Miscellaneous Industries: Case 5
Residential Building Construction in Beijing

Introduction

Energy consumption in buildings accounts for 25 percent of total energy consumption in China. In the colder regions of northern China, energy consumption in buildings accounts for 30 to 40 percent of the total. Regions classified as heating regions include those regions for which the average daily temperature is less than or equal to 5^{o}C more than 90 days per year. Regions meeting that criteria include Northeast China, North China, and Northwest China. Within those regions, there are 3.1 billion m^2 of heating area —34.9 percent of that area is supplied by central heating systems with coal consumption of 46.5 million tce and 65.1 percent of the area is supplied without central heating (typically using heating stoves) with coal consumption of 47.6 million tce. Heating of buildings in those three regions accounts for nine (9) percent of total energy consumption in China.

As a rule, buildings in China tend to be inefficient in terms of heat utilization. As indicated in Table 1, a comparison of comparable buildings in northern China with Canadian and northern European buildings having similar climates suggests that differences in heat loss are substantial. Heat transfer coefficients are 4-5 times higher for external walls, 2.5-5.5 times higher for roofing structures, 1.5-2.2 times higher for external windows, and 3-6 times the difference in air tightness of structures.

Table 1. Heat Transfer Coefficients for External Walls and Roofs in Selected Chinese Cities and International Comparisons

City/Country	External Walls	Roofs
1. China		
Beijing		
a. Base case	6.40	1.26
b. Conservation case	6.40	0.91
Harbin		
a. Base case	3.26	0.77
b. Conservation case	3.26	0.64
2. Sweden	2.00	0.12
3. Canada		
a. Weather like Harbin	2.22	0.31
b. Weather like Beijing	2.86	0.40
4. Denmark	2.90	0.20
5. England		0.45

Half of the heat loss from buildings is attributed to windows, and a fourth of the loss is attributed to external walls. To address the issue of energy conservation in buildings, the *Energy Saving Design Standard for Buildings* was published in 1986 by the Ministry of Construction. The report requires that new housing construction save 30 percent of energy requirements from the 1980 and 1981 base. The report required cost effective investment alternatives and local implementation by 1990. By the year 1996, energy standards are to be raised to 50 percent above the early 1980s base. Based upon these new standards, it is estimated that up to 879.6 million tons of coal could be saved by the year 2005.

Early pilot projects were constructed in Beijing, Xian, and Harbin. In Beijing, the *Detailed Rules and Regulations on Energy Savings for Buildings in Beijing Area* were implemented. The first project built under the new standards was the northern section of Anyuanbeili Residential Quarter located at the Asian Games Village in Beijing. The project including 132,000 m^2 of floor space within the 17 block housing complex was in operation by 1990. It is estimated the Quarter has achieved energy savings of 34.1 percent.

Technology Assessment

Energy-saving design was incorporated into the northern section of the Quarter accounting for 86 percent of the area's square footage. Priority was given to a number of design elements including: windows and doors, external walls, roofing structures, stairwells, and pipelines. Specific approaches included:

External Walls - The Energy Saving Design Standards for Buildings in Beijing requires thermal resistance in external walls to be up to that of 490 mm brick walls. Composite materials with insulation were used in various combinations. For high rise buildings, 250 mm thick walls were used: for multi-story and public buildings, 240-360 mm thick walls were used. The wall structures satisfied heat loss criteria with reduced thickness and weight and with more usable floor space.

Thermal Insulation - Rather than solid bricks typically used in construction, air pockets were created between the external wall and the inner surface board plastered with insulation. Three different insulation materials including polystyrene board, rock-wool board, and glass-wool board were used. Different types of surface board and slab were used as well. Insulating mortar also was plastered on the inside of the external brick. An air retaining gypsum board then was applied for additional thermal insulation.

Four methods were used for thermal insulation outside the external walls. External insulation methods used in various parts of the Quarter included:

- aerated concrete blocks attached to external concrete walls,
- polystyrene boards reinforced with EC mortar on external brick walls,
- a layer of rock-wool with steel mesh attached to external brick walls, and
- a layer of air retaining pearlite mortar spayed on the external surface.

Doors and Windows - To decrease heat transmission loss through windows and doors, 25A hollow, air-tight steel exterior windows were used. The project also used for the first time, single frame/double glass steel and steel/plastic frame windows. External doors and balcony doors were filled with thermal insulation material.

Roofing/Flooring - On flat roof structures, regenerated polystyrene boards were used to supplement traditional aerated concrete block surfaces. Under sloping roofs, polystyrene boards or glass ceiling facings were used along with high efficiency thermal insulation. In other cases, thermal air barriers were alternated with aerated concrete slabs. Polystyrene boards were plastered under the building floor as insulation.

Heating Pipes - The project used cyanogen-polyester plastic thermal pipes to reduce heat loss in transmission. Thermal expansion valves were adopted to control indoor temperature in the two-line heating systems in some buildings in the quarter.

Financial Analysis

Investment costs with and without the project are shown in Table 2. It is estimated that building costs for the project were 1.8 percent higher than costs using traditional building practices increasing from 417.82 to 425.21 yuan per square meter. Cost differentials were higher for multi-story and public buildings (6.3 and 4.8 percent differentials) and lower for high rise buildings (1.0 percent differential).

Table 2. Investment With and Without Project (1,000 yuan)

		With Project		Without Project	
Item	Total Bldg. Area (m^2)	Unit Costs (Yuan/m^2)	Total Costs	Unit Costs (Yuan/m^2)	Total Costs
1.High-rise bldg.	104625.70	435.82	45597.97	431.40	45135.53
2.Multi-story bldg.	8373.60	345.19	2890.48	324.77	2719.49
3.Public bldg.	18377.86	401.24	7373.94	382.93	7037.48
4.Sub-total	131377.16	1182.25	55862.40		54892.50
5.Heat network			284.10		253.30
6.Total			56146.50		55145.80

Annual operating costs are projected to decrease by 34.6 percent with the project from 1.01 million to 659 thousand yuan. Coal use decreases from 4,300 to 2,814 tons, while coal costs decrease from 645,000 to 422,100 yuan. Power and water usage are estimated to decrease by a comparable ratio.

Table 3. Operating Costs With and Without Project (1,000 yuan)

Items	With Project	Without Project
Total operating costs	658.50	1006.20
1. Coal costs	422.10	645.00
2. Power costs	79.00	125.80
3. Water supply	32.90	50.30
4. Other costs	124.50	22212.00
*Coal price is 159 yuan/t		
Total coal use (t)	2814.00	4300.00

The financial cash flow with and without the project is shown in Table 4. The analysis is based on a three year construction period with differential investment costs of 1.001 million RMB yuan. At project completion, annual non-coal operating cost savings amount to 124,800 yuan. The net present value for the project is - 1.082 million yuan reflecting actual cost savings with the project. The internal rate of return is 26.4 percent and the payback period is six years (three years after project completion).

Table 4. Financial Cash Flow With and Without Project (1,000 yuan)

	With Project			Without Project			Incremental			
Year	Investmen	Coal	Other Costs	Investme	Coal Use	Other Costs	Investment	Coal Use	Other Costs	Total
1	16844.00			16543.70			300.30	0.00	0.00	300.30
2	28073.30			27.572.9			500.40	0.00	0.00	500.40
3	11229.20			11029.20			200.00	0.00	0.00	200.00
4		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
5		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
6		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
7		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
8		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
9		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
10		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
11		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
12		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
13		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
14		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
15		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
16		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
17		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
18		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
19		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
20		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
21		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
22		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
23		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
24		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
25		422.10	236.40		645.00	361.20	0.00	(222.90)	(124.80)	(347.70)
Total	56146.50	9286.20	5200.80	55145.80	14190.00	7946.40	1000.70	(4903.80)	(2745.60)	(6,648.70)
PV	45411.87	2296.78	1286.33	44602.47	3509.64	1965.40	809.40	(1212.87)	(679.08)	(1,082.55)
IRR										26.35%

Energy Conservation

Table 5 shows energy use indices with and without the project. Coal use per square meter decreases by 45.9 percent in high rise buildings and by 32.0 percent in multi-story buildings. Overall, as indicated in Table 6 below, the project results in a 34.6 percent decrease in coal usage from 4,300 to 2,841 tons per year with a comparable decrease in power usage.

Table 5. Energy Use Indices With and Without Project

	With Project		Without Project	
Items	Thermal Use W/m^2	Coal Use kg/m^2	Thermal Use W/m^2	Coal Use kg/m^2
1. High-rise building	19.86	13.66	35.67	25.23
2. Multi-story building	25.73	17.70	37.82	26.02

Environmental Benefits

With energy conservation construction practices, annual CO_2 emissions decrease from 3246 to 2145 tons, a 33.9 percent decrease. SO_2 emissions decrease from 76.2 to 50.3 tons, while TSP decreases from 1.2 to 1.1 tons per year (Table 6).

Table 6. Environmental Impacts With and Without Project

Item	Unit	With Project	Without Project	Reduction
1.Coal	tce	2841.00	4300.00	1459.00
2.CO_2	t	2144.70	3246.11	1101.41
3.SO_2	t	50.34	76.19	25.85
4.TSP	t	1.07	1.2	0.56

Economic/Environmental Assessment

Table 7 depicts the economic/environmental cash flow for the project. Using economic prices, the rate of return for the project increases from 23.15 to 23.76 percent reflecting higher energy prices. The inclusion of local environmental benefits increases the rate of return to 24.07 percent. The incremental cost of CO_2 reduction is -143.46 RMB yuan per ton indicating that global environmental benefits are being realized at a negative economic cost. Net benefits per ton are a positive 143.46 yuan per ton increasing to 147.78 yuan per ton with local environmental benefits from reduced SO_2 and TSP emissions included.

Table 7. Incremental Economic/Environmental Cash Flow Analysis (1000 yuan)

Year	Total Costs	Emissions Global CO2 (t)	Emissions Local SO2 (t)	Emissions Local TSP (t)	Econ Value of Local Pollution Reduction	Net Economic/ Environmental Benefits
1	300.30	0.00	0.00	0.00	0.00	(300.30)
2	500.40	0.00	0.00	0.00	0.00	(500.40)
3	200.00	0.00	0.00	0.00	0.00	(200.00)
4	(306.76)	(1,101.41)	(25.85)	(0.55)	4.76	311.52
5	(306.76)	(1,101.41)	(25.85)	(0.55)	4.76	311.52
6	(306.76)	(1,101.41)	(25.85)	(0.55)	4.76	311.52
7	(306.76)	(1,101.41)	(25.85)	(0.55)	4.76	311.52
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22	(306.76)	(1,101.41)	(25.85)	(0.55)	4.76	311.52
23	(306.76)	(1,101.41)	(25.85)	(0.55)	4.76	311.52
24	(306.76)	(1,101.41)	(25.85)	(0.55)	4.76	311.52
25	(306.76)	(1,101.41)	(25.85)	(0.55)	4.76	311.52
Total	(5,748.02)	(24,231.10)	(568.70)	(12.07)	104.70	5,852.72
PV	(859.78)	(5,993.13)	(140.66)	(2.99)	25.90	885.67
IRR	23.76%					24.07%

	CO2	COAL
Total Incremental Cost/Ton of CO2 Reduction (yuan at 12%)	(143.46)	(108.30)
At RMB/US$ = 5.50	($26.08)	($19.69)
Total Net Benefits/Ton of CO2 Reduction (yuan at 12%)	143.46	108.30
At RMB/US$ = 5.50	$26.08	$19.69
Net Benefits Incl'g Local Env. Benefits/Ton of CO2 Reduction	147.78	111.56
At RMB/US$ = 5.50	$26.87	$20.28