271
Subtotal	2,895	10,088	1,389	1,054	0	4,632	830	672	792	22,351
Total										1,446,123

Table B.3. Residential Buildings and Floorspace[a]

Year	Number of Dwellings	Average Area (m^2)	Floorspace (million m^2)
1980	620,400	53.4	33.1
1985	701,300	54.4	38.1
1990	807,300	54.0	43.6
1991	(b)	(b)	44.5
1992	(b)	(b)	45.5
1993	(b)	(b)	46.3
1994	(b)	(b)	47.2
1995	(b)	(b)	48.1
1996	889,400	55.1	49.0

(a) Estimates for 1980-1990 are from TACIS (1994). Total floorspace estimates from 1991-1996 are from Ekono Energy (1996). Number of dwellings in 1996 is from JTC (1996). Average area in 1996 is estimated from the total floorspace and number of dwellings, and is consistent with the trend toward larger apartments.

(b) No data available.

Table B.4. Design Heat Demand and Annual Energy Use Estimate Assuming 2,143 Equivalent Hours at Full Load

	Specific Energy Demand (W/m^2) by Design Temperature			Annual Energy Use	Annual Energy Use
Stories	-20°C	-22°C	-25°C	(kWh/m^2)	($Gcal/m^2$)
1-2	205	208	213	446	.38
3-4	117	121	126	259	.22
≥5	79	82	86	176	.15

where Qa is annual heat consumption in Gcal, Qd is design heat load in Gcal/hr, HDD is the number of heating degree days per year, and ΔT is the difference between the design indoor temperature (18°C) and the design outdoor temperature (-22°C). HDD is calculated as the difference between the design indoor temperature (18°C) and the average outdoor temperature during the heating season (-1.1°C) times the length of the heating season (187 days), or 3572 HDD. The value of FLEOH can be derived from this equation as:

$$\text{FLEOH} = \frac{24 \text{ hours/day} * \text{HDD}}{\Delta T} = \frac{24 * 3{,}572}{40} = 2{,}143 \text{ hours/year}$$

Based on these design data, it is clear that specific energy use is highly dependent on the number of building stories. Average specific energy use can be estimated by weighting the estimates in Table B.4 by the size distribution data cited above. The resulting estimate for average annual specific energy use is 0.17 Gcal/m^2.

Several estimates of average specific energy consumption are found in the literature. One study cites design annual specific energy consumption in Kyiv at 155 kwh/m^2 (0.13 Gcal/m^2) (based on net area), and estimates actual consumption at 250 kwh/m^2 (0.22 Gcal/m^2), or about 60% higher than the design values (IEA 1996). This value may include heat use for hot water.

In another study, specific energy intensity estimates for Kyiv were derived from a combination of measurement and modeling approaches (TACIS 1994). The simulation model used in this assessment was calibrated using 4 months of metered data on two high-rise apartment buildings. Based on this work, the specific energy intensity for heating over the entire season was estimated to range from 0.11 to 0.28 Mwh/m^2 (0.09 to 0.24 Gcal/m^2).

More recently, residential specific energy consumption was estimated for buildings supplied by Kievenergo based on annual fuel use, assumptions about the efficiency of the heat transmission and distribution network (20% losses), and the fraction of Kyiv residential floorspace served by Kievenergo (56%) (Ekono Energy 1996). These estimates are given in terms of energy use per unit volume. Using the energy use and floorspace data, these values can be recalculated on a per-unit floorspace basis, yielding an estimate of actual average consumption in 1995 of 191 kwh/m^2 (0.16 Gcal/m^2). Because of fuel and capacity constraints in 1995, this fuel consumption is estimated to be far below actual consumption had there been no such constraints. In this case, specific energy use is estimated at 260 kwh/m^2 (0.22 Gcal/m^2), or about 36% higher than actual heat consumption in 1995.

These results are based on estimates that 56% of Kievenergo heat is supplied to residential customers. Kievenergo data found in Joseph Technology Corporation (JTC 1996) suggest that the supply to residential buildings in 1995 was significantly higher, or about 69% (the sum of residential and construction cooperative housing) of the total. These data are presented in Table B.5. It is not clear what the source of this discrepancy is; however, if the higher value is used, the resulting estimates of specific heat consumption would be 0.23 Gcal/m^2 in 1995 with energy supply constraints, and about 0.30 Gcal/m^2 without energy supply constraints.

Table B.5. Kievenergo 1995 Actual District Heat Supply (JTC 1996)

Type of Customer	Heat Supply (1000 Gcal)[a]	Percentage of Total Heat Supply
Industrial	4,188	31.1
Communal Housing	13	0.1
Residential Housing	7,669	57.0
Construction Coop. Housing	1,560	11.6
Green Houses	22	0.2
Garage Construction Coop.	14	0.1
Wholesale Customers and Dist.	--	--
Total	13,454	100

(a) Total heat supply is not exactly equal to the sum of the components in the reference. The estimates given here are as cited in Joseph Technology Corporation (JTC 1996).

The Ekono Energy (1996) estimates include heat use for hot water. Because of the lack of hot water metering in Kyiv, there are few data on hot water consumption in residential buildings. Estimates of hot water consumption range from about 70% of the design consumption of 105 liters/person/day (Ekono Energy 1996), to more than 300 liters/person/day (IEA 1996). Direct estimates of heat energy use for hot water can be made from Kievenergo data found in Joseph Technology Corporation (JTC 1996). In this report, Kievenergo estimates of thermal energy supply for 1996 are given by quarter. Assuming that third quarter (July to September) thermal energy supply is almost exclusively for hot water, the consumption of heat for hot water can be estimated for the entire year. Based on these data, hot water heat consumption is estimated at 0.06 Gcal/m^2, compared to space heat energy use of 0.16 Gcal/m^2, or total heat energy use of 0.22 Gcal/m^2. Hence, hot water energy use amounts to 28% of total energy consumption.

Based on the above data, residential specific energy consumption for normal heat supply conditions is estimated based on design heat loads for space heating, or a floorspace weighted average value of 0.17 Gcal/m^2. Heat energy consumption for hot water is estimated as 28% of the total heat consumption, or 0.07 Gcal/m^2, for a total heat consumption of 0.24 Gcal/m^2. These appear to be conservative estimates for total actual heat consumption in periods of normal heat supply.

Baseline energy consumption is estimated as the product of specific energy consumption and estimated floorspace for each of the building types. The estimated annual residential energy consumption is presented in Table B.6 for each of the four building types.

Table B.6. Residential Building Baseline Energy Consumption Estimates

Building Type	Floorspace (million m^2)	Annual Energy Use (thousand Gcal)
2-story	4.8	2,569
5-story	16.8	3,545
9-story	16.8	3,545
14-story	9.6	2,026
Total	48.1	11,685

Appendix C

Efficiency Measure Cost Data

Appendix C

Efficiency Measure Cost Data

This appendix provides the estimated quantity of materials and installed costs of the efficiency measures, by building type, for the prototypes used for the institutional and residential buildings sectors. Material costs and quantities are also presented for average buildings for the institutional sector.[(a)] The quantities of material for the institutional buildings were estimated based on analysis of specific buildings in Kyiv, or based on design calculations. Per unit labor requirements were based on professional judgment and were drawn from analysis conducted for the Enterprise Housing Divestiture Project (EHDP) Staff Appraisal Report (SAR) conducted for the World Bank in Russia (World Bank 1996). The quantities of material, equipment, and labor for the residential sector are also drawn primarily from the EHDP SAR. Cost estimates were derived from a variety of sources, including direct quotes from both foreign and domestic equipment suppliers, as well as from other building efficiency assessments in Eastern Europe (PNNL 1995, 1996; World Bank 1996). The ratio of Ukrainian labor to foreign labor to install the measures ranges from 5:1 to 8:1 depending on the measure. Ukrainian labor rates are estimated at $5.00 per hour, foreign labor rates at $55.00 per hour.

C.1 Institutional Buildings Sector

The institutional buildings sector is modeled using nine categories of buildings: hospitals, polyclinics, and hospital administration buildings; kindergartens, schools, higher education buildings and student hostels; and theaters and art galleries/museums. Within these broad categories, the building prototypes are further subdivided by age and size (in this case number of stories). The age classes used are buildings built before 1958, those built from 1958 to 1980, and those built after 1980. These age classes roughly delineate architectural practices that impact thermal performance, and are described further in Appendix A. The size classes were chosen to match the existing building stock and include 1 to 2 story buildings, 3 to 4 story buildings, and buildings greater than 4 stories, except for student hostels, which were modeled using residential prototypes (5 and 9 stories).

Not all building categories include examples of each of the building subcategories. For example, there are no kindergartens or schools greater than 4 stories. Also, some building categories have very little floorspace in a particular subcategory, hence these subcategories were not included as a prototype. In total, 33 prototypes are used to model the institutional buildings sector. These are presented in Table C.1.

(a) For a discussion of the conversion from prototype to average buildings, see Section 3.2.1.

Table C.1. Institutional Building Sector Prototypes

Building Type	Building Subtypes	Number Prototypes
Hospitals	1 to 2 stories before 1958	1
	2 to 4 stories, 1958-1980 and after 1980	2
	>4 stories, 1958-1980 and after 1980	2
Polyclinics	1 to 2 stories before 1958	1
	3 to 4 stories, 1958-1980 and after 1980	2
	>4 stories after 1980	1
Hospital Administration	1 to 2 stories before 1958 and 1958-1980	2
	>4 stories, 1958-1980 and after 1980	2
Kindergartens	1 to 2 stories, all age groups	3
Schools	3 to 4 stories, all age groups	3
Higher Education	3 to 4 stories, all age groups	3
	>4 stories, 1958-1980 and after 1980	2
Hostels	5 stories and 9 stories	2
Theaters	1 to 2 stories, 1958-1980	1
	3 to 4 stories, before 1958	1
	>4 stories, after 1980	1
Art Galleries/Museums	1 to 2 stories, before 1958 and after 1980	2
	3 to 4 stories, before 1958	1
	>4 stories, after 1980	1
Total		33

Table C.2 provides the estimated installed cost of the 20 measures considered applicable to institutional buildings in Kyiv. The costs are developed to show the quantity of labor, cost of labor, and the installed cost of the measure. Table C.3 illustrates the penetration of each efficiency measure in the general building categories. Not all retrofit options apply to each building prototype. For example, ceiling fans are only applicable in buildings with high ceilings, such as cultural buildings. In addition, many retrofit measures are not found to be cost-effective in some or all building types. Within building categories the number of cost-effective efficiency measures also varies by building vintage and size, though this variation is small compared to the differences between building categories.

Table C.4 presents the total material requirements and total installed costs for each of the efficiency measures and each of the 33 institutional building prototypes, as well as the total costs for each building. In Table C.5, these values are presented per average building for the Kyiv building stock. The total per building costs in Table C.5 match the per building investment requirements in Appendix E, Table E.1.

Table C.2. Measure Cost Data

Measure Category/Description	Equipment Unit	Equipment Per Unit Cost ($)	Labor Hours/Unit Domestic	Labor Hours/Unit Foreign	Labor Ratio Dom./For.	Labor Cost/Unit ($)[a] Domestic	Labor Cost/Unit ($)[a] Foreign	Total Cost Per Unit Installed ($)
Envelope								
Exterior Side Walls	m^2	10.50	0.92	0.18	5	4.58	10.08	25.17
Roof Insulation	m^2	23.41	0.28	0.06	5	1.42	3.12	27.94
Attic Insulation	m^2	6.45	0.31	0.06	5	1.54	3.39	11.38
Basement Floor Insulation	m^2	6.00	0.10	0.02	5	0.50	1.10	7.59
Weatherstrip Windows and Doors	m	0.90	0.09	0.01	8	0.44	0.61	1.96
Storm Windows and Weatherstripping	each	60.00	4.17	0.83	5	20.83	45.83	127
High Perf. Glass and Weatherstripping	m^2	24.50	1.17	0.23	5	5.83	12.83	43.17
Third Window Pane	m^2	13.00	1.11	0.22	5	5.53	12.16	30.68
Radiator Heat Reflectors	each	5.16	0.33	0.04	8	1.64	2.26	9.07
Air Handling								
Ceiling Fans	per fan	163	2.50	0.50	5	12.50	27.50	203
Ventilation Heat Recovery	m^3/hr	2.20	0.03	0.01	5	0.13	0.28	2.60
Domestic Water Heating								
Hot Water Heat Exchanger (weighted average)	bldg.	1,748	27.62	5.52	5	138	304	2,190
Storage Water Heater	bldg.	2,480	41.67	8.33	5	208	458	3,147
Low-Flow Showerheads	each	7.69	0.22	0.03	8	1.11	1.53	10.32
Faucet Aerators	each	3.00	0.13	0.02	8	0.67	0.92	4.58
Apartment-Level Meters	each	95	2.50	0.50	5	12.50	27.50	135
Insulate Pipes	m	3.30	0.17	0.03	5	0.85	1.87	6.02
Heating System								
Building-Level Meters	each	2,800	10.00	2.00	5	50	110	2,960
Retrofit Heating System (weighted average)	bldg.	7,198	114	22.75	5	569	1,251	9,018
Radiator Balancing Valves	each	14.25	0.83	0.17	5	4.17	9.17	27.58

(a) Labor rates are $5.00 per hour for domestic labor and $55.00 per hour for foreign labor.

Table C.3. Penetration of Efficiency Measures by Building Type

Institutional Building Owner and Category	Envelope	Weatherstrip	Air Handling	Domestic Water Heating			Heating System		
	Radiator Reflector	Windows Doors	Ceiling Fans	Low-Flow Shower	Faucet Flow Restrictors	Heat Exch.	Building Meters	Riser Bal. Valves	System Retrofit
Municipal Dept. of Health									
Hospitals	x	x		x	x	x	x	x	x
Polyclinics	x	x			x	x	x	x	x
Administration	x	x				x	x	x	x
Municipal Dept. of Ed.									
Kindergartens	x	x			x	x	x	x	x
Schools	x	x			x	x	x	x	x
Ministry of Education									
Education Buildings	x	x		x	x	x	x	x	x
Hostels	x	x		x	x	x	x	x	x
Municipal Dept. of Culture									
Theaters		x	x			x	x	x	x
Art Galleries/Museums		x	x			x	x	x	x

Table C.4. Institutional Prototype Building Material Requirements and Costs

Institutional Building Prototype	Radiator Reflector		Weather-stripping		Ceiling Fans		Heating Syst. Ret.		Shower-heads		Aerators		Heat Meters		DHW Heat Ex.		Total
	Each	Cost ($)	Meters	Cost ($)	Each	Cost ($)	Bldg(a)	Cost ($)	Each	Cost ($	Each	Cost ($)	Each	Cost ($)	Each(a)	Cost ($)	Cost ($)
Small Hospital, before 1957	97	879	731	1,430	0	0	0.94	8,457	16	165	22	99	2	5,005	2.06	4,510	16,035
Medium Hospital, before 1957	194	1,759	1,463	2,860	0	0	1.42	12,842	32	330	43	199	2	5,939	3.13	6,849	23,928
Medium Hospital, 1958 to 1980	194	1,759	1,463	2,860	0	0	1.42	12,842	32	330	43	199	2	6,229	3.13	6,849	24,218
Large Hospital, 1958 to 1980	291	2,638	2,194	4,290	0	0	1.67	15,034	48	496	65	298	1	3,330	3.66	8,018	26,087
Large Hospital, after 1980	291	2,638	2,194	4,290	0	0	1.67	15,034	48	496	65	298	1	1,945	3.66	8,018	24,702
Small Polyclinic, before 1957	97	879	731	1,430	0	0	0.93	8,404	16	0	22	99	2	6,800	1.02	2,241	17,612
Medium Polyclinic, 1958 to 1980	194	1,759	1,463	2,860	0	0	1.29	11,652	32	0	43	199	3	8,435	1.42	3,107	24,904
Medium Polyclinic, after 1980	194	1,759	1,463	2,860	0	0	1.29	11,652	32	0	43	199	1	3,751	1.42	3,107	20,220
Large Polyclinic, after 1980	291	2,638	2,194	4,290	0	0	1.84	16,632	48	0	65	298	1	3,655	2.03	4,435	27,513
Small Hosp. Admin., before 1957	97	879	731	1,430	0	0	0.93	8,404	16	0	22	0	4	10,565	0.34	747	21,278
Small Hosp.Admin., 1958 to 1980	97	879	731	1,430	0	0	0.93	8,404	16	0	22	0	3	9,762	0.34	747	20,475
Large Hosp. Admin., 1958 to 1980	291	2,638	2,194	4,290	0	0	1.84	16,632	48	0	65	0	3	8,223	0.68	1,478	31,784
Large Hosp. Admin., after 1980	291	2,638	2,194	4,290	0	0	1.84	16,632	48	0	65	0	1	3,427	0.68	1,478	26,987
Kindergartens, before 1957	140	1,269	2,056	4,021	0	0	1.51	13,578	10	0	25	115	5	14,230	1.24	2,716	33,213
Kindergartens, 1958 to 1980	140	1,269	2,056	4,021	0	0	1.51	13,578	10	0	25	115	3	8,158	1.24	2,716	27,141
Kindergartens, after 1980	140	1,269	2,056	4,021	0	0	1.51	13,578	10	0	25	115	2	5,442	1.24	2,716	24,425
Schools, before 1957	280	2,538	4,113	8,043	0	0	2.04	18,422	20	0	50	229	2	5,977	1.68	3,684	35,210
Schools, 1958 to 1980	280	2,538	4,113	8,043	0	0	2.04	18,422	20	0	50	229	1	4,344	1.68	3,684	33,577
Schools, after 1980	280	2,538	4,113	8,043	0	0	2.04	18,422	20	0	50	229	1	3,533	1.68	3,684	32,766
Med. Higher Ed., before 1958	140	1,269	2,056	4,021	0	0	1.51	13,578	20	0	25	115	1	2,860	1.24	2,716	21,843
Med. Higher Ed., 1958 to 1980	140	1,269	2,056	4,021	0	0	1.51	13,578	10	0	25	115	1	3,237	1.24	2,716	22,220
Med. Higher Ed., after 1980	140	1,269	2,056	4,021	0	0	1.51	13,578	10	0	25	115	1	2,774	1.24	2,716	21,756
Large Higher Ed., 1958 to 1980	280	2,538	4,113	8,043	0	0	2.07	18,653	20	0	50	229	1	3,556	1.70	3,731	33,020
Large Higher Ed., after 1980	280	2,538	4,113	8,043	0	0	2.07	18,653	20	0	50	229	1	2,801	1.70	3,731	32,265
Medium Hostels	300	2,720	0	0	0	0	1.37	12,388	90	929	180	825	1	2,744	1.76	3,854	23,460
Large Hostels	405	3,672	0	0	0	0	1.42	12,768	108	1,115	216	990	1	3,244	1.81	3,972	25,760
Small Theaters	0	0	1,554	3,039	14	2,842	1.60	14,405	0	0	0	0	3	7,821	0.28	607	28,108
Medium Theaters	0	0	1,554	3,039	14	2,842	1.60	14,405	0	0	0	0	1	2,952	0.28	607	23,238
Large Theaters	0	0	1,554	3,039	14	2,842	1.60	14,405	0	0	0	0	1	3,948	0.28	607	24,235
Small Art Galleries/Museums, before 1958	0	0	2,196	4,294	15	3,045	1.66	14,977	0	0	0	0	5	13,482	0.29	631	35,798
Small Art Galleries/Museums, after 1980	0	0	2,196	4,294	15	3,045	1.66	14,977	0	0	0	0	3	8,968	0.29	631	31,285
Medium Art Galleries/Museums	0	0	2,196	4,294	15	3,045	1.66	14,977	0	0	0	0	2	6,371	0.29	631	28,688
Large Art Galleries/Museums	0	0	2,196	4,294	15	3,045	1.66	14,977	0	0	0	0	2	727	0.29	631	23,044

(a) Heating system retrofit and hot water heat exchanger costs and costs per unit capacity are a function of system size. The quantity value expressed here, when multiplied by the average system cost, yields the system cost for each building prototype. It does not have any other physical significance.

Table C.5. Average Institutional Building Requirements and Costs

Institutional Building Type	Radiator Reflectors		Weather-stripping		Ceiling Fans		Heating Syst. Ret.		Shower-heads		Aerators		Heat Meters		DHW Heat Ex.		Total
	Each	Cost ($	Meters	Cost ($)	Each	Cost ($)	Bldg	Cost ($)	Each	Cost ($	Each	Cost ($	Each	Cost ($	Each	Cost ($)	Cost ($)
Small Hospital, before 1957	57	520	432	846	0	0	0.55	5,001	9	98	13	59	1.00	2,960	1.22	2,667	12,151
Medium Hospital, before 1957	91	826	687	1,344	0	0	0.67	6,033	15	155	20	93	0.94	2,790	0.68	3,218	14,460
Medium Hospital, 1958 to 1980	113	1,025	852	1,667	0	0	0.83	7,484	19	193	25	116	1.23	3,630	1.82	3,991	18,105
Large Hospital, 1958 to 1980	259	2,345	1,950	3,814	0	0	1.48	13,363	43	441	58	265	1.00	2,960	3.26	7,127	30,314
Large Hospital, after 1980	462	4,188	3,483	6,812	0	0	2.65	23,869	76	787	103	473	1.04	3,088	5.81	12,730	51,948
Small Polyclinic, before 1957	39	358	297	582	0	0	0.38	3,419	7	0	9	40	0.93	2,767	0.42	912	8,077
Medium Polyclinic, 1958 to 1980	94	850	707	1,382	0	0	0.62	5,630	15	0	21	96	1.38	4,075	0.69	1,501	13,534
Medium Polyclinic, after 1980	149	1,350	1,123	2,196	0	0	0.99	8,947	25	0	33	152	0.97	2,880	1.09	2,386	17,912
Large Polyclinic, after 1980	236	2,136	1,777	3,475	0	0	1.49	13,469	39	0	53	241	1.00	2,960	1.64	3,592	25,873
Small Hosp. Admin., before 1957	23	208	173	338	0	0	0.22	1,985	4	0	5	0	0.84	2,496	0.08	176	5,203
Small Hosp.Admin., 1958 to 1980	29	260	216	422	0	0	0.28	2,482	5	0	6	0	0.97	2,884	0.10	221	6,269
Large Hosp. Admin., 1958 to 1980	162	1,471	1,224	2,393	0	0	1.03	9,277	27	0	36	0	1.55	4,587	0.38	825	18,553
Large Hosp. Admin., after 1980	251	2,279	1,895	3,706	0	0	1.59	14,367	41	0	56	0	1.00	2,960	0.58	1,277	24,589
Kindergartens, before 1957	29	262	425	831	0	0	0.31	2,806	2	0	5	24	0.99	2,941	0.26	561	7,426
Kindergartens, 1958 to 1980	51	460	746	1,459	0	0	0.55	4,926	4	0	9	42	1.00	2,960	0.45	985	10,833
Kindergartens, after 1980	73	665	1,078	2,108	0	0	0.79	7,117	5	0	13	60	0.96	2,852	0.65	1,423	14,225
Schools, before 1957	145	1,318	2,136	4,176	0	0	1.06	9,566	10	0	26	119	1.05	3,103	0.87	1,913	20,196
Schools, 1958 to 1980	199	1,808	2,929	5,728	0	0	1.45	13,119	14	0	36	163	1.05	3,094	1.20	2,624	26,535
Schools, after 1980	248	2,248	3,643	7,123	0	0	1.81	16,315	18	0	44	203	1.06	3,129	1.49	3,263	32,280
Med. Higher Ed., before 1958	149	1,347	2,183	4,269	0	0	1.60	14,415	21	0	27	122	1.03	3,036	1.32	2,883	26,073
Med. Higher Ed., 1958 to 1980	143	1,294	2,097	4,100	0	0	1.54	13,844	10	0	25	117	1.12	3,300	1.26	2,769	25,425
Med. Higher Ed., after 1980	191	1,735	2,812	5,499	0	0	2.06	18,568	14	0	34	157	1.28	3,793	1.70	3,714	33,467
Large Higher Ed., 1958 to 1980	233	2,113	3,423	6,695	0	0	1.72	15,526	17	0	42	191	1.00	2,960	1.42	3,105	30,589
Large Higher Ed., after 1980	296	2,683	4,347	8,500	0	0	2.19	19,714	21	0	53	242	1.00	2,960	1.80	3,943	38,041
Medium Hostels	352	3,188	0	0	0	0	2	14,522	106	1,089	211	967	1.09	3,217	2.06	4,518	27,502
Large Hostels	370	3,350	0	0	0	0	1	11,651	99	1,018	197	903	1.00	2,960	1.66	3,625	23,507
Small Theaters	0	0	588	1,150	5	1,076	0.60	5,452	0	0	0	0	1.00	2,960	0.10	230	10,867
Medium Theaters	0	0	1,638	3,203	15	2,996	1.68	15,185	0	0	0	0	1.05	3,112	0.29	639	25,135
Large Theaters	0	0	1,165	2,278	10	2,131	1.20	10,799	0	0	0	0	1.00	2,960	0.21	455	18,623
Small Art Galleries/Museums, before 1958	0	0	482	943	3	669	0.36	3,288	0	0	0	0	1.00	2,960	0.06	138	7,998
Small Art Galleries/Museums, after 1980	0	0	534	1,045	4	741	0.40	3,644	0	0	0	0	0.74	2,182	0.07	153	7,764
Medium Art Galleries/Museums	0	0	847	1,657	6	1,175	0.64	5,778	0	0	0	0	0.83	2,458	0.11	243	11,310
Large Art Galleries/Museums	0	0	8,941	17,485	61	12,398	6.76	60,983	0	0	0	0	8.76	2,960	1.17	2,568	96,394

(a) Heating system retrofit and hot water heat exchanger costs and costs per unit capacity are a function of system size. The quantity value expressed here, when multiplied by the average system cost, yields the system cost for each building prototype. It does not have any other physical significance.

C.2 Residential Building Sector

Four prototype buildings were used to estimate the efficiency potential of the residential sector. The prototype building configurations and materials requirements were derived from an analysis conducted for the EHDP Staff Appraisal Report (World Bank 1996) conducted for the World Bank in Russia. Where necessary, material costs were revised to reflect typical costs in Ukraine. Energy savings estimates were developed using a simulation model. The model inputs were adopted from a study of residential sector buildings in the Czech Republic (PNNL 1996) and matched to the most similar prototypes in the Russia EHDP analysis. Finally, residential building stock information was used to develop sector-level energy savings and investment requirements. The building prototypes and floorspace are presented in Table C.6. The unit requirements and costs for each prototype building are presented in Table C.7. These costs are equivalent to costs per apartment ranging from $223 to $755.

Table C.6. Residential Section Building Prototypes

Building Type	Floorspace (million m^2)
2-story, Brick Construction, with Attic	4.81
5-story, Panel Construction, with Attic	16.84
9-story, Panel Construction, No Attic	16.84
14-story, Panel Construction, No Attic	9.62
Total	48.10

Table C.7. Residential Prototype Building Material Requirements and Costs

Prototype	Reflectors		Substation Controls		Showerheads		Aerators		Building Heat Meters		Apartment Hot Water Meters		Total
	Each	Cost ($)	Bldg.	Cost ($)	Each	Cost ($)	Each	Cost ($)	Each	Cost ($)	Each	Cost ($)	Cost ($)
2-story	22	203	0.20	1,609	8	112	16	80	1	2,960	8	1,080	6,044
5-story	300	2,770	1.58	12,588	90	1,259	180	900	1	2,960	90	12,150	32,626
9-story	405	3,740	1.63	12,974	108	1,510	216	1,080	1	2,960	108	14,580	36,844
14-story	364	3,361	1.66	13,200	98	1,371	196	980	1	2,960	98	13,230	35,102

Appendix D

Efficiency Measure Performance Analysis

Appendix D

Efficiency Measure Performance Analysis

D.1 Introduction

The performance of 20 retrofit measures was evaluated using the estimated efficiency improvement and the estimated installed costs presented in Appendix C. This appendix contains a discussion of the economic evaluation and estimated efficiency potential for the institutional and residential sectors.

D.1.1 Common Economic Values

The measures were analyzed by three economic metrics: simple payback, net present value (NPV), and internal rate of return (IRR). These metrics and the approach to selecting the efficiency measures are discussed in Section 3.2.

Values of key economic factors underlying the analysis are

- price of district heat energy is $22/Gcal
- real annual escalation rate of district heat energy is 2.5%
- ratio of Ukrainian to foreign labor ranges from 5:1 to 8:1, depending on the efficiency measure
- hourly wage of foreign labor is $55.00
- hourly wage of Ukrainian labor is $5.00
- annual real discount rate is 10%.

D.1.2 Technical Analysis

The performance (efficiency improvements) of the measures were estimated for the institutional and residential sectors using A Simplified Analysis Method (ASEAM) building energy simulation program applied to the building prototypes described in Appendix C. Weather data for Kyiv were used in the simulations, with Kyiv having an estimated 3572 heating degree days.[(a)]

Each of the measures was evaluated separately by simple payback to develop their respective economic performance for each building prototype. The measures were then grouped to capture interactive effects with respect to efficiency improvement and reevaluated by economic metric to ensure that the minimum simple payback was achieved. Finally, the sensitivities of the measures to the cost of heat and the efficiency measure installed costs were examined using an IRR threshold of 10%. An IRR of 10% is the point where the net present value of the project goes to zero.

Although the residential prototypes may not fully reflect the residential building stock in Kyiv, the simulations are felt to adequately represent the applicable measures, efficiency potential, and level of investment. Note, too, that the residential sector is not the focus of this analysis, but that it is considered for reasons of completeness. The residential sector is estimated to consume about 45% of district heat energy provided by hot water and about 68% of the buildings sector heat energy consumption.

D.2 Measure Analysis

D.2.1 Institutional Sector

Of the 20 measures considered, the following eight were determined to satisfy the cost-effectiveness criteria in one or more of the institutional building prototypes:

- window and door weatherstripping
- radiator reflectors
- substation-level heat controller
- riser balancing valves

(a) Heating degree days in Ukraine are defined as the product of the length of the heating season (187 days in Kyiv) and the difference between the design indoor temperature and the outdoor average temperature (18°C and -1.1°C, respectively).

- hot water heat exchangers
- low-flow showerheads
- faucet aerators
- ceiling fans.

Building-level heat meters are included in all efficiency measure packages. Although the heat meter does not itself provide energy savings, it is felt to be critical to the performance of an energy efficiency program, and is essential for verification and operations purposes.

The economic performance for the institutional sector prototypes is shown in Tables D.1 to D.3 for the three economic criteria. Simple paybacks by prototype building range from 3.3 years for schools, to nearly 7.4 years for art galleries/museums. Simple paybacks are lowest for buildings constructed between 1958 and 1980 due to the construction practices in that period that lead to higher heat consumption. Paybacks also tend to be shorter for larger buildings, due to the lower cost per unit capacity for retrofit equipment (e.g., substation controllers) as the equipment sizes increase, and the lower costs per unit floorspace for heat meters; these effects offset the impact of decreasing energy intensity for larger buildings (Table B.1). These trends are also reflected in the IRR and NPV Tables D.2 and D.3.

The economic performance of the efficiency measures is summarized in Table D.4 for the major institutional buildings sector categories and for the entire sector. Total institutional buildings sector performance is impacted most heavily by kindergartens and schools, which together account for more than 57% of the institutional sector floorspace included in this analysis.

The sensitivity of the IRR metric to the measure performance and material costs is shown in Tables D.5 and D.6. From these data it can be seen that the IRR is relatively sensitive to changes in measure performance and material costs for hospital administration buildings and art galleries/museums, but relatively insensitive for other building types. Material prices would have to more than double for the IRR to drop below 10% (indicated as shaded area in data tables) for these buildings. Measure performance would have to drop to less than half its predicted value before the IRR would fall below 10%.

Table D.1. Institutional Building Sector Simple Paybacks

Institutional Building Owner and Category	Simple Payback by Vintage and Size (years)									
	Pre-1958			1958-1980			Post-1980			Weighted Average
	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	
Municipal Dept. of Health										
Hospitals	7.6	6.9	6.9	3.8	3.8	2.9	3.8	3.3	3.3	3.8
Polyclinics	8.7	8.7	8.7	3.9	3.9	3.9	3.9	3.9	3.8	4.3
Administration	12.8	12.8	12.8	6.6	4.0	4.0	6.6	4.0	4.0	6.1
Municipal Dept. of Ed.										
Kindergartens	7.9	7.9		3.5			3.7	3.7		3.6
Schools	4.8	4.8		3.0	3.0		3.3	3.3		3.3
Ministry of Education										
Education Buildings	5.4	5.4	5.4	2.9	2.9	3.0	3.3	3.3	3.3	3.4
Hostels	5.3	5.3	5.3	5.3	5.3	3.9			5.3	4.2
Municipal Dept. of Culture[(a)]										
Theaters		4.1	4.1	3.2					3.7	3.9
Art Galleries/Museums	10.7	8.6	8.6			4.7	6.4	6.4		7.4
All Buildings										3.6

(a) Payback calculations include costs for electricity consumed in ceiling fans, and hence will differ slightly from payback estimated from heat energy cost savings and investment costs. The difference is less than 2 percent.

Table D.2. Institutional Building Sector Internal Rate of Return

Institutional Building Owner and Category	Internal Rate of Return by Vintage and Size (%)									
	Pre-1958			1958-1980			Post-1980			Weighted Average
	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	
Municipal Dept. of Health										
Hospitals	12.4	14.2	14.2	28.2	28.2	36.2	28.2	32.4	32.4	27.8
Polyclinics	9.9	9.9	9.9	27.1	27.1	27.4	27.1	27.4	27.6	24.4
Administration	4.3	4.3	4.3	15.0	26.3	26.3	15.0	26.3	26.1	16.4
Municipal Dept. of Ed.										
Kindergartens	11.6	11.6		30.6			28.8	28.8		31.7
Schools	21.8	21.8		35.4	35.4		31.8	31.8		29.1
Ministry of Education										
Education Buildings	19.1	19.1	19.1	36.2	36.2	35.9	31.7	31.7	32.2	31.6
Hostels	19.5	19.5	19.5	19.5	19.5	27.5			19.5	25.4
Municipal Dept. of Culture										
Theaters		26.1	26.1	32.7					28.5	26.8
Art Galleries/Museums	6.8	10.2	10.2			22.1	15.4	15.4		12.9
All Buildings										29.2

Table D.3. Institutional Building Sector Net Present Value

Institutional Building Owner and Category	Net Present Value by Vintage and Size ($)									
	Pre-1958			1958-1980			Post-1980			Floorspace of Buildings
	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	
Municipal Dept. of Health										
Hospitals	51,284	56,245	14,901	96,202	474,736	1,524,025	80,113	84,313	1,419,859	3,801,676
Polyclinics	-24,403	-9,800	-1,303	34,464	261,169	52,921	14,761	213,484	498,678	1,039,970
Administration	-55,146	-7,136	-8,895	29,974	28,316	51,939	7,894	20,296	66,241	133,483
Subtotal	-28,265	39,309	4,703	160,640	764,221	1,628,884	102,767	318,093	1,984,778	4,975,129
Municipal Dept. of Ed.										
Kindergartens	25,783	769	0	5,971,965	0	0	2,668,563	607,371	0	9,274,450
Schools	29,981	1,245,493	0	122,033	8,923,438	0	99,084	3,972,941	0	14,392,970
Subtotal	55,764	1,246,262	0	6,093,997	8,923,438	0	2,767,647	4,580,312	0	23,667,420
Ministry of Education										
Education Buildings	45,216	443,680	65,283	179,002	2,117,216	2,724,355	77,227	341,372	1,251,144	7,244,495
Hostels	26,092	80,468	94,306	11,487	117,233	2,796,618	0	0	241,263	3,367,467
Subtotal	71,308	524,148	159,590	190,489	2,234,449	5,520,973	77,227	341,372	1,492,407	10,611,962
Municipal Dept. of Culture										
Theaters	0	235,735	16,545	44,262	0	0	0	0	25,297	321,839
Art Galleries/Museums	-22,143	9,559	3,393	0	0	71,943	10,171	8,228	0	81,152
Subtotal	-22,143	245,294	19,938	44,262	0	71,943	10,171	8,228	25,297	402,991
Total										39,657,502

Table D.4. Institutional Buildings Sector Prototype Economic Performance by Economic Metric

	Economic Metric		
Building Type	**Payback**	**IRR (%)**	**NPV ($)**
Hospitals	3.8	27.8	3,801,676
Polyclinics	4.3	24.4	1,039,970
Administration	6.1	16.4	133,483
Kindergartens	3.6	31.7	9,274,450
Schools	3.3	29.1	14,392,970
Higher Education	3.4	31.6	7,244,495
Hostels	4.2	25.4	3,367,467
Theaters	3.9	26.8	321,839
Art Galleries/Museums	7.4	12.9	81,152
Total	3.6	29.2	39,657,502

Table D.5. Sensitivity of Institutional Sector Internal Rate of Return to Efficiency Measure Performance

Energy Savings - % of Estimated	IRR as a Function of Energy Savings (%)								
	Hospital	**Polyclinic**	**Hospital Admin.**	**Kinder-gartens**	**Schools**	**Higher Education**	**Hostels**	**Theaters**	**Art Galleries/ Museums**
100	27.8	24.4	16.4	31.7	29.1	31.6	25.4	26.8	12.9
95	26.3	23.1	15.4	30.1	27.6	30.0	24.0	25.4	12.0
90	24.9	21.8	14.3	28.5	26.1	28.4	22.7	24.0	11.0
85	23.4	20.4	13.3	26.9	24.6	26.8	21.3	22.6	10.1
80	21.9	19.1	12.2	25.2	23.1	25.1	19.9	21.1	9.1
75	20.4	17.7	11.1	23.6	21.5	23.5	18.5	19.6	8.0
70	18.9	16.3	9.9	21.9	19.9	21.8	17.0	18.1	7.0
65	17.3	14.8	8.7	20.1	18.3	20.1	15.5	16.6	5.9
60	15.7	13.3	7.5	18.4	16.6	18.3	14.0	15.0	4.8
55	14.0	11.8	6.2	16.5	14.9	16.5	12.4	13.3	3.6
50	12.3	10.1	4.9	14.7	13.1	14.6	10.7	11.6	2.3
45	10.5	8.4	3.4	12.7	11.2	12.7	9.0	9.8	1.0
40	8.6	6.7	1.9	10.7	9.3	10.6	7.2	7.9	-0.5

Table D.6. Sensitivity of Institutional Sector Internal Rate of Return to Efficiency Measure Installed Costs

Energy Savings - % of Estimated	IRR as a Function of Installed Costs (%)								
	Hospital	**Polyclinic**	**Hospital Admin.**	**Kinder-gartens**	**Schools**	**Higher Education**	**Hostels**	**Theaters**	**Art Galleries/ Museums**
100	27.8	24.4	16.4	31.7	29.1	31.6	25.4	26.8	12.9
120	22.9	20.0	12.9	26.3	24.1	26.2	20.8	22.1	9.8
140	19.3	16.7	10.2	22.3	20.4	22.3	17.4	18.6	7.3
160	16.5	14.1	8.1	19.2	17.4	19.2	14.7	15.8	5.4
180	14.2	11.9	6.4	16.7	15.1	16.7	12.6	13.6	3.8
200	12.3	10.1	4.9	14.7	13.1	14.6	10.7	11.7	2.4
220	10.6	8.6	3.6	12.9	11.4	12.8	9.2	10.1	1.2
240	9.2	7.3	2.4	11.4	10.0	11.3	7.8	8.7	0.2
260	8.0	6.1	1.4	10.0	8.7	10.0	6.6	7.4	-0.8

D.2.2 Residential Sector

Of the 20 measures considered, the following five were determined to satisfy the cost-effectiveness criteria:

- radiator reflectors
- low-flow showerheads
- faucet aerators
- substation heat controller
- building heat meters.

The economic performance for the residential sector prototypes is shown in Table D.7 by the three economic criteria. The sensitivity of the IRR metric to fuel price and material costs is shown in Tables D.8 and D.9.

Table D.7. Residential Sector Prototype Economic Performance by Economic Metric

Building Type	Payback (years)	IRR (%)	NPV ($)
2-story	4.5	23.4	5,679
5-story	4.0	26.4	38,463
9-story	3.0	35.7	71,303
14-story	2.5	41.6	85,331
Average	3.4	32.4	56,052

These data show that material costs would have to increase by 1.8 times for 2-story and over 3.5 times for 14-story buildings before the IRR would drop to 10%. Measure performance could be as low as 55% of the predicted value for 2-story buildings to less than 30% of the predicted value for 14-story buildings for the IRR to fall below 10%.

Table D.8. Sensitivity of Residential Sector Internal Rate of Return to Efficiency Measure Performance

Energy Savings	IRR as a Function of Energy Savings			
% of Estimated	2-Story	5-Story	9-Story	14-Story
100	23.4	26.4	35.7	41.6
95	22.1	25.1	33.9	39.6
90	20.8	23.7	32.2	37.5
85	19.5	22.2	30.4	35.5
80	18.2	20.8	28.6	33.4
75	16.9	19.3	26.7	31.3
70	15.5	17.9	24.9	29.2
65	14.1	16.3	23.0	27.1
60	12.6	14.7	21.1	24.9
55	11.1	13.1	19.1	22.7
50	9.5	11.4	17.0	20.4
45	7.8	9.7	14.9	18.1
40	6.1	7.8	12.8	15.7
35	4.2	5.9	10.4	13.2
30	2.2	3.7	8.0	10.5

Table D.9. Sensitivity of Residential Sector Internal Rate of Return to Efficiency Measure Installed Costs

Installed Costs	IRR as a Function of Installed Costs			
% of Estimated	2-Story	5-Story	9-Story	14-Story
100	23.4	26.4	35.7	41.6
120	19.1	21.8	29.8	34.8
140	15.9	18.3	25.4	29.8
160	13.3	15.5	22.0	26.0
180	11.3	13.3	19.3	23.0
200	9.5	11.4	17.0	20.4
220	8.0	9.8	15.1	18.3
240	6.7	8.5	13.5	16.5
260	5.5	7.2	12.1	14.9
280	4.5	6.1	10.8	13.5
300	3.6	5.2	9.6	12.3
320	2.7	4.3	8.6	11.2
340	2.0	3.5	7.7	10.1

D.3 Efficiency Potential

This section provides the estimated efficiency potential for both the institutional and residential sectors. The estimated potential is calculated as the product of the building type floorspace estimates in Appendix A and the corresponding estimate of energy savings per unit floorspace for each of the building prototypes.

D.3.1 Institutional Sector

Estimates of institutional sector efficiency potential in Gcal per year are presented in Table D.10 by building type, vintage, and size. Table D.11 presents the estimated efficiency potential as a percentage of the baseline energy consumption (Table B.2.). Energy savings range from 19.6% of baseline to 28.7% with a floorspace weighted average of 26.2%.

Annual institutional buildings sector energy cost savings can be estimated from the annual energy savings using the first year heat price of $22. These data are presented in Table D.12 by building type, vintage, and size. The majority of savings are in the building types schools and kindergartens, which dominate the buildings included in this analysis on the basis of floorspace. Table D.13 summarizes the efficiency potential estimates by building category, and also shows the fractional contribution of each building category to the total energy savings.

Table D.10. Energy Savings (Gcal/year)

Institutional Building Owner and Category	Efficiency Potential of Buildings by Vintage and Size (Gcal/year)									
	Pre-1958			1958-1980			Post-1980			Total Efficiency Potential
	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	
Municipal Dept. of Health										
Hospitals	2,923	2,432	644	953	4,702	13,790	793	795	13,393	40,426
Polyclinics	1,024	411	55	446	3,379	713	191	2,878	6,876	15,974
Administration	613	79	99	549	446	819	144	320	1,079	4,148
Subtotal	4,560	2,923	798	1,947	8,527	15,322	1,129	3,993	21,349	60,548
Municipal Dept. of Ed.										
Kindergartens	1,792	53	0	51,983	0	0	26,258	5,976	0	86,063
Schools	428	17,791	0	994	72,677	0	898	36,016	0	128,805
Subtotal	2,220	17,845	0	52,977	72,677	0	27,157	41,993	0	214,868
Ministry of Education										
Education Buildings	701	6,880	1,012	1,401	16,572	22,040	702	3,101	11,257	63,665
Hostels	348	1,074	1,259	153	1,565	26,235	0	0	3,221	33,856
Subtotal	1,049	7,954	2,271	1,554	18,137	48,275	702	3,101	14,478	97,521
Municipal Dept. of Culture										
Theaters	0	2,205	155	302	0	0	0	0	227	2,889
Art Galleries/Museums	568	470	167	0	0	909	163	132	0	2,409
Subtotal	568	2,675	322	302	0	909	163	132	227	5,299
Total										378,236

Table D.11. Percentage Energy Savings

Institutional Building Owner and Category	Percentage Energy Savings of Buildings by Vintage and Size (%)									
	Pre-1958			1958-1980			Post-1980			Weighted Average
	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	
Municipal Dept. of Health										
Hospitals	24.8	24.9	24.9	25.3	25.3	25.8	25.3	26.3	26.3	25.8
Polyclinics	25.9	25.9	25.9	27.4	27.4	27.4	27.4	27.4	27.4	27.2
Administration	23.5	23.5	23.5	24.7	27.5	27.5	24.7	27.5	27.8	26.2
Municipal Dept. of Ed.										
Kindergartens	24.6	24.6		26.1			26.4	26.4		26.2
Schools	27.3	27.3		27.2	27.2		27.9	27.9		27.4
Ministry of Education										
Education Buildings	24.7	24.7	24.7	25.8	25.8	27.2	26.2	26.2	27.9	26.5
Hostels	19.0	19.0	19.0	19.0	19.0	23.1			19.0	22.0
Municipal Dept. of Culture										
Theaters		28.7	28.7	28.7					28.7	28.7
Art Galleries/Museums	19.6	19.6	19.6			19.6	19.6	19.6		19.6
All Buildings										26.2

Table D.12. Energy Savings ($/year)

Institutional Building Owner and Category	Value of Efficiency Potential by Building, Vintage, and Size ($/year)									
	Pre-1958			1958-1980			Post-1980			Total Efficiency Potential
	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	
Municipal Dept. of Health										
Hospitals	65,920	54,839	14,529	21,486	106,029	310,969	17,893	17,934	302,015	911,613
Polyclinics	23,098	9,276	1,234	10,055	76,198	16,086	4,307	64,893	155,063	360,211
Administration	13,812	1,787	2,228	12,369	10,066	18,463	3,257	7,215	24,335	93,532
Subtotal	102,830	65,903	17,990	43,910	192,292	345,518	25,457	90,042	481,413	1,365,355
Municipal Dept. of Ed.										
Kindergartens	40,401	1,204	0	1,172,226	0	0	592,124	134,769	0	1,940,725
Schools	9,657	401,192	0	22,412	1,638,873	0	20,255	812,167	0	2,904,557
Subtotal	50,058	402,396	0	1,194,639	1,638,873	0	612,379	946,936	0	4,845,282
Ministry of Education										
Education Buildings	15,810	155,133	22,826	31,594	373,694	497,007	15,821	69,934	253,836	1,435,655
Hostels	7,855	24,225	28,391	3,458	35,294	591,589	0	0	72,633	763,446
Subtotal	23,665	179,358	51,218	35,053	408,987	1,088,596	15,821	69,934	326,469	2,199,100
Municipal Dept. of Culture										
Theaters	0	49,629	3,439	6,711	0	0	0	0	5,068	64,848
Art Galleries/Museums	12,707	10,542	3,734	0	0	20,424	3,566	2,919	0	53,892
Subtotal	12,707	60,172	7,173	6,711	0	20,424	3,566	2,919	5,068	118,740
Total										8,528,477

Table D.13. Institutional Buildings Sector Efficiency Potential

Building Type	Efficiency Potential (thousand Gcal)	Efficiency Potential ($/year)	Fraction of Total Savings (%)
Hospitals	40	911,613	10.7
Polyclinics	16	360,211	4.2
Administration	4	93,532	1.1
Kindergartens	86	1,940,725	22.8
Schools	129	2,904,557	34.1
Higher Education	64	1,435,655	16.8
Hostels	34	763,446	9.0
Theaters	3	64,848	0.8
Art Galleries/Museums	2	53,892	0.6
Total	378	8,528,477	100.0

D.3.2 Residential Sector

Table D.14 presents the cost-effective efficiency potential in the residential buildings sector by building prototype, both in Gcal and annual cost savings based on the first-year heat cost.

Table D.14. Residential Building Sector Efficiency Potential

Building Type	Efficiency Potential (thousand Gcal/year)	Efficiency Potential (million $/year)	Fraction of Efficiency Potential (%)
2-story	451	11.3	14.8
5-story	873	21.8	28.7
9-story	1,070	26.8	35.2
14-story	645	16.1	21.2
Total	3,039	76.0	100.0

Appendix E

Investment Requirements

Appendix E

Investment Requirements

E.1 Introduction

The investment requirements for the retrofit measure packages are estimated from the installed costs presented in Appendix C and the floorspace estimates described in Appendix A. This appendix contains a discussion of the estimated investment requirements for both the institutional and residential sectors.

E.1.1 Institutional Sector

The total investment requirements estimated for the prototype buildings for the institutional sector are shown in Table E.1 by building category, vintage, and size. Using the prototype building floorspace data, these values can be converted to estimates of investment requirements per square meter of floorspace. These estimates are presented by building category, vintage, and size in Table E.2. Finally, per-square-meter investment levels are used in conjunction with floorspace estimates from Appendix A (Table A.1) to estimate total institutional sector investment requirements. These data are presented in Table E.3 along with the total investment requirements by building category, and the total investment requirements for the institutional buildings sector.

Institutional buildings sector investment requirements are driven by the substation controller retrofits, which represent about half of the total investment. The second most expensive ECO is generally hot water heat exchangers; however, the per building cost of hot water heat exchangers is a strong function of building type. Heat meters, which are installed in all buildings, add an additional $3,000 per building to the investment requirements.

Investment requirements by building category are summarized in Table E.4. Total institutional sector investment requirements are $31.1 million for 7.2 million square meters of floorspace, reflecting a floorspace weighted mean investment level of $4.31/m^2. This investment level reflects a fairly conservative package of ECOs that meet the 5-year simple payback investment requirement at $22/Gcal for heat costs. The total institutional sector investment represents the investment needed to retrofit only that fraction of the institutional floorspace found to be suitable for inclusion in the World Bank loan package. While additional institutional building floorspace exists, the budget structure and ownership/operation status for these buildings was not considered suitable for inclusion in the loan package.

Table E.1. Institutional Building Sector Investment Requirements per Building

Institutional Building Owner and Category	Investment per Building by Vintage and Size ($/Bldg.)									
	Pre-1958			1958-1980			Post-1980			Average Investment
	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	
Municipal Dept. of Health										
Hospitals	12,151	14,460	19,920	6,726	18,105	30,314	22,405	29,305	51,948	21,719
Polyclinics	8,077	10,137	10,785	3,929	13,534	20,722	4,207	17,912	25,873	14,143
Administration	5,203	11,445	28,532	6,269	8,092	18,553	7,154	9,667	24,589	8,309
Municipal Dept. of Ed.										
Kindergartens	7,426	9,519		10,833			14,225	17,692		11,771
Schools	6,598	20,196		6,103	26,535		9,661	32,280		24,987
Ministry of Education										
Education Buildings	21,257	26,073	24,553	10,270	25,425	30,589	13,249	33,467	38,041	27,703
Hostels	20,820	21,403	21,500	9,166	37,418	23,507			27,502	23,994
Municipal Dept. of Culture										
Theaters		25,135	14,112	10,867					18,623	21,295
Art Galleries/Museums	7,998	11,310	32,112			96,394	7,764	18,843		12,809
Average										18,505

Table E.2. Institutional Building Sector Investment Requirements per Square Meter

Institutional Building Owner and Category	Investment per Square Meter of Buildings by Vintage and Size ($/m^2)									
	Pre-1958			1958-1980			Post-1980			Weighted Average Investment Level
	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	
Municipal Dept. of Health										
Hospitals	8.59	6.43	6.43	6.49	6.49	4.75	6.49	4.56	4.56	5.45
Polyclinics	8.30	8.30	8.30	5.85	5.85	4.87	5.85	4.87	4.45	5.29
Administration	9.20	9.20	9.20	8.87	4.63	4.63	8.87	4.63	3.96	6.21
Municipal Dept. of Ed.										
Kindergartens	6.67	6.67		5.54			5.04	5.04		5.38
Schools	3.61	3.61		3.46	3.46		3.38	3.38		3.47
Ministry of Education										
Education Buildings	4.56	4.56	4.56	4.63	4.63	3.41	4.54	4.54	3.34	3.92
Hostels	4.77	4.77	4.77	4.77	4.77	4.22			4.77	4.37
Municipal Dept. of Culture										
Theaters		5.23	5.23	6.29					5.45	5.32
Art Galleries/Museums	7.42	5.97	5.97			4.82	6.50	6.50		6.08
All Buildings										4.31

Table E.3. Institutional Building Sector Total Investment Requirements

Institutional Building Owner and Category	Total Investment by Vintage and Size ($)									
	Pre-1958			1958-1980			Post-1980			Total Invest-ment
	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	<3 Stories	3-4 Stories	>4 Stories	
Municipal Dept. of Health										
Hospitals	498,182	375,952	99,602	80,715	398,313	909,417	67,216	58,610	987,011	3,475,019
Polyclinics	201,931	81,096	10,785	39,292	297,754	62,165	16,829	250,773	595,084	1,555,709
Administration	176,888	22,890	28,532	81,491	40,460	74,213	21,461	29,001	98,355	573,290
Subtotal	877,002	479,938	138,919	201,499	736,527	1,045,795	105,506	338,383	1,680,449	5,604,018
Municipal Dept. of Ed.										
Kindergartens	319,309	9,519	0	4,062,210	0	0	2,176,477	495,371	0	7,062,886
Schools	46,183	1,918,577	0	67,132	4,908,904	0	67,625	2,711,557	0	9,719,980
Subtotal	365,492	1,928,096	0	4,129,342	4,908,904	0	2,244,102	3,206,929	0	16,782,866
Ministry of Education										
Education Buildings	85,028	834,330	122,763	92,431	1,093,260	1,468,286	52,997	234,266	836,910	4,820,270
Hostels	41,640	128,419	150,503	18,333	187,092	2,280,142	0	0	385,031	3,191,160
Subtotal	126,668	962,748	273,267	110,763	1,280,352	3,748,429	52,997	234,266	1,221,941	8,011,430
Municipal Dept. of Culture										
Theaters	0	201,076	14,112	21,734	0	0	0	0	18,623	255,545
Art Galleries/Museums	135,971	90,480	32,112	0	0	96,394	23,293	18,843	0	397,093
Subtotal	135,971	291,556	46,224	21,734	0	96,394	23,293	18,843	18,623	652,638
Total										31,050,952

Table E.4. Institutional Buildings Sector Investment Requirements

Building Type	Investment Requirements ($)		
	Per Building	Per m^2	Total
Hospitals	21,719	5.45	3,475,019
Polyclinics	14,143	5.29	1,555,709
Administration	8,309	6.21	573,290
Kindergartens	11,771	5.38	7,062,886
Schools	24,987	3.47	9,719,980
Higher Education	27,703	3.92	4,820,270
Hostels	23,994	4.37	3,191,160
Theaters	21,295	5.32	255,545
Art Galleries/Museums	12,809	6.08	397,093
Total	18,505	4.31	31,050,952

E.1.2 Residential Sector

The investment requirements for the residential sector are shown in Table E.5 by building category. Residential sector investment requirements are more than an order of magnitude greater than institutional sector requirements, due to the large amount of floorspace in the residential sector. As with the institutional buildings sector, substation heat controllers are one of the largest investment requirements, accounting for 30 to 40% of the total investment. The per building cost to install apartment-level heat meters is comparable to the substation cost, however, accounting for about one third of the total investment. Building heat meter costs are again estimated at $3,000 per building.

Table E.5. Residential Building Sector Investment Requirements

	Investment Requirements ($)		
Building Type	Per Building	Per m^2	Total (millions)
2-story	6,044	13.49	64.9
5-story	32,626	4.08	68.7
9-story	36,844	6.64	111.8
14-story	35,102	4.08	39.2
Total	31,939	5.92	284.5

Appendix F

Review of Literature

Appendix F

Review of Literature

Four studies that focused some or all of their effort on the buildings sector were reviewed. Key findings of each pertaining to the buildings sector are presented in this section.

Of the four, the TACIS report, provides the most comprehensive assessment of efficiency potential. Information in all the reports focused on the residential buildings sector, but the combined information was helpful in developing the institutional sector efficiency potential in this assessment. Major findings of the studies are discussed below.

F.1 Feasibility Study for Heat Supply and Energy Efficiency Project Kyiv, Ukraine (Ekono Energy 1996)

In the Ekono Energy report, the absence of heat meters required that design data be used to estimate heat consumption. A number of standards and regulations were used to develop the following per-square-meter design estimates in W/m^2 for Kyiv:

	Existing Buildings (W/m^2)		
Building Height	**No Efficiency**	**Improved Efficiency**	**New Buildings**
1-2 Stories	208.2	196.8	168.8
3-4 Stories	120.6	114.2	93.4
>5 Stories	81.8	77.8	76.2

Of the total 1995 building sector heat demand of 7412.1 Gcal/hr (8620.2 MW), it was estimated that 2406.7 Gcal/hr (2799 MW) were accounted for by public buildings and 5005.4 Gcal/hr (5,821.3 MW) by residential buildings. The total energy, 6298 Gcal/hr, was used for heat and ventilation, and 1114 Gcal/hr was used for hot water. The information was provided in terms of peak demand (Gcal/hr), not in terms of calories of consumption.

The discussion focused mainly on the residential sector. It was estimated that there was 48.6 million square meters of residential floorspace in Kyiv in 1995.

With respect to heat loss, the following information was provided. A value of 1.0 W/m^2K (U-value) was used for calculating heat loss through walls. This value was felt to accurately reflect the properties of

older brick and concrete construction and the deteriorated condition of sandwich wall construction, which theoretically has a heat loss coefficient as low as 0.3 W/m^2K (U-value). Ground floor and roof heat losses were felt to be much higher than the theoretical values 0.7 and 0.6 to 0.8 W/m^2K. The assumed U-value of 2.3 W/m^2K of windows was also felt to be much higher due to infiltration around the frames. In addition to infiltration around door frames, closing mechanisms often do not work properly.

Domestic hot water consumption was estimated in the range of 70 to 80 dm^3/person/day (liters/person/day), rather than the design value of 105 to 110 dm^3/person/day. Heat is usually distributed through radiators at a design temperature of 95/70°C (105/70°C in some cases), and there is an absence of controls. In recent years the supply temperature of water has been lower so overheating has not been common.

A number of energy conservation measures were discussed. Control measures included building and radiator-level heat controls, and building-level hot water controls. Other measures were balancing valves (risers), pipe insulation, wall insulation, and weatherstripping. Estimates of the reduction in energy consumption were provided for some of the measures as follows:

Controls	
Building Level	15-20%
Hot Water	N/A
Thermostatic Valves	N/A
Balancing Valves	5-7%
Pipe Insulation	N/A
Wall Insulation	15%
Weatherstripping	N/A

Pipe insulation and weatherstripping were estimated to have short paybacks, while wall insulation was expected to have long paybacks, though these values were not quantified.

The annual theoretical heat consumption per cubic meter is estimated to be 140.56 kWh, and the actual heat consumption per cubic meter in 1995 is estimated to have been 94.87. This compares to the actual 1994 per cubic meter consumption in Finland of 45.5 kWh. Data from the TACIS report estimates annual per cubic meter building sector consumption of 110 to 280 kWh in Kyiv. Annual values provided for the Czech republic ranged from 100 to 130 kWh and 80 kWh for Switzerland.

The building sector efficiency potential was felt to be small in view of the current prices and economic situation. Controls are felt to be the most economically attractive measures, providing significant reductions in energy consumption, but only modest reductions in capacity. It was estimated that reductions in peak capacity requirements of 2 to 4% could be achieved from a buildings sector efficiency program.

F.2 Ukraine District Heating Project (JTC 1996)

The Joseph Technology Corporation report includes information on the distribution of nonresidential buildings and an estimate of the number of residential buildings (33,320) and apartments (889,440). Residential floorspace is estimated at 49 million m^2, with 10% in buildings of 1 to 4 stories, 70% in buildings of 5 to 9 stories, and 20% in buildings having more than 9 stories. Projections of population and living space per person are provided: 1995 population of 2.7 million and 18 m^2 per person; 2010 population of 3.052 million and 22.7 m^2 per person.

Peak demand for the building sector was estimated for 1995 as follows:

	Peak Demand (Gcal/hr)
Heating	5,472
Ventilation	581
Hot Water	1,101
Peak Demand by Customer Class	**Peak Demand (Gcal/hr)**
Industrial	
Steam	1,520 (2,535 tons/hr)
Hot Water	3,465
Buildings	7,155
Total	12,140

Forecasts of heat demand are provided for the industrial and buildings sectors. Peak demand is projected to increase from 12,140 Gcal/hr to 17,290 Gcal/hr.

A number of residential buildings sector efficiency measures were discussed. These were

- *External Insulation*. Apply polystyrene panels to increase the R-value to 11 or 12. The estimated cost is \$6/ft^2 or \$2,500/apartment.

- *Windows*. Install double or triple panes and use caulking and weatherstripping. The estimated cost is \$2,000/apartment.

- *Weatherstripping*. The estimated cost is \$50/apartment.

- *Thermostatic Valves*. The estimated cost is \$150/apartment.

- *Heat Meters*. The estimated cost is \$1,500 per apartment building.

- *Domestic Hot Water Taps*. The estimated cost is $20/apartment.

- *Heat Supply Substations*. Substation modernization is estimated to be $32,400/substation.

The total estimated cost for 33,320 buildings, 888,440 apartments, and substations at 50% penetration (16,700 buildings, 1,125 substations, and 445,000 apartments) is $2,172.3 million. Analysis indicates that supply-side measures are a more cost-effective option than demand-side measures, but a 5 to 6% reduction in peak demand is considered in the analysis.

F.3 Energy Policies of Ukraine (IEA 1996)

This report provided an overview of the entire energy sector of Ukraine, which includes technical and policy recommendations. Only those sections that pertain to the technical analysis of the buildings sector are discussed in this review.

The average energy expenses for a typical family of four in Kyiv is estimated as follows:

Central (district) Heat	1.4 million KRB ($8.00)
Hot Water	1.6 million KRB ($9.14)
Gas (for cooking)	800,000 KRB ($4.57)
Electricity	(180 kWh) 900,000 KRB ($5.14)
Total Monthly Energy Bill	4.7 million KRB ($26.85)
Average Monthly Earnings	14 million KRB ($80)

The source for these figures is the Ukrainian Academy of Sciences.

Theoretical heat demand using present building standards is 9.3 MWh/yr for an apartment with net living area of about 60 m^2 (71 m^2 gross). Actual consumption is estimated to be 14 to 16 MWh/yr.

Factors that bear upon household implementation of efficiency measures are

- households are not billed for actual consumption, hence they have no incentive to conserve

- households do not have sufficient information about efficiency measures

- equipment/materials are expensive and sometimes difficult to obtain.

Building standards, if enforcement and education were provided, would bring new housing up to Western European levels of consumption. Appliance labeling, scheduled to be implemented in 1996, would also be expected to improve energy efficiency.

The report notes that the tariffs for district heat are based on production and transmissions costs. Production costs factor in fuel and operating expenses, but not depreciation expenses. Transmission costs are calculated to cover losses of 7%; losses are estimated to range from 10 to 15%. These tariffs are subject to approval by Regional Energy Committees and according to guidelines set by the Ministry of Economy. Tariffs are higher for industrial customers than for residential customers, and the Ministry of Economy provides a subsidy to apartment or homeowners. The average heat tariff is about $2.60/GJ, about half the economic level. A World Bank estimate is that the marginal cost of heat from a coal-fired plant is about $10/GJ with 10 to 15% transmission losses.

In Kyiv, residential customers are estimated to account for about two-thirds of district heat supplied, and the hot water to steam ratio is 85:15. Average consumption is estimated at 1.7GJ/m^2/yr as compared to about 0.7 to 0.75 GJ/m^2/yr for countries such as Denmark, Belgium, and Finland.

Transmission and distribution losses are estimated to be 17%, and water losses are estimated to surpass 3% in some hot water systems and 5 to 10% in steam systems.

District heat is usually billed on estimated consumption, and legislation is calling for installation of heat meters so consumers can be charged for actual consumption.

Water consumption is estimated to be 328 liters/day as compared to about 150 to 240 liters/day in industrialized countries.

The average cost of water and heat meters is about 700 million KRB per building, and these meters are expected to reduce consumption by about 15 to 20% initially and 35 to 50% in the longer term.

Retrofits to provide for metering and control of heat in apartments would require the installation of thermostatic valves, bypasses, and throttle valves. This retrofit is estimated to cost $300/apartment.

F.4 Study of the Potential for Developing Actions to Improve the Overall Energy Efficiency in the Building Sector in Ukraine (TACIS 1994)

The TACIS report presents an assessment of potential energy efficiency measures for buildings in Kyiv and the expected energy savings from these measures.

The report provided an extensive discussion of the physical characteristics of the measures, their installation, and implementation in existing and new buildings. The implementation discussion included the human resources available as well as an estimate of the quantity of labor required. An extensive discussion was also provided for the domestic production of insulation and glazing.

Measures evaluated were

- *Temperature Controls*. This consisted of three measures for near-term implementation and two measures for the longer term:

  1. Control indoor temperature at 18°C, and balance system through installation of thermostatic bypass valves at the radiator and balancing valves in the vertical lines.

  2. Employ night and weekend setback in public buildings.

  3. Install building-level heat meters to enable billing for actual heat consumption.

  4. Install hot water circulation pumps and heat exchangers with temperature controls in place of the existing "venturi" systems.

  5. Install balancing valves on the building inlets.

- *Insulation*. This consisted of two classes of measures.

  1. Insulate exterior walls, roofs, and attics.

  2. Weatherstrip windows and doors.

The study selected a sample of 31 buildings: 18 residential, 3 office, 3 education, 2 hotel, 1 cultural, 1 sport, 1 retail, and 2 other. A number of measures were analyzed by computer analysis, and two residential buildings and the serving substation were metered from 15 October to 15 December 1993. Estimates of the achievable reduction in space heating energy were evaluated for thermostatic regulation, thermostatic regulation with setback, thermostatic valves with setback and wall and roof insulation, and thermostatic valves with setback and wall insulation (note the setback applied only to the nonresidential buildings). The efficiency improvements using an 18°C base temperature yielded savings as follows:

	Range	**Average**
Thermostatic Regulation	14-25%	18%
Thermostatic Regulation with Setback	44-53%	50%
Thermostatic Regulation with Setback and W/R Ins.	17-70%	
Thermostatic Regulation with Setback and Wall Ins.	20-70%	

An economic analysis was conducted for nine of the residential prototypes and one office building. The economic analysis also provided an estimate of the quantities and costs of equipment, materials, and labor. Using a heat price of $14.25/MWh, the analysis showed that temperature controls had a payback

ranging from 0.9 to 5 years, and that the addition of wall and roof insulation increased the payback beyond 5 years for all building types and up to 26.1 years. The office building with setback controls exhibited the shortest payback.

Recommendations were to install regulation equipment on existing buildings. A similar set of measures was examined for new buildings, and both insulation and regulation were generally found to be cost-effective. The energy gains in existing buildings due to regulation and insulation were twice as much as for regulation alone; in new buildings the energy gains were found to be three times that of regulation alone.

Estimates of the efficiency potential were developed for Kyiv; these ranged from a low of 20% (987,350 MWh/yr) to a high of 55% (2,858,600 MWh/yr).

Domestic manufacture of certain equipment/materials was also assessed for insulating materials, glazing materials, and heat regulation equipment. For each, an estimate of the market size was made along with the necessary investment and associated level of employment.