Electric Motors Industry: Case 1
High Efficiency Motor Production

Introduction

Electric power consumption in China has increased rapidly in recent years, and that trend is projected to continue over the remainder of this decade. In 1990, electricity consumption was 250 twh. By 1997, it is estimated that electricity consumption will increase to 470 twh, an 88 percent increase over the 1990 base.

Meeting this increased consumption demand will require both increased generating capacity and a substantial increase in energy efficiency. The current case study assesses options for increased energy efficiency in small and medium electric motors manufacture. Small and medium electric motors (0.55 to 1000 kw) currently account for 60 percent of electric power consumption. Of that figure, 88.6 percent of power output is generated from 0.55-200 kw three phase low voltage induction motors as indicated in Table 1.

Table 1. Annual Yield of Three Phase Motors

Motor Capacity (kw)	Annual Yield (kw)	Motor Capacity (kw)	Annual Yield (kw)
0.55	55.00	22	2500.00
0.75	75.00	30	2300.00
1.1	150.00	37	2000.00
1.5	600.00	45	1900.00
2.3	800.00	55	1800.00
3.0	1000.00	75	1500.00
4.0	1400.00	90	1000.00
5.5	2000.00	110	900.00
7.5	2500.00	132	800.00
11	3000.00	160	700.00
15	2800.00	200	400.00
19	2800.00	Total	32980.00

Of the present stock of induction motors, 70 percent are JO2 series motors similar to motors produced abroad thirty years ago. The remaining 30 percent of stock consists primarily of Y series (IP44) motors similar to motor technology used commonly in more industrialized countries some twenty years ago. Beginning in the mid-1970s, high efficiency Yx motors were introduced. By 1990, 60 percent of motors below 125 horse power sold in the USA were high efficiency motors. Although China began development of high efficiency motors in 1982, the market share for high efficiency motors remains low.

The average efficiency for high efficiency Yx motors is three percentage points higher than standard Y motors. A shift from standard to high efficiency motors offers the potential of substantial power savings. According to the Shanghai Electrical Apparatus Research Institute (SEARI), electric motors of 6.5 gw capacity are required per year and an additional 5 gw of motors are required per year for replacement. At a load factor of 60 percent and annual operating time of 5000 hours, the use of high efficiency Yx as opposed to standard Y motors would result in annual savings of 1235 gwh. Those power savings would eliminate the need for 100 mw of generating capacity equivalent to annual financial savings of 250 million RMB yuan.

To accelerate the conversion to high efficiency motors, the national standard GB12497 for "Economic Operation of Three Phase Induction Motors" requires that efficient motors be used for all applications where annual operating time exceeds 3000 hours with a load factor of 50 percent.

Technology Assessment

The production shift from standard Y series (IP44) motors to the high efficiency Yx series motors involves process changes as indicated in Table 2 below. Low loss silicon steel plates are used for the motor core, while sine windings and axial flow fans are used to reduce mechanical, core, and stray load losses. Additional copper is used to reduce the copper loss of stators and rotors.

Table 2. Comparison of Motor Assembly Process for Y and Yx Series Motors

Items	Y Series	Yx Series
Design	Design experience	CAD, optimization design
Core assembly	Hot rolled steel plates 2.2 w/kg	Cold rolled silicon steel plates 1.7 w/kg
Winding	Normal windings	Sine windings
Machine housing	Rotor aluminum casting	Automatic diecast machines with proper technical parameters
Fans	Centrifugal type fans with 37 % efficiency	Axial flow type fans with 60 % efficiency

The total power generating loss is reduced by 20 percent with the use of high efficiency motors. A comparison of electricity savings between Y and Yx motors at different motor capacities and operating conditions is shown in Table 3. Electricity savings increase with increased motor capacity, increased load factor, increased operating hours and increased operating speed.

Table 3. Annual Electricity Savings Between Y and Yx Motors

Speed (r/min)	3000				1500				1000			
Load Fac (%)	75	50	75	50	75	50	75	50	75	50	75	50
Oper'g. Hours	6000		3000		6000		3000		6000		3000	
Capacity (kw)	Annual Electricity Savings (kwhs)											
1.5	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	580	544	290	272
2.2	ERR	ERR	ERR	ERR	738	559	369	279	684	519	342	259
3.0	870	751	435	376	882	774	441	387	662	423	331	211
4.0	566	399	283	199	902	642	451	321	814	452	407	226
5.5	771	390	385	195	1108	595	554	298	675	257	338	129
7.5	1155	488	577	244	1055	536	527	268	1504	900	752	450
11.0	2425	1912	1212	956	1939	1262	969	631	2047	1215	1023	608
15.0	3566	2957	1783	1478	2377	1432	1189	716	2040	1552	1020	776
18.5	3337	1836	1668	918	1759	1385	880	692	2002	1355	1001	678
22.0	4711	4201	2356	2100	1843	1242	922	621	2004	1033	1002	516
30.0	5508	5302	2754	2651	2023	1569	1011	785	4139	2685	2069	1343
37.0	5916	5364	2958	2682	3834	2452	1917	1226	4860	2879	2430	1440
45.0	5886	4951	2943	2476	4161	2645	2080	1323	3730	2359	1865	1180
55.0	8643	7664	4321	3832	5340	3412	2670	1706	4540	1904	2270	952
75.0	12545	10429	6272	5214	8422	6988	4211	3494	ERR	ERR	ERR	ERR
90.0	12578	10779	6289	5390	7735	6452	3867	3226	ERR	ERR	ERR	ERR

As indicated earlier, the annual output of motors in the 0.5-90 kw capacity range account for 75 percent of total output in China. Within this capacity range, high efficiency motors improve average efficiency by three percentage points reducing power loss by 24 percent. Most motors above 90 kw have eight or more poles, and starting performance becomes a constraint for high efficiency motor applications. Operating characteristics for standard and high efficiency motors are indicated in Table 4. Motor usage is limited to applications with one-way rotation and ordinary demand starting requirements.

Table 4. Comparison of Operating Conditions For Y and Yx Motors

Items	Y Series	Yx Series
Capacity range (kw)	0.55-220	1.5-90
Pole number	2,4,6,8,10	2,4,6
Insulation class	B	T
Locked rotor torque	Large	Small
Total loss	100	80
Average efficiency (%)	87.5	90.5
Material use (kg)	100	105
Slip rate	Small	Smaller
Rotation direction	Bidirectional	Unidirectional

Table 5 shows electricity expenditures per mwh saved in purchasing new motors. As the current price of electricity is running in the neighborhood of 250 per mwh, costs of electricity savings of less than 250/mwh offer user benefits. In 90.7 percent of the combinations of motor capacity and operating conditions, the cost of electricity saved using high efficiency motors is less than the purchase price of electricity. Per unit savings are greatest at higher load factors and operating hours. High efficiency motors are less feasible for six pole motors. When the same analysis is run for replacement of existing motors, 33 percent of the combinations remain feasible as indicated in Table 6. The majority of those feasible combinations are for two pole motors of 15-90 kw capacity.

Table 5. Electricity Savings Cost for Purchasing New Yx Motors

Motor Type	Two Poles Motor				Four Poles Motor				Six Poles Motor			
Load Factor (%)	75		50		75		50		75		50	
	Electricity Savings Cost in Various Operation Hours (yuan/mwh)											
Motor Capacity (kw)	3000	6000	3000	6000	3000	6000	3000	6000	3000	6000	3000	6000
1.50	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	134.25	67.13	143.05	71.53
2.20	ERR	ERR	ERR	ERR	100.22	50.11	132.45	66.23	133.56	66.78	176.01	88.00
3.00	93.95	46.97	108.52	54.41	92.71	46.35	105.69	52.85	207.46	103.73	324.91	162.45
4.00	180.85	90.43	256.56	128.28	112.23	56.11	157.72	78.86	185.35	92.68	333.77	166.88
5.50	178.20	89.10	352.39	176.19	123.99	61.99	230.67	115.34	243.81	121.91	639.34	319.67
7.50	130.76	65.38	309.45	154.72	143.13	71.57	281.89	140.95	113.93	56.97	190.37	95.18
11.00	90.80	45.40	115.13	57.57	113.55	56.78	174.47	87.23	107.57	53.78	181.16	90.58
15.00	68.80	34.40	82.96	41.48	103.18	51.59	171.30	85.65	165.32	82.66	217.29	108.64
18.50	79.93	39.96	145.26	72.63	179.59	89.79	228.15	114.07	210.75	105.37	311.29	155.64
22.00	69.35	34.67	77.77	38.89	177.23	88.62	262.99	131.49	231.85	115.93	449.85	224.92
30.00	80.29	40.15	83.42	41.71	219.62	109.81	283.06	141.53	147.74	73.87	227.74	113.87
37.00	82.63	41.32	91.13	45.56	143.01	71.50	223.63	111.81	154.86	77.43	261.42	130.71
45.00	108.94	54.47	129.51	64.75	147.38	73.69	231.84	115.92	251.08	125.54	397.00	198.50
55.00	92.68	46.34	104.51	52.26	142.36	71.18	222.77	111.39	234.57	117.29	559.39	279.70
75.00	78.96	39.48	94.99	47.49	113.41	56.71	136.69	68.35	ERR	ERR	ERR	ERR
90.00	90.28	45.14	105.34	52.67	140.08	70.04	167.93	83.97	ERR	ERR	ERR	ERR

* i=0.12, operation hours, 3000 and motor lifespan 10 years

Table 6. Electricity Savings Cost for Yx Motors Replacing Existing Y Motors

Motor Type	Two Pole Motors				Four Pole Motors				Six Pole Motors			
Load Factor (%)	75		50		75		50		75		50	
	Electricity Savings Cost in Various Operation Hours (yuan/mwh)											
Motor Capacity (kw)	3000	6000	3000	6000	3000	6000	3000	6000	3000	6000	3000	6000
1.50	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	402.76	201.38	429.16	214.58
2.20	ERR	ERR	ERR	ERR	300.65	150.33	397.36	198.68	400.68	200.34	528.02	264.01
3.00	281.84	140.92	326.46	163.23	278.12	139.06	317.07	158.54	622.37	311.19	974.72	487.36
4.00	542.55	271.28	769.68	384.84	336.69	168.34	473.16	236.58	556.06	278.03	1001.30	500.65
5.50	534.61	267.31	1057.17	528.58	371.96	185.98	692.02	346.01	731.44	365.72	1918.02	959.01
7.50	392.27	196.13	928.35	464.17	429.40	214.70	845.68	422.84	341.80	170.90	571.10	285.55
11.00	272.41	136.20	345.39	172.70	340.66	170.33	523.41	261.70	322.70	161.35	543.48	271.74
15.00	206.39	103.20	248.89	124.45	309.53	154.76	513.90	256.95	495.97	247.99	651.86	325.93
18.50	239.78	119.89	435.78	217.89	538.76	269.38	684.44	342.22	632.24	316.12	933.86	466.93
22.00	208.05	104.02	233.32	116.66	531.69	265.85	788.96	394.48	695.55	347.78	1349.55	674.77
30.00	240.88	120.44	250.27	125.13	658.87	329.43	849.17	424.59	443.23	221.62	683.21	341.61
37.00	247.89	123.95	273.38	136.69	429.02	214.51	670.88	335.44	464.59	232.30	784.26	392.13
45.00	326.82	163.41	388.52	194.26	442.15	221.08	695.51	347.76	753.23	376.62	1191.00	595.50
55.00	278.05	139.02	313.54	156.77	427.08	213.54	668.32	334.16	703.72	351.86	1678.18	839.09
75.00	236.05	118.45	284.96	142.48	340.24	170.12	410.08	205.04	ERR	ERR	ERR	ERR
90.00	270.84	135.42	316.03	158.02	420.24	210.12	503.80	251.90	ERR	ERR	ERR	ERR

*** i=0.12, operation hours, 3000 and motor lifespan 10 years**

For comparison purposes, 4 pole 18.5 kw and 6 pole 30 kw motors are used. These motors are widely used and have relatively stable manufacturing costs. Table 7 compares operating costs for both standard and high efficiency motors based on data from Huada Electric Machine Plant. The plant is located in Wuxi, Jiangsu Province.

The primary difference in cost between motors is raw material costs which are 15.6 percent higher for high efficiency motors. Other operating costs are either the same or show little difference per unit. The selling price for high efficiency Yx type motors is 30 percent higher per unit than that for standard Y-type motors.

Table 7. Operating Costs for Standard and High Efficiency Motors

Items	4 Pole 18.5 kw		6 Pole 30 kw	
	Y-180M	Yx-180M	Y-225M	Yx-225M
1. Raw Materials Use				
a. Silicon steel plate (kg)	133.02	133.02	215.70	215.70
b. Electric-magnetic wire (kg)	11.47	12.04	18.60	19.53
c. Isolation painting (kg)	0.05	0.05	0.08	0.08
2. Raw materials price (yuan/kg)				
a. Silicon steel plate	3.50	4.14	3.50	4.14
b. Electric magnetic wire	26.00	28.65	26.00	28.82
c. Isolation painting	112.00	245.60	97.50	244.13
3. Raw materials cost	896.50	1036.76	1518.40	1756.44
a. Silicon steel plate	466.00	551.00	755.00	893.00
b. Electric magnetic wire	298.20	344.98	483.60	562.91
c. Isolation painting	5.60	12.28	7.80	19.53
d. Others	126.70	128.50	272.00	281.00
4. Power	17.70	17.70	30.01	30.01
5. Salary & welfare	34.80	36.54	59.02	61.97
6. Loss of waste products	20.41	20.41	34.61	34.61
7. Maintenance	63.00	63.00	106.83	106.83
8. Management	153.02	153.02	259.47	259.47
9. Total cost	1185.43	1327.43	2008.34	2249.33
10. Selling price	1673.10	2175.03	3239.63	4211.52
11. Gross benefits	487.67	847.60	1231.29	1962.19
12. Tax	203.02	343.95	658.50	666.74
13. Net Benefit	284.65	503.65	572.79	1295.45

Table 8 shows investment costs for the project. Total investment costs are expected to be 38.5 million RMB yuan, with most of the costs incurred in the first two years. The majority of costs are for equipment and instrumentation as existing workshops

will be employed. Principal equipment purchases include a machine tool system, aluminum casting system, high speed punch system, and mold processing equipment.

Table 8. Investment Schedule (1,000 yuan)

Items	Unit	Unit Price	Cost
1. Motor design CAD system	1	1000	1000
2. Machine tool center system	2	2500	5000
3. Numerical controlled AL casting system	2	1500	3000
4. Rotor processing system	5	160	800
5. High speed punch machine	1	3000	3000
6. Mould processing equipment	1	3000	3000
7. Isolation processing equipment	1	1200	1200
8. Test system	1	2000	2000
9. Painting system	1	1000	1000
10. Installation			11500
11. Land purchases			3000
12. License			1000
13. Others			3000
Total			38500
Investment Schedule			
		First year:	21790
		Second year:	11060
		Third year:	5650

With the project, motor production capacity will increase from 600 to 1000 mw, while actual production is expected to increase from 500 to 800 mw as indicated in Table 9. Operating costs double from 48.9 to 97.9 million yuan with the project. Sales income more than doubles from 54.0 to 112.0 million yuan. Per unit operating costs increase by 25.2 percent, while motor selling price increases by 30 percent for high efficiency relative to standard motors.

Table 9. Major Production Indicators With and Without Project

Items	Without Project	With Project
1. Motor production capacity (mw)	600	1000
2. Motor production yield (mw)	500	800
3. Operating costs (1000 yuan):	48880	97950
a. Raw materials	36870	73700
b. Energy	1620	2750
c. Maintenance	1840	5500
d. Salary & welfare	2450	2810
e. Depreciation	6100	13190
4. Selling cost (1000 yuan)	242	500
5. Sales price (yuan/kw)	108	140
6. Sales income (1000 yuan)	54000	112000
7. Tax (1000 yuan)	1377	2868
8. Company benefit (1000 yuan)	3510	10682

Incremental cash flow with and without the project is indicated in Table 10. With investment costs of 38.5 million yuan, the project generates a net present value of 31.1 million yuan. The payoff period for the project is six years, three years after renovation is complete. The project's internal rate of return is 26.2 percent suggesting that the project is viable at a thirty percent price differential for high efficiency Yx series motors relative to standard Y series motors.

Table 10. Incremental Cash Flow With and Without Project (1000 yuan)

Year	Investment			Operating Costs					Total Cost	Total Benefits	Net Benefits
	Old Equip Replace	NewEquip Purchase	Investment Subtotal	Raw Materials	Energy Use	Maintenance	Salary & Others	Total Oper Cost			
1		21790.00	21790.00					0.00	21790.00		-21790.00
2		11060.00	11060.00					0.00	11060.00		-11060.00
3		5650.00	5650.00					0.00	5650.00		-5650.00
4			0.00	36830.00	1130.00	3660.00	360.00	41980.00	41980.00	57742.0	15762.00
5			0.00	36830.00	1130.00	3660.00	360.00	41980.00	41980.00	57742.0	15762.00
6			0.00	36830.00	1130.00	3660.00	360.00	41980.00	41980.00	57742.0	15762.00
7			0.00	36830.00	1130.00	3660.00	360.00	41980.00	41980.00	57742.0	15762.00
8			0.00	36830.00	1130.00	3660.00	360.00	41980.00	41980.00	57742.0	15762.00
9			0.00	36830.00	1130.00	3660.00	360.00	41980.00	41980.00	57742.0	15762.00
10			0.00	36830.00	1130.00	3660.00	360.00	41980.00	41980.00	57742.0	15762.00
11			0.00	36830.00	1130.00	3660.00	360.00	41980.00	41980.00	57742.0	15762.00
12			0.00	36830.00	1130.00	3660.00	360.00	41980.00	41980.00	57742.0	15762.00
13			0.00	36830.00	1130.00	3660.00	360.00	41980.00	41980.00	57742.0	15762.00
Total	0.0	38500.00	38500.00	368300.00	11300.00	36600.00	3600.00	419800.00	458300.00	577420.00	119120.00
PV	0.0	32293/9	32293.9	148119.8	4544.5	14719.5	1447.8	168831.7	201125.6	232222.0	31096.4
Irr											26.19%

In actuality, the project returns may be somewhat lower depending on the transition schedule used in converting current operating equipment from the production of Y to Yx series motors. Retiring current equipment ahead of schedule will reduce the net present value of the project to 5.76 yuan/kw and decrease the project's internal rate of return to 14.5 percent. In either case, project viability is very sensitive to the sales price for high efficiency motors. A 50 percent increase in price even with the early retirement of existing equipment will raise the internal rate of return of 40.4 percent. Yet, at this price, high efficiency motors no longer appear viable to consumers. More attention needs to be given to the price sensitivity of high efficiency motors from both producer and consumer perspectives.

Energy Conservation

Table 11 indicates energy savings by electric motors users with and without the project. Power savings increase over time as the stock of high efficiency motors in operation increases. By year 10, annual power savings are expected to amount to 17,824 mwh based on the production scale proposed at the Huada plant.

Table 11. Energy Use by Users With and Without Project

Year	Ann. Stock of Motors (MW)	Annual Power Use (mwh)		Incremental
		With Project	Without Project	
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	1000	2902	3000	(98)
5	1800	5224	5400	(176)
6	100250	290943	300750	(9807)
7	100250	290943	300750	(9807)
8	173950	504833	521850	(17017)
9	176700	512814	530100	(17286)
10	182200	528776	546600	(17824)
11	185010	536931	555030	(18099)
12	198200	575211	594600	(19389)
13	198700	576662	596100	(19438)

* The efficiency is raised about 3%, operation hours are 5000 and load factor is 60%

Environmental Benefits

As with energy conservation, environmental benefits increase as the stock of high efficiency motors in operation increases. With the proposed projected, annual CO_2 emissions are reduced by 5,169 tons by year 10. SO_2 and TSP emissions are reduced by 178 and 196 tons per year, respectively, by the tenth year.

Table 12. Emissions Reduction by High Efficiency Motor Use (User Benefits)

Year	CO2(t)	SO2(t)	TSP(t)
1	0.00	0.00	0.00
2	0.00	0.00	0.00
3	0.00	0.00	0.00
4	28.37	.98	1.08
5	51.07	1.76	1.94
6	2844.05	98.07	107.88
7	2844.05	98.07	107.88
8	4934.89	170.17	187.19
9	5012.90	172.86	190.14
10	5168.93	178.24	196.06
11	5248.65	180.99	199.09
12	5622.85	193.89	213.28
13	5637.03	194.38	213.82

* Emission Factor Items	Factor (kg/mwh)
1. CO2	290
2. SO2	10
3. TSP	11

Economic/Environmental Assessment

Table 13 depicts the economic/environmental cash flow for the project. The internal rate of return decreases from 26.26 to 25.9 percent. As energy costs are already valued at economic prices, the adjustment is downward due to labour cost adjustments. Including local air pollution benefits with the project, the rate of return increases to 25.93 percent. This figure may underestimate local environmental benefits as most of these benefits accrue from electric motor usage rather than production. More attention needs to be given to user benefits in subsequent work. When adjusted for output in Table 14, the incremental cost of CO_2 reduction remains substantial at 7,924 yuan per ton. Still, net benefits per ton CO_2 reduction are positive at 323 or 332 yuan per ton with local environmental benefits included.

Table 13. Incremental Economic/Environmental Cash Flow Analysis (1000 yuan)

				Emissions				
				Global	Local		Econ Value of Local	Net Economic/
Year	Total Costs	Total Benefits	Net Benefits	CO2 (t)	SO2 (t)	TSP (t)	Pollution Reduction	Environmental Benefits
1	21,790.00	0.00	(21,790.00)	0.00	0.00	0.00	0.00	(21,790.00)
2	11,060.00	0.00	(11,060.00)	0.00	0.00	0.00	0.00	(11,060.00)
3	5,650.00	0.00	(5,650.00)	0.00	0.00	0.00	0.00	(5,650.00)
4	42,428.00	58,000.00	15,572.00	(28.37)	(0.98)	(1.08)	0.25	15,572.25
5	42,428.00	58,000.00	15,572.00	(51.07)	(1.76)	(1.94)	0.44	15,572.44
6	42,428.00	58,000.00	15,572.00	(2,844.05)	(98.07)	(107.88)	24.68	15,596.68
7	42,428.00	58,000.00	15,572.00	(2,844.05)	(98.07)	(107.88)	24.68	15,596.68
8	42,428.00	58,000.00	15,572.00	(4,934.89)	(170.17)	(187.19)	42.82	15,614.82
9	42,428.00	58,000.00	15,572.00	(5,012.90)	(172.86)	(190.14)	43.50	15,615.50
10	42,428.00	58,000.00	15,572.00	(5,168.93)	(178.24)	(196.06)	44.85	15,616.85
11	42,428.00	58,000.00	15,572.00	(5,248.65)	(180.99)	(199.09)	45.54	15,617.54
12	42,428.00	58,000.00	15,572.00	(5,622.85)	(193.89)	(213.28)	48.79	15,620.79
13	42,428.00	58,000.00	15,572.00	(5,637.03)	(194.38)	(213.82)	48.91	15,620.91
Total	462,780.00	580,000.00	117,220.00	(37,392.79)	(1,289.41)	(1,418.35)	324.45	117,544.45
PV	202,927.3	233,259.6	30,332.3	(12,483.44)	(430.46)	(473.51)	108.32	30,440.62
IRR			25.90%					25.93%

Table 14. Incremental Economic/Environmental Cash Flow Analysis Adjusted for Output (1000 yuan)

Year	Total Costs	Total Benefits	Net Benefits	Emissions Global CO2 (t)	Emissions Local SO2 (t)	Local TSP (t)	Econ Value of Local Pollution Reduction	Net Economic/ Environmental Benefits
1	13,618.75	0.00	(13,618.75)	0.00	0.00	0.00	0.00	(13,618.75)
2	6,912.50	0.00	(6,912.50)	0.00	0.00	0.00	0.00	(6,912.50)
3	3,531.25	0.00	(3,531.25)	0.00	0.00	0.00	0.00	(3,531.25)
4	10,354.63	16,000.00	5,645.38	(17.73)	(0.61)	(0.67)	0.15	5,645.53
5	10,354.63	16,000.00	5,645.38	(31.92)	(1.10)	(1.21)	0.28	5,645.65
6	10,354.63	16,000.00	5,645.38	(1,777.53)	(61.29)	(67.42)	15.42	5,660.80
7	10,354.63	16,000.00	5,645.38	(1,777.53)	(61.29)	(67.42)	15.42	5,660.80
8	10,354.63	16,000.00	5,645.38	(3,084.30)	(106.36)	(116.99)	26.76	5,672.14
9	10,354.63	16,000.00	5,645.38	(3,133.06)	(108.04)	(118.84)	27.19	5,672.56
10	10,354.63	16,000.00	5,645.38	(3,230.58)	(111.40)	(122.54)	28.03	5,673.41
11	10,354.63	16,000.00	5,645.38	(3,280.41)	(113.12)	(124.43)	28.46	5,673.84
12	10,354.63	16,000.00	5,645.38	(3,514.28)	(121.18)	(133.30)	30.49	5,675.87
13	10,354.63	16,000.00	5,645.38	(3,523.15)	(121.49)	(133.64)	30.57	5,675.94
Total	127,608.75	160,000.00	32,391.25	(23,370.49)	(805.88)	(886.47)	202.78	32,594.03
PV	61,827.0	64,347.5	2,520.4	(7,802.2)	(269.0)	(295.9)	67.70	2,588.13

	CO2	COAL
Total Incremental Cost/Ton of CO2 Reduction (yuan at 12%)	7,924.36	5,892.47
At RMB/US$ = 5.50	$1,440.79	$1,071.36
Total Net Benefits/Ton of CO2 Reduction (yuan at 12%)	323.04	240.21
At RMB/US$ = 5.50	$58.74	$43.67
Net Benefits Incl'g Local Env. Benefits/Ton of CO2 Reduction	331.72	246.66
At RMB/US$ = 5.50	$60.31	$44.85

Electric Motors Industry: Case 2
Variable Speed Motor Production

Introduction

Improved energy efficiency in electric motors can be realized in one of two ways. The first option is to raise the efficiency of the motor itself; the second option is to control power utilization with variable speed drives. Variable speed motors have wide application, although electric fans and pumps are particularly adaptable to variable speed operating conditions.

Based on 1988 data, the total capacity of electric motors used to drive fans and pumps in China had reached 90 gw with 165 twh of electricity consumption (31 percent of total electricity consumption). It is estimated that 50 percent of these fans and pumps are required to vary operating speeds in use. With standard electric motors, power flow is regulated using baffles or valves which can result in substantial energy loss. With variable speed motors, power flow is regulated be varying speed control. It is estimated that replacement of fan and pump motors with variable speed motors would decrease energy use by 20 percent or 33 twh per year enough to forego the construction of a 6.6 gw thermal power plant.

Research on variable speed motors began in China during the 1970s; by the early 1980s a nationwide unified design effort was sponsored by the Shanghai Electrical Apparatus Research Institute (SEARI). Still, the application of variable speed motors for industrial use lags considerably behind Western usage. The present output of variable speed motors amounts to 500 units per year. That production falls far short of the estimated current demand of 1 gw which is projected to increase to 1.5 gw by the end of the decade.

Technology Assessment:

There are three basic types of variable speed motor technology which include:

- electromagnetic coupling motors (YCT series),
- pole changing multi-speed motors (YD series), and
- variable frequency motors (VF series).

Electromagnetic Coupling Motors (YCT series): Electromagnetic coupling motors consist of a Y series motor along with an electromagnetic coupling and controller. The motors have a negative feedback link to allow smooth and continuous speed variation within a wide speed range. This series allows easy conversion of standard AC motors.

Pole Changing Multi-speed Synchronous Motors (YD series): YD series motors come in two-, three-, and four-speed models. Two-speed YD motor design is based on pole changing on single-winding pulse-amplitude-modulation (PAM). The pole ratio may be designed as multiple pole ratios, eg. 4/2, 8/4, or 12/6, or as non-multiple ratios, eg. 8/6, 6/4, etc. For three and four-speed models, a hybrid scheme of two windings and PAM is used. Because speed variation is achieved by changing the connection of winding terminals, YD series motors have more terminals than standard motors - six for two-speed, nine for three speed and twelve for four speed models. Frame sizes tend to be larger also ranging from H80 to H280 sizes.

Variable Frequency Drive Motors (YF series): With VF drives, a frequency converter is used to control the stader voltage and frequency of the motor simultaneously to vary motor speed. Controls may be either external or internal. VF drives have better performance and higher efficiency than the other two variable speed options. They are more costly initially with higher repair and maintenance expenses as well.

A comparison of motor operating performances is listed in Table 1. The VF model offers the highest energy savings averaging 30 percent over standard models compared to 20 percent average savings for YCT and YD models. The VF models are more expensive with higher maintenance expenses as noted above. The projected market share for each model is YCT (48.3 percent), VF (6.0 percent), and YD (45.7 percent).

Table 1. Comparison of Operating Performance for Variable Speed Models

Item	YCT Model	VF Model	VD Model
Speed Change Principle	Slip change	Frequency change	Number of poles changed
Maintenance	Moderate	High technology reqd.	Moderate
Reliability	High	Depending on quality of elements	High
Interference with power network	None	Some disturbance	None
Price	Approx. 300 yuan/kw	Approx. 1000 yuan/kw	Approx. 200 yuan/kw
Power factor	High	Higher	High
Average energy savings	20 %	30 %	20 %
Demand in 1992 (units)	400	180	400
Demand in 2000 (units)	2800	350	2650
Relative cost	Higher	Highest	Moderate

Variable speed motors are generally used for two purposes. In the first case, they are used for operation control with textile or printing and dyeing machinery where motor speed is adjusted to control product quality. In the second case, they are used to reduce energy usage for fans, pumps, etc. Table 2 shows energy savings using variable speed motors at different motor capacities and operating conditions. Energy savings rates for YCT and YD series motors are assumed to be 20 percent, while energy savings for YF series motors are 30 percent relative to standard motors.

Table 2. Annual Electricity Savings from the Use of Variable Speed Motors

Motor Type	YCT Motors				YD Motors				VF Motors			
Operation Hour	1500	3000	4500	6000	1500	3000	4500	6000	1500	3000	4500	6000
Capacity (kw)	Annual Electricity Savings Cost (kwh)											
1.5	270	540	810	1080	270	540	810	1080	405	810	1215	1620
2.2	396	792	1188	1584	396	792	1188	1584	594	1188	1782	2376
3.0	540	1080	1620	2160	540	1080	1620	2160	810	1620	2430	3240
4.0	720	1440	2160	2880	720	1440	2160	2880	1080	2160	3240	4320
5.5	990	1980	2970	3960	990	1980	2970	3960	1485	2970	4455	5940
7.5	1350	2700	4050	5400	1350	2700	4050	5400	2025	4050	6075	8100
11.0	1980	3960	5940	7920	1980	3960	5940	7920	2970	5940	8910	11880
15.0	2700	5400	8100	10800	2700	5400	8100	10800	4050	8100	12150	16200
18.5	3330	6660	9990	13320	3330	6660	9990	13320	4995	9990	14985	19980
22.0	3960	7920	11880	15840	3960	7920	11880	15840	5940	11880	17820	23760
30.0	5400	10800	16200	21600	5400	10800	16200	21600	8100	16200	24300	32400
37.0	6660	13320	19980	26640	6660	13320	19980	26640	9990	19980	29970	39960
45.0	8100	16200	24300	32400	8100	16200	24300	32400	12150	24300	36450	48600
55.0	9900	19800	29700	39600	9900	19800	29700	39600	14850	29700	44550	59400
75.0	13500	27000	40500	54000	13500	27000	40500	54000	20250	40500	60750	81000
90.0	16200	32400	48600	64800	16200	32400	48600	64800	24300	48600	72900	97200
110.0	19800	39600	59400	79200	19800	39600	59400	79200	29700	59400	89100	118800
132.0	23760	47520	71280	95040	23760	47520	71280	95040	35640	71280	106920	142560
160.0	28800	57600	86400	115200	28800	57600	86400	115200	43200	86400	129600	172800
200.0	36000	72000	108000	144000	36000	72000	108000	144000	54000	108000	162000	216000
220.0	39600	79200	118800	158400	39600	79200	118800	158400	59400	118800	178200	237600

*Load factor is about 60%, YCT & YD motors energy savings rates are 20%, VF energy savings rate is 30%

Table 3 shows estimated energy savings for replacing existing motors indicated in yuan per mwh for each of the three variable speed motor series. Again, savings are indicated at different motor capacities and operating levels. The motor lifespan is assumed to be 10 years and replacement is for existing motor stock. Energy savings are least costly the larger the motor capacity and the higher the operating hours. At current prices of 250 yuan per mwh, 67.9 percent of the listed capacity/use combinations offer cost savings. Savings are highest for YD and YCT motors with 94.0 and 71.4 percent of the capacity/use combinations offering cost savings. With five year life expectancies for motors, energy cost savings occur for 47.6 percent of the combinations listed.

Table 3. Electricity Savings Cost for Users Replacing Existing Motors

Motor Type	YCT Motors				YD Motors				VF Motors			
Operation Hour	1500	3000	4500	6000	1500	3000	4500	6000	1500	3000	4500	6000
Capacity (kw)	Annual Electricity Savings Cost (yuan/mwh)											
1.5	714.5	357.2	238.2	178.6	476.3	238.2	158.8	119.1	1587.8	793.9	529.3	396.9
2.2	562.7	281.3	187.6	140.7	375.1	187.6	125.0	93.8	1250.4	625.2	416.8	312.6
3.0	557.2	278.6	185.7	139.3	371.4	185.7	123.8	92.9	1238.2	619.1	412.7	309.5
4.0	492.4	246.2	164.1	123.1	328.2	164.1	109.4	82.1	1094.1	547.1	364.7	273.5
5.5	443.7	221.9	147.9	110.9	295.8	147.9	98.6	74.0	986.0	493.0	328.7	246.5
7.5	350.6	175.3	116.9	87.6	233.7	116.9	77.9	58.4	779.0	389.5	259.7	194.8
11.0	333.6	166.8	111.2	83.4	222.4	111.2	74.1	55.6	741.3	370.7	247.1	185.3
15.0	306.6	153.3	102.2	76.7	204.4	102.2	68.1	51.1	681.4	340.7	227.1	170.4
18.5	301.7	150.8	100.6	75.4	201.1	100.6	67.0	50.3	670.4	335.2	223.5	167.6
22.0	282.3	141.2	94.1	70.6	188.2	94.1	62.7	47.1	627.4	313.7	209.1	156.8
30.0	277.4	138.7	92.5	69.4	184.9	92.5	61.6	46.2	616.5	308.2	205.5	154.1
37.0	268.7	134.4	89.6	67.2	179.2	89.6	59.7	44.8	597.2	298.6	199.1	149.3
45.0	270.5	135.3	90.2	67.6	180.3	90.2	60.1	45.1	601.1	300.6	200.4	150.3
55.0	265.3	132.6	88.4	66.3	176.8	88.4	58.9	44.2	589.5	294.7	196.5	147.4
75.0	282.5	141.2	94.2	70.6	188.3	94.2	62.8	47.1	627.7	313.9	209.2	156.9
90.0	258.8	129.4	86.3	64.7	172.5	86.3	57.5	43.1	575.1	287.6	191.7	143.8
110.0	310.9	155.4	103.6	77.7	207.2	103.6	69.1	51.8	690.8	345.4	230.3	172.7
132.0	283.1	141.6	94.4	70.8	188.8	94.4	62.9	47.2	629.2	314.6	209.7	157.3
160.0	291.5	145.7	97.2	72.9	194.3	97.2	64.8	48.6	647.7	323.8	215.9	161.9
200.0	255.5	127.8	85.2	63.9	170.3	85.2	56.8	42.6	567.8	283.9	189.3	141.9
220.0	299.3	149.6	99.8	74.8	199.5	99.8	66.5	49.9	665.0	332.5	221.7	166.3

*I=0.12, motor's lifespan 10 year, load factor 60%

Table 4 shows similar capacity/use combinations but in this case the electricity savings are for new rather than replacement motors. Here, energy cost savings are realized for 84.9 percent of the combinations listed. Again, the cost of energy savings are lowest for YD and YCT series motors. When motor lifespan is reduced to five years, actual cost savings are realized in 67 percent of the combinations.

Table 4. Electricity Savings Cost for Users Purchasing New Motors

Motor Type	YCT Motors				YD Motors				VF Motors			
Operation Hour	1500	3000	4500	6000	1500	3000	4500	6000	1500	3000	4500	6000
Capacity (kw)	Annual Electricity Savings Cost (yuan/mwh)											
1.5	476.3	238.2	158.8	119.1	238.2	119.1	79.4	59.5	1429.0	714.5	476.3	357.2
2.2	375.1	187.6	125.0	93.8	187.6	93.8	62.5	46.9	1125.4	422.0	281.3	211.0
3.0	371.4	185.7	123.8	92.9	185.7	92.9	61.9	46.4	1114.3	417.9	278.6	208.9
4.0	328.2	164.1	109.4	82.1	164.1	82.1	54.7	41.0	984.7	369.3	246.2	184.6
5.5	295.8	147.9	98.6	74.0	147.9	74.0	49.3	37.0	887.4	332.8	221.9	166.4
7.5	233.7	116.9	77.9	58.4	116.9	58.4	39.0	29.2	701.1	262.9	175.3	131.5
11.0	222.4	111.2	74.1	55.6	111.2	55.6	37.1	27.8	667.2	250.2	166.8	125.1
15.0	204.4	102.2	68.1	51.1	102.2	51.1	34.1	25.6	613.3	230.0	153.3	115.0
18.5	201.1	100.6	67.0	50.3	100.6	50.3	33.5	25.1	603.3	226.3	150.8	113.1
22.0	188.2	94.1	62.7	47.1	94.1	47.1	31.4	23.5	564.7	211.7	141.2	105.9
30.0	184.9	92.5	61.6	46.2	92.5	46.2	30.8	23.1	554.8	208.1	138.7	104.0
37.0	179.2	89.6	59.7	44.8	89.6	44.8	29.9	22.4	537.5	201.6	134.4	100.8
45.0	180.3	90.2	60.1	45.1	90.2	45.1	30.1	22.5	541.0	202.9	135.3	101.4
55.0	176.8	88.4	58.9	44.2	88.4	44.2	29.5	22.1	530.5	198.9	132.6	99.5
75.0	188.3	94.2	62.8	47.1	94.2	47.1	31.4	23.5	565.0	211.9	141.2	105.9
90.0	172.5	86.3	57.5	43.1	86.3	43.1	28.8	21.6	517.6	194.1	129.4	97.1
110.0	207.2	103.6	69.1	51.8	103.6	51.8	34.5	25.9	621.7	233.1	155.4	116.6
132.0	188.8	94.4	62.9	47.2	94.4	47.2	31.5	23.6	566.3	212.4	141.6	106.2
160.0	194.3	97.2	64.8	48.6	97.2	48.6	32.4	24.3	582.9	218.6	145.7	109.3
200.0	170.3	85.2	56.8	42.6	85.2	42.6	28.4	21.3	511.0	191.6	127.8	95.8
220.0	199.5	99.8	66.5	49.9	99.8	49.9	33.3	24.9	598.5	224.4	149.6	112.2

Case 1: Zhejiang Variable Speed Motors Manufacturing Works

Zhejiang Variable Speed Works is the leading manufacturer of variable speed motors in China. The plant's current capacity of electric motors is 400 units; output for the year 1991 was 350 units with 110 units of YCT motors produced. The plant also has been involved in technology development with the Variable Speed Research Institute and Scientific Research and Testing Center located in the plant.

Plant expansion plans will increase production capabilities from the current capacity of 400 motors to a capacity of 620 motors with the project as indicated in Table 5. In the with project case, the bulk of capacity (600 motors) is allocated for YCT motor production split evenly between 0.55-90 kw and 110-500 kw motors. The remaining 20 motors are allocated to YF series motor production.

Table 5. Major Production Indicators With and Without Project at Zhejiang

	With Project			Without Project	
Items	0.55-90 kw	110-500 kw	VF motor	0.55-90 kw	110-500 kw
1. Production capacity (units)	300	300	20	200	200
2. Production yield (units)	250	250	20	175	175
3. Sales price (yuan/kw)	360	240	1000	360	240
4. Sales cost (1000 yuan)	900	600	200	650	450
5. Total sales income (1000 yuan)	90000	60000	20000	63000	42000
6. Sales Tax	3600	2400	800	2400	1680

Investment costs for the project are expected to be 21 million RMB yuan over a three year renovation period as indicated in Table 6. The principal project costs are for the processing machine system and technology transfer which collectively account for half of project costs. Other investment costs are incurred for the variable frequency production line, testing equipment and additional machine tools.

Table 6. Investment Costs With Project at Zhejiang (1000 yuan)

Items	Unit	Unit Cost	Total Cost	Purchase Period
1. Frequency production line	1	1500	1500	2 & 3
2. Frequency test equipment	1	1500	1500	2 & 3
3. Processing machine system	2	3000	6000	2 & 3
4. 2.5 m Vertical machine toll	1	500	500	1
5. Vertical miller	1	500	500	1
6. Low resistance producers	1	1000	1000	1
7. Motor testing system	1	1500	1500	2
8. CAD system	1	500	500	2
9. Special machine tools			1500	2
10. Equipment completion			500	2
11. Installation			2000	1, 2 & 3
12. Technology transfer			4000	1
Total			21000	
Investment Schedule				
1. First Year			7000	
2. Second Year			9000	
3. Third Year			5000	

Tables 7 and 8 show financial cash flows at Zhejiang with and without the project. At full operation, operating cost increase by 67.1 percent from 86.5 to 144.5 million yuan. Under both cases, raw material costs at 82.4 percent of total operating costs are the principal variable cost. Total benefits increase by from 105 to 170 million yuan.

Table 7. Financial Cash Flow With the Project at Zhejiang (1000 yuan)

	Investment			Operational Cost							
Year	Old Equip Replace	New Equip Purchase	Subtotal	Raw Material	Energy Use	Mainte-nance	Salary & Others	Subtotal	Total Cost	Total Benefit	Net Benefits
1	2000	7000	9000	70000	2200	3300	11000	86500	95500	105000	9500
2		9000	9000	70000	2200	3300	11000	86500	95500	105000	9500
3		5000	5000	70000	2200	3300	11000	86500	91500	105000	13500
4			0	98000	2800	4200	14000	119000	119000	140000	21000
5			0	119000	3400	5100	17000	144500	144500	170000	25500
6			0	119000	3400	5100	17000	144500	144500	170000	25500
7			0	119000	3400	5100	17000	144500	144500	170000	25500
8			0	119000	3400	5100	17000	144500	144500	170000	25500
9			0	119000	3400	5100	17000	144500	144500	170000	25500
10			0	119000	3400	5100	17000	144500	144500	170000	25500
Total	2000	21000	23000	1022000	29800	44700	149000	1245500	1268500	1475000	206500
PV	1786	16984	18769	541341	15947	23921	79736	660945	679715	785353	105639

Table 8. Financial Cash Flow Without the Project at Zhejiang (1000 yuan)

	Investment			Operational Cost							
Year	Old Equip Replace	New Equip Purchase	Subtotal	Raw Material	Energy Use	Mainte-nance	Salary & Others	Subtotal	Total Cost	Total Benefit	Net Benefits
1	2000		2000	70000	2200	3300	11000	86500	88500	105000	16500
2			0	70000	2200	3300	11000	86500	86500	105000	18500
3			0	70000	2200	3300	11000	86500	86500	105000	18500
4			0	70000	2200	3300	11000	86500	86500	105000	18500
5			0	70000	2200	3300	11000	86500	86500	105000	18500
6			0	70000	2200	3300	11000	86500	86500	105000	18500
7			0	70000	2200	3300	11000	86500	86500	105000	18500
8			0	70000	2200	3300	11000	86500	86500	105000	18500
9			0	70000	2200	3300	11000	86500	86500	105000	18500
10			0	70000	2200	3300	11000	86500	86500	105000	18500
Total	2000	0.0	2000	700000	22000	33000	110000	865000	867000	1050000	183000
PV	1786	0.0	1786	395516	12430	18646	62152	488744	490530	593273	102743

Incremental cash flow with and without the project is indicated in Table 9. The net present value for the project is 23.5 million yuan with an internal rate of return of 15.6 percent. The payback period for the project is seven years (four years after the construction phase of the project).

Table 9. Incremental Cash Flow With and Without Project at Zhejiang (1000 yuan)

	Investment			Operational Cost							
Year	Old Equip Replace	New Equip Purchase	Subtotal	Raw Material	Energy Use	Mainte-nance	Salary & Others	Subtotal	Total Cost	Total Benefit	Net Benefits
1	0	7000	7000	0.0	0	0	0	0	7000	0	(7000)
2	0	9000	9000	0.0	0	0	0	0	9000	0	(9000)
3	0	5000	5000	0.0	0	0	0	0	5000	0	(5000)
4	0	0	0	28000	600	900	3000	32500	32500	35000	2500
5	0	0	0	49000	1200	1800	6000	58000	58000	65000	7000
6	0	0	0	49000	1200	1800	6000	58000	58000	65000	7000
7	0	0	0	49000	1200	1800	6000	58000	58000	65000	7000
8	0	0	0	49000	1200	1800	6000	58000	58000	65000	7000
9	0	0	0	49000	1200	1800	6000	58000	58000	65000	7000
10	0	0	0	49000	1200	1800	6000	58000	58000	65000	7000
Total	0	21000	21000	322000	7800	11700	39000	380500	401500	425000	23500
PV	0	16984	16984	145825	3517	5275	17584	172201	189185	192080	2895
IRR											15.56%

Energy and Environmental Benefits

Table 10 indicates energy and environmental benefits from the proposed project at Zhejiang. Annual power savings are projected to be 86,400 mwh. Annual CO_2 emissions reduction is estimated to be 26,351 tons. Reductions of SO_2 and TSP emissions are projected at 819 and 741 tons per year, respectively.

Table 10. Energy and Environmental Benefits at Zhejiang

Items	YCT	VF	Total
1. Incremental yield (mw)	150.00	20.00	170.00
2. Power saving rate (%)	20.00%	30.00%	*
3. Annual power savings (mwh)	72000.00	14400.00	86400.00
4. Annual emission reductions			
CO2(t)	21958.82	4391.76	26350.59
SO2 (t)	682.70	136.54	819.23
TSP (t)	617.54	123.51	741.05

Case 2: Chining Enterprise Electrical Works in Shenyang

Chining Enterprise Electrical Works at Shenyang is one of the leading manufacturers of small and medium electrical motors in China. The plant's current annual production capacity is 600 motors. The Chining plant plans to expand its annual production capacity for variable speed motors to 610 from its current capacity of 50 variable speed motors (all YCT series). As indicated in Table 11, that capacity will include 400 YCT, 200 YD, and 10 YF motors.

Table 11. Major Production Indicators With and Without Project at Shenyang

	With Project			Without Project	
Items	YCT	YD	VF	YCT	YD
1. Production capacity (units)	400	200	10	50	
2. Production yield (units)	330	170	10	25	
3. Sales price (yuan/kw)	320	200	1000	320	200
4. Sales cost (1000 yuan)	1100	400	100	90	
5. Total sales income (million yuan)	105.6	34	10	8	
6. Sales Tax	4600	1450	450	370	

As indicated in Table 12, investment costs for the project at Shenyang are expected to be 20.3 million RMB yuan over a three year renovation period. The principal project costs are for a processing center, numeric control machines, and technology transfer. Other processing and testing equipment and installation make up the bulk of the remaining investment costs.

Table 12. Investment Costs With Project at Shenyang (1000 yuan)

Items	Unit	Unit Cost	Total Cost	Purchase period
1. Motor processing machine	5	300	1500	1 & 2
2. Numeric control machine	4	600	2400	1 & 2
3. Processing center	1	3500	3500	2
4. Numeric controlled cutting machine	2	250	500	1
5. Paint machine	1	80	80	1 & 2
6. Motor test system	1	1200	1200	1, 2 & 3
7. Speed adjuster for production line	1	600	600	2
8. Computer station	1	1000	1000	1 & 2
9. Equipment completion	3	500	1500	2 & 3
10. Installation			5500	1, 2 & 3
11. Technology transfer			2500	
Total			20280	
Investment Schedule				
1. First year			7723	
2. Second year			9573	
3. Third year			2983	

Tables 13 and 14 show financial cash flows at Shenyang with and without the project. At full operation, operating cost increase by 54.5 percent from 93.5 to 144.5 million yuan. Under both cases, raw material costs at 82.4 percent of total operating costs are the principal variable cost. Total benefits increase by 72.4 percent.

Table 13. Financial Cash Flow With the Project at Shenyang (1000 yuan)

	Investment			Operational Cost							
Year	Old Equip Replacemt	NewEquip Purchase	Subtotal	Raw Material	Energy Use	Mainte-nance	Salary & Others	Subtotal	Total Cost	Total Benefit	Net Benefits
1		7723.30	7723.30	5510.00	140.00	200.00	540.00	6390.00	14113.30	8000.00	-6113.30
2		9573.40	9573.40	5510.00	140.00	200.00	540.00	6390.00	15963.40	8000.00	-7963.40
3		2983.30	2983.30	5510.00	140.00	200.00	540.00	6390.00	9373.30	8000.00	-1373.30
4				45500.00	1160.00	1450.00	2700.00	50810.00	50810.00	76653.15	25843.15
5				88800.00	2000.00	2800.00	5000.00	98600.00	98600.00	149600.00	51000.00
6				88800.00	2000.00	2800.00	5000.00	98600.00	98600.00	149600.00	51000.00
7				88800.00	2000.00	2800.00	5000.00	98600.00	98600.00	149600.00	51000.00
8				88800.00	2000.00	2800.00	5000.00	98600.00	98600.00	149600.00	51000.00
9				88800.00	2000.00	2800.00	5000.00	98600.00	98600.00	149600.00	51000.00
10				88800.00	2000.00	2800.00	5000.00	98600.00	98600.00	149600.00	51000.00
Total	0.0	20280.00	20280.00	594830.00	13580.00	18850.00	34320.00	661580.00	681860.00	998253.15	316393.15
PV	0.0	16651.11	16651.11	274173.35	6299.20	8717.91	16077.26	305267.72	321918.83	458815.02	136896.18

Table 14. Financial Cash Flow Without the Project at Shenyang (1000 yuan)

	Investment			Operational Cost							
Year	Old Equip Replacemt	NewEquip Purchase	Subtotal	Raw Material	Energy Use	Mainte-nance	Salary & Others	Subtotal	Total Cost	Total Benefit	Net Benefits
1			0.00	5510.00	140.00	200.00	540.00	6390.00	6390.00	8000.00	1610.00
2			0.00	5510.00	140.00	200.00	540.00	6390.00	6390.00	8000.00	1610.00
3			0.00	5510.00	140.00	200.00	540.00	6390.00	6390.00	8000.00	1610.00
4			0.00	5510.00	140.00	200.00	540.00	6390.00	6390.00	8000.00	1610.00
5			0.00	5510.00	140.00	200.00	540.00	6390.00	6390.00	8000.00	1610.00
6			0.00	5510.00	140.00	200.00	540.00	6390.00	6390.00	8000.00	1610.00
7			0.00	5510.00	140.00	200.00	540.00	6390.00	6390.00	8000.00	1610.00
8			0.00	5510.00	140.00	200.00	540.00	6390.00	6390.00	8000.00	1610.00
9			0.00	5510.00	140.00	200.00	540.00	6390.00	6390.00	8000.00	1610.00
10			0.00	5510.00	140.00	200.00	540.00	6390.00	6390.00	8000.00	1610.00
Total	0.00	0.00	0.00	55100.00	1400.00	2000.00	5400.00	63900.00	63900.00	80000.00	16100.00
PV	0.00	0.00	0.00	31132.73	791.03	1130.04	3051.12	36104.93	36104.93	45201.78	9096.86

Incremental case flow with and without the project is indicated in Table 15. Once plant expansion is completed in year five, the project shows substantial net

benefits. The net present value for the project is 50.4 million yuan with an internal rate of return of 42.4 percent. The payback period for the project is four years (one year after the construction phase of the project).

Table 15. Incremental Cash Flow With and Without the Project at Shenyang (1000 yuan)

	Investment			Operational Cost							
Year	Old Equip Replacemt	NewEquip Purchase	Subtotal	Raw Material	Energy Use	Mainte-nance	Salary & Others	Subtotal	Total Cost	Total Benefit	Net Benefits
1	0.00	7723.30	7723.30	0.00	0.00	0.00	0.00	0.00	7723.30	0.00	-7723.30
2	0.00	9573.40	9573.40	0.00	0.00	0.00	0.00	0.00	9573.40	0.00	-9573.40
3	0.00	2983.30	2983.30	0.00	0.00	0.00	0.00	0.00	2983.30	0.00	-2983.30
4	0.00	0.00	0.00	39990.00	1020.00	1250.00	2160.00	44420.00	44420.00	68653.15	24233.15
5	0.00	0.00	0.00	83290.00	1860.00	2600.00	4460.00	92210.00	92210.00	141600.00	49390.00
6	0.00	0.00	0.00	83290.00	1860.00	2600.00	4460.00	92210.00	92210.00	141600.00	49390.00
7	0.00	0.00	0.00	83290.00	1860.00	2600.00	4460.00	92210.00	92210.00	141600.00	49390.00
8	0.00	0.00	0.00	83290.00	1860.00	2600.00	4460.00	92210.00	92210.00	141600.00	49390.00
9	0.00	0.00	0.00	83290.00	1860.00	2600.00	4460.00	92210.00	92210.00	141600.00	49390.00
10	0.00	0.00	0.00	83290.00	1860.00	2600.00	4460.00	92210.00	92210.00	141600.00	49390.00
Total	0.00	20280.00	20280.00	539730.00	12180.00	16850.00	28920.00	597680.00	617960.00	918253.15	300293.15
NPV	0.00	16651.11	16651.11	243040.62	5508.17	7587.87	13026.14	269162.80	285813.91	413613.23	127799.32
IRR											81.51%

Environmental benefits were not calculated for this case study. Emissions reductions per unit energy saved should be similar to the figures used above in the Zhejiang case.

Electric Motors Industry: Case 3
Electric Motor Repair Center

Introduction

The current capacity of electric motors in use in China is 330 gw. Of that figure, 70 percent of capacity is in the 0.55-100 kw range. Annual repairs of electric motors currently account for 3-5 percent of the total mounting stock and amount to 10 gw of small and medium motors per year. The distribution of electric motors by use category and capacity range is indicated in Table 1. Motors used for pumps, compressors and fans account for 77.6 percent of usage. The most frequent repair need is stader winding which accounts for 80 percent of repair services. Bearings, shafts, and fans account for most of the remaining repair needs.

Table 1. Total Repairs Capacity (mw)

Sector	.55-18.5kw	22-100kw	Total
1. Machine tools	600.00	30.00	630.00
2. Textile machines	400.00	10.00	410.00
3. Pumps	1400.00	2100.00	3500.00
4. Fans	850.00	900.00	1750.00
5. Compressors	850.00	1600.00	2450.00
6. Metal rolling	50.00	100.00	150.00
7. Building material	250.00	80.00	330.00
8. Others	400.00	300.00	700.00
Total	4800.00	5120.00	9920.00

At the present time, no large specialized motor repair center exists in China. Large and medium-sized motors typically are maintained and repaired within the repair unit of large enterprises while small motors are repaired in small repair workshops or repair rooms. It is estimated that nearly 1000 such enterprises operate throughout the country. These repair shops use simple repair instruments and in general lack testing equipment so that the operating efficiency of repaired motors is reduced. Efficiency losses for small to medium JO2 series 4 pole motors range from 0.73 to 1.76 percentage points. The highest losses are for small motors decreasing to 0.73 percentage point losses for motors of 75 and 90 kw capacity.

The primary causes of efficiency reduction include:

- oxidation of iron core during operation resulting in 20 percent increase in iron loss,
- enlargement of air gap resulting in 10 percent loss of stader copper, and
- bad insulating treatment resulting in 5 percent of total loss.

Technology Assessment

Principal repair options include:

- removal of old coils,
- design and replacement of windings,
- improved insulation treatment,

- use of magnetic wedges, and
- change fans to axial flow models.

Magnetic Wedges: The use of magnetic wedges to seal slot openings may cause the no-load loss of electric motors to be reduced by 20 percent and the stray-load loss by 30 percent. Motor efficiency can be raised by 0.5-2 percent at full-load, 2-6 percent at light-load, and 1-3.5 percent at 60 percent load. Annual motor repairs using magnetic wedges amount to 6 gw with annual power savings of 200 gwh.

Fans and Covers: Changing fans and fan covers during repair can improve energy efficiency by more than one percent. Based on 1 gw of motors requiring fan repairs, annual power savings could amount to 60 gwh.

Optimal Motor Design: Motors used to drive machine tools amount to 15 gw capacity. The use of computer optimization design techniques can improve operating efficiencies by 6-13 percent. At 4000 operating hours per year, 600 kwh can be saved. If 100,000 motors are repaired per year using design optimization, annual power savings could amount to 60 gwh.

Pole Changing Repair: An estimated 60 percent of fans and pumps in China are operating at constant flow. Of those fans and pumps, 40 percent are operating at 50-70 percent of rated flow capacity. For that reason, motor repairs using pole changing assembly offer substantial savings potential for a large subset of fan and pump motors. If 10,000 motors with a 500 mw capacity are repaired with pole changing assemblies, 640 gwh of power can be saved per year.

Efficiency comparisons for motors repaired using standard and high efficiency repair techniques are indicated in Table 2. Also listed are relative repair prices in yuan/kw for small and medium-sized motors. Options considered include: 1) magnetic wedge, 2) fan replacement, 3) design optimization, 4) pole changing, and 5) standard repair techniques. The highest efficiency improvements are for design optimization and pole changing repairs. These repairs tend to be the most expensive repair options as well.

Table 2. Efficiency Improvements and Relative Costs for Alternate Motor Repair Options

Repair Method		Magnetic wedge (1)	Replacing fans (2)	Optimizat'n design (3)	Changing poles (4)	Standard repairs (5)
Efficiency increase (%)		0.5-2	0.5-2	7-10	10-20	-
Repair price	0.55-18.5 kw	11.47	21.33	64.00	64.67	53.07
(yuan/kw)	22-100 kw	10.81	21.62	47.30	47.84	43.51

Electricity savings and relative cost of energy savings are compared in Tables 3 and 4. Table 3 is based on efficiency comparisons for small motors with an average capacity of 7.5 kw, while Table 4 is based on mid-sized motors with an average capacity of 37 kw. Relative to standard repair techniques (option 5), all but one of the efficiency improving repair methods for both sized motors offer cost effective energy savings. Design optimization for small motors less than 18.5 kw produce energy savings at a cost of 311.48 yuan/mwh, a cost exceeding the current cost of electricity of 250 yuan/mwh. Energy cost savings are substantial for larger capacity motors. Actual savings in use will depend on applications, operating hours, and load factors.

Table 3. Electricity Savings and Relative Costs for Alternate Repair Options (0.55-18.5 kw, average capacity 7.5 kw)

Repair method	1	2	3	4*	5
Repair cost (yuan)	86.00	160.00	480.00	485.00	398.00
Efficiency improvement (%)	1.30	3.20	9.50	10.00	-
Load factor (%)	60.00	60.00	15.00	60.00	60.00
Annual operating hours	4000	4000	4000	4000	4000
Annual power savings (kwh)	234.00	576.00	427.50	1800.00	-
Discounted cost savings (yuan/mwh)	101.95	77.06	311.48	74.75	-
Cost savings (yuan/mwh)	148.95	172.94	-61.48	175.25	-

* Energy savings rate rather than efficiency improvement.
Sales price for power is 250 yuan/mwh.

Table 4. Electricity Savings and Relative Costs for Alternate Repair Options (22.0-100 kw, average capacity 37 kw)

Repair method	1	2	3	4*	5
Repair cost (yuan)	400.00	800.00	1750.00	1770.00	1610.00
Efficiency improvement (%)	1.70	2.70	9.50	10.00	-
Load factor (%)	60.00	60.00	15.00	60.00	60.00
Annual operating hours	4000	4000	4000	4000	4000
Annual power savings (kwh)	4080.00	6480.00	5700.00	24000	-
Discounted cost savings (yuan/mwh)	27.20	34.25	85.17	20.46	-
Cost savings (yuan/mwh)	222.80	215.75	164.83	229.54	-

* Energy savings rate rather than efficiency improvement.

Financial Analysis

Investment costs to establish a motor repair center are shown in Table 5. The figures are based on experience at the Shanghai Electrical Motor Service Center operating at 600 mw of motor repair per year. Total investment costs are expected to be 7.1 million RMB yuan. The highest cost investment items include on-site materials, testing equipment, insulation machines, and a metal processor. Equipment lifetime is projected at 10 years.

Table 5. Investment for Motor Repairs Center (1,000 yuan)

Items	Unit	Price Per Unit	Total Cost	Lifespan(years)
1.Temperature controlled heater	3.00	150.00	450.00	10.00
2.Winding removal machine	2.00	15.00	30.00	10.00
3.Washing machine	1.00	8.00	8.00	10.00
4.Rewinding machine	6.00	5.00	30.00	10.00
5.Insulation machine	2.00	450.00	900.00	10.00
6.Dynamic balance machine	4.00	25.00	100.00	10.00
7.Metal processor	1.00	800.00	800.00	10.00
8.Lifting Equipment	2.00	125.00	250.00	10.00
9.Transportation equipment	11.00	50.00	550.00	10.00
10. On duty materials	20.00	104.00	2080.00	10.00
11. Test Equipment	1.00	925.00	925.00	10.00
12. Technical transfer fee	1.00	400.00	400.00	
13. Advertisement fee	1.00	600.00	600.00	
Total			7123.00	

Operating costs per motor are shown in Table 6. Costs are delineated for each of five motor repair options described above and by motor size range with average capacities of 7.5 and 37 kw. Motor repair costs differ substantially by type of repair. Magnetic wedges on the low end average 17.5 to 22.5 percent of standard repair costs depending on size range. Design optimization and pole switching repairs that involve the highest efficiency improvements are the most costly options averaging between 10.9 and 11.7 percent above standard motor repair costs.

Table 6. Motor Repair Operating Costs (yuan/motor)

Capacity	0.55-18.5kw (Average 7.5kw)					22-100kw (average 37kw)				
Repairs Methods	1.00	2.00	3.00	4.00	5.00	1.00	2.00	3.00	4.00	5.00
Cost Items										
1. Raw Materials	8.00	108.00	215.00	215.00	193.00	40.00	420.00	760.00	765.00	694.00
a. Wire			185.00	185.00	168.00			710.00	710.00	644.00
b. Isolation			30.00	30.00	25.00			50.00	55.00	50.00
c. Magnetic	8.00					40.00				
d. Fans		108.00					420.00			
2. Salary & Welfare	40.00	10.00	100.00	100.00	90.00	180.00	20.00	350.00	355.00	320.00
3. Waste Products	0.90	2.00	6.00	6.00	5.00	4.00	4.00	30.00	30.00	27.00
4. Maintenance	5.10	6.00	20.00	23.00	20.00	24.00	18.00	60.00	65.00	60.00
5. Total Cost	54.00	126.00	341.00	344.00	308.00	248.00	462.00	1200.00	1215.0	1101.00
6. Repairs Price	86.0	160.00	480.00	85.00	398.00	400.00	800.00	1750.0	1770.0	1610.00
7. Profit & Tax	32.00	34.00	139.00	141.00	90.00	152.00	338.00	550.00	555.00	509.00
a. Profit	19.20	20.40	83.40	84.60	79.20	91.20	202.80	330.00	333.00	305.40
b. Tax	12.80	13.60	55.60	56.40	10.80	60.80	135.20	220.00	222.00	203.60

Table 7 shows operating costs per kw based on a 600 mw repair facility again delineated by motor repair method and motor capacity range. Relative cost comparisons between motor repair methods are similar to those depicted in Table 6.

Table 7. Motor Repair Operating Costs (yuan/kw)

Capacity	0.55-18.5kw (Average 7.5kw)					22-100kw (average 37kw)				
Repairs Methods	1.00	2.00	3.00	4.00	5.00	1.00	2.00	3.00	4.00	5.00
Cost Items										
1. Raw Materials	1.07	14.40	28.67	28.67	25.73	1.08	11.35	20.54	20.68	18.76
a. Wire	0.00	0.00	24.67	24.67	22.40	0.00	0.00	19.19	19.19	17.41
b. Isolation	0.00	0.00	4.00	4.00	3.33	0.00	0.00	1.35	1.49	1.35
c. Magnetic	1.07	0.00	0.00	0.00	0.00	1.08	0.00	0.00	0.00	0.00
d. Fans	0.00	14.40	0.00	0.00	0.00	0.00	11.35	0.00	0.00	0.00
2. Salary & Welfare	5.33	1.33	13.33	13.33	12.00	4.86	0.54	9.46	9.59	8.65
3. Waste Products	0.12	0.27	0.80	0.80	0.67	0.11	0.11	0.81	0.81	0.73
4. Maintenance	0.68	0.80	2.67	3.07	2.67	0.65	0.49	1.62	1.76	1.62
5. Total Cost	7.20	16.80	45.47	45.87	41.07	6.70	12.49	32.43	32.84	29.76
6. Repair Price	11.47	21.33	64.00	64.67	53.07	10.81	21.62	47.30	47.84	43.51
7. Profit & Tax	4.27	4.53	18.53	18.80	12.00	4.11	9.14	14.86	15.00	13.76
a. Profit	2.56	2.72	11.12	11.28	10.56	2.46	5.48	8.92	9.00	8.25
b. Tax	1.71	1.81	7.41	7.52	1.44	1.64	3.65	5.95	6.00	5.50

Financial cash flow with and without the project is shown in Table 8. Operating costs stabilize at 11.25 million yuan in year five. Of that figure, 58.1 percent of operating costs are for raw materials with 34.0 percent of costs being labour expense. By year five, annual revenues reach 16.2 million yuan. The project generates a net present value of 13.8 million yuan over a ten year operating period with a payback period of four years. The internal rate of return for the project is 44.8 percent suggesting that the project is very viable. The success of the project in operation will depend to a large extent on the relative acceptance of users to improved efficiency in motor repair and to the successful targeting of efficiency improvement in various use categories.

Table 8. Financial Cash Flow Analysis With and Without Project (1,000 yuan)

Year	Invest - New Equip Purch	Operating Cost: Raw Material	Waste Products	Maintenance	Salary & Others	Total Oper'g Cost	Total Cost	Total Benefits	Net Benefits
1	7123.00						7123.00	0.00	-7123.00
2	0.00	1958.90	61.78	207.72	1146.08	3374.47	3374.47	4860.43	1485.96
3	0.00	3917.79	123.56	415.44	2292.16	6748.95	6748.95	9720.86	2971.92
4	0.00	5223.72	164.72	553.92	3056.22	8998.60	8998.60	12961.15	3962.55
5	0.00	6529.65	205.93	692.40	3820.27	11248.25	11248.25	16201.44	4953.19
6	0.00	6529.65	205.93	692.40	3820.27	11248.25	11248.25	16201.44	4953.19
7	0.00	6529.65	205.93	692.40	3820.27	11248.25	11248.25	16201.44	4953.19
8	0.00	6529.65	205.93	692.40	3820.27	11248.25	11248.25	16201.44	4953.19
9	0.00	6529.65	205.93	692.40	3820.27	11248.25	11248.25	16201.44	4953.19
10	0.00	6529.65	205.93	692.40	3820.27	11248.25	11248.25	16201.44	4953.19
11	0.00	6529.65	205.93	692.40	3820.27	11248.25	11248.25	16201.44	4953.19
Total	7123.00	56807.99	1791.57	6023.85	33236.35	97859.76	104982.7	140952.54	35969.78
PV	6359.82	26608.28	839.15	2821.51	15567.57	45836.51	52196.33	66020.72	13824.39
IRR									44.77%

Energy Conservation

Energy conservation benefits are depicted in Table 9. Based on annual repairs of 800 mw, annual electricity savings range from 24.06 to 72.18 gwh depending on the number of operating hours in use. Using 4000 annual operating hours, annual electricity savings are estimated at 48.12 gwh.

Table 9. Energy Conservation Benefits for Alternate Motor Repair Options (mwh)

Repairs Method	Repair Total (kw)	Effic Improv (%)	Load Factor (%)	Annual Operating Hours: 2000	4000	6000
1. Light load design	100.00	9.00	15.00	2700.00	5400.00	8100.00
2. Magnetic wedges	500.00	1.30	60.00	7800.00	15600.00	23400.00
3. Fan replacement	100.00	1.30	60.00	1560.00	3120.00	4680.00
4. Pole changing	100.00	10.00	60.00	12000.00	24000.00	36000.00
Total	800.00			24060.00	48120.00	72180.00

Environmental Benefits

Emissions reductions increase over the first several years of the project stabilizing by year six. At that time, annual CO_2 emissions are expected to decrease by 73,379 tons. SO_2 and TSP emissions are projected to decrease by 2,281 and 2,063 tons per year, respectively.

Table 10. Emissions Reduction With Project

Year	Power Save (gwh)	Emissions Reduction CO2 (t)	SO2 (t)	TSP (t)
1	-	-	-	-
2	48.12	14675.81	456.27	412.72
3	96.24	29351.63	912.54	825.44
4	144.36	44027.44	1368.80	1238.16
5	192.48	58703.25	1825.07	1650.89
6	240.60	73379.06	2281.34	2063.61
7	240.60	73379.06	2281.34	2063.61
8	240.60	73379.06	2281.34	2063.61
9	240.60	73379.06	2281.34	2063.61
10	240.60	73379.06	2281.34	2063.61
Total	1684.20	513653.45	15969.38	14445.25
PV	799.96	243974.38	7585.11	6861.18

	Emission Factor (kg/mwh)	Abatement Benefit (yuan/t)
1. CO2	304.98	N/A
2. SO2	9.48	182.77
3. TSP	8.58	62.60

Economic/Environmental Assessment

Table 11 depicts the economic/environmental cash flow for the project. Using economic prices, the internal rate of return increases from 44.8 to 47.7 percent reflecting slightly higher energy prices. Including local air pollution benefits with the project, the rate of return increases to 50.9 percent. The incremental cost of CO_2 reduction is 207.56 RMB yuan per ton. Still, net benefits per ton CO_2 reduction are 63.04 or 70.49 with local environmental benefits included.

Table 11. Incremental Economic/Environmental Cash Flow Analysis (1000 yuan)

Year	Total Costs	Total Benefits	Net Benefits	Emissions Global CO2 (t)	Emissions Local SO2 (t)	Local TSP (t)	Econ Value of Local Pollution Reduction	Net Economic/ Environmental Benefits
1	7,123.00	0.00	(7,123.00)	-	-	-	0.00	(7,123.00)
2	3,259.87	4,860.43	1,600.57	(14.68)	(456.27)	(412.72)	109.23	1,709.79
3	6,519.73	9,720.86	3,201.13	(29.35)	(912.54)	(825.44)	218.46	3,419.59
4	8,692.98	12,961.15	4,268.18	(44.03)	(1,368.80)	(1,238.16)	327.69	4,595.86
5	10,866.22	16,201.44	5,335.22	(58.70)	(1,825.07)	(1,650.89)	436.91	5,772.13
6	10,866.22	16,201.44	5,335.22	(73.38)	(2,281.34)	(2,063.61)	546.14	5,881.36
7	10,866.22	16,201.44	5,335.22	(73.38)	(2,281.34)	(2,063.61)	546.14	5,881.36
8	10,866.22	16,201.44	5,335.22	(73.38)	(2,281.34)	(2,063.61)	546.14	5,881.36
9	10,866.22	16,201.44	5,335.22	(73.38)	(2,281.34)	(2,063.61)	546.14	5,881.36
10	10,866.22	16,201.44	5,335.22	(73.38)	(2,281.34)	(2,063.61)	546.14	5,881.36
11	10,866.22	16,201.44	5,335.22	-	-	-	0.00	5,335.22
Total	101,659.13	140,952.54	39,293.41	(513.65)	(15,969.38)	(14,445.25)	3,823.00	43,116.41
PV	50,639.57	66,020.72	15,381.15	(243.97)	(7,585.11)	(6,861.18)	1,815.84	17,196.99
IRR			47.69%					50.86%

	CO2
Total Incremental Cost/Ton of CO2 Reduction (yuan at 12%)	207.56
At RMB/US$ = 5.50	$37.74
Total Net Benefits/Ton of CO2 Reduction (yuan at 12%)	63.04
At RMB/US$ = 5.50	$11.46
Net Benefits Incl'g Local Env. Benefits/Ton of CO2 Reduction	70.49
At RMB/US$ = 5.50	$12.82

Electric Motors Industry: Case 4
Steam Trap Production

Introduction

Annual coal production in China reached one billion tons by 1989. Of that figure, 300 million tons were consumed by the nearly 450,000 industrial boilers in use. The boilers in turn produced 800,000 tons of steam accounting for one-third of total energy output in China. At present development patterns, annual output of raw coal will reach 1.4 million tons by the end of the decade with 500 million tons used in industrial boilers. Industrial boiler use at that time will account for 25 million tons per year of CO_2 emissions.

The energy efficiency of steam heating systems in China continues to lag behind international averages. Table 1 compares relative efficiencies in China with Western European averages. Overall system efficiencies are roughly half of Western European comparables. To address this issue, China has focused on boiler efficiency improvements over the past decade. Operating efficiencies for new and renovated boilers now average 60 percent efficiency compared to 80 percent efficiency in Western Europe. A parallel effort needs to be expended to improve efficiency in the steam piping network as well as in steam driven equipment.

Table 1. Thermal Efficiency for Steam Heating Systems in China and Western Europe

Efficiency	China	Western Europe
Boiler Efficiency	55 - 60 %	80 %
Piping Network Efficiency	85 - 90 %	95 - 98 %
Equipment Efficiency	35 - 37 %	50 - 55 %
Total Efficiency	< 20 %	> 38 %

Although a number of technical solutions exist to improve piping network efficiency, the present case study focuses on the expansion of steam trap production where substantial potential for efficiency improvement exists. The current annual production of steam traps in China amounts to 1 million units. The Ministry of Machinery and Electronics estimates that 12 million traps per year are required to meet needed efficiency improvements in the industrial sector. Qualitative changes are needed as well as the life expectancy of current Chinese traps is 3 to 4 months compared with Western European averages of 1 to 2 years.

The proposed project involves expansion of steam trap production at Yangzhou Valve Factory. The factory is located at the intersection of the Grand Canal and Yangtze River allowing good land and water transportation connections. The factory also lies within the Shanghai Economic Zone. The primary products of the plant are traps, safety valves, gate valves, and globe valves. The plant has adapted new production technology to expand its product line in recent years, but outdated equipment continues to prevent the plant from achieving the production efficiency and precision necessary to meet both quantitative and qualitative demands.

Technology Assessment

A number of options exist for improving the efficiency of steam piping networks. Those options include: 1) steam traps, 2) pressure reducing valves, 3) safety valves, 4) heat exchangers, 5) temperature-controlled valves, 6) steam-water separators, 7) condensate recovery pumps, 8) flash tanks, 9) blow-down valves, and 10) waste heat recovery equipment. Of these ten options, only the first four options have been produced at any volume to date within China. Even in those cases, enterprises tend to be small and have trouble meeting both the volume and precision requirements for wide spread application in industrial operations. Applications include use in a wide variety of durable and nondurable manufacturing settings and commercials buildings.

Of the options for improving efficiency in steam piping networks, steam traps offer the widest possible application and the most obvious energy saving potential. With steam trap production, substantial economies-of-scale exist. Wider application in the Chinese industrial sector will require greater precision to increase operating efficiencies and product durability.

Financial Analysis

The proposed project is designed to increase steam trap production at the Yangzhou Valve Factory from 20,000 to 200,000 steam traps per year. The analysis does assume production at capacity with the project even though the factory is operating currently at 60 percent of capacity. Total sales income is expected to increase from 2,300 to 40,000 yuan with the project. Sales price increases from 140 to 200 yuan per set due to qualitative change in steam trap production.

Table 2. Major Production Indicators With and Without Project

Items	With Project	Without Project	Incremental
1. Production capacity (‘000 sets)	200	20	180
2. Actual production (‘000 sets)	200	12	188
3. Total sales (‘000 sets)	200	12	188
4. Sales price (yuan/set)	200.00	140.00	60.00
5. Sales income (million/yuan)	40.00	1.68	38.32

Total project investment is expected to be 15.57 million RMB yuan to be incurred over a three year construction period. The majority of investment (10.9 million yuan) is accounted for by equipment purchases which include forging equipment, heat treatment equipment, metal cutting and grinding tools, welding devices, testing facilities and computer equipment. The majority of the other expenses are incurred for civil work and utilities upgrade.

Table 3. Investment With the Project (1000 yuan)

Items	Year 1	Year 2	Year 3	Total
1. Equipment	205	9710	1000	10915
2. Installation	20	970	100	1090
3. Overhaul	70	80	100	250
4. Building	500	500	200	1200
5. Other		1800	310	2110
Total	795	13060	1710	15565

Operating costs with and without the project are shown in Table 4. Annual operating costs are projected to increase by 1567 percent with the project from 1.83 to 30.57 million yuan. This figure is consistent with the projected increase in output from 12,000 to 200,000 units. Raw material purchases increase at the same rate.

Table 4. Operating Cost With and Without the Project (1000 yuan)

Items	With Project	Without Project	Incremental
1. Energy	858.00	51.48	806.52
2. Raw materials	8780.00	526.80	8253.20
3. Salary & welfare	6292.00	377.52	5914.48
4. Repairs	680.40	40.82	639.58
5. Management	915.20	54.91	860.29
6. Sales cost	343.20	20.59	322.61
7. Sales tax	2600.00	156.00	2444.00
8. Depreciation	572.00	34.32	537.68
9. Interest	429.00	25.74	403.26
10. Others	9095.00	545.70	8549.30
Total	30564.80	1833.89	28730.91

Tables 5 and 6 depict financial cash flows with and without the project. As indicated above, investment costs with the project amount to 15.57 million yuan. Deleting transfer payments, operating costs beginning in year four increase from 1.62 to 26.96 million yuan. Total benefits increase by 2281 percent due to both price and output effects.

Table 5. Financial Cash Flow With the Project (1000 yuan)

Year	Investment		Operating Costs						Total Cost	Total Benefit	Net Benefits
	New Equipment	Subtotal	Coal	Raw Material	Repairs/ Maintnce	Salary/ Welfare	Other	Subtotal			
1	795.00	795.00	51.48	526.80	95.74	377.52	566.29	1617.83	2412.83	1680.00	-732.83
2	13060.00	13060.00	51.48	526.80	95.74	377.52	566.29	1617.83	14677.83	1680.00	-12997.83
3	1710.00	1710.00	51.48	526.80	95.74	377.52	566.29	1617.83	3327.83	1680.00	-1647.83
4		0.00	858.00	8780.00	1595.60	6292.00	9438.20	26963.80	26963.80	40000.00	13036.20
5		0.00	858.00	8780.00	1595.60	6292.00	9438.20	26963.80	26963.80	40000.00	13036.20
		0.00	858.00	8780.00	1595.60	6292.00	9438.20	26963.80	26963.80	40000.00	13036.20
7		0.00	858.00	8780.00	1595.60	6292.00	9438.20	26963.80	26963.80	40000.00	13036.20
8		0.00	858.00	8780.00	1595.60	6292.00	9438.20	26963.80	26963.80	40000.00	13036.20
9		0.00	858.00	8780.00	1595.60	6292.00	9438.20	26963.80	26963.80	40000.00	13036.20
10		0.00	858.00	8780.00	1595.60	6292.00	9438.20	26963.80	26963.80	40000.00	13036.20
Total	15565.00	15565.00	6160.44	63030.40	11456.41	45176.56	67766.28	193600.08	209165.08	285040.00	75874.92
PV	12338.32	12338.32	2910.77	29786.16	5413.08	21345.62	32019.11	91474.74	103813.05	133970.75	30157.69

Table 6. Financial Cash Flow Without the Project (1000 yuan)

Year	Investment		Operating Costs						Total Cost	Total Benefit	Net Benefits
	New Equipment	Subtotal	Coal	Raw Material	Repairs/ Maintnce	Salary/ Welfare	Other	Subtotal			
1		0.00	51.48	526.80	95.74	377.52	566.29	1617.83	1617.83	1680.00	62.17
2		0.00	51.48	526.80	95.74	377.52	566.29	1617.83	1617.83	1680.00	62.17
3		0.00	51.48	526.80	95.74	377.52	566.29	1617.83	1617.83	1680.00	62.17
4		0.00	51.48	526.80	95.74	377.52	566.29	1617.83	1617.83	1680.00	62.17
5		0.00	51.48	526.80	95.74	377.52	566.29	1617.83	1617.83	1680.00	62.17
6		0.00	51.48	526.80	95.74	377.52	566.29	1617.83	1617.83	1680.00	62.17
7		0.00	51.48	526.80	95.74	377.52	566.29	1617.83	1617.83	1680.00	62.17
8		0.00	51.48	526.80	95.74	377.52	566.29	1617.83	1617.83	1680.00	62.17
9		0.00	51.48	526.80	95.74	377.52	566.29	1617.83	1617.83	1680.00	62.17
10		0.00	51.48	526.80	95.74	377.52	566.29	1617.83	1617.83	1680.00	62.17
Total	0.00	0.00	514.80	5268.00	957.36	3775.20	5662.92	16178.28	16178.28	16800.00	621.72
PV	0.00	0.00	290.87	2976.54	540.93	2133.07	3199.68	9141.09	9141.09	9492.37	351.29

Incremental cash flow with and without the project is indicated in Table 7. After the three year construction phase of the project, annual net benefits reach 12.74 million yuan. Net present value for the project is 29.81 million yuan. The payback period for the project is five years (three years after project completion). The internal rate of return for the project is 52.41 percent which makes the project very viable from a financial perspective. A critical assumption in this case is that sufficient demand is generated to keep the expanded plant at capacity production. The second critical assumption is that relative production costs can at least remain constant while output quality is increased.

Table 7. Incremental Cash Flow With and Without Project (1000 yuan)

	Investment		Operating Costs								
Year	New Equipment	Subtotal	Coal	Raw Material	Repairs/ Maintnce	Salary/ Welfare	Other	Subtotal	Total Cost	Total Benefit	Net Benefits
1	795.00	795.00	0.00	0.00	0.00	0.00	0.00	0.00	795.00	0.00	-795.00
2	13060.00	13060.00	0.00	0.00	0.00	0.00	0.00	0.00	13060.00	0.00	-13060.00
3	1710.00	1710.00	0.00	0.00	0.00	0.00	0.00	0.00	1710.00	0.00	-1710.00
4	0.00	0.00	806.52	8253.20	1499.86	5914.48	8871.91	25345.97	25345.97	38320.00	12974.03
5	0.00	0.00	806.52	8253.20	1499.86	5914.48	8871.91	25345.97	25345.97	38320.00	12974.03
6	0.00	0.00	806.52	8253.20	1499.86	5914.48	8871.91	25345.97	25345.97	38320.00	12974.03
7	0.00	0.00	806.52	8253.20	1499.86	5914.48	8871.91	25345.97	25345.97	38320.00	12974.03
8	0.00	0.00	806.52	8253.20	1499.86	5914.48	8871.91	25345.97	25345.97	38320.00	12974.03
9	0.00	0.00	806.52	8253.20	1499.86	5914.48	8871.91	25345.97	25345.97	38320.00	12974.03
10	0.00	0.00	806.52	8253.20	1499.86	5914.48	8871.91	25345.97	25345.97	38320.00	12974.03
Total	15565.00	15565.00	5645.64	57772.40	10499.05	41401.36	62103.36	177421.80	192986.80	268240.00	75253.20
PV	12338.32	12338.32	2619.89	26809.63	4872.15	19212.55	28819.43	82333.65	94671.96	124478.37	29806.41
IRR											52.41%

Energy Conservation and Environmental Benefits

Table 8 shows incremental energy savings and emissions reductions over a ten year period. At full operation, annual energy savings are projected to be 980,000 tce. Annual CO_2 emissions are expected to decrease by 739,810 tons, while SO_2 and TSP emissions are projected to decrease by 23,000 and 20,810 tons per year, respectively.

Table 8. Energy Use and Atmospheric Emissions Reduction With Project

Year	Trap Yield ('000)	Coal Savings ('000 tce)	C02 Reduction ('000 t)	S02 Reduction ('000 t)	TSP Reduction ('000 t)
1	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00
4	96.00	480.00	362.36	11.27	10.19
5	196.00	980.00	739.81	23.00	20.81
6	196.00	980.00	739.81	23.00	20.81
7	196.00	980.00	739.81	23.00	20.81
8	196.00	980.00	739.81	23.00	20.81
9	196.00	980.00	739.81	23.00	20.81
10	196.00	980.00	739.81	23.00	20.81
Total	1272.00	6360.00	4801.23	149.27	135.02
PV	573.13	2865.66	2163.32	67.26	60.84

Economic/Environmental Assessment

Table 9 depicts the economic/environmental cash flow for the project. Using economic prices, the internal rate of return increases from 52.41 to 52.76 percent reflecting slightly higher energy prices. Including local air pollution benefits with the project, the rate of return increases to 52.78 percent. Adjusting for output in Table 10, the incremental cost of CO_2 reduction is 8,845 RMB yuan per ton, the highest cost per ton of

all of the projects assessed. Still, net benefits per ton CO_2 reduction are 19,099 yuan, the highest net benefits per ton among the 24 cases considered. With local environmental benefits included, net benefits per ton increase to 19,107 yuan. The scale effect of this project appears to have some influence on the magnitude of both costs and benefits per ton CO_2 reduction.

Table 9. Incremental Economic/Environmental Cash Flow Analysis (1000 yuan)

Year	Total Costs	Total Benefits	Net Benefits	Emissions CO2 (t)	Emissions SO2 (t)	Emissions TSP (t)	Economic Value of Pollution Reduction	Net Economic/ Environmental Benefits
1	795.00	0.00	(795.00)	0.00	0.00	0.00	0.00	(795.00)
2	13,060.00	0.00	(13,060.00)	0.00	0.00	0.00	0.00	(13,060.00)
3	1,710.00	0.00	(1,710.00)	0.00	0.00	0.00	0.00	(1,710.00)
4	25,238.44	38,320.00	13,081.56	(362.36)	(11.27)	(10.19)	2.70	13,084.26
5	25,238.44	38,320.00	13,081.56	(739.81)	(23.00)	(20.81)	5.51	13,087.07
6	25,238.44	38,320.00	13,081.56	(739.81)	(23.00)	(20.81)	5.51	13,087.07
7	25,238.44	38,320.00	13,081.56	(739.81)	(23.00)	(20.81)	5.51	13,087.07
8	25,238.44	38,320.00	13,081.56	(739.81)	(23.00)	(20.81)	5.51	13,087.07
9	25,238.44	38,320.00	13,081.56	(739.81)	(23.00)	(20.81)	5.51	13,087.07
10	25,238.44	38,320.00	13,081.56	(739.81)	(23.00)	(20.81)	5.51	13,087.07
Total	192,234.05	268,240.00	76,005.95	(4,801.23)	(149.27)	(135.02)	35.73	76,041.68
PV	94,322.65	124,478.37	30,155.73	(2,163.32)	(67.26)	(60.84)	16.10	30,171.83
IRR			52.76%					52.78%

Table 10. Incremental Economic/Environmental Cash Flow Analysis Adjusted for Output (1000 yuan)

Year	Total Costs	Total Benefits	Net Benefits	Global Emissions CO2 (t)	Local Emissions SO2 (t)	Local Emissions TSP (t)	Econ Value of Local Pollution Reduction	Net Economic/ Environmental Benefits
1	47.70	0.00	(47.70)	0.00	0.00	0.00	0.00	(47.70)
2	783.60	0.00	(783.60)	0.00	0.00	0.00	0.00	(783.60)
3	102.60	0.00	(102.60)	0.00	0.00	0.00	0.00	(102.60)
4	0.00	720.00	720.00	(7.55)	(0.23)	(0.21)	0.06	720.06
5	0.00	720.00	720.00	(30.20)	(0.94)	(0.85)	0.22	720.22
6	0.00	720.00	720.00	(30.20)	(0.94)	(0.85)	0.22	720.22
7	0.00	720.00	720.00	(30.20)	(0.94)	(0.85)	0.22	720.22
8	0.00	720.00	720.00	(30.20)	(0.94)	(0.85)	0.22	720.22
9	0.00	720.00	720.00	(30.20)	(0.94)	(0.85)	0.22	720.22
10	0.00	720.00	720.00	(30.20)	(0.94)	(0.85)	0.22	720.22
Total	933.90	5,040.00	4,106.10	(188.73)	(5.87)	(5.31)	1.40	4,107.50
NPV	740.30	2,338.84	1,598.54	(83.70)	(2.60)	(2.35)	0.62	1,599.17

	CO2	COAL
Total Incremental Cost/Ton of CO2 Reduction (yuan at 12%)	8,844.99	6,677.17
At RMB/US$ = 5.50	$1,608.18	$1,214.03
Total Net Benefits/Ton of CO2 Reduction (yuan at 12%)	19,099.17	14,418.16
At RMB/US$ = 5.50	$3,472.58	$2,621.48
Net Benefits Incl'g Local Env. Benefits/Ton of CO2 Reduction	19,106.62	14,423.78
At RMB/US$ = 5.50	$3,473.93	$2,622.50