PN-ACR-974

SERBIA EMERGENCY ENERGY EFFICIENCY PROGRAM

ENERGY CONSERVATION MEASURES IMPLEMENTED IN THE MUNICIPALITY OF KRAGUJEVAC

EVALUATION REPORT

May 2002

Prepared by

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for

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Serbia's energy consumption, particularly for space heating, imposes serious challenges to the country's recovery. Households and Municipal Institutions are facing difficulties paying for energy/heat, while energy producers- particularly electricity- face supply shortages. Heavy subsidies to the prices of electricity and district heat had exacerbated the situation by encouraging high consumption levels. The budgets of cities and energy enterprises are strained to provide the subsidies, making it difficult to increase energy supplies. Energy efficiency is clearly one of the methods to relieve the supply shortages, while also providing social protection against the inevitable removal of subsidies.

USAID designed the Serbia Emergency Energy Efficiency Program (SEEEP) with the objective of promoting energy efficiency at national level. The key element of the program is the widespread demonstration of financially attractive energy saving technologies, which will attract both private and public investments toward the repetition of the demonstration projects. The anticipated large number of repetitions will in turn have a substantial impact in reducing energy consumption at national level, with a consequent reduction in government expenditures.

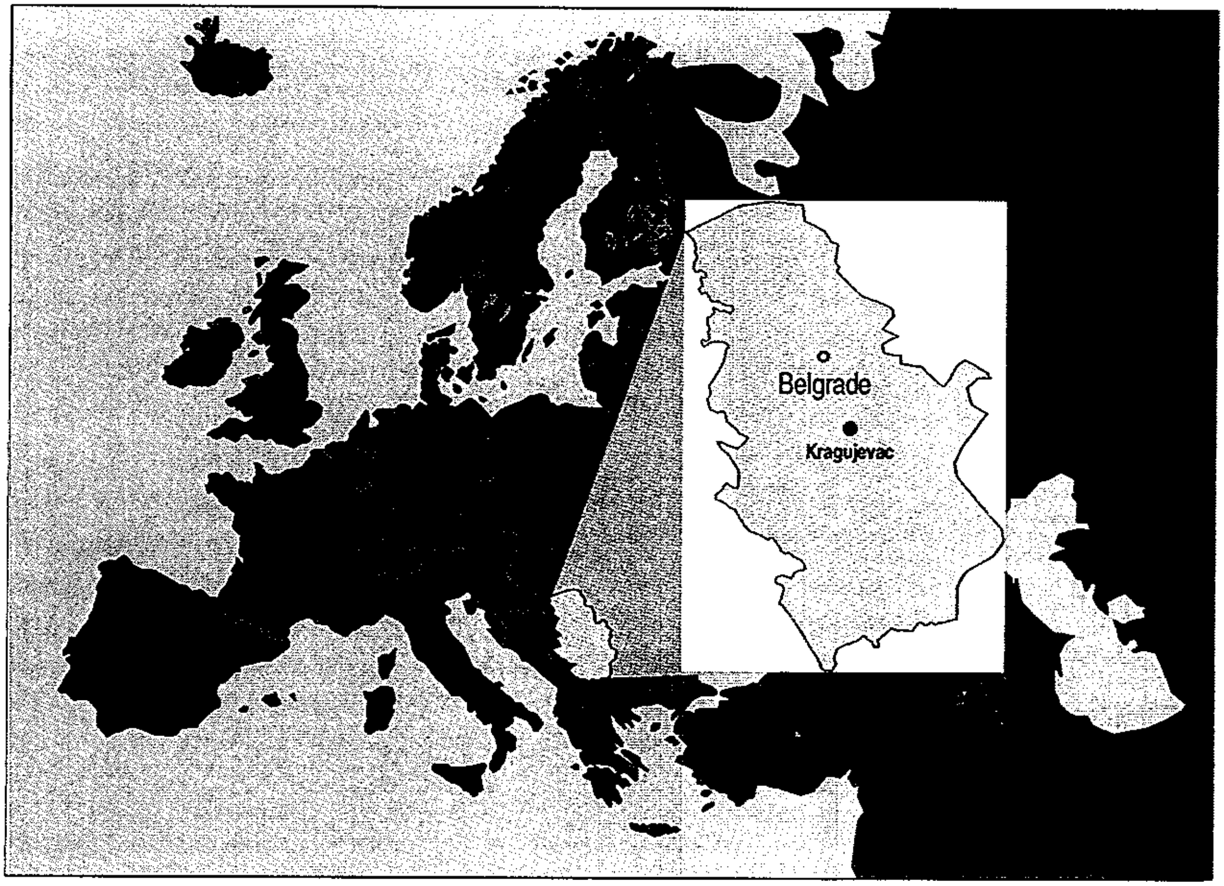
The practical implementation of SEEEP consisted in the installation of numerous energy efficiency demonstration projects. For the purpose of evaluating the energy savings achieved by each project, it was decided to use winter season 2000-2001 as the baseline period, and winter season 2001-2002 for the measurement of energy consumption after the implementation of the projects.

As USAID contractor for SEEEP, in Spring 2001 Nexant performed a rapid assessment of the potential thermal and electric energy savings achievable in selected institutional buildings, to use as demonstration projects throughout Serbia. The assessment identified, in five Serbian Municipalities, approximately forty potential energy efficiency measures, offering various degrees of financial feasibility, and submitted them to USAID for approval. USAID reviewed them and approved 16 for immediate implementation.

One of the Municipalities in which several approved measures had been implemented is the Municipality of Kragujevac.

Kragujevac got an early start in industrialization with the manufacturing of artillery field pieces in the fist half of the 19th century, and boast many "first" in Serbia, including the first power station in 1884. Today the city is an important industrial center, with approximately 1,160 private companies, including manufacture of passenger cars, commercial vehicles, sport and hunting arms and food processing. Kragujevac is situated approximately 144 km south of Belgrade, in a predominantly farming area, occupying an area of 835 km^2, with 57 settlements, and a population of 200,000.

This Post-Implementation Evaluation Report illustrates the energy efficiency measures implemented in the Municipality of Kragujevac, and the resulting savings.


Belgrade
Kragujevac

The methodology applied for the calculation of savings achieved by the energy efficiency measures implemented by Nexant within the framework of the Serbian Emergency Energy Efficiency Program is based on the guidelines established by the International Performance Measurement & Verification Protocol (IPMVP, Ref. 1), issued by the U.S. Department of Energy in October 1997.

The methodology is discussed in detail in Nexant report entitled "Measurement and Verification Plan". The specific steps used for the collection of the necessary energy consumption data, and the calculation of savings, achieved by the various measures, are described in this report. The methodology has been applied consistently to all the measures. The data collected and the results of the analyses are presented in a latter section of this report.

2.1 Calculation Procedure

The energy saving due to an Energy Conservation Measures (ECM) implemented in a facility is determined by comparing the quantity of energy consumed in the facility, or part thereof, during a specified baseline period, before the installation of the ECM, and the quantity of energy consumed during a corresponding period of the same characteristics (i.e. length, weather conditions, etc...) after the installation of the ECM. By subtracting 'actual energy consumption after ECM installation' from 'adjusted energy consumption before ECM installation' we obtain:

Energy Saving = Adjusted energy consumption before ECM installation -
-Actual energy consumption after ECM installation

2.1.1 *Adjusted Energy Consumption Before ECM Installation*

Energy consumption before ECM installation is estimated either from direct measurement of various parameters, or from historical data obtained from the utilities, municipalities, or other relevant sources.

In most situations, energy consumption pattern or parameters affecting the energy consumption change for various reasons after installation. These changes typically include change in operating hours, change in operating or ambient temperature, change in energy requirement, change in level of comfort, etc. To estimate energy saving, it is necessary that the measurements, before and after, reflect energy usage under similar conditions.

Two important parameters that changed from the baseline period to the after ECM installation period have been addressed already in Nexant's Rapid Assessment Report, precisely:

- All facilities complained that during the baseline period, i.e. winter season 2000-2001, the quantity of heating fuel available was not sufficient to create an adequate level of comfort for the occupants of the facility. Use of supplementary portable electric heaters improved somewhat the situation, but not to satisfactory levels. To equalize the conditions before and after the ECM installation, the before energy consumption was adjusted to reflect an adequate level of comfort (i.e. approximately 18-20 °C indoor temperature). The adjustment was obtained by multiplying the effective consumption, estimated from the information received, by the following factor:

<u>Comfort Level factor</u> = $(T_c - T_{w1}) / (T_a - T_{w1})$

Where:	T_c=	Indoor comfort temperature (approx 20°C)
	T_a=	Indoor temperature actually experienced in Winter 2000-2001, as estimated from verbal information obtained during site visits
	T_{w1}=	Monthly average outdoor temperature in Winter 2000-2001, as obtained from the Serbian National Weather Institute

- The prices charged for heating fuels and electricity were heavily subsidized during the baseline period, and did not reflect the realistic international market levels toward which prices are now inevitably moving, as government subsidies are being reduced or abolished. To reflect a realistic estimate, the calculation of energy costs has been based on the following realistic prices:

Electricity	$ 0.05 per kWh
Light Oil	$ 0.23 per Litre
Heavy Oil	$ 0.18 per Litre
Natural Gas	$ 0.10 per m^3
Coal	$ 33.5 per ton (this reflects price of locally produced coal, not an international price)

Other important parameters considered for the adjustment include:

- The baseline winter season 2000-2001 has been an exceptionally mild one, while winter season 2001-2002, during which the measures have been implemented, and the after ECM installation measurements taken, is the harshest winter on record in Serbia for the last 30 years. The adjustment was obtained by multiplying the effective consumption, estimated from the information received, by the following factor:

<u>Winter Rigidity factor</u> = $(T_c - T_{w2}) / (T_c - T_{w1})$

Where: T_c= Indoor comfort temperature (approx 20°C)

T_{w1} = Monthly average outdoor temperature in Winter 2000-2001, as obtained from the Serbian National Weather Institute

T_{w2} = Monthly average outdoor temperature in Winter 2001-2002, as obtained from the Serbian National Weather Institute

- In case of applications where new high efficiency lighting technology is used, the wattage of the old lamps has to be adjusted to reflect the illumination level (Lux) provided by the new system. This is obtained by multiplying the Wattage of the old lamps by a factor equal to the ratio of the new illumination level to the old illumination level.

These adjustments made the winter season 2000-2001 energy consumption data comparable to the winter season 2001-2002 energy consumption data.

2.1.2 Actual Energy Consumption After ECM Installation

The usual method for deriving energy consumption data after ECM installation is to use direct measurements or recording of various parameters. However, since the ECM installations were completed in February 2002, the only measured data available refer to March and April 2002. These data were used as a basis to extrapolate the data to cover the months of October 2001 through February 2002, *when the ECMs were still being installed.*

The extrapolation of the actual consumption data measured in March-April 2002 was done under the basic assumption that *the rate at which thermal energy is consumed is linearly proportional to the indoor-outdoor temperature differential.*

To extrapolate the March-April 2002 consumption data to the months of October 2001 through February 2002, we must derive the equation of the line representing the consumption on the Cartesian plane defined by axis X (temperature differential) and axis Y (hourly thermal consumption). The line contains the two known points:

$$P_1 (X_1, Y_1) \quad \text{and} \quad P_2 (X_2, Y_2)$$

Where:

X_1= hourly consumption in March 2002
Y_1= indoor-outdoor temperature differential in March 2002

X_2= hourly consumption in April 2002
Y_2= indoor-outdoor temperature differential in April 2002

The equation of the line is then derived as:

$$\boxed{aX + bY + c = 0}$$

Where:

$a = Y_1 - Y_2$
$b = X_2 - X_1$
$c = X_1 Y_2 - X_2 Y_1$

The extrapolated consumption data for the months of October 2001 through February 2002 are then obtained by entering the known indoor-outdoor temperature differentials in the equation, calculating the hourly consumptions, and multiplying it by the known number of hours of operation per month.

2.1.3 Energy Saving, Cost Saving, and Simple Payback Period

Annual energy saving was calculated by subtracting the post-installation energy consumption from the adjusted pre-installation energy consumption, over the entire winter season, i.e. from October 1st through April 15th.

Annual cost saving was calculated by multiplying the annual energy saving by the realistic price of fuel and/or electricity.

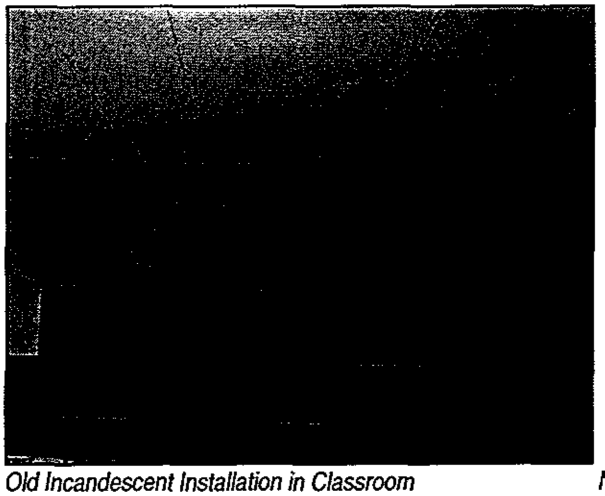
Simple Payback period was calculated by dividing the capital cost of the implementation by the annual cost saving.

All calculations were performed using Excel spreadsheet programs.

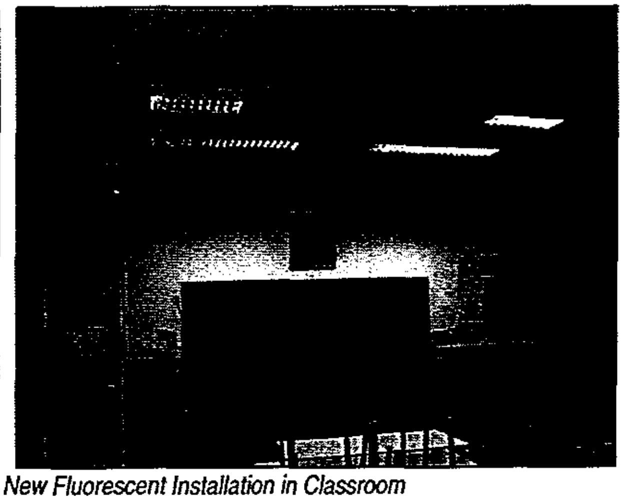
This is an elementary educational facility for children up to 15 years of age. The facility was built in 1990, consists of a one-story building, with an area 808 m^2, and operates in two shifts. The building is heated with accumulator-type electric heaters, and the lighting system consists primarily of very low efficiency incandescent lamps, installed on the ceiling.

3.1 LIGHTING SYSTEM UPGRADE - PROJECT DESCRIPTION

Nexant, on behalf of USAID, replaced the old incandescent type lighting system with fluorescent lighting, complete with fluorescent tubes, electro magnetic ballasts, and fixtures. Four new fluorescent lighting units were installed in each of the large classrooms, two lighting units in each of the small classrooms, and one lighting unit in each of the toilet rooms, for a total of 108 assemblies. This lighting retrofit demonstrates the energy saving potential of new lighting technology. The school is benefiting by saving energy, and cost, and by an improved learning environment for the children.



Old Incandescent Installation in Classroom



New Fluorescent Installation in Classroom

3.1.1 Baseline Energy Use

Lamp Wattage – The aggregate lamp Wattage of the incandescent lamps to be replaced in the facility was recorded.

Operating Hours – The annual (based on daily and weekly) facility operating hours was derived from the school operating schedule.

Light Level – Light levels (Lux) at different locations in the various rooms were recorded. The average light level in the facility was estimated from the recorded data.

Adjusted pre-installation energy consumption – This adjusted consumption was obtained as the product of the recorded aggregate Wattage and the recorded operating time. The product was then multiplied by two factors. The first factor is intended to equalize the number of operation hours between baseline pre-installation period and the post-installation period (note: in our case this factor is 1 since the operating hours are the same in the two periods). The second factor is intended to equalize the light levels pre and post installation. We have therefore:

$$\text{Adjusted pre-installation consumption} = \text{Recorded Aggregate Wattage} \times \text{Recorded Operating Hours} \times \frac{\text{Operating hours after ECM installation}}{\text{Operating hours before ECM installation}} \times \frac{\text{Average Lux level after ECM installation}}{\text{Average Lux level before ECM installation}}$$

Pre-Installation Baseline					
	January	February	March	April	Average
Total Lamp Wattage [W]	10,025	10,025	10,025	10,025	10,025
Hours of operation [h]	225	360	270	172	257
Illumination [lux]	75	75	75	75	75
Energy Consumption [kWh]	2,256	3,609	2,707	1,724	2,574
Adjusted Energy Consumption [kWh] (adjusted for hours of operation & lumen)	4,511	7,218	5,414	3,449	5,148
Adjusted Annualized Energy Consumption, kWh	**39,839**				

3.1.2 Post-Installation Energy Use

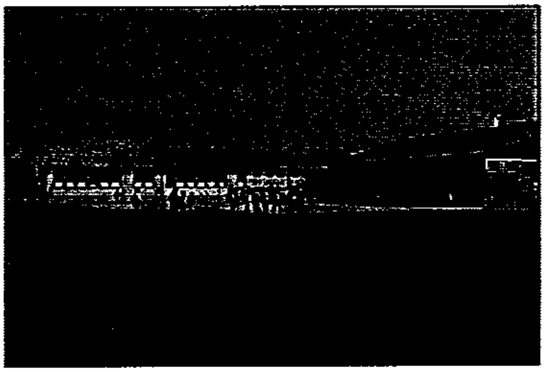
Post-Installation Energy Consumption in kWh is obtained by multiplying the total Wattage by the total operating hours. The ballasts energy consumption is included in the total Wattage.

Post-Installation Measurement					
	January	February	March	April	Average
Total Lamp Wattage, W	4,428	4,428	4,428	4,428	4,428
Hours of operation [h]	225	360	270	172	257
Illumination [lux]	150	150	150	150	150
Actual Energy Consumption [kWh]	996	1,594	1,196	762	1,137
Adjusted Annualized Energy Consumption, kWh	**8,798**				

3.1.3 Energy Savings

As mentioned, the energy savings were calculated as the difference between the adjusted pre-installation consumption , and the post-installation consumption. The result is summarized in the following table, which also shows a comparison between the actual savings and the saving estimate made before the installation, during the rapid assessment.

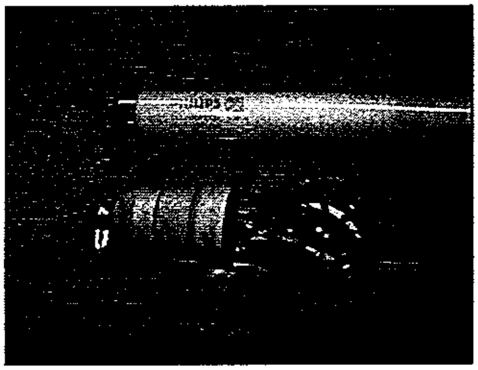
Assessment	Actual	Estimate
Annual Energy Saving, kWh	31,041	11,121
Annual Cost Saving, $	$1,552	$556
Implementation Cost, $	$2,777	$1,225
Payback Period, Yrs.	1.8	2.2



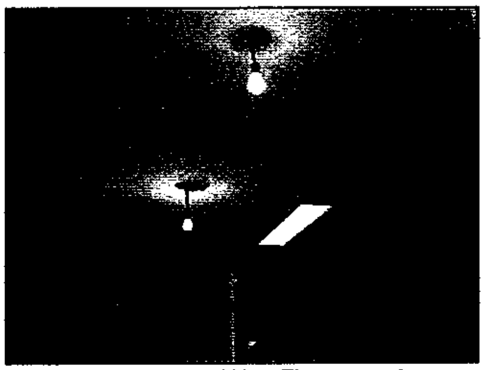
This is an elementary educational facility for children up to 15 years of age. The facility was built in 1990. The building has one story only, with an area of 1,137 m^2, nine large classrooms, five small rooms, and several auxiliary rooms. The school space is insufficient to accommodate all the students in one single shift, so they are forced to operate in multiple shifts. Heating is provided by coal and wood stoves, and lighting by very low efficiency incandescent lamps installed on the ceiling.

4.1 LIGHTING SYSTEM UPGRADE - PROJECT DESCRIPTION

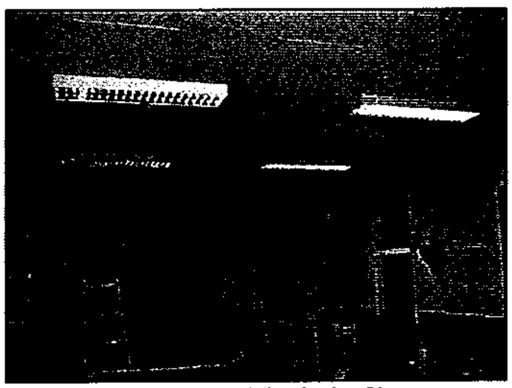
Nexant on behalf of USAID installed a new fluorescent lighting system complete with fluorescent tubes, electro magnetic ballasts, and fixtures. Four new fluorescent lighting units have been installed in each large classroom, two units in each small classroom, and one unit in each toilet room, for a total of 96 units.



Lamps Old and New



Old Incandescent and New Fluorescent Lamps



New Fluorescent Lighting in the Classroom

4.1.1 Baseline Energy Use

Lamp Wattage – The aggregate lamp Wattage of the incandescent lamps to be replaced in the facility was recorded.

Operating Hours – The annual (based on daily and weekly) facility operating hours was recorded based on the school operating schedule.

Light Level – Light levels (Lux) at different locations in the various rooms were recorded. The average light level in the facility was estimated from the recorded data.

Adjusted pre-installation energy consumption – This adjusted consumption was obtained as the product of the recorded aggregate Wattage by the recorded operating time, and then multiplied by tow factors. The first factor is intended to equalize the number of operation hours between baseline pre-installation period and the post-installation period (note: in our case this factor is 1 since the operating hours are the same in the two periods). The second factor is intended to equalize the light levels pre and post installation. We have therefore:

$$\text{Adjusted pre-installation consumption} = \text{Recorded Aggregate Wattage} \times \text{Recorded Operating Hours} \times \frac{\text{Operating hours after ECM installation}}{\text{Operating hours before ECM installation}} \times \frac{\text{Average Lux level after ECM installation}}{\text{Average Lux level before ECM installation}}$$

Pre-Installation Baseline					
	January	February	March	April	Average
Total Lamp Wattage [W]	11,200	11,200	11,200	11,200	11,200
Hours of operation [h]	225	360	270	172	257
Illumination [lux]	140	140	140	140	140
Energy Consumption [kWh]	2,520	4,032	3,024	1,926	2,876
Adjusted Energy Consumption [kWh] (adjusted for hours of operation & lumen)	2,700	4,320	3,240	2,064	3,081
Adjusted Annualized Energy Consumption, kWh	**23,844**				

4.1.2 Post-Installation Energy Use

Post-Installation Energy Consumption in kWh was obtained by multiplying the total Wattage by the total operating hours. The ballasts energy consumption is included in the total Wattage.

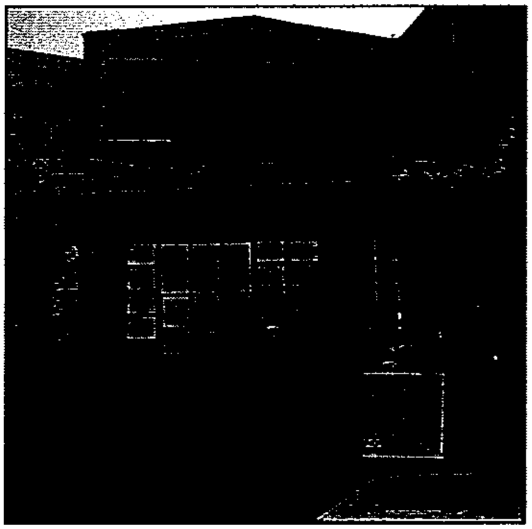
Post-Installation Measurement					
	January	February	March	April	Average
Total Lamp Wattage, W	5,760	5,760	5,760	5,760	5,760
Hours of operation [h]	225	360	270	172	257
Illumination [lux]	150	150	150	150	150
Actual Energy Consumption [kWh]	1,296	2,074	1,555	991	1,479
Adjusted Annualized Energy Consumption, kWh	**11,445**				

4.1.3 Energy Savings

As mentioned, the energy savings were calculated as the difference between the adjusted pre-installation consumption , and the post-installation consumption. The result is summarized in the following table, which also shows a comparison between the actual savings and the saving estimate made before the installation, during the rapid assessment.

Assessment	Actual	Estimate
Annual Energy Saving, kWh	12,399	10,809
Annual Cost Saving, $	$620	$538
Implementation Cost, $	$2,511	$2,200
Payback Period, Yrs.	4.1	4.1

The school is a multi-disciplinary classical music school, built in 1954 as part of a fine arts center, with students ranging from 6 years to 19 years of age. The school is heated by the municipal district heating plant, through a substation located inside the school building. The municipal district heating plant charges the school a flat heating fee based on its floor area.



5.1 HEATING SYSTEM

5.1.1 Description

Nexant on behalf of USAID installed a control system for the heating system hot water supply, and thermostatic control valves and radiator insulation for the existing radiators. The main feature of this energy efficiency upgrade is a flow control system at the district heating substation, which enables the regulation of the flow of hot water depending on the outdoor ambient temperature, the facility hot water usage, and time-of-day operation. The system also meters the thermal energy supplied to the facility. This application greatly enhances the school's ability to control the temperature in each classroom, and as a result save energy for the Municipality.

New Electronic controls

New calorimeter

5.1.2 Baseline Energy use

Thermal Energy Consumption - Historical thermal energy consumption data for every month during the winter season of year 2000-2001 was obtained from the Municipality.

Electrical Energy Consumption - At the time of the energy audit for the rapid assessment, the school complained of overheating. It has been assumed, therefore, that no electric energy was used to supply additional heat.

Operating Hours – The facility operating hours for the heating season was recorded, on the basis on the school's schedule.

Average Indoor Ambient Temperature – Historical average indoor ambient temperature data was obtained from the school

Average Outdoor Ambient Temperature – This information was obtained, for each winter month, from the National Weather Institute.

Adjusted pre-installation energy consumption. The historical energy consumption, obtained from the Municipality, was adjusted by the Winter Rigidity factor, as explained at paragraph 2.1.1 above.

The Baseline Energy Use summary is shown in the following Table:

Pre-Installation (Baseline) Data		2000			2001			
	Annualized Average/Total	October	November	December	January	February	March	April
District Heating Energy Consumption, kWh	462,000	33,000	82,500	99,000	99,000	66,000	49,500	33,000
Electrical Energy Consumption, kWh		N/A	N/A	N/A	N/A	N/A	N/A	N/A
Adjusted Dist. Htg. Energy Consumption, kWh	613,456	59,053	116,431	150,975	121,846	56,571	58,651	49,929
Adjusted Electrical Energy Consumption, kWh		N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hours of Operation	1,500	144	264	276	140	256	276	144
Average Outdoor Ambient Temperature, °C	—	11	6	1	(1)	2	6	11
Average Indoor Ambient Temperature, °C	—	19	18	17	17	17	18	19
Average Differential Ambient Temperature, °C		8	12	16	18	15	12	8
Average Wall Temperature °C - Outside Surface	—	13	6	2	-	2	7	12
Average Wall Temperature °C - Inside Surface	—	25	25	26	27	26	25	25
Average Differential Wall Temperature, °C	—	13	19	25	27	24	19	13
Average Wall Thickness, m	—	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total Shield Surface Area, m^2	—	60	60	60	60	60	60	60
Average Wall Thermal Conductivity, W/m^2-°C/m	—	2	2	2	2	2	2	2
Total Heat Loss thru Wall Across Radiators, kWh	15,460	913	2,544	3,430	1,917	3,116	2,590	950
Adjusted Total Heat Loss Across Radiators, kWh	30,127	2,462	5,411	7,883	3,556	4,026	4,625	2,165

5.1.3 Post-Installation Energy use

The installed control system is provided with a calorimeter which meters the thermal energy supplied by the district heating plant. The meter reading was recorded on the first day, last day, and two intermediate days of the month. The thermal energy consumption is determined as the difference of the two readings at the beginning and the end of the period.

Average Outdoor Ambient Temperature – Average outdoor ambient temperature was obtained from the National Weather Institute.

Average Indoor Ambient Temperature – Indoor ambient temperature was recorded several times a day over a 24-hour period at three typical different locations on the first day, last day, and two intermediate days of the month. Average indoor ambient temperature for the month was estimated from these data.

Average Differential Ambient Temperature – Average differential ambient temperature was obtained by subtracting the average outdoor ambient temperature from the average indoor ambient temperature for each winter month. This data was used to extrapolate the energy consumption to the winter months when the installation was not yet completed, following the procedure explained at paragraph 2.1.2 above.

The Post-installation Energy Use summary is shown in the following table:

Post-Installation Data								
		2001			2002			
		Adjusted Monthly Data						
	Annualized Average/Total	October	November	December	January	February	March	April
District Heating Energy Consumption, kWh	175,826	13,552	31,970	46,603	21,701	21,000	30,000	11,000
Electrical Energy Consumption, kWh	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Energy Consumption, kWh	175,826	13,552	31,970	46,603	21,701	21,000	30,000	11,000
	-	-	-	-	-	-	-	-
Hours of Operation	1,500	144	264	276	140	256	276	144
Average Outdoor Ambient Temperature, °C	—	8	5	(2)	(0)	7	9	9
Average Indoor Ambient Temperature, °C	—	22	22	22	22	20	23	21
Average Ambient Temperature Difference, °C	—	14	18	24	22	13	14	12
Average Wall Temperature °C - Outside Surface	—	12	8	2	4	10	12	15
Average Wall Temperature °C - Inside Surface	—	22	22	22	22	22	23	21
Average Wall Temperature Difference, °C	—	10	14	20	18	12	11	6
Average Wall Thickness, m	—	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total Shield Surface Area, m2	—	91	91	91	91	91	91	91
Average Wall Thermal Conductivity, W/m2-°C/m	—	2	2	2	2	2	2	2
Total Heat Loss Across Radiators, kWh	15,263	1,101	2,825	4,219	1,926	2,348	2,215	627

5.1.4 Energy Savings

As mentioned, the energy savings were calculated as the difference between the adjusted pre-installation consumption , and the post-installation consumption. The result is summarized in the following table, which also shows a comparison between the actual savings and the saving estimate made before the installation, during the rapid assessment.

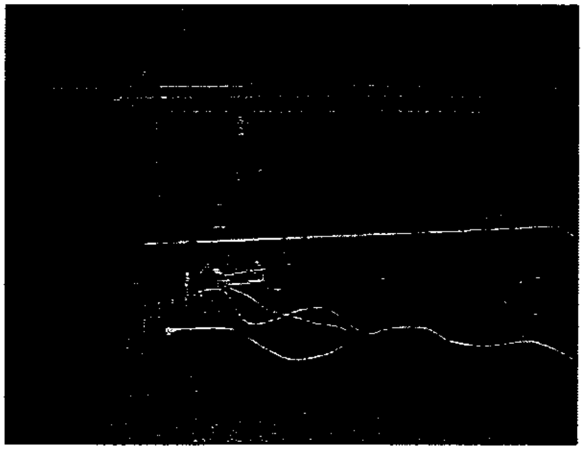
Annual Energy and Cost Saving		
	For Facility	
	Estimated	Actual
District Heating Energy Saving, kWh/Yr	140,000	607,820
Electric Energy Saving, kWh/Yr	-	-
District Heating Cost Saving, $/Yr	$3,174	$21,882
Electric Cost Saving, $/Yr	$0	$0
Total Cost Saving, $/Yr	$3,174	$21,882
Implementation Cost, $	$10,901	$10,813
Simple Payback Period, Yrs	3.4	0.5

5.2 RADIATOR THERMAL SHIELDS

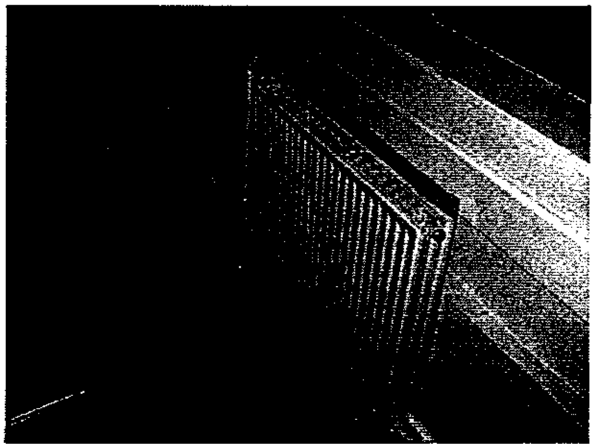
5.2.1 Description

All radiators facing cold surfaces (walls or windows exposed to the outdoor) were provided with thermal insulators installed between the radiator and the cold surface. To estimate the effectiveness of the radiator thermal shield, heat loss through the wall in the vicinity of the radiators is estimated before and after the installation of the radiator shield.

Dismount radiators and Install Shield



Flush and Clean Radiators



Re mount Radiators and Install Thermostatic Valves

5.2.1 Energy Savings

The energy savings were calculated on the basis of the following parameters:

Average Wall Thickness and Average Wall Thermal Conductivity – These two parameters were obtained from the building technical characteristics.

Average Wall Temperature – Outside Surface and Inside Surface of the wall were measured behind baseline radiators (i.e. left temporarily without thermal insulation), and behind the radiators with thermal insulation.

Average Heat Loss - The wall thickness, wall thermal conductivity, inside and outside surface temperature values, and total thermal shields area were used to estimate heat loss through the wall.

The calculated energy saving is summarized in the following table, which also shows a comparison with the saving estimate made before the installation, during the rapid assessment.

Annual Energy and Cost Saving		
	For Radiator Shield	
	Estimated	**Actual**
District Heating Energy Saving, kWh/Yr	6,512	20,645
Electric Energy Saving, kWh/Yr		
District Heating Cost Saving, $/Yr	$148	$743
Electric Cost Saving, $/Yr		
Total Cost Saving, $/Yr	$148	$743
Implementation Cost, $	$901	$901
Simple Payback Period, Yrs	6.1	1.2