

Miscellaneous Industries: Case 1 Coal Briquetting for Household and Industrial Use at Luanshan and Chongqing

Introduction

China is the largest producer and consumer of coal in the world. Currently, coal accounts for 76.1 percent of primary energy consumption in China with consumption subdivided between fuel coal at 88 percent and feedstock coal at 12 percent. Table 1 below depicts the relative distribution of coal consumption among use categories in China. Industrial furnaces and kilns account for 48.8 percent of coal consumption, power generation for 26.1 percent, and cooking stoves for 20.1 percent of the total. Steam locomotive and thermal power use collectively account for the remaining five percent of consumption.

**Table 1. Consumption of Coal as Fuel by Use Category in China
(Percentage of Total)**

Use	Power Generation	Thermal Power	Steam Locomotive	Industrial Furnace/Kiln	Stoves & Cooking
Share (%)	26.1	2.4	2.6	48.8	20.1

While consumption levels in China remain high, relative fuel efficiencies remain low as indicated in Table 2. On average, heat efficiencies are 44 percent lower than is the case in industrialized countries. The heat efficiencies of industrial and residential furnaces in China average 55 percent compared with averages of 70 to 80 percent in industrialized countries. Comparative figures for thermal power generation are somewhat closer at 28 and 35 percent. For residential stoves and cooking, the gap of relative efficiencies between China and averages for industrial countries remains substantial at 28 versus 50 percent. Relative efficiencies are affected both by the technology in place and the quality of the coal used.

**Table 2. Average Heat Efficiencies for Combustion Equipment
in Industrialized Countries and China
(percent)**

Combustion Equipment	Industrial Countries	China
Industrial & Residential Furnaces	70-80*	55
Thermal Power Generation	35	28
Industrial Kilns	50-60	20-30
Locomotives	>25**	5-8
Residential Stoves/Cooking	60	15-20
Average	50	28

* Oil base furnaces

** Internal combustion engines

A second issue of particular concern is the environmental costs associated with heavy coal utilization. The National Atmospheric Quality Monitoring Network estimates that annual particulate emissions from coal combustion amount to 13.6 million tons,

accounting for 93 percent of particulate emissions in China. Sulfur dioxide emissions are estimated to be 14.8 million tons or 62 percent of total SO₂ emissions. At the same time, annual carbon dioxide emissions approximate one billion tons, almost 1/11th of the world's total emissions.

To promote fuel efficiency and to reduce air pollution, the State Council, Energy Ministry and National Environmental Protection Agency have promoted the use of coal briquetting. Currently, over 1000 kilns for briquetting have been constructed in China. Further expansion of coal briquetting operations have been central to both the Seventh and Eighth Five Year Plans.

On average, fuel savings using coal briquetting amount to 10-20 percent for furnaces, 10-15 percent for steam engines, and 20-25 percent for residential stoves and cooking. Ash reduction averages around 70 percent for furnaces and 60 to 80 percent for stoves. Currently, annual coal consumption for industrial boilers, steam locomotives, and kilns is about 500 million tons, while domestic and cooking stoves consume 200 million tons per year. The cases that follow examine a domestic honeycomb coal plant at Luanshan in Shandong and a plant producing briquettes for industrial boiler use at the Lishuwan plant in Chongqing.

Case Study 1: Domestic Coal Briquette Plant at Luanshan

The Luanshan briquette plant is part of the Shandong Linyi mining administration. The plant, located along the border between Rizhao City and Junan County, is a state owned enterprise with domestic honeycomb coal as its primary output. The plant has a productivity of 25 thousand tons and employs 20 workers. The plant was built with an investment of 590,000 yuan and provides briquette to 8,000 households.

Technology Assessment

The operation uses local anthracite coal with a heat content of 27,170 kJ/kg and a sulfur content of 1.5 percent. Lime is used as a neutralizing agent and gangue from coal washing operations is used as an adhesive in briquette production. Materials are screened with lump coal greater than 50 mm broken manually. The remaining material is fed through an iron separator to a crusher. Material less than 3 mm is mixed with water at 12-14 percent concentration. The mixture goes through leaching treatment for about 8-16 hours. The leached material then goes to the shaping bin for molding before drying. The heat content of the honeycomb coal is 19,771-20,000 kJ/kg.

Financial Analysis

Investment costs for the project amounted to 3.53 million RMB yuan as indicated in Table 3. Building and installation costs amounted to 746.6 thousand yuan. Principal equipment costs are for the honeycomb shaping mill (297,000 yuan), belt conveyors (174,000 yuan), crushers (70,000 yuan), and transformers (67,400 yuan).

Table 3. Investment With Project at Luanshan (1,000 yuan)

Items	Costs
1. Equipment	1,113.00
2. Buildings	511.60
3. Installation	235.00
4. Others	1,668.80
Total	3,528.40

The project is based on a plant producing 60,000 tons of domestic honeycomb coal per year to meet the demand for 36,000 households. As indicated in Table 4, coal as feed stock at 6.44 million yuan annually and 107.4 yuan per ton is the principal cost amounting to 89.2 percent of direct operating costs. Energy expenses amount to 284.9 thousand yuan (4.8 yuan per ton), sulfur fixation amounts to 240 thousand (4.0 yuan per ton), and labour amounts to 132 thousand (2.2 yuan per ton). Transfer payments of 630 thousand RMB yuan are paid to cover sales taxes and depreciation.

Table 4. Operating Costs and Benefits With Project at Luanshan (1,000 yuan)

Items	Unit	Price (Yuan)	Total Use	Total Cost (1000 yuan)	Unit Cost (yuan/t)
1. Salary & welfare	person	4000.00	33	132.00	2.20
a. Skilled	person	-	21	-	-
b. Unskilled	person	-	12	-	-
2. Raw material consumption				6441.00	107.35
a. Coal as feedstock	t	120.00	51000	6120.00	102.00
b. Striking materials	t	13.50	6000	81.00	1.35
c. Sulfur fixation	t	80.00	3000	240.00	4.00
3. Energy use	tce			284.85	4.75
a. Water	t	0.50	900	0.45	0.01
b. Power	mwh	400.00	525	210.00	3.50
c. Fuel oil	t	3720.00	20	74.40	1.24
4. Other costs				361.20	6.02
a. Repairs & maintenance costs				38.40	0.64
b. Management costs				22.80	0.38
c. Sales costs				300.00	5.00
5. Transfers (other costs not shown in cash flow table)				630.00	10.50
a. Sales taxes				336.00	5.60
b. Depreciation				294.00	4.90
6. Total costs					
a. With transfers				7487.85	124.80
b. Without transfers				6857.85	114.30
7. Sales price		160.00		-	-
8. Sales income				9600.00	160.00
9. Net income				2112.15	35.20
10. Onduty materials				200.00	3.33

Annual briquette yield(t) 60,000 tons

Table 5 depicts the project financial cash flow for the project. The project has a positive cash flow by the second year with a payback period of three years. The facility has an expected lifetime of 10 years with a net present value after year 11 of 8.68 million yuan. The internal rate of return for the project is 63.4 percent. With sales taxes removed the internal rate of return declines to 54.1 percent. In either event, the project offers a high rate of return on investment.

Table 5. Financial Cash Flow With Project at Luanshan (1,000 yuan)

Year	Investment			Operating Costs					Sub-total	Total costs	Total benefit	Net Benefit (Tax-free)	Net Benefit (With tax)
	Equipment & installation	On duty materials	Sub-total	Raw materials	Energy costs	Repair & maint	Salary & others						
1	3528.40	200.00	3728.40						3728.40			(3728.40)	(3728.40)
2			0.00	6441.00	284.85	61.20	432.00	7219.05	7219.05	9600.00	2380.95	2044.95	2044.95
3			0.00	6441.00	284.85	61.20	432.00	7219.05	7219.05	9600.00	2380.95	2044.95	2044.95
4			0.00	6441.00	284.85	61.20	432.00	7219.05	7219.05	9600.00	2380.95	2044.95	2044.95
5			0.00	6441.00	284.85	61.20	432.00	7219.05	7219.05	9600.00	2380.95	2044.95	2044.95
6			0.00	6441.00	284.85	61.20	432.00	7219.05	7219.05	9600.00	2380.95	2044.95	2044.95
7			0.00	6441.00	284.85	61.20	432.00	7219.05	7219.05	9600.00	2380.95	2044.95	2044.95
8			0.00	6441.00	284.85	61.20	432.00	7219.05	7219.05	9600.00	2380.95	2044.95	2044.95
9			0.00	6441.00	284.85	61.20	432.00	7219.05	7219.05	9600.00	2380.95	2044.95	2044.95
10			0.00	6441.00	284.85	61.20	432.00	7219.05	7219.05	9600.00	2380.95	2044.95	2044.95
11			0.00	6441.00	284.85	61.20	432.00	7219.05	7219.05	9600.00	2380.95	2044.95	2044.95
Total	3528.40	200.00	3728.40	6441.00	2848.50	612.00	4320.00	72190.50	75918.90	96000.00	20081.10	16721.10	16721.10
PV	3150.36	178.57	3328.93	32493.83	1437.02	308.74	2179.37	36418.97	39747.90	48430.48	8682.59	6987.52	6987.52
											63.39%	54.12%	

Briquette break even price is 131.32 yuan/ton

User costs with and without the project are shown in Table 6. The key in terms of user costs is increased fuel efficiency with coal briquettes which is double the relative efficiency of conventional coal (30 percent versus 15 percent). The increased fuel efficiency offsets the higher price and lower heat value per unit weight for coal briquettes. On balance, annual coal usage decreases by 31.3 percent from 2.40 to 1.65 tons and annual fuel costs decrease by 8.3 percent from 288 to 264 yuan. The annual fuel cost savings are offset partly by the cost of a briquette stove (18.50 yuan) and the repair costs for the stove incurred every other year (3.00 yuan).

Table 6. User Costs With and Without Project at Luanshan

Items	With project	Without project	Incremental
1. Annual coal use (t)	1.65	2.40	0.75
2. Coal heat value (kcal/kg)	3951.52	4547.28	595.76
3. Price of coal (yuan/t)	160.00	120.00	(40.00)
4. Annual fuel costs (yuan)	264.00	288.00	24.00
5. Efficiency of coal use (%)	30.00	15.00	(15.00)
6. Total energy use (tce)	0.28	0.23	(0.05)
7. Briquetter stove price (yuan)	18.50		(18.50)
8. Stove repairs costs (yuan)	3.00		(3.00)

The incremental cash flow from the user's perspective is shown in Table 7. As indicated above, annual fuel costs with the project decrease from 288 to 262 yuan. Stove costs amount to 18.50 yuan while bi-annual repair costs amount to 3.00 yuan. With an expected lifetime of 10 years for the stove, the project yields a present value of cost savings of 112,800 RMB yuan. The payback period is two years.

Table 7. User's Cash Flow With and Without Project at Luanshan (1,000 yuan)

Year	With Project			Without Project			Energy Use (tce)		
	Investment	Coal Use	Total Cost	Investment	Coal Use	Total Cost	Incremental Cost	With Project	Without Project
1	18.50	264.00	282.50		288.00	288.00	(5.50)	0.28	0.23
2		264.00	264.00		288.00	288.00	(24.00)	0.28	0.23
3	3.00	264.00	267.00		288.00	288.00	(21.00)	0.28	0.23
4		264.00	264.00		288.00	288.00	(24.00)	0.28	0.23
5	3.00	264.00	267.00		288.00	288.00	(21.00)	0.28	0.23
6		264.00	264.00		288.00	288.00	(24.00)	0.28	0.23
7	3.00	264.00	267.00		288.00	288.00	(21.00)	0.28	0.23
8		264.00	264.00		288.00	288.00	(24.00)	0.28	0.23
9	3.00	264.00	267.00		288.00	288.00	(21.00)	0.28	0.23
10		264.00	264.00		288.00	288.00	(24.00)	0.28	0.23
Total	30.50	2640.00	2670.50	0.00	2880.00	2880.00	(209.50)	2.79	2.34
NPV	22.79	1491.66	1514.45	0.00	1627.26	1627.26	(112.81)	1.58	1.32
Useful energy cost: (yuan/tce)			959.22			1231.51	272.28		

Coal break-even price is about 99.98 yuan/ton when briquetter price is 40 yuan higher than its cost

Energy Conservation

The project uses 51,000 tons of coal per year as feed stock with substantially smaller inputs of striking materials, power, and oil used as indicated in Table 8. Energy use with the project amounts to 34,112 tce; energy use without the project is 55,224 tce. Project energy savings amount to 21,112 tce.

Table 8. Total Energy Use With Project (Luanshan Case)

Items	Unit	Co-factor	Use	tce	kgce/t
1. Coal as feedstock	t	0.650	51000.00	33130.19	552.17
2. Striking materials	t	0.123	6000.00	740.00	12.33
3. Water	t	1.212	900.00	0.11	0.00
4. Power	mwh	0.404	525.00	212.10	3.54
5. Oil	t	1.480	20.00	29.60	0.49
Total			58445.00	34111.99	568.53
Without project coal use			85010.91	55224.06	
Energy savings with project				21112.07	

Environmental Benefits

Per unit and total atmospheric emissions with and without the project are indicated in Table 9. Annual CO₂ emissions are projected to decrease by 38.2 percent from 41,689 to 25,751 tons. Other emissions reductions are more substantial still. SO₂ emissions are reduced by 62.9 percent, while TSP and NO_x emissions decrease by 75.3 and 52.3 percent, respectively.

Table 9. Environmental Impacts With and Without Project at Luanshan

Items	With Project	Without Project	Incremental
1. SO ₂ emission (kg/tce)	3.86	6.43	(2.57)
2. TSP emission (kg/tce)	11.72	29.30	(17.58)
3. NO _X emission (kg/tce)	4.61	5.97	(1.36)
4. CO ₂ emission (kg/tce)	651.00	651.00	0.00
5. SO ₂ total emission (t)	131.67	355.09	(223.42)
6. TSP total emission (t)	399.79	1618.07	(1218.27)
7. NO _X total emission (t)	157.26	329.69	(172.43)
8. CO ₂ total emission (t)	25751.49	41689.20	(15937.71)

Case Study 2: Lishuwan Boiler Briquette Pilot Plant in Chongqing

The Lishuwan briquette pilot project is located in the Shapingba Development Zone of Chongqing City. The plant is a subsidiary of Congealing Fuel Company, a publicly owned enterprise. The Lishuwan plant produces coal briquettes for use in industrial boilers.

The city of Chongqing has a population of 15 million and a heavy industrial base with 2000 industrial boilers in operation. Annual coal consumption for industrial boilers amounts to 12 million tons. Coal that is used in Chongqing tends to be high in sulfur content ranging as high as 7-8 percent. The problem is compounded by local climatic conditions that allow for poor air circulation. As a result, particulates and SO₂ do not dissipate readily, and local air quality conditions are poor. To address this problem, the local fuel company began to design and plan a pilot briquette operation. Construction on the plant began in 1988 with completion scheduled for late 1992. As of this writing, the plant has still not begun operations.

Technology Assessment

The process technology is similar to that employed at Luanshan. Raw coal is brought in and screened. Lump coal above 30 mm is crushed before the coal is combined and blended with lime to neutralize the sulfur content. The material then passes through an iron separator and is fine crushed and sent to the agitator. Separately, caustic soda, weathered coal, and lignin liquor are combined to form an adhesive agent. The materials are combined in a reaction tank and put under pressure before being sent to the agitator where they are mixed with coal. The mixture is then rolled, shaped, and dried. The caustic soda, weathered coal, lignin liquor as well as the lime help to weatherproof the coal. An additional weatherproofing is applied at the end of the process to maintain performance especially under wet weather conditions.

Financial Analysis

Table 10 shows project investment for the briquetting plant at Chongqing. The project is projected to cost 19.89 million RMB yuan. Building costs are projected at 5.37 million yuan, while equipment costs are projected at 7.01 million yuan.

Table 10. Investment With Project at Chongqing (1,000 yuan)

Items	Value
1.Equipment	7010.00
2.Buildings	5370.00
3.Installation	1300.00
4.Others	6205.50
Total	19885.50

Total operating costs amount to 29.05 million RMB yuan as indicated in Table 11. The largest single cost is coal as feedstock which at 20.57 million RMB yuan amounts to 70.8 percent of operating costs. The majority of the remaining costs are accounted for by energy use (2,498 yuan), transfer payments (2,368 yuan), and repairs, maintenance, and management costs (1,922 yuan).

Table 11. Operating Costs With Project at Chongqing (1,000 yuan)

Items	Unit	Price (Yuan)	Total Use	Total Costs	Average
1. Salary & welfare	person	3600.00	160.00	576.00	2.88
a. Skilled	person	3600.00	95.00	342.00	1.71
b. Unskilled	person	3600.00	65.00	234.00	1.17
2. Raw material consumption				21086.54	105.43
a. Coal as feedstock	1000 t	121.00	170.00	20570.00	102.85
b. Striking materials	1000 t	16.79	26.00	436.54	2.18
c. Sulfur fixation	1000 t	20.00	4.00	80.00	0.40
3. Energy use				2498.12	12.49
a. Water	1000 t	0.60	1.00	0.60	0.00
b. Power	mwh	600.00	3945.00	2367.00	11.84
c. Fuel oil	1000 t	3720.00	35.00	130.20	0.65
d. Fuel coal	1000 t	121.00	2.63	0.32	0.00
4. Other costs				2522.00	
a. Repairs & maintenance costs				1000.00	5.00
b. Management costs				922.00	4.61
c. Sales costs				600.00	3.00
5. Transfers				2368.00	
a. Sales tax				1648.00	8.24
b. Depreciation				720.00	3.60
6. Total costs					
a. With transfers				29050.66	145.25
b. Without transfers				26682.66	133.41
7. Sales income		26.59		34000.00	170.00
8. Net income				31632.00	158.16
1. Annual briquetter yield	1000t	26.59	200.00	5318.00	

* Sales price yuan/t 160.00

The financial cash flow with the project is shown in Table 12. Net present value for the project is 16.12 million RMB yuan. The payback period for the project is five years (five years after the construction phase of the project). The internal rate of return is 28.95 percent. This return is substantially lower than the return at Luanshan due to higher per unit operating costs.

Table 12. Financial Cash Flow Analysis With Project at Chongqing (1,000 yuan)

Year	Investment	Operating Costs				Subtotal	Total Costs	Total Benefits	Net Benefits
		Raw Materials	Energy Costs	Repairs/ Maint.	Salary/ Others				
1	23285.5					0.0	23285.5		-23285
2	0.0	21086.5	2498.1	1922.0	1176.0	26682.7	26682.7	34000.0	7317.3
3	0.0	21086.5	2498.1	1922.0	1176.0	26682.7	26682.7	34000.0	7317.3
4	0.0	21086.5	2498.1	1922.0	1176.0	26682.7	26682.7	34000.0	7317.3
5	0.0	21086.5	2498.1	1922.0	1176.0	26682.7	26682.7	34000.0	7317.3
6	0.0	21086.5	2498.1	1922.0	1176.0	26682.7	26682.7	34000.0	7317.3
7	0.0	21086.5	2498.1	1922.0	1176.0	26682.7	26682.7	34000.0	7317.3
8	0.0	21086.5	2498.1	1922.0	1176.0	26682.7	26682.7	34000.0	7317.3
9	0.0	21086.5	2498.1	1922.0	1176.0	26682.7	26682.7	34000.0	7317.3
10	0.0	21086.5	2498.1	1922.0	1176.0	26682.7	26682.7	34000.0	7317.3
11	0.0	21086.5	2498.1	1922.0	1176.0	26682.7	26682.7	34000.0	7317.3
Total	23285.5	210865.4	24981.2	19220.0	11760.0	266826.6	290112.1	340000.0	49887.9
PV	20790.6	106378.3	12602.6	9696.2	5932.7	134609.8	155400.4	171524.6	16124.2
									28.95%

Briquetter break even price is 154.02 yuan/ton.

The user's cash flow analysis is shown in Table 13. Coal use with the project increases more than investment expenditures fall. Although annual boiler and repair costs are higher with the project (56,000 versus 44,180 yuan), annual savings in coal costs of 20.5 percent more than make up for these initial expenditures. The present value of incremental costs to users amounts to 181,470 yuan.

Table 13. Users Cash Flow Analysis With and Without Project (1,000 yuan)

Year	With Project			Without Project			Incremental
	Investment	Coal Use	Total Costs	Investment	Coal Use	Total Costs	
1	44.18	213.90	258.07	56.00	169.96	225.96	32.12
2	44.18	213.90	258.07	56.00	169.96	225.96	32.12
3	44.18	213.90	258.07	56.00	169.96	225.96	32.12
4	44.18	213.90	258.07	56.00	169.96	225.96	32.12
5	44.18	213.90	258.07	56.00	169.96	225.96	32.12
6	44.18	213.90	258.07	56.00	169.96	225.96	32.12
7	44.18	213.90	258.07	56.00	169.96	225.96	32.12
8	44.18	213.90	258.07	56.00	169.96	225.96	32.12
9	44.18	213.90	258.07	56.00	169.96	225.96	32.12
10	44.18	213.90	258.07	56.00	169.96	225.96	32.12
Total	441.76	2138.96	2580.73	560.00	1699.56	2259.56	321.17
PV	249.61	1208.56	1458.17	316.41	960.29	1276.70	181.47

Energy Conservation

Table 14 shows user's energy consumption with and without the project. Boiler efficiency increases from 55 to 65 percent. As a result, energy use decreases by 15.4 percent from 772.4 to 653.6 tce, and annual fuel cost increases from 169,960 to 213,900 yuan.

Table 14. User's Energy Consumption With and Without Project

Items	With Project	Without Project	Incremental
1. Boiler capacity (t/h)	2.00	2.00	0.00
2. Efficiency of boiler	0.65	0.55	0.10
3. Annual energy use (tce)	653.57	772.40	(118.83)
4. Annual coal use (t)	1336.85	1404.59	(67.74)
5. Annual fuel cost (1000 yuan)	213.90	169.96	43.94
6. Boiler price (1000 yuan)	350.00	350.00	0.00
7. Boiler's lifespan (year)	8.50	7.00	1.50
8. Annual boiler cost (1000 yuan)	41.18	50.00	(8.82)
9. Annual repair cost (1000 yuan)	3.00	6.00	(3.00)
10. Total annual cost (1000 yuan)	258.07	225.96	32.12
11. Coal Price (yuan/t)	160.00	121.00	39.00

* User's coal briquetter break-even price is 136 yuan/t.

Environmental Benefits

Table 15 depicts environmental impacts associated with the project. CO₂ emissions decrease by 12.8 percent from 87,234 to 76,107 tons. SO₂ emissions decrease by 59.5 percent, while TSP and NO_x emissions are reduced by 66.9 and 33.1 percent, respectively.

Table 15. Environmental Impacts With and Without Project

Items	With Project	Without Project	Incremental
1. Sulfur content (%)	5.10	6.00	(0.90)
2. Total coal use (1000 t)	200.00	210.13	(10.13)
3. Total energy use (1000 t)	100.82	115.56	(14.74)
4. SO ₂ emission (t)	4335.00	10716.86	(6381.86)
5. TSP discharge (t)	1391.27	4206.21	(2814.94)
6. NO _x emission (t)	463.76	693.33	(229.58)
7. CO ₂ emission (t)	76107.27	87233.71	(11126.44)
* Emission factors:	With	Without	
CO ₂ (kg/tce)	754.91	754.91	
TSP (kg/tce)	13.80	36.40	
NO _x (kg/tce)	4.60	6.00	

Economic/Environmental Assessment

Table 16 depicts the economic/environmental cash flow for the project. Using economic prices, the internal rate of return increases from 63.08 to 63.44 percent reflecting slightly higher coal prices. Including local air pollution benefits with the project, the rate of return increases to 66.68 percent. The incremental cost of CO₂ reduction is 496.03 RMB yuan per ton. Still, net benefits per ton CO₂ reduction are positive at 106.31 yuan increasing to 113.66 yuan per ton with local environmental benefits included.

Table 16. Incremental Economic/Environmental Cash Flow Analysis (1000 yuan)

Year	Total Costs	Total Benefits	Net Benefits	Global	Emissions	Local	Econ Value	Net	
				CO2 (t)	Local SO2 (t)	TSP (t)	of Local Pollution Reduction	Economic/Environmental Benefits	
1	3,728.40	0.00	(3,728.40)	0.00	0.00	0.00	0.00	(3,728.40)	
2	7,205.85	9,600.00	2,394.15	(15.94)	(223.42)	(1,218.27)	117.10	2,511.25	
3	7,205.85	9,600.00	2,394.15	(15.94)	(223.42)	(1,218.27)	117.10	2,511.25	
4	7,205.85	9,600.00	2,394.15	(15.94)	(223.42)	(1,218.27)	117.10	2,511.25	
5	7,205.85	9,600.00	2,394.15	(15.94)	(223.42)	(1,218.27)	117.10	2,511.25	
6	7,205.85	9,600.00	2,394.15	(15.94)	(223.42)	(1,218.27)	117.10	2,511.25	
7	7,205.85	9,600.00	2,394.15	(15.94)	(223.42)	(1,218.27)	117.10	2,511.25	
8	7,205.85	9,600.00	2,394.15	(15.94)	(223.42)	(1,218.27)	117.10	2,511.25	
9	7,205.85	9,600.00	2,394.15	(15.94)	(223.42)	(1,218.27)	117.10	2,511.25	
10	7,205.85	9,600.00	2,394.15	(15.94)	(223.42)	(1,218.27)	117.10	2,511.25	
Total	68,581.05	86,400.00	17,818.95	(143.44)	(2,010.77)	(10,964.45)	1,053.88	18,872.83	
PV	37,609.79	45,670.71	8,060.92	(75.82)	(1,062.88)	(5,795.77)	557.08	8,618.00	
IRR			63.44%					66.68%	
					<u>CO2</u>	<u>COAL</u>			
Total Incremental Cost/Ton of CO2 Reduction (yuan at 12%)					496.03	350.09			
At RMB/US\$ = 5.50					\$90.19	\$63.65			
Total Net Benefits/Ton of CO2 Reduction (yuan at 12%)					106.31	75.04			
At RMB/US\$ = 5.50					\$19.33	\$13.64			
Net Benefits Incl'g Local Env. Benefits/Ton of CO2 Reduction					113.66	80.22			
At RMB/US\$ = 5.50					\$20.67	\$14.59			

Miscellaneous Industries: Case 2

Steam Coal Washing and Screening at Datong and Xuzhou

Introduction

Coal accounts for 75 percent of primary energy production in China. In 1991, China produced 1.08 billion tons of coal, with 0.48 billion tons produced at mines under the control of the National Coal Cooperative. Despite some progress in recent years relative efficiencies of coal utilization in China remain low by international standards and currently average less than 30 percent in terms of thermal energy conversion. Coal requirements per output value also remain high.

The sheer volume of coal consumption in China has created serious air pollution problems with both local and global implications. Given the level of industrialization now occurring in China, coal utilization must be accompanied by greater energy efficiency, and the coal that is burned must be burned cleaner than has been the case in the past. One option to this problem is to improve coal quality through coal washing, screening and processing to improve energy efficiency as well as to reduce the per unit level of emissions.

By the end of 1991, 179 coal washing plants had been established in China with a design capacity of 241.7 million tons as indicated in Table 1. Annual production amounted to 195.8 million tons of processed coal (18.1 percent of total production). Steam washed coal accounts for 68.5 million tons per year, 35.0 percent of washed coal and 6.3 percent of total production. Coke coal washing plants account for the remaining 65 percent of coal washing production and 11.7 percent of total production.

**Table 1. Capacity and Annual Production of Coal Washing Plants in China, 1991
(million/tons)**

	Number of Plants	Design Capacity	Annual Production
Steam coal	64	82.31	68.5
Coke coal	115	159.35	127.3
Total coal	179	241.66	195.8

Coal washing serves several purposes removing debris and mineral impurities as well as reducing sulfur and ash content. The need for coal washing and screening has become increasingly important with the development of mechanized coal mining in China. By 1991, mechanization in state controlled mines had increased to 65 percent. Because mechanized mining is less selective, foreign matter and ash content typically are higher. A recent survey of mechanized mine operators found that mechanized mining is 5-7 percent higher in ash content than explosive mining methods.

The ash content in raw coal from state controlled mines is as high as 29.6 percent. With coal washing, ash content drops by 39 percent to 18.2 percent content. Among steam coal operations, the ash content of raw coal averages 27.4 percent, while the ash content of washed coal drops to 21.5 percent, a 21 percent decrease.

The benefits of coal washing include improved energy efficiency, transportation cost savings and air pollution benefits. Energy efficiency studies indicate that power plant efficiency is decreased by 0.2 percent for each percentage increase in ash content. Given average ash reductions of 5-7 percent attributed to washing for steam coal and still higher reductions for coking coal, the overall efficiency savings could be substantial.

Among commodity categories, coal accounts for the highest freight volume representing 40 percent of rail freight and the longest transportation distance averaging 510 km per haul. Because coal washing and processing reduces both volume and weight, transportation costs are reduced as well. In 1991, 196 million tons of coal were washed from which 43 million tons of gangue was removed, a 22.1 percent weight loss. For steam coal, 69 million tons were processed with a weight loss of 11.9 percent.

In terms of atmospheric emissions, the average sulfur content of Chinese coal is 1.72 percent, with high sulfur coal accounting for 52.7 percent of the total stock. Coal washing can remove 40 percent of the sulfur in high sulfur coal and 50 percent of the pyritic sulfur. Given environmental and public health concerns relating to acid rain and H₂S, China's annual SO₂ emissions of 16 million tons must be addressed, and coal washing has been shown to be more cost effective in doing so than has flue gas desulfurization.

Case 1: Yanzishan Coal Washing/Screening Plant at Datong

Yanzishan coal mine under Datong Coal Mining Administration is located 27 km from Datong City in Shanxi Province. The Datong Coal Mining Administration produced 30 million tons of coal in 1991 with an average transportation distance of 1100 km. Yanzishan mine has a proven reserve of 375.5 million tons. The annual design capacity for coal washing at Yanzishan is 4 million tons, but in 1991 only 2.4 million tons were actually produced. The Sitai plant scheduled for completion in 1992 will increase capacity by an additional 5.3 million tons.

Raw coal mined at Yanzishan has an ash content of 13 percent, 1.3 percent sulfur and 13 percent volatile material. After the coal is washed and separated, lump coal above 13 mm is redirected for further separation, while coal under 13 mm is sold directly. The final products include washed lump coal (50-100mm), washed medium coal (25-50 mm), washed small coal (13-25 mm), and fine coal (less than 13 mm). Washed lump coal is used in paper mills, chemical plants, and steam locomotives. The fine coal is used in power plants and industrial boilers.

As indicated in Table 2, 41.8 percent of the processed coal is classified as small to large (lump) coal for which prices range from 43.90 to 50.10 yuan per ton. Powdered coal (less than 13 mm) accounts for 37.8 percent of the total. Fine and compressed slime (11.1 percent) for which a reduced value is derived and gangue (9.4 percent) for which no value is attributed account for the remainder of output. Raw coal in comparison commands a price of 27.80 yuan per ton as established by the National Price Administration, Ministry of Energy and National Coal Corporation. The weighted average of washed coal from the plant is 32.63 yuan per ton.

Table 2. Washed Coal Quality and Sales Price in Datong Case

Item	Total (%)	Ash (%)	Water (%)	Sulfur (%)	Heat Value (kcal/kg)	Price (yuan/t)	Share of Price (yuan)
1. Total feeder	100.00	16.86		1.38	6000.00	27.80	27.80
2. Total products	90.65	10.61	3.53	0.88	6434.85		32.63
a. Lump	9.72	6.95	6.40	0.46	6600.00	46.50	4.52
b. Medium	20.15	6.95	6.40	0.46	6600.00	50.10	10.10
c. Small	11.91	6.95	10.82	0.46	6600.00	43.90	5.23
d. Powder	37.75	13.38		1.27	6300.00	28.70	10.83
e. Fine slime	8.02	13.87		1.10	6300.00	18.00	1.44
f. Compressed slime	3.10	17.66		1.27	6200.00	16.30	0.51

Case 2: Quantai Coal Preparation Plant at Xuzhou

The Quantai Coal Mine under Xuzhou Coal Mining Administration is located 17.5 km northeast of Xuzhou City in Jiangsu Province. The Xuzhou Coal Mining Administration produced 13,539,000 tons of coal in 1991 with an average travel distance of 400 km. Quantai mine has proven reserves of 52.02 million tons with a design capacity of 900,000 tons per year. In 1991, mine production was 1.27 million tons of which a third of the coal was coking coal.

After construction of the preparation plant, the ash content of coal has been reduced to 20.2 percent compared to 30.1 percent for raw coal as indicated in Table 3. The ash content of fine coal drops to 12.6 percent, while powdered coal remains at 24.3 percent. The value of the coal varies considerably by size and eventual use. Fine coal, accounting for 31.2 percent of raw weight, sells for 66.60 for fine grade coal, while mixed lump coal sells for 55.70 yuan per ton. Screened powder coal which amounts to 53.4 percent of raw weight sells for 34.30 yuan per ton. Accounting for lower valued coal fine slime and waste gangue, the weighted average price for washed coal is 37.82 yuan per ton, compared to 26.90 yuan per ton for raw coal.

Table 3. Washed Coal Quality and Price in Xuzhou Case

Item	Total (%)	Ash (%)	Water (%)	Sulfur (%)	Heat Value (kcal/kg)	Price (yuan/t)	Share of Price (yuan)
1. Total feeder	100.00	30.36	7.57	0.50	4300.00	26.90	26.90
2. Total products	84.62	20.17	7.95	0.35	5035.15		37.82
a. Other fine coal	22.87	12.61	8.84	0.25	6300.00	66.60	15.23
b. Mixture lump	7.42	13.20	4.97	0.25	5900.00	55.70	4.13
c. Fine slime	0.93	26.75	23.93	0.50	3500.00	16.00	0.14
d. Coal powder	53.40	24.26	7.71	0.40	4400.00	34.30	18.32

Financial Analysis

Major production indicators at Datong and Xuzhou are shown in Table 4. At Datong, the annual yield is established at 4.5 million tons per year, the design capacity for the Yanzishan plant. At Xuzhou, a washed coal yield of 860,000 tons per year was used (900,000 tons design capacity * 84.6 percent yield.) Prices for raw and washed coal

at Datong are 38.92 and 44.38 yuan per ton. At Xuzhou, raw and washed coal prices are 37.66 and 52.96 yuan per ton, respectively.

Table 4. Major Production Indicators With and Without Project at Datong and Xuzhou

Items	Datong Case		Xuzhou Case	
	With Project	Without Project	With Project	Without Project
1. Total coal sales (1000 t)	4500.00	4500.00	860.00	860.00
a. Washed coal	1880.10		260.49	
b. Powder coal	1698.70		459.24	
c. Coal mud	500.40		8.01	
d. Waste rock	420.80		132.26	
2. Coal sales price (Yuan/t)	44.38	38.92	52.96	37.66
a. Washed coal	63.38		89.50	
b. Powder coal	40.18		48.02	
c. Coal mud	24.54		22.40	
d. Waste rock	0.00		0.00	
3. Coal price adjustment	1.40			

Investment costs for the two projects are shown in Table 5. The facility at Datong is the larger project with an investment cost of 64.4 million yuan. The majority of investment costs are building expenses (34.6 million yuan) followed by equipment purchase (14.8 million). Principal equipment purchases include screens, dense-denim separators and compressors. At Xuzhou, investment costs amount to 9.05 million yuan. Of that figure, the processing building cost is 3.25 million yuan, while equipment and installation amount to 3.01 million yuan.

Table 5. Investment With Project at Datong and Xuzhou (1,000 Yuan)

Items	Investment	
	Datong Case	Xuzhou Case
1. Buildings	34628.10	3247.00
2. Equipment	14745.20	2364.00
3. Installation	3225.10	649.00
4. Renovation		2550.00
5. Other	11816.00	240.00
Total	64414.40	9050.00

Operating costs and sales income for both projects are indicated in Table 6. The principal operating expense is the cost of coal (valued at shipment point). At Datong, raw material costs amount to 95.2 percent of total operating costs. At Xuzhou, the figure is 93.5 percent of operating costs.

Table 6. Operating Costs and Sales Income With Project at Datong and Xuzhou

Items	Datong Case		Xuzhou Case	
	Per Unit	Total	Per Unit	Total
1. Operating costs (1000 Yuan)	29.21	131445.00	28.78	24750.80
a. Raw material	27.80	125100.00	26.90	23134.00
b. Other materials	0.60	2700.00	0.48	412.80
c. Power	0.35	1575.00	0.59	507.40
d. Salary	0.09	405.00	0.48	412.80
e. Maintenance	0.37	1665.00	0.33	283.80
2. Sales income (1000 Yuan)	32.67	146818.22	37.83	32533.19
a. Washed coal	47.50	89295.48	63.93	16653.09
b. Powder coal	28.70	48752.69	34.30	15751.93
c. Coal mud	17.53	8770.05	16.00	128.16
d. Waste rock	0.00	0.00	0.00	0.00
3. Net income (1000 Yuan)	3.46	15373.22	9.05	7782.39

The incremental cash flow with and without the project for the Datong case is shown in Table 7. The net present value of the project is 15.6 million yuan. The internal rate of return is 18.8 percent with a payback period of six years. The returns on investment are sensitive to the price of coal which despite market reform continued to be low as of 1990. A 40 percent increase in the price of coal results in a net present value of 57.0 million yuan, an internal rate of return of 34.8 percent, and a payback period of five years.

Table 7. Incremental Cost Flow Analysis With and Without Project at Datong (million yuan)

Year	Investment Costs	Operating Costs	Total Costs	Sales Income	Net Benefits
1	64.41		64.41		(64.41)
2		131.45	131.45	146.82	15.37
3		131.45	131.45	146.82	15.37
4		131.45	131.45	146.82	15.37
5		131.45	131.45	146.82	15.37
6		131.45	131.45	146.82	15.37
7		131.45	131.45	146.82	15.37
8		131.45	131.45	146.82	15.37
9		131.45	131.45	146.82	15.37
10		131.45	131.45	146.82	15.37
Total	64.41	1183.01	1247.42	1321.36	73.94
PV	57.51	625.33	682.84	698.47	15.62
IRR					18.80%

*. The washed coal break even price is 31.90 yuan/ton.

The incremental cash flow table for the Xuzhou case study is shown in Table 8. At Xuzhou, financial returns are substantially higher than at Datong due in large part to a higher market price for washed coal at Xuzhou. The net present value at Xuzhou is 28.9 million yuan. The internal rate of return is 85.7 percent with a three year payback period. The project becomes more viable still with higher prices for washed coal, but relative prices for washed coal must be examined in light of raw coal prices with market reform.

Table 8. Incremental Cost Flow Analysis With and Without Project at Xuzhou (million yuan)

Year	Investment Costs	Operating Costs	Total Costs	Sales Income	Net Benefits
1	9050.00		9050.00		(9050.00)
2		24750.80	24750.80	32533.19	7782.39
3		24750.80	24750.80	32533.19	7782.39
4		24750.80	24750.80	32533.19	7782.39
5		24750.80	24750.80	32533.19	7782.39
6		24750.80	24750.80	32533.19	7782.39
7		24750.80	24750.80	32533.19	7782.39
8		24750.80	24750.80	32533.19	7782.39
9		24750.80	24750.80	32533.19	7782.39
10		24750.80	24750.80	32533.19	7782.39
Total	9050.00	222757.20	231807.20	292798.67	60991.47
PV	8080.36	117748.61	125828.97	154772.27	28943.30
IRR					85.67

*. The washed coal break even price is 30.75 yuan/ton.

In both the Datong and Xuzhou cases, financial returns are less if actual output figures are used rather than design levels as indicated in Tables 9 and 10. At Datong, actual output for 1990 was 2.377 million tons compared to the 4.5 million ton capacity figure used above. The net present value declines to -18.88 million yuan and the internal rate of return declines to 2.6 percent. At Xuzhou, the actual output for 1990 was 401,000 tons rather than the 860,000 tons of washed coal estimated at capacity. Using the lower output figures, the net present value decreases to 9,183 million yuan with a 37.9 percent rate of return. In both cases, the financial returns associated with the projects are sensitive to the price of both raw and washed coal and to actual production levels.

Table 9. Incremental Cash Flow Analysis With and Without Project at Datong (million yuan - actual output 2.377 million tons)

Year	Investment Costs	Operating Costs	Total Costs	Sales Income	Net Benefits
1	64.41		64.41		(64.41)
2		6943	69.43	77.55	8.12
3		6943	69.43	77.55	8.12
4		6943	69.43	77.55	8.12
5		6943	69.43	77.55	8.12
6		6943	69.43	77.55	8.12
7		6943	69.43	77.55	8.12
8		6943	69.43	77.55	8.12
9		6943	69.43	77.55	8.12
10		6943	69.43	77.55	8.12
Total	64.41	624.89	689.30	697.97	8.67
PV	57.51	330.31	387.83	368.95	(18.88)
IRR					2.60%

*. The washed coal break even price is 34.30 yuan/ton.

Table 10. Incremental Cash Flow Analysis With and Without Project at Xuzhou (million yuan - actual output 401,000 tons)

Year	Investment Costs	Operating Costs	Total Costs	Sales Income	Net Benefits
1	9050.00		9050.00		(9050.00)
2		11540.78	11540.78	15169.54	3628.76
3		11540.78	11540.78	15169.54	3628.76
4		11540.78	11540.78	15169.54	3628.76
5		11540.78	11540.78	15169.54	3628.76
6		11540.78	11540.78	15169.54	3628.76
7		11540.78	11540.78	15169.54	3628.76
8		11540.78	11540.78	15169.54	3628.76
9		11540.78	11540.78	15169.54	3628.76
10		11540.78	11540.78	15169.54	3628.76
Total	9050.00	103867.02	112917.02	136525.89	23608.87
PV	8080.36	54903.71	62984.07	72167.07	9183.00
IRR					37.87%

*. The washed coal break even price is 33.02 yuan/ton.

Energy Conservation

As indicated in Table 11, usable energy increases from 2.12 to 2.29 million tce at Datong with the project, a 7.9 percent increase. At Xuzhou, usable energy increases by 8.9 percent from 290.56 to 316.38 thousand tce with the project. Energy savings at production capacity amount to 184,850 tce per year at Datong and to 28,380 tce per year at Xuzhou.

Table 11. Energy Benefits With and Without Project at Datong and Xuzhou

Items	Datong Case		Quantai Case	
	With Project	Without Project	With Project	Without Project
1. Total coal use (1000 t)	4500.00	4500.00	860.00	860.00
2. Transfer distance (km)	1100.00	1100.00	400.00	400.00
3. Amount of delivery (1000 t)	4079.20	4500.00	727.74	860.00
4. Total delivery (10 ⁶ t.km)	4487.12	4950.00	291.10	344.00
5. Delivery cost rate (Yuan/t.km)	0.04	0.04	0.04	0.04
6. Ash rate (%)	16.86	27.80	20.17	30.06
7. Combustion efficiency (%)	61.02	55.00	60.44	55.00
8. Heat value (kcal/kg)	6434.85	6000.00	5035.15	4300.00
9. Total energy delivery ('000tce)	3749.86	3857.14	523.47	528.29
10. Coal indoor cost (yuan/tce)	92.31	92.63	94.09	85.27
11. Total useful energy ('000tce)	2288.05	2121.43	316.38	290.56
12. Useful energy cost (yuan/tce)	151.28	168.42	155.68	155.04
13. Total energy saving ('000tce/year)	184.85		28.38	
14. Unit energy use savings (kgce/tce)	47.92		53.71	
15. Delivery energy use (tce)	4487.12	4950.00	291.10	344.00
16. Unit delivery energy saving	0.12		0.10	
17. Total energy savings per tce (kgce)	48.04		53.81	

*. Coal delivery energy use is about 1 tce per million km.t.

Environmental Benefits

Per unit atmospheric emissions with and without the project are shown in Table 12. At Datong, CO₂ emissions decrease by 4.6 percent from 754.91 to 720.31 kg/tce. At Xuzhou, CO₂ emissions decrease by 5.1 percent from the same base to 716.37 kg/tce. The more substantial gains are in terms of local environmental benefits. In the Datong

case, SO₂ emissions decrease by 40.7 percent, while TSP and Ash reductions amount to 37.1 and 41.3 percent, respectively. Similarly, at Xuzhou, the SO₂ reduction is 35.6 percent, while TSP decreases by 33.6 percent and Ash by 42.7 percent. The differences in emissions reduction is due principally to higher initial levels of SO₂ at Datong and to higher initial ash content at Xuzhou.

Table 12. Environmental Impacts With and Without Project at Datong and Xuzhou (Kg/tce)

Items	Datong Case		Quantai Case	
	With Project	Without Project	With Project	Without Project
I. Direct emissions				
1. CO2	754.91	754.91	754.91	754.91
2. SO2	17.24	26.99	6.79	9.78
3. TSP	10.72	17.04	20.39	30.69
4. Ash	115.53	196.70	280.41	489.35
II. Indirect emissions				
1. CO2	(34.60)		(38.54)	
2. SO2	(1.24)		(0.50)	
3. TSP	-		-	
4. Ash	-		-	
III. Total				
1. CO2	720.31	754.91	716.37	754.91
2. SO2	16.01	26.99	6.30	9.78
3. TSP	10.72	17.04	20.39	30.69
4. Ash	115.53	196.70	280.41	489.35
Energy savings(tce)	45.83	51.05		

*Note: Energy for coal washing including electricity and water use has been deducted from energy savings.

Economic/Environmental Assessment

Table 13 depicts the economic/environmental cash flow based on the Datong case study. Using economic prices, the internal rate of return increases from 18.80 to 18.88 percent reflecting slightly higher energy prices. Including local air pollution benefits with the project, the rate of return nearly doubles to 36.56 percent as local environmental benefits are substantial. The incremental cost of CO₂ reduction is 681.02 RMB yuan per ton. Still, net benefits per ton CO₂ reduction are positive at 15.78 yuan per ton increasing to 61.60 yuan per ton with local environmental benefits included.

Table 13. Incremental Economic/Environmental Cash Flow Analysis (Datong Case) (million yuan)

Year	Total Costs	Total Benefits	Net Benefits	Global	Emissions		Econ Value of Local Pollution Reduction	Net Economic/ Environmental Benefits	
				CO2 (t)	Local SO2 (t)	Local TSP (t)			
1	64.41	0.00	(64.41)	0.00	0.00	0.00	0.00	(64.41)	
2	131.40	146.82	15.41	(210.70)	(44.08)	(25.54)	9.66	25.07	
3	131.40	146.82	15.41	(210.70)	(44.08)	(25.54)	9.66	25.07	
4	131.40	146.82	15.41	(210.70)	(44.08)	(25.54)	9.66	25.07	
5	131.40	146.82	15.41	(210.70)	(44.08)	(25.54)	9.66	25.07	
6	131.40	146.82	15.41	(210.70)	(44.08)	(25.54)	9.66	25.07	
7	131.40	146.82	15.41	(210.70)	(44.08)	(25.54)	9.66	25.07	
8	131.40	146.82	15.41	(210.70)	(44.08)	(25.54)	9.66	25.07	
9	131.40	146.82	15.41	(210.70)	(44.08)	(25.54)	9.66	25.07	
10	131.40	146.82	15.41	(210.70)	(44.08)	(25.54)	9.66	25.07	
Total	1,247.05	1,321.36	74.31	(1,896.33)	(396.76)	(229.82)	86.90	161.21	
PV	682.65	698.47	15.82	(1,002.39)	(209.73)	(121.48)	45.94	61.75	
IRR			18.88%					36.56%	
				<u>CO2</u>		<u>COAL</u>			
Total Incremental Cost/Ton of CO2 Reduction (yuan at 12%)				681.02		834.88			
At RMB/US\$ = 5.50				\$123.82		\$151.80			
Total Net Benefits/Ton of CO2 Reduction (yuan at 12%)				15.78		19.34			
At RMB/US\$ = 5.50				\$2.87		\$3.52			
Net Benefits Incl'g Local Env. Benefits/Ton of CO2 Reduction				61.60		75.52			
At RMB/US\$ = 5.50				\$11.20		\$13.73			

