Technical, Economic, and Financial Assessment of Energy Efficiency Investment Options for the Foshan Oceano Ceramics Co., Ltd.

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Guangdong Economic and Trade Commission

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January 2008

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1 Summary

1.1 INTRODUCTION

This report details the recommendations and conclusions of an energy study co-sponsored by The Guangdong Economic and Trade Commission, The Institute for Sustainable Communities, the Guandong Energy Conservation and Monitoring Center, and the Foshan Oceano Ceramics Co., Ltd. (FOC).[1]

This study targeted energy efficiency measures (EEMs) addressing motors, drives, compressed air, transformers, and heat recovery. Section 2 contains a facility energy usage table and a statistical analysis of energy use and production. Section 3 discusses each recommended measure in detail. A summary of recommended energy efficiency measures is shown in Table 1-3.

Section 4 provides information on best practices regarding energy-efficiency opportunities at the plant. Section 5 presents the economic and financial analysis of all the EEMs studied, and the financial incentives we recommend that the Economic and Trade Commission consider offering FOC for various combinations of EEMs the plant might choose. Section 6 outlines our recommended approach for monitoring and verifying installation and performance of the recommended EEMs

1.2 CURRENT ENERGY USE

The total annual consumption of the Foshan Oceano Ceramics Co. for 2006 was 32,282 TCE. Table 1-1 presents a summary of the consumption of the main energy sources at the facility.

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[1] Stephen Booth of SGB PC (SGB) conducted the technical study of energy-efficiency measures. Booth also developed the monitoring and verification (M&V) approach for the motor efficiency measures in Appendix 7.2-7.5. John Plunkett and Francis Wyatt of Green Energy Economics Group conducted the economic analysis of energy-efficiency measure costs and performance developed in the technical study, and the financial analysis and incentive design. We gratefully acknowledge the information provided by the management and staff of FOC.

Table 1-1
Energy Consumption Summary

Energy Type	Consumption	Unit	Tons Coal Equiv. TCE	Percent Of Total TCE	Percent Of Total Price	Annual Cost (rmb)
Electricity	35,432,700	KWh	4,355	13%	34%	30,158,882
Heavy Oil	10,012	Tons	14,303	44%	34%	30,132,185
Diesel	1,557	Tons	2,268	7%	5%	4,778,790
Standard Diesel	168	Tons	245	1%	1%	516,145
Coal	8,027	Tons	5,734	18%	14%	12,076,012
Coal Fluid Slurry	4,292	Tons	3,064	9%	7%	6,451,812
Liquefied Petroleum Gas	1,349	Tons	2,313	7%	5%	4,876,680
Totals			**32,282**	**100%**	**100%**	**88,990,505**

From Table 1-1 we can conclude that although saving energy on all levels is important, focusing on electricity, heavy oil, and coal will produce the highest benefits on a cost basis.

1.3 RECOMMENDED ENERGY EFFICIENCY MEASURES (EEMS)

We recommend seven (6) EEMs for implementation at the Foshan Oceano Ceramics Co. Table 1-2 describes the EEMs recommended and subjected to financial analysis.

Table 1-2
Summary of Recommended Energy Efficiency Measures

	Measure	Construction Cost (rmb)	Demand Savings (KW)	Energy Savings (KWh)	Energy Savings (Tons Oil)	Energy Cost Savings (rmb)	Simple Payback (years)
EEM-1	High-E Motors	2,147,867	292.3	1,781,250		1,516,129	1.4
EEM-2	Variable Speed Drives	3,976,200	3,193.8	5,028,116		4,279,732	0.9
EEM-3	Drive Belt Up-grade	720,698	35.6	284,431		242,096	3.0
EEM-4	Replace Transformers	360,000	31.0	271,630		231,201	1.6
EEM-5	Repair CA Leaks	34,000	41.3	330,400		281,223	0.1
EEM-6	Drying Out Optimization				2,000	6,000,000	3.3
	Total Without EEM-6	**7,238,765**	**3,594.0**	**7,695,827**		**6,550,380**	**1.1**

1.4 Economic and Financial Analysis Results

All the recommended EEMs were found to provide cost-effective efficiency power plant (EPP) resources to the Guangdong electricity grid. Guangdong would benefit most if FOC installed all recommended EEMs. Net economic benefits over the life expectancies of all recommended measures are estimated at ￥15,855,512 in 2008 present worth, on total economic costs of ￥6,700,459.

Any EEM or combination of EEMs with simple payback periods longer than one year require FOC to raise capital, by some mix of additional borrowing and equity investment. Though all of the EEMs provide attractive annual rates of return, some of the recommended EEMs have simple paybacks greater than one year. The combination of all of the EEMs provides a simple payback slightly over one year and an annual rate of return of 91%. If FOC were to obtain financing, positive cash flow could be acquired in less than a year (0.7) with a 147% annual rate of return.

Savings from some of the recommended EEMs could probably qualify for sale as Certified Emission Reductions (CERs) under the UN's Clean Development

Mechanism. Proceeds from the sale of CERs could cover 16% of the cost of all the recommended EEMs combined.

2 Energy Use Profile

2.1 Facility Description

Foshan Oceano Ceramics Co. Ltd. is a Chinese-foreign joint venture which manufactures high-quality vitrified floor and wall tile for the construction trades. Oceano's tile features low water absorption, extreme hardness, high resistance to scratching and dirt, uniform luster, and high gloss. Oceano is the first ceramics facility in Guandong Province to earn ISO 9001 Quality Management System and ISO 14001 Environment Management System certifications.

In 2006 Oceano's total production was 4,138,772 square meters of tile for a total value of 250,000,000 ¥. This equates to a value of 60.4 ¥ per square meter of tile. Total plant energy consumption was 32,282 TCE at a cost of 88,990,500 ¥. Energy consumption per unit of product was 78 TCE per 10,000 meters squared of tile, or 21.5 ¥ per meter squared: slightly more then one third of the total value. There are 900 employees at the facility, 300 people for each of the 3-shifts/day, 7-days per week.

Production at Oceano uses a new process called "Monocottura" in which the tile body and glaze is fired simultaneously. The process begins when raw materials of non-uniform dimensions are loaded into the facility's (26) electric motor driven ball mills and ground with stone "balls" and water to achieve a uniform consistency of clay. The clay is then dried using air and steam generated by burning heavy oil to an acceptable moisture content. The clay is pressed into tile shapes and coated with a glaze called frit. The tiles are then further dried using 250 degree C exhaust gasses from the kilns. Once the tiles are dry they are passed into one of the facility's five Roller Hearth Kilns that vary in length from 130 to 200 meters to be fired in a continuous process at up to 1,250 degrees C. using synthetic gas generated from the site's coal gasification plant. The firing process takes from 80 to 90 minutes. Once cooled, the tiles are planed flat, and then polished to a high gloss using electric spindle polishers. The finished tiles are then inspected, packaged and shipped.

2.2 ENERGY USE PROFILE

Although we were not shown the power plant it is our understanding that the main uses of energy that equate to 89% of the total value by cost are: heavy oil (34%), coal (21%), and electricity (34%).

The heavy oil is used to generate steam that is used in the coal gasification process, and in drying out the clay. The coal is converted to a synthetic gas in a gasification process in which steam, air, and approximately 2,200 Kilograms per hour of coal are consumed to generate between 6,000 and 7,500 meters cubed of gas with a heating value of approximately 6,270 KJ/meter cubed. The gas is compressed to 7.0 kPa and delivered to the kilns for firing. Approximately 10% of the heating value of the gas is recovered from the exhaust of the kilns to assist in drying the tiles. The electricity on site is used primarily to drive process motors for the ball mills, polishers, fans, pumps, and conveyors. The polishing process uses approximately 65% of the electricity, the ball mills about 14%, the remaining 21% is used by cooling fans and water pumps.

We were not provided with the actual fuel bills, but the summary provided by the facility indicated the annual rates of consumption and unit costs summarized in Table 2-1.

Table 2-1
Annual Energy Consumption by Fuel Type

Energy Type	Consumption	Unit	Cost Per Unit (rmb)
Electricity	35,432,700	KWh	0.85116
Heavy Oil	10,012	Tons	3,010
Diesel	1,557	Tons	3,069
Standard Diesel	168	Tons	3,067
Coal	8,027	Tons	1,504
Coal Fluid Slurry	4,292	Tons	1,503
Liquefied Petroleum Gas	1,349	Tons	3,615

2.3 END-USE ELECTRICAL EQUIPMENT

Company personnel provided us with a list of the motor driven equipment and processes used in the facility. An electrical energy end-use breakdown is presented in Table 2.1. Of the end uses the tile planing and polishing process represent the largest electrical energy end use, followed by: Ball Mills, air compressors, and ventilation fans. Approximately 5% of the energy consumption is attributed to lighting and limited air-conditioning.

Table 2-1
Electrical Energy Use Breakdown by Equipment

Process	Annual Electric Consumption (KWh)	Percent of Total
Rough Polishing	9,399,073	26.5%
Tile Planing	7,834,557	22.1%
Fine Polishing	5,794,447	16.4%
Ball Mills	4,882,868	13.8%
Lighting and Comfort Cooling	1,774,042	5.0%
Air Compressors	1,505,409	4.2%
Ventilation Fans	1,285,322	3.6%
Water Pumps	501,591	1.4%
Cooling Fans	448,463	1.3%
Mist Machines	434,779	1.2%
Moisture Exhausts	399,001	1.1%
Smoke Exhausts	398,054	1.1%
Heat Exhausts	380,675	1.1%
Burner Fans	356,991	1.0%
Stirring Mixers	37,429	0.1%
Totals	**35,432,701**	**100.0%**

The above breakdown is not entirely accurate because the motor list provided by the facility did not include hours of operation, motor amperage, number of motors operating simultaneously, or actual counts and horsepower of motors used in the polishing operation.

The information provided in addition to assumed values for numbers of motors operating, and motor loads, is presented in Appendix 8.1 (Motor Powered Equipment). We calculated the annual electrical motor energy use in Appendix 8.1 to be 33,658,660 kWh/yr. If the owner is interested in pursuing these measures it is recommended that the missing information be provided so that more detailed calculations can be performed.

3 Energy Efficiency Measures

This section provides details of recommended Energy Efficiency Measures (EEMs) for Foshan Oceano Ceramics Co. located in Guangdong. Six (6) EEMs have been studied and are recommended for implementation. They are listed below.

- EEM-1 Replace Y-Series Motors with YX-Series Motors
- EEM-2 Install Variable Frequency Drives (VFD's) on systems with variable loads or on systems that are throttled.
- EEM-3 Replace standard V-Belts with Synchronous Belts or Cogged V-belts on all belt driven systems.
- EEM-4 Consider installing S11 or S13 transformers when replacing existing transformers.
- EEM-5 Repair compressed air leaks and maintain air distribution system.
- EEM-6 Minimize water use, and optimize the drying-out process for removing moisture from the clay.

These EEMs should be reviewed to determine if they are consistent with the actual operational requirements of Foshan Oceano Ceramics Co. and the desires of facility management. The following sections present estimated implementation costs as well as energy and cost savings for each measure.

3.1 EEM-1 Replace Y-Series Motors with YX-Series Motors

Description:	The plant is equipped primarily with Y series standard efficiency motors Premium YX-series motors have efficiencies of approximately 1% to 3% than their standard-efficiency counterparts. Purchasing YX-series motors would save much energy and cost over motors' lifetime.
Action:	Replace Y series motors with YX-series motors.
Recommendation:	This EEM is cost effective and is recommended for implementation.

ENERGY IMPACTS

Total Cost (¥)	Annual Energy Savings (kWh)	Annual Savings (¥)		
1,870,000	1,781,250	1,516,130		
			Simple Payback (years):	**1.2**

3.1.1. Discussion

Company personnel provided us with a list of all large motors used in the process. Most motors are standard-efficiency Y-series motors. Premium-efficiency YX-series motors are commercially available, and are between 1% and 3% more efficient than standard-efficiency motors. Although they cost between 30% and 50% more to purchase than standard-efficiency motors, YX-series motors have significantly lower life-cycle costs.

Appendix 8.2 (Potential Motor Requirements) shows the motor replacement analysis. Y-series motors cost between ¥100 and ¥120 per rated kW, and YX-series motors cost up to 50% more. Thus, we used a cost of ¥170 per kW equipment cost plus ¥25 per kW for installation in Appendix 8.2.

3.1.2. Recommendation

We recommend replacing Y-series YX-series motors. The economics are favorable for the motors to be replaced immediately due to the long run-time per year.

3.1.3. Energy Savings, Cost Savings, and Implementation Cost

Table 3.2 is a list of motor efficiencies taken directly from the publication “The Chinese Market for Electric Motors and Motor Speed Controls” (Hinge, Nadel, Yande, Lan, Chunxuan. ACEEE. 1997). These efficiencies are identical to those reported in the more recent publication “The China Motor Systems Energy Conservation Program: A Major National Initiative to Reduce Motor System Energy Use in China” (Nadel, Wanxing, Liu, McKane. DOE Office of Scientific &

Technical Information. 2001). See appendix table 8.3 for a breakdown of energy and cost savings and implementation cost per application.

Table 3-2
Motor Efficiencies

Rated	Output		Chinese Motor Series			
			(IEC Test Proc.)			
(kW)	(HP)	JO2	Y(IP44)	YX	Y2	Y2E
0.55	0.75	74.0	73		71.0	73.5
0.75	1.0	76.5	74.5		73.0	75.5
1.1	1.5	79.0	78.0		75.0	76.5
1.5	2.0	80.5	79.0		78.0	79.5
2.2	3.0	82.0	81.0	86.3	80.0	82.0
4.0	5.0	85.0	84.5	88.3	84.0	86.0
5.5	7.5	86.0	85.5	89.5	85.0	87.0
7.5	10	87.0	87.0	90.3	87.0	88.0
15	20	88.0	88.5	91.8	89.0	91.0
18.5	25	89.0	91.0	93.0	90.7	92.7
22	30	89.5	91.5	93.2	91.2	93.0
30	40	90.0	92.2	93.5	92.0	93.5
45	60	91.0	92.3	94.1	93.0	94.2
55	75	91.5	92.6	94.5	93.2	94.5
75	100	92.0	92.7	94.7	93.8	94.7
90	125	92.0	93.5	95.0	94.2	95.0
110	150		93.5		94.5	
132	175		94.0		94.8	

Note: efficiencies are shown for totally-enclosed fan-cooled 4-pole motors

Source: Hinge, Nadel, Yande, Lan, Chunxuan. "The Chinese Market for Electric Motors and Motor Speed Controls." American Council for an Energy-Efficient Economy 1997: p. 24.

3.2 EEM-2 Install Variable Frequency Drives (VFDs)

Description:	Many of the systems in the facility have variable loads such as the cooling fan loads that vary with the seasons, or are throttled to adjust for variations in production loads. By installing VFD's on motors significant energy savings will result.			
Action:	Install variable frequency drives on motors with variable loads. Control either manually, by pressure, or by temperature in accordance with the requirements of the process.			
Recommendation:	This EEM is cost effective and is recommended for implementation.			
ENERGY IMPACTS				
Total Cost (¥)	**Annual Energy Savings (kWh)**	**Annual Cost Savings (¥)**		
3,976,200	**5,028,100**	**4,280,000**	**Simple Payback (years):**	**0.9**

3.2.1. Discussion

The fan/ pump affinity laws show that the load on a motor in kW varies as the cubic function of the motor revolutions per minute for centrifugal loads. For variable torque, non-centrifugal loads, demand varies as a squared function of the motor speed similar to mixing operations. For constant torque loads, the demand varies linearly with motor speed. An example of a constant torque load is the ball mills or conveyors. By slowing the motors down when the process is not fully loaded significant savings will result. Appendix 8.3 (Variable Frequency Drive Measures) shows the cost and savings associated with the installation of VFD's on selected motors.

3.2.2. Recommendation

The installation of variable frequency drives is recommended due to the large cost savings associated with the measure, the increased motor life, and the flexibility the drives provide to the operator to carefully match the motor power to the load.

3.2.3. Energy and Cost Savings

The installation of Variable frequency drives could affect 54 motors with a total connected rating of 3,976 kW. The energy and cost savings per application are listed in the appendix in Table 8.3.

3.2.4. Implementation Cost

The implementation of variable frequency drives involves both an electrical installation component and a controls component. The electrical installation component requires the installation of the drive between the power source and the driven load. The controls component requires a signal from the process whether it is manual from the operator or, from temperature or pressure sensor that will be processed by the drive controls to modify the motor speed. The drive cost has been estimated at 850 ¥ per kW of load plus an additional 150 ¥ per kW for installation and controls for a total of 1,000 ¥ per kW.

3.3 EEM-3 Replace Standard V-Belts with Synchronous Belts

Description:	The majority of the air moving equipment, and the ball mills are V-belt driven to transmit power and to change the drive revolutions per minute. Each of these loads is driven with standard V-belt drives. Standard V-belts of this type have an efficiency of about 92% which indicates that about 8% of the work produced by the motor is lost as heat as the belts flex and slip as they go around the pulleys. Synchronous-belts are available and have an efficiency of transmission of 98%, cogged V-belts have a transmission efficiency of 95%.
Action:	Replace standard V-belts with synchronous and cogged belts.
Recommendation:	This EEM is cost effective and is recommended for implementation.

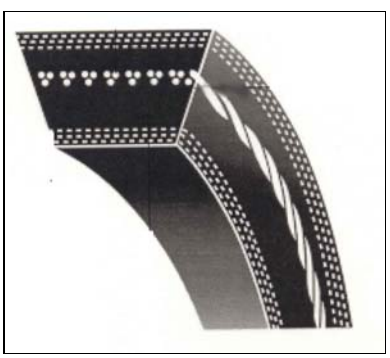
ENERGY IMPACTS

Total Cost (¥)	Annual Energy Savings (kWh)	Annual Cost Savings (¥)		
720,698	**284,431**	**242,096**		
			Simple Payback (years):	**3.0**

3.3.1. Discussion

The belt driven loads on site have motors equipped with standard V-belts with smooth inner surfaces. Figure 3-1 shows a cross-section of a standard V-belt. The smooth inner surface permits a significant amount of slip between the belts and the sheaves. The slip is exaggerated when multiple belts of slightly different lengths and wear patterns serve the same load.

Figure 3-1
Standard V-Belt



Belt drives in motor driven applications allow flexibility in positioning the motor, and allow process rotating speed to be set based on pulley diameters. Wellmaintained standard V-belts have been shown to have an efficiency of approximately 93%, meaning that about 7% of the work produced by the motor is lost as heat as the belts flex and slip going around the pulleys. Over time the efficiency of v-belts deteriorates due to uneven wear and incorrect tensioning. By installing Synchronous or toothed belts with corresponding toothed sprockets slip is virtually eliminated.

Synchronous belts provide a positive transmission of power similar to a chain drive but require no lubrication, resist corrosion, are un-affected by abrasive particles, can operate in wet conditions, and do not experience break-down in efficiency over time. Where it is difficult or impossible to install synchronous belts due to the configuration of the equipment, such as in the case of the ball mills, Cogged V-belts can offer a significant improvement over standard V-belts.

According to the Department of Energy's (DOE) Industrial Technologies Program (ITP), synchronous belts increase the efficiency of transmission by approximately 6%, cogged V-belts by 3%. In addition to significantly improving power-transmission efficiency, synchronous belts also last at least four times longer, and cogged V-belts two times longer than standard V-belts. This considerably reduces the equipment downtime and replacement costs. However, synchronous belts are more costly than comparable standard V-belts. Table 3-4 summarizes the characteristics of different belt types.

Table 3-4
Drive Belt Characteristics Comparison

Comparison of Belt Drive Characteristics

	Typical Efficiency Range (%)	Suitable for Shock Loads	Periodic Maintenance Required	Change of Pulleys Required	Special Features
V-Belts	90–98	Yes	Yes	No	Low initial cost.
Cogged V-Belts	95–98	Yes	Yes	No	Easy to retrofit. Reduced slip.
Flat Belts	97–99	Yes	No	Yes, but low cost	Medium- to high-speed applications. Low noise. Low slip.
Synchronous Belts	97–99	No	No	Yes, with higher cost	Low- to medium-speed applications. No slip. Noisy. May have problems matching speed.

Source: de Almeida and Greenberg 1994

3.3.2. Recommendation

Because of the advantages, the use of synchronous belts is recommend in virtually all V-belt applications except for the ball mills where replacement of the sheaves would be nearly impossible without replacing the entire ball mill drum.

3.3.3. Energy and Cost Savings

The following calculations are based on assumed motor loads based on the size of the drive motors and continuous operation. Appendix 8.4 (Synchronous and Cogged Belt Measures) shows the results of demand and energy savings from replacing standard V-belts with synchronous belts. The results assume that standard V-belts are 92% efficient, cogged V-belts are 95% efficient and synchronous belts are 98% efficient.

Two calculations incorporated into Appendix 8.4 are as follows:

Existing Demand = (Rated KW of Motor) x (Motor Load Factor) / (Motor Efficiency)

Demand Savings = Existing Demand x [1 – (Std V-Belt Eff / Efficient Belt Eff)]

3.3.4. Implementation Cost

We approximated the belt size and sheave size of a number of belt driven systems throughout the facility and developed cost estimates to replace the sheaves and v-belts with synchronous sprockets and belts. The average cost of the retrofits was 517 ¥ per kW of motor load.

3.4 EEM-4 Replace S9 Transformers with S11 or S13 Transformers

Description: Many of the electrical transformers operating in China are S7 or S9 standard efficiency units. Two higher efficiency options exist for transformer replacement: premium-efficiency S11 transformers, or ultra-high efficiency S13 units. Although S11 transformers are more expensive to purchase, and S13 transformers can be difficult to purchase, their increased efficiency gives them a lower life-cycle cost.

Action: Consider installing S11 or S13 transformers to replace S9 transformers.

ENERGY IMPACTS

Incremental Cost (¥)	Annual Energy Savings (kWh)	Annual Savings (¥)		
360,000	**271,600**	**231,200**	**Simple Payback (years):**	**1.6**

3.4.1. Discussion

The facility did not provide a list of transformers, the operating capacities, or the model numbers. The total connected device load (motors, gasification plant, and lighting load) is approximately 11,600 KVA, so the estimated minimum transformer capacity will be greater then 12,000 KVA. Currently all older S7 transformers are required to be phased out according Chinese relevant regulations. If the plant is up-grading any of their existing transformers it is recommended that each replacement be evaluated for higher-efficiency alternatives.

Table 3-5
Transformer Analysis

	Number of Transformers	Total Capacity (MVA) for replacement	Power saving potential (KW)	Unit increment cost (Yuan/kVA)	Increment Investment if replaced by S11 (rmb)	Annual electricity saving per increment (KWh)	Annual saving /a (replaced by S11, million Yuan)	Simple Payback (years)
S9		12.000		100	1,200,000			
S11 Replacement		12.000	31.01	30	360,000	271,630	231,201	1.56
Total		**12.000**	**31.01**	**130**	**1,560,000**	**271,630**	**231,201**	**6.75**

Three major types of transformers are commercially available: standard-efficiency S9 transformers, high-efficiency S11 transformers, and ultra-high-efficiency S13. This study used costs and savings for replacing what we believe are the existing S9 transformers with S11 transformers. S11 transformers may become standard practice in the next few years. At the time this report was being written S13 transformers were being manufactured in China but were not yet universally available. During any transformer replacement the availability of the new higher efficiency S13 units should be investigated.

3.4.2. Recommendation

We recommend considering S11 transformers to replace existing S9 transformers whenever the facility chooses either to replace failed transformers, to up-grade to larger transformers when processes are expanded. According to the following analysis, the payback to recoup the additional (or incremental) cost of purchasing S11 transformers rather than S9 transformers would be 1.6 years.

3.4.3. Energy Savings, Cost Savings, and Implementation Cost

It was assumed that the transformers are 38% loaded, and the power factor is 85%. The average efficiency improvement is 0.8 % to go from S9 to S11 transformers. The anticipated life of the S9 or S11 transformers is 20 years. The total cost to install S9 transformers is 100 ¥/KVA. The cost to install S11 transformers is 130¥ /KVA. Data was not available for the cost to up-grade to S13 transformers, but should be evaluated if there is a serious effort to upgrade transformers.

3.5 EEM-5 Repair Compressed Air Leaks and Maintain Air Distribution System

Description:	Compressed air leaks often contribute to a large portion of demand in a compressed air system. Most industrial plants have a compressed air leak load between 20% and 75%. Instrumentation and processes consume large amounts of compressed air at many individual locations and these locations are susceptible to leakage. Repairing leaks is a cost-effective way to save energy in a compressed air system.			
Action:	Repair compressed air leaks, and maintain compressed air distribution system on at least a semi-annual basis.			
Recommendation:	This EEM is cost effective and is recommended for implementation.			
ENERGY IMPACTS				
Total Cost (¥)	**Annual Energy Savings (kWh)**	**Annual Savings (¥)**		
34,000	**330,400**	**281,200**		
			Simple Payback (years):	**0.1**

3.5.1. Discussion

Compressed air leaks in an air distribution system increase compressed demand and compressor power consumption. Repairing leaks and maintaining a compressed air distribution system is a cost-effective way to avoid excess compressor power consumption.

Foshan Oceano Ceramics Co. is equipped with seven air compressors to supply compressed air primarily for instrumentation and production. We did not perform a leak inspection. However, from past consulting experience, air leaks account for between 20% and 75% of air demand in a plant with no regular maintenance policy.

Compressed air leaks most commonly exist at threaded connection points, rubber hose connections, valves, regulators, seals, and old pneumatic equipment. Air leaks in industry typically average about 0.085 m3/min.

3.5.2. Recommendation

We recommend finding all compressed air leaks and repairing the leaks. This may involve tightening fittings, replacing thread-sealing tape, patching hoses, replacing seals, or replacing leaky equipment. In addition, we recommend maintaining the compressed air distribution system by performing an inspection and repair of compressed air leaks on at least a semi-annual basis.

3.5.3. Energy and Cost Savings

Guangdong Foshan Oceano Ceramics Co. is equipped with seven air compressors with a total connected load of 572 KW and an estimated capacity of 100 meters cubed per minute.

Although we were not able to monitor the compressors we assume that the average output of the compressed air system is approximately 36 % of its maximum capacity, or 36 m3/min.

As stated earlier, air leaks account for between 20% and 75% of air demand in a plant with no regular maintenance policy. Assuming air leaks may account for 20% of the air demand in Guangdong Foshan, the air lost to leaks may be approximately 7.2 m3/min. Because a typical compressed air leak consumes approximately 0.085 m3/min, about 85 leaks would account for 7.2 m3/min.

The power saved by eliminating 85 leaks or the estimated 7.2 m3/min is :

7.2 m3/min x (572 kW / 100 m3/min) = 41.3 kW

Company personnel informed us that the compressors operate 8,000 hours a year. Thus, annual electrical energy saved would be approximately 330,400 kWh. At a rate of ¥0.85116 per kWh, the annual cost savings would be approximately ¥ 281,200.

3.5.4. Implementation Cost

The cost of repairing a compressed air leak, including parts and labor, is typically ¥400. The cost of repairing 85 leaks would be approximately ¥34,000.

3.6 EEM-6 Clay/Tile Drying Out Optimization

Description:	Foshan Oceano Ceramics Co. Uses a significant amount of fuel oil to fire boilers to generate steam for drying clay and tiles prior to firing. Decreasing this fuel consumption could easily generate the largest single energy efficiency improvement at the facility.
Action:	Study options for cost effective ways to reduce the quantity of water used in the process, increase drying without the use of fossil fuels such as enhanced drying air-flow, longer dwell time in the clay processing, and possibly the use of solar radiation for drying.
Recommendation:	This EEM requires further study to determine the optimum course of action and associated costs.

ENERGY IMPACTS

Total Cost (¥)	Annual Energy Savings (Tons Oil)	Annual Cost Savings (¥)		
	2,000	6,000,000		
			Simple Payback (years):	**NA**

3.6.1. Discussion

During our brief tour of the Oceano Facility we were not able to spend much time reviewing the process used to dry the clay as it exited the ball mills. Typically the clay is allowed to settle for some time to separate much of the water from the clay. The clay is usually then mixed with hot air to drive additional moisture from the clay prior to forming into tiles. Once the tiles are formed they are further dried with the application of more heat. At this facility much of the tile drying process is accomplished with heat recovered from the firing process. This recovery heat is estimated to save the facility 8% of the total drying oil consumption. It may be possible to save up to an additional 20% of the total oil consumption by looking at ways to optimize the earlier two drying steps. Means to accomplish this savings would likely result from either increasing the dwell time of the initial air-clay separation, increasing air-flow in the dryer, breaking the clay down into smaller clumps for drying, or using solar radiation to enhance drying.

3.6.2. Recommendation

The drying process is the single largest energy consumer in the plant. Any improvements would yield both a large reduction in the plant's CO2 emissions, as well as a large decrease in production cost per tile. Careful study should be performed on this process to determine the best method for improving the energy efficiency of this process.

3.6.3. Energy and Cost Savings

The energy cost associated with the clay drying processes is estimated at 30,000,000 rmb per year. Reducing this cost by 20% would realize a savings of 6,000,000 rmb per year, or a reduction in production cost of 1.45 rmb/m2

3.6.4. Implementation Cost

The implementation cost associated with this measure will have to be carefully evaluated along with the possible options. Small improvements may be possible a low cost by modifying the process such as increasing the settling time between the ball mill and the drying processes, or by increasing air-flow in the dryer. Larger savings would likely be realized by increasing the surface area of the dryer, better fragmentation of the clay, or by using solar radiation to enhance drying.

4 Best Practices in Energy Efficiency

This section provides Information for the Foshan Oceano Ceramics Co. on energy-efficiency measures that require further investigation to quantify savings and costs. This section provides information on recent technological advances and best practices for the improving efficiency of energy intensive equipment not examined in detail in Section 3:

- Compressed Air Systems
- HVAC
- Lighting

4.1 Best Practices in Compressed Air Systems

Maintain Pressure at Lowest Possible Level – Greater energy is required to compress air to a higher pressure. Higher pressure compressed air not only is generated less efficiently, but also leaks faster through holes and orifices in the system, thereby causing higher output than necessary.

Compress Coldest Air Possible – Air is denser at lower temperatures, thus requires less energy to compress. For energy efficiency, it is advisable to use the coldest air possible for compression, which in most cases is outdoor air. Outdoor air can be ducted directly to the compressor's intake, or windows/doors/vents can be left open to draw outdoor into the room.

Repair Compressed Air Leaks – Air leaks in a distribution system increase compressed air demand thus increasing a compressor's electrical load.

Operate Rotary-Screw Compressors in Load/Unload Mode – Rotary-screw compressors have two major modes of capacity control: load/unload control, and modulation control. In load/unload control, the compressor's inlet valve repeatedly opens completely and closes completely to maintain air discharge pressure within a certain range. When the inlet valve is open, the compressor generates its full-load air output. When the inlet valve is closed, the compressor generates no compressed air. Sump pressure decreases when unloaded, thus causing the compressor to draw between 40% and 45% of its full-load power.

In modulation control, compressed air output is controlled by the compressor's modulating inlet valve. Power (kW) to the compressor decreases in a linear fashion as air output (scfm) decreases, but only decreases to approximately 70% of its full-load power at the point when it generates no compressed air.

Properly Stage Compressors – In a multiple compressor system, the compressors' operation should be staged so that the compressor with highest part-load efficiency operates as the trim compressor, and the compressors with the lowest part-load efficiencies carry the base load. Reciprocating compressors and variable frequency drive (VFD) compressors have the best part-load efficiency; standard rotary-screw compressors have lower part-load efficiency; and centrifugal compressors have the least part-load efficiency.

Use Electric Motor Tools Instead of Pneumatic Tools when Feasible – According to the U.S. Department of Energy's Compressed Air Challenge Program, compressed air systems are only 10% - 15% efficient. This is due in part to the requirement to reject heat when compressing air, and to the requirement that compressed air exits pneumatic equipment at a velocity greater than zero. Therefore, compressed air is not recommended to produce work if electric motors (about 90% efficient) can alternately be used.

Several pneumatic tools are used in the facility's. It is up to the discretion of management whether any pneumatic equipment can be replaced by electric alternatives.

4.2 Best Practices in HVAC

Buildings that support the Foshan Oceano Ceramics Co., particularly offices, control rooms, and break rooms have heating, ventilation, and air conditioning (HVAC) systems. The following are best practices in HVAC.

Temperature Setback – Setpoint temperatures can be set back during cold season, and set forward during warm season when a room is unoccupied for long periods of time. Doing so reduces building heating and cooling load. For example, office room temperatures can be setback during night hours. To better control temperature setback, programmable thermostats can be installed to automatically setback temperature based on time of day.

Do Not Overventilate – According to building standards, a minimum of 0.57 cubic meters per minute (cmm) of fresh outdoor air is required per person occupying a commercial or office building. Ventilation rates significantly higher than 0.57 cmm cause more outdoor to be conditioned than necessary. Typically, ventilation rates can be turned down in an office building at night when not occupied. To better control ventilation rates, a demand control ventilation (DCV) system can be installed that controls ventilation based on monitored CO2 levels within the building.

Utilize Economizer Controls – Due to internal sources of heat such as machinery, people, electronics, etc., buildings often require cooling even on moderately cool days. If large amounts of cool outdoor air are brought into a building during those types of days, little or no mechanical cooling would be necessary to meet the cooling load. Economizer controls perform this function by controlling outdoor air intake based on outdoor temperature to minimize mechanical cooling. In a system with economizer controls, outdoor air intake is maximized during moderately cool days, and minimized during cold days and hot days.

Employ Variable Air Volume (VAV) System Rather than Constant Air Volume (CAV) System – A constant air volume (CAV) system delivers air to each zone in an HVAC system at a constant flow rate. Because supply air flow is constant, it often needs to be both heated and cooled (particularly during moderate temperature days) in order to balance its temperature to the zone setpoint. Simultaneous heating and cooling is inefficient.

A variable air volume (VAV) system varies the amount of air delivered to each zone based on the heating or cooling load. Supply air flow is highest during peak heating and cooling days, and lowest during moderate temperature days. Varying supply air minimizes the need to simultaneous heat and cool.

Use Variable Speed Supply Fan in VAV System – A variable speed supply fan is ideal for a variable air volume (VAV) system. A variable frequency drive (VFD) can be installed on a fan motor to allow for variable speed. Without a variable speed supply fan, inlet air dampers would need to be employed, which build fan pressure and result in inefficiencies. Slowing a fan down when less flow is needed is the most efficient method of flow control.

4.3 BEST PRACTICES IN LIGHTING

The Foshan Oceano Ceramics Co. utilizes lighting in the offices, in the process buildings, and on the connecting roadways. The following are best practices in lighting.

Super T8 Fluorescent Technology – In general it is recommended that T12 fluorescent lamps and magnetic ballasts be replaced with standard T8 lamp and electronic ballast combinations. However, new “Super T8” technology is now available for 4-foot linear T8 systems that offer even greater energy and demand savings than the standard T8 replacement.

Advanced T8 lighting systems consist of high-lumen, high CRI, extended-life T8 lamps used in combination with matched “program-start” low ballast factor electronic ballasts. This lamp and ballast combination offers system efficacies (Lumens/Watt) approximately 15-20% higher than standard T8 systems. The lamps used in Super T8 systems have at least 20% longer lamp life than standard T8 lamps, decreasing maintenance costs. The incremental cost for Super T8 vs. standard T8 is about 8 rmb per lamp and 62 rmb per ballast.

Compact Fluorescents – Compact fluorescent lights (CFL’s) are premium-efficient lights designed to replace incandescent lights. CFL bulbs typically draw between 13 and 20 watts, as compared with incandescent bulbs that draw between 50 and 100 watts. CFL’s, by design, output equal or greater light than their corresponding incandescent bulbs. In addition, CFL bulbs last about 10,000 hours, whereas incandescent bulbs last about 1,000 hours.

High Bay Fluorescent Lights – High-bay fluorescent (HBF) lights, which typically consist of six 4-ft T8 lamps in specially-designed high-efficiency fixtures, are an energy-efficient alternative to high intensity discharge (HID) lights. The high-bay fluorescents lights draw about 227 W per fixture while putting out the same lumens as a HID light that draws 450 W. In addition, the color-rendering index (CRI), a measurement of light quality (daylight having a CRI of 1), of a HBF fixture is 0.85 as opposed to 0.65 for HID lights. The experience of most industrial clients who have switched from HID to HBF lighting has been overwhelmingly positive. The areas under the new lights are visibly brighter, and workers report that they can see better with the new lights.

Occupancy Controls – Occupancy controls can be used to dramatically reduce operating hours of certain types of lighting fixtures. Occupancy sensors activate lighting when someone enters the space. When the space is vacated, an adjustable delay mechanism turns off the lights after a selected time period. All occupancy sensors incorporate field adjustable time delays so that the lights will not immediately turn off when someone leaves the area. This prevents unnecessary cycling of the lighting and allows a worker in a location hidden from the sensor to finish their task before the lights turn off. In addition, most sensors incorporate field adjustable sensitivity so that the reach of the sensor will not turn the lights on when there is movement in an adjoining area.

Daylight Harvesting Sensors – A daylight-harvesting sensor senses the amount of available daylight, and turns off lights when an adjustable daylight threshold is obtained. An adjustable "lag" prevents the fixture from cycling quickly during variable daylighting conditions. This system is also used in buildings that incorporate skylights or monitors for daylighting. Another efficient design using this system involves controlling lighting fixtures within 10' of glazed exterior walls, while the rest of the lighting fixtures in the space are controlled by other means.

5 Economic and Financial Analysis

We conducted an economic and financial analysis of the energy-efficiency measures (EEMs) studied in Section 3. Using the performance estimates for the EEMs, we projected the lifetime benefits as the marginal electricity supply costs that the power grid would avoid. We compared the present worth of EEM benefits with their costs to determine cost-effectiveness. The financial analysis considers the EEM as a financial investment by the customer by comparing the cash flows that would result from electricity bill savings with the initial outlay made by the customer to pay for it. Financing could reduce the customer's initial outlay for the EEM, which would make the cash flow from bill reductions more financially attractive.

Based on this cash-flow analysis of cost-effective EEMs, we show that with financing the Facility's initial outlay could be lowered enough to make the bill savings pay for its EEM investments in less than a year.

Table 5-1 presents the results of our economic and cashflow analysis of various sets of EEMs with three financing options. Note that the S11 analysis should only be considered representative. We recommend further evaluation of the technical suitability and cost-effectiveness of S13 transformers compared to the S11 series, given the likelihood that S11 will become standard practice soon and the domestic availability of S13 transformers. If suitable and cost-effective compared to S11 technology, we recommend substituting S13 transformers in place of the S11 transformers in our analysis.

We also recommend further examination of the dying out process. The potential energy cost savings nearly equals the total of all of the other EEMs combined. Preliminary estimates indicate potential oil savings of 2,000 tons per year, providing 6 million RMB cost savings per year.

Table 5-1

Summary of Foshan Oceano Ceramics Efficiency Measures Economic and Financial Analysis

	Motor Retrofit	Variable Frequency Drives			Drive Belt Upgrade		Transformer Scheduled Replacement	Transformer Early Retirement	Compressed Air Leak Repair	Total All Measures [1]+[2]+[3]+[4]+[6]+[7a]+[8] without [5] & [7b]		
	[1]	Centrifugal [2]	Variable Torque [3]	Constant Torque [4]	Cogged V-Belt [5]	Synchronous [6]	[7a]	[7b]	[8]	100% Customer Equity	Conventional 3-Year Loan	EPP Loan
Total Measure Cost (not discounted)	¥ 2,147,867	¥ 1,035,000	¥ 13,200	¥ 2,928,000	¥ 972,920	¥ 720,698	¥ 360,000	¥ 1,560,000	¥ 34,000	¥ 7,238,765	¥ 7,238,765	¥ 7,238,765
Customer Down Payment										¥ 7,238,765	¥ 3,619,382	¥ 3,619,382
Financed Cost										¥ 0	¥ 3,619,382	¥ 3,858,261
EPP Economic Analysis												
Benefits (Avoided Generation, T&D)	¥ 5,327,829	¥ 7,452,050	¥ 76,105	¥ 7,511,252	¥ 579,355	¥ 850,750	¥ 1,199,856	¥ 1,199,856	¥ 138,127	¥ 22,555,970	¥ 22,555,970	¥ 22,555,970
Total Costs (see Note)	¥ 1,609,561	¥ 1,035,000	¥ 13,200	¥ 2,928,000	¥ 972,920	¥ 720,698	¥ 360,000	¥ 939,124	¥ 34,000	¥ 6,700,459	¥ 6,700,459	¥ 6,700,459
Net Economic Benefits	¥ 3,718,269	¥ 6,417,050	¥ 62,905	¥ 4,583,252	-¥ 393,565	¥ 130,052	¥ 839,856	¥ 260,733	¥ 104,127	¥ 15,855,512	¥ 15,855,512	¥ 15,855,512
Benefit/Cost Ratio	3.31	7.20	5.77	2.57	0.60	1.18	3.33	1.28	4.06	3.37	3.37	3.37
CDM-CER Present Value (max 10 years)	¥ 423,653	Not applicable	Not applicable	¥ 597,272	¥ 46,069	¥ 67,649	¥ 64,605	¥ 64,605	Not applicable	¥ 1,153,178	¥ 1,153,178	¥ 1,153,178
% of Total Measure Cost	20%			20%	5%	9%	18%	4%		16%	16%	16%
% of Customer Down Payment										16%	32%	32%
Customer Financial Analysis												
Simple payback on measure cost (years)	1.42	0.49	0.61	1.37	6.00	2.98	1.56	7.00	0.12			
Simple payback with financing (years)										1.11	0.69	0.70
Internal Rate of Return without financing	73%	208%	167%	76%	14%	34%	67%	17%	727%	91%	91%	91%
Internal Rate of Return with financing										91%	147%	146%

Note: Total Costs in EPP Economic Analysis reflect early retirement cost credit for postponing future scheduled replacements.
Benefits and costs in EPP Economic Analysis are all discounted to 2008.

5.1 EEP Economic Analysis

We analyzed the economics of the electricity savings estimated for several packages of EEMs as substitutes for the electricity supply they would avoid. Electric energy savings avoid coal-fired generation on the margin; peak demand savings avoid transmission and distribution capacity costs. We estimated these benefits over the life expectancy of the electricity savings using avoided supply costs from the Asian Development Bank Pre-feasibility Study for Establishing An Efficiency Power Plant Demonstration Project for Guangdong Province. We compared the present worth of these avoided supply costs with the total costs of the EEMs over their lifetime.

We also estimated the potential proceeds from possible sales of Certified Emission Reductions (CER) under the Clean Development Mechanism (CDM) of the Kyoto Protocols on climate change. We used a value of ¥86.74 per metric ton of CER sold, based on a review of current trading prices paid. We calculated the present worth of proceeds from 10 years of CER sales or the measure life, whichever is shorter.

For transformers, the first step of the economic analysis was to compare the benefits and costs of choosing high-efficiency upgrades at the time of scheduled replacement of the existing equipment. Transformers were also examined for early retirement. Transformers were cost effective as either a scheduled replacement upgrade or early retirement retrofit. However, waiting for the time of natural replacement provides greater economic net benefits.

High-efficiency Motors, Variable Frequency Drives, Synchronous Belts, and Compressed Air Leak Repair, were all treated as retrofits. Had more information been available for age of existing motors and annual hours of use, then motors would have also been examined at the time of scheduled replacement. All of the motors considered for variable frequency drives (VFDs) and synchronous belts were found cost effective except. Cogged V-belts were considered for the ball mixers but were found to not be cost effective with the current cost and saving assumptions.

Following are further details of the economic assessment of efficiency measure packages:

Motor Retrofit – Retire motors early, rather than wait to replace the motors at the end of their lifetimes.

Economic analysis of early retirement must consider two factors. The first is the future decline in initial energy savings that occurs when the existing equipment would have been replaced anyway with new technology that is more efficient than the existing model but less efficient than the high-efficiency EEM installed now. The second factor that must be accounted for in the economic analysis of early retirement is its effect on the future timing of scheduled replacement. By interrupting the normal replacement schedule, early retirement postpones all future replacement investments by the age of the existing equipment. For example, retiring early a 10-year-old motor with five years of life remaining will push back for 10 years the next scheduled motor replacement (and all subsequent replacements thereafter). The deferral of these future investments is a cost savings that is credited to the present worth of the total measure cost of the retrofit.

Variable Frequency Drives -- The savings for variable frequency drives depends heavily on the application. Therefore, we examined 3 unique types of motor loads: centrifugal, variable torque, and constant torque. We found all 3 cost effective, but with varying degrees.

S11 Transformers -- The existing transformers are likely near the end of their useful lifetimes, so we examined this both as a scheduled replacement and an early retirement. The costs and savings for the scheduled replacement were incremental to the new baseline S9 transformers. The early retirement of transformers included the full cost of installing a S11 transformer. We question the economics of the S11 transformer upgrade at scheduled replacement because the technology is rapidly gaining widespread market acceptance. If the market norm is indeed S11, then no additional savings can be attributed to the EEM for EPP planning (or for CDM sales of certified emission reductions). Consequently, we recommend further study of the technical suitability, performance and costs of S13 technology before committing to promotion of S11 transformers.

5.2 CUSTOMER CASH FLOW ANALYSIS AND FINANCING OPTIONS

The cashflow analysis valued the electricity savings from EEMs according to the relevant electricity tariff. These cashflows were first evaluated and compared to the outlay the company would have to make absent any financing. We computed the simple payback period for each EEM and the total cost-effective EEM package considered in the economic analysis. This indicates how long it would take the annual electricity bill savings to pay for the customer's total measure cost. We also computed the rate of return the casfhlows would produce based on the customer's initial outlay for the EEMs at their full measure costs. The rate of return is a better indicator of the long-term financial performance of the customer's EEM investment compared to competing investment opportunities available elsewhere in the enterprise.

Cost-effective EEMs offer FOC simple payback periods ranging from 0.12 years (i.e. 1.4 months) for repairing compressed air leaks to 3 years for synchronous belts. The rate of return FOC would earn from investing in each EEM ranges from 34% for synchronous belts to 727% for repairing compressed air leaks.

The financial analysis is shown for 3 financing scenarios:

- 100% Customer Equity – no outside financing
- Conventional 3-year Loan
- Guangdong Efficiency Power Plant Loan – using funds from the Asian Development Bank

The difference between these three options was found to be very little. This is due to the high cost effectiveness of these particular EEMs.

In addition to the summary results found in Table 5-1, the following tables provide more detail on the cash flow for each of these scenarios.

Table 5-2
Cash Flow with 100% Customer Equity

Year	Annual Payments (Principal & Interest)	Annual Electric Savings	Net Annual Cashflow	Net Cumulative Cashflow
0			¥-7,238,765	¥-7,238,765
1	0	¥6,550,380	¥6,550,380	¥-688,384
2	0	¥6,457,232	¥6,457,232	¥5,768,848
3	0	¥6,650,949	¥6,650,949	¥12,419,797
4	0	¥6,850,477	¥6,850,477	¥19,270,274
5	0	¥7,055,992	¥7,055,992	¥26,326,266
6	0	¥7,267,671	¥7,267,671	¥33,593,937
7	0	¥7,485,701	¥7,485,701	¥41,079,638
8	0	¥7,710,273	¥7,710,273	¥48,789,911
9	0	¥7,941,581	¥7,941,581	¥56,731,492
10	0	¥8,179,828	¥8,179,828	¥64,911,320
11	0	¥310,714	¥310,714	¥65,222,034
12	0	¥320,036	¥320,036	¥65,542,070
13	0	¥329,637	¥329,637	¥65,871,707
14	0	¥339,526	¥339,526	¥66,211,233
15	0	¥349,712	¥349,712	¥66,560,944
16	0	¥360,203	¥360,203	¥66,921,148
17	0	¥371,009	¥371,009	¥67,292,157
18	0	¥382,139	¥382,139	¥67,674,296
19	0	¥393,604	¥393,604	¥68,067,900
20	0	¥405,412	¥405,412	¥68,473,312
21	0	¥0	¥0	¥68,473,312

Table 5-3
Cash Flow with Conventional 3-Year Loan

Year	Annual Payments (Principal & Interest)	Annual Electric Savings	Net Annual Cashflow	Net Cumulative Cashflow
0			¥-3,619,382	¥-3,619,382
1	¥-1,333,143	¥6,550,380	¥5,217,237	¥1,597,855
2	¥-1,333,143	¥6,457,232	¥5,124,089	¥6,721,944
3	¥-1,333,143	¥6,650,949	¥5,317,806	¥12,039,749
4	¥-0	¥6,850,477	¥6,850,477	¥18,890,226
5	0	¥7,055,992	¥7,055,992	¥25,946,218
6	0	¥7,267,671	¥7,267,671	¥33,213,889
7	0	¥7,485,701	¥7,485,701	¥40,699,591
8	0	¥7,710,273	¥7,710,273	¥48,409,863
9	0	¥7,941,581	¥7,941,581	¥56,351,444
10	0	¥8,179,828	¥8,179,828	¥64,531,272
11	0	¥310,714	¥310,714	¥64,841,987
12	0	¥320,036	¥320,036	¥65,162,022
13	0	¥329,637	¥329,637	¥65,491,659
14	0	¥339,526	¥339,526	¥65,831,185
15	0	¥349,712	¥349,712	¥66,180,897
16	0	¥360,203	¥360,203	¥66,541,100
17	0	¥371,009	¥371,009	¥66,912,109
18	0	¥382,139	¥382,139	¥67,294,249
19	0	¥393,604	¥393,604	¥67,687,852
20	0	¥405,412	¥405,412	¥68,093,264
21	0	¥0	¥0	¥68,093,264

Table 5-4
Cash Flow with Guangdong EPP Loan

Year	Annual Payments (Principal & Interest)	Annual Electric Savings	Net Annual Cashflow	Net Cumulative Cashflow
0			¥-3,619,382	¥-3,619,382
1	¥-1,385,249	¥6,550,380	¥5,165,131	¥1,545,749
2	¥-1,385,249	¥6,457,232	¥5,071,983	¥6,617,732
3	¥-1,385,249	¥6,650,949	¥5,265,700	¥11,883,432
4	¥-119,346	¥6,850,477	¥6,731,131	¥18,614,563
5	0	¥7,055,992	¥7,055,992	¥25,670,555
6	0	¥7,267,671	¥7,267,671	¥32,938,226
7	0	¥7,485,701	¥7,485,701	¥40,423,928
8	0	¥7,710,273	¥7,710,273	¥48,134,200
9	0	¥7,941,581	¥7,941,581	¥56,075,781
10	0	¥8,179,828	¥8,179,828	¥64,255,609
11	0	¥310,714	¥310,714	¥64,566,323
12	0	¥320,036	¥320,036	¥64,886,359
13	0	¥329,637	¥329,637	¥65,215,996
14	0	¥339,526	¥339,526	¥65,555,522
15	0	¥349,712	¥349,712	¥65,905,234
16	0	¥360,203	¥360,203	¥66,265,437
17	0	¥371,009	¥371,009	¥66,636,446
18	0	¥382,139	¥382,139	¥67,018,585
19	0	¥393,604	¥393,604	¥67,412,189
20	0	¥405,412	¥405,412	¥67,817,601
21	0	¥0	¥0	¥67,817,601

Finally, Table 5-1 provides the estimated present worth of ten years of CER sales under CDM. Because the Under 1-Year Payback measures are so financially attractive without any financial incentive, we doubt seriously that these EEMs would qualify for CDM. For the other EEMs and packages, potential CER proceeds at expected market trading prices could offset much of the customer contribution. CER proceeds would cover 16% of the project cost. This analysis indicates that pursuing these recommended EEMs as CDM projects would be attractive for Guangdong and FOC.

6 Measurement and Verification

Efficiency programs commonly include a measurement & verification (M&V) process to assure that specific efficiency projects and tasks have been carried out and are performing effectively. An M&V process involves site inspections of implemented projects that have received incentives through the efficiency program. Site inspections consist of documenting project installations, and often measuring to determine the facility's performance improvement after retrofit.

M&V processes are essential in determining the success of an efficiency program. Post-retrofit measurements establish the difference between theoretical projected energy savings and actual savings. Program incentives may then be modified based on realized actual savings. Repetitive problems are often discovered through the M&V process, which can be dealt with and solved. Solving problems and identifying strong and weak points is an effective way to fine tune a program. Moreover, sound M&V procedures will be absolutely necessary if it is intended to pursue CER sales through the CDM mechanism.

M&V processes have added much value to efficiency programs in New England and California. The following steps illustrate a typical M&V procedure.

Review Project Files – Invoices and documents regarding approval of efficiency projects are reviewed.

Decide Which Sites to Evaluate – Based on client type and what energy-efficient equipment each client installed, a sample of clients is chosen for evaluation. The sample selected should represent the program's entire client population with 10% relative precision.

Visually Inspect Sites – Verify that the implemented projects are consistent with project files. On site inspections, decide which pieces of equipment should be logged.

Install Loggers – Loggers should be installed on new pieces of equipment or upgraded equipment. Equipment should be logged for a period of one to four weeks.

Analyze Data – Data analysis determines energy savings. Volatile factors such as daily operating hours, building occupancy level, and weather conditions should be taken into account during analysis.

Determine Savings – Savings are determined by comparing the energy use and performance of an efficient system with the performance of standard baseline system.

Submit Report – The evaluation report is submitted to program management. The report includes a comparison of projected savings before project implementation and savings based on measurements after implementation. Reported results help determine the effectiveness of an efficiency program, and help recommend possible improvements.

7 Conclusions and Recommendations

Here we consolidate and reiterate the conclusions and recommendations from our technical, economic, and financial analysis of the 6 EEMs examined in this study.

7.1 Technical Assessment

We find that all EEMs studied are technically feasible. We conclude that they will save 7.7 million kWh, and 2000 tons of oil annually, and recommend that FOC install them all as soon as possible. Each EEM is summarized below.

7.1.1. EEM-1 Replace Y-Series Motors with YX-Series Motors

Most plant motors are standard-efficiency Y-series motors. Premium-efficiency YX-series motors are commercially available, and are between 1% and 3% more efficient than standard-efficiency motors. We recommend replacing Y-series with YX-series motors.

7.1.2. EEM-2 Install Variable Frequency Drives (VFDs)

Although production at the facility is nearly constant, many of the motor-driven loads are variable due to throttling that occurs in the processes, or due to seasonal variations in temperature or humidity. Slowing motor revolutions down when the motors are not fully loaded can result in significant energy savings. We recommend installing VFD's on motors with centrifugal loads that vary more then 10% and for other applications as detailed in the appendix.

7.1.3. EEM-3 Replace Standard V-Belts with Synchronous belts

Standard V-belts have been shown to have an efficiency of approximately 92%, indicating that approximately 8% of the work produced by the motor is lost as heat as the belts flex and slip going around the pulleys. Over time the efficiency of V-belts deteriorates due to wear and incorrect tensioning. Synchronous belts are available that are similar to the timing belt on modern cars. These belts have raised ridges perpendicular to the length of the belt that lock into corresponding grooves machined into the sprockets similar to the meshing of gear teeth. Synchronous belts have an efficiency of approximately 98%. Synchronous belts require the replacement of both the belts and the sheaves for utilization. When the installation of Synchronous belts is not possible due to cost, equipment configuration, or equipment loading cogged V-belts can be used as a low cost means to improve the drive efficiency.

7.1.4. EEM-4 Consider Installing S11 Transformers When Replacing Existing Transformers

Foshan Oceano Ceramics Co. should consider replacement of any remaining S7 transformers, and may want to consider replacing S9 transformers now or at the end of their useful life. Three major types of transformers are commercially available: standard-efficiency S9 transformers, high-efficiency S11 transformers, and premium-efficiency S13 transformers. S13 transformers are most efficient because they undergo the least core losses but may not be readily available at this time. We recommend considering installing S11 and if possible S13 transformers when replacing existing transformers.

7.1.5. EEM-5 Repair Compressed Air Leaks and Maintain Air Distribution System

Compressed air production is very costly from an energy consumption perspective. Due to the very large number of piping connections, seals, valves, pneumatic devices, and controls that are attached to a compressed air system the network of pipe and tubing becomes very complex in a facility of this size. Unfortunately with all the piping and connections there is often a significant portion of overall compressed air production that is lost to leakage. By initiating a comprehensive plan to find and repair leaks on a bi-annual basis large energy savings will result.

7.1.6. EEM-6 Drying out optimization

The drying process is the single largest energy consumer in the plant. Any improvements would yield both a large reduction in the plant’s CO2 emissions, as well as a large decrease in production cost per tile. Careful study should be performed on this process to determine the best method for improving the energy efficiency of this process.

7.2 ECONOMIC AND FINANCIAL ASSESSMENT

Table 7-1 summarizes the results of the economic and financial analysis of each of the six EEMs studied and of five combined.

Table 7-1
Summary of Foshan Oceano EEM Economic and Financial Analysis

	Motor Retrofit	Variable Frequency Drives			Drive Belt Upgrade	Transformer Scheduled Replacement	Compressed Air Leak Repair	Total All Measures [1]+[2]+[3]+[4]+[6]+[7a]+[8]		
	[1]	Centrifugal [2]	Variable Torque [3]	Constant Torque [4]	Synchronous [6]	[7a]	[8]	100% Customer Equity	Conventional 3-Year Loan	EPP Loan
Total Measure Cost (not discounted)	¥2,147,867	¥1,035,000	¥13,200	¥2,928,000	¥720,698	¥360,000	¥34,000	¥7,238,765	¥7,238,765	¥7,238,765
Customer Down Payment								¥7,238,765	¥3,619,382	¥3,619,382
Financed Cost								¥0	¥3,619,382	¥3,858,261
EPP Economic Analysis										
Benefits (Avoided Generation, T&D)	¥5,327,829	¥7,452,050	¥76,105	¥7,511,252	¥850,750	¥1,199,856	¥138,127	¥22,555,970	¥22,555,970	¥22,555,970
Total Costs (see Note)	¥1,609,561	¥1,035,000	¥13,200	¥2,928,000	¥720,698	¥360,000	¥34,000	¥6,700,459	¥6,700,459	¥6,700,459
Net Economic Benefits	¥3,718,269	¥6,417,050	¥62,905	¥4,583,252	¥130,052	¥839,856	¥104,127	**¥15,855,512**	**¥15,855,512**	**¥15,855,512**
Benefit/Cost Ratio	3.31	7.20	5.77	2.57	1.18	3.33	4.06	3.37	3.37	3.37
CDM-CER Present Value (max 10 years)	¥423,653	Not applicable	Not applicable	¥597,272	¥67,649	¥64,605	Not applicable	¥1,153,178	¥1,153,178	¥1,153,178
% of Total Measure Cost	20%			20%	9%	18%		16%	16%	16%
% of Customer Down Payment								16%	32%	32%
Customer Financial Analysis										
Simple payback on measure cost (years)	2.00	1.00	1.00	2.00	3.00	2.00	1.00			
Simple payback with financing (years)								1.11	0.69	0.70
Internal Rate of Return without financing	73%	208%	167%	76%	34%	67%	727%	91%	91%	91%
Internal Rate of Return with financing								91%	147%	146%

Note: Total Costs in EPP Economic Analysis reflect early retirement cost credit for postponing future scheduled replacements.
Benefits and costs in EPP Economic Analysis are all discounted to 2008.

7.2.1. ECONOMIC ASSESSMENT

The recommended EEMs all provide energy savings at life-cycle costs well below the avoided cost of coal-fired electricity supply. Maximum economic net benefits to Guangdong will be realized if FOC installs all cost-effective EEMs as soon as possible.

The total economically feasible potential for EEP investment at the plant is 7.7 million kWh/year, with an estimated peak demand reduction of 1,634 kW. The total (undiscounted) investment required is 7 million RMB. It is expected to yield benefits in the form of avoided generation and T&D costs of 22 million RMB, for net economic benefits to Guangdong Province of 15.8 million yuan.

We estimated the benefits but were unable to estimate the potential costs of optimizing the drying out process. We recommend further examination of this option to determine its likely costs and more precise benefits. If found to be cost effective, it should be added to the package of efficiency measures.

7.2.2. FINANCIAL ASSESSMENT

The EEMs recommended provide attractive paybacks and cash flow when treated together. Though these EEMs provide a payback of just over a year with

100% customer financing, the payback could be lowered to less than 9 months with financing through either a conventional loan or a Guangdong Efficiency Power Plant loan. Based on the particular assumptions used in this analysis, there did not appear to be much of a difference in the cash flow for the two types of financing.

Several of the EEMs may qualify for recognition as Certified Emission Reductions (CERs) under the UN’s Clean Development Mechanism (CDM). With simple payback periods under one year, EEM-2, EEM-3 and EEM-8 are highly unlikely to qualify for CDM treatment. Potential proceeds of 1.1 million RMB are possible from implementation of the others. We recommend further examination of the prospects for developing this as a CDM project.

We understand that early retirement of still-functioning equipment may raise accounting issues for the enterprise. We recommend that isolation of these issues and develop appropriate accounting treatment with a Chinese accounting expert.

8 Appendix

8.1 MOTOR POWERED EQUIPMENT

Motor Powered Equipment

	Model #	Quan. (1)	Installed KW (2)	Number of Motors in Operation (3)	Rated KW (4)	Actual KW (5)	Annual Operating Time (Hour) (6)	Existing Motor Efficiency	Motor Load Correction Factor (7)	Annual Energy Consumption KWh (8)
#6 Mist Machine	Y280M-4	1	90	1	90	81.8	8000	93.5%	36.1%	236,225
#6 Smoke Exhaust	Y280S-4	1	75	1	75	68.8	8000	92.7%	36.1%	198,553
#6 Heat Exhaust	Y225M-4	1	45	1	45	41.4	8000	92.3%	36.1%	119,648
#6 Quick Cooling	Y200L2-4	1	37	1	37	34.1	8000	92.2%	36.1%	98,484
#6 Indirect Cooling	Y180M-4	1	22	1	22	20.4	8000	91.5%	36.1%	59,006
#6 Burner Fan	Y225M-4	1	45	1	45	41.4	8000	92.3%	36.1%	119,648
#6 Dry Cooling	Y160M-4	1	11	1	11	10.7	8000	87.8%	36.1%	30,764
#6 Dry Heat Exhaust	Y160L-4	1	15	1	15	14.4	8000	88.5%	36.1%	41,595
#6 Dry Moisture Exhaust	Y225M-4	1	45	1	45	41.4	8000	92.3%	36.1%	119,648
#5 Burner Fan	Y200L-4	1	37	1	37	34.1	8000	92.2%	36.1%	98,484
#5 Heat Exhaust	Y225M-4	1	45	1	45	41.4	8000	92.3%	36.1%	119,648

	Model #	Quan. (1)	Installed KW (2)	Number of Motors in Operation (3)	Rate d KW (4)	Actual KW (5)	Annual Operating Time (Hour) (6)	Existing Motor Efficiency	Motor Load Correction Factor (7)	Annual Energy Consumptio n KWh (8)
#5 Indirect Cooling		1	22	1	22	20.4	8000	91.5%	36.1%	59,006
Unreadable		1	45	1	45	41.4	8000	92.3%	36.1%	119,648
Unreadable		1	15	1	15	14.4	8000	88.5%	36.1%	41,595
#5 Dry Moisture Exhaust	Y225M-4	1	45	1	45	41.4	8000	92.3%	36.1%	119,648
#5 Ventilation Fan	Y160L-4	1	15	1	15	14.4	8000	88.5%	36.1%	41,595
# 3 & 4 Mist Machine	Y280S-4	1	75	1	75	68.8	8000	92.7%	36.1%	198,553
#3 Smoke Exhaust	Y200L-4	1	30	1	30	27.7	8000	92.2%	36.1%	79,852
#3 Dry Moisture Exhaust	Y200L-4	1	30	1	30	27.7	8000	92.2%	36.1%	79,852
#3 Burner Fan	Y180M-4	1	22	1	22	20.4	8000	91.5%	36.1%	59,006
#3 Indirect Cooling	Y180L-4	1	22	1	22	20.4	8000	91.5%	36.1%	59,006
#3 Heat Exhaust	Y180M-4	1	18.5	1	18.5	17.3	8000	91.0%	36.1%	49,891
#3 Quick Cooling	Y160M-4	1	15	1	15	14.4	8000	88.5%	36.1%	41,595
#4 Smoke Exhaust	Y225M-4	1	45	1	45	41.4	8000	92.3%	36.1%	119,648
#4 Dry Moisture Exhaust	Y200L-4	1	30	1	30	27.7	8000	92.2%	36.1%	79,852

	Model #	Quan. (1)	Installed KW (2)	Number of Motors in Operation (3)	Rate d KW (4)	Actual KW (5)	Annual Operating Time (Hour) (6)	Existing Motor Efficiency	Motor Load Correction Factor (7)	Annual Energy Consumptio n KWh (8)
#4 Burner Fan	Y200L-4	1	30	1	30	27.7	8000	92.2%	36.1%	79,852
#4 Indirect Cooling	Y180L-4	1	22	1	22	20.4	8000	91.5%	36.1%	59,006
#4 Quick Cooling	Y160M-4	1	15	1	15	14.4	8000	88.5%	36.1%	41,595
#4 Heat Exhaust	Y180M-4	1	18.5	1	18.5	17.3	8000	91.0%	36.1%	49,891
Oil Storage	YB180M-4	1	18.5	1	18.5	17.3	8000	91.0%	36.1%	49,891
Ventilation Blower	Y250M-2	1	55	1	55	50.5	8000	92.6%	36.1%	145,763
Ventilation Blower	Y225M-2	1	45	1	45	41.4	8000	92.3%	36.1%	119,648
Pressure Pump	YB2-280M-2	1	90	1	90	81.8	8000	93.5%	36.1%	236,225
Deep Water Pump	R95-MA-10	1	5.5	1	5.5	5.5	8000	84.5%	36.1%	15,974
Waste Water Pump	Y200L-4	1	30	1	30	27.7	8000	92.2%	36.1%	79,852
Waste Water Pump	Y225M-4	1	45	1	45	41.4	8000	92.3%	36.1%	119,648
Tile Planing Machine	Y160L-4	133	1995	133	15	1916.1	8000	88.5%	51.1%	7,834,557
Tile Polishing Machine	Y160M-4	133	1463	133	11	1417.2	8000	87.8%	51.1%	5,794,447
Tile Rough Polishing Machine	Y180M-4	133	2461	133	18.5	2298.7	8000	91.0%	51.1%	9,399,073
Ball Mill	QMP3200* 4650-18T	6	540	6	90	490.9	5100	93.5%	36.1%	903,562
Ball Mill	XQM-23T	6	540	6	90	490.9	5100	93.5%	36.1%	903,562

	Model #	Quan. (1)	Installed KW (2)	Number of Motors in Operation (3)	Rate d KW (4)	Actual KW (5)	Annual Operating Time (Hour) (6)	Existing Motor Efficiency	Motor Load Correction Factor (7)	Annual Energy Consumptio n KWh (8)
Ball Mill	XQM-40T	14	1848	14	132	1671.1	5100	94.0%	36.1%	3,075,743
Stirring Mixer	Y160M-4	1	11	1	11	10.7	8000	87.8%	36.1%	30,764
Stirring Mixer	Y100L-4	1	2.2	1	2.2	2.3	8000	81.0%	36.1%	6,666
Ventilation Blower	Y315M3-6	1	132	1	132	119.4	8000	94.0%	36.1%	344,621
Ventilation Blower	Y315M1-6	1	90	1	90	81.8	8000	93.5%	36.1%	236,225
Ventilation Blower	Y280M-4	1	90	1	90	81.8	8000	93.5%	36.1%	236,225
Air Compressor	SA55	1	55	1	55	50.5	8000	92.6%	36.1%	145,763
Air Compressor	L55-7	1	55	1	55	50.5	8000	92.6%	36.1%	145,763
Air Compressor	GA55P	1	55	1	55	50.5	8000	92.6%	36.1%	145,763
Air Compressor	GA75+AP-7.5	1	75	1	75	68.8	8000	92.7%	36.1%	198,553
Compressor	KD3200T	1	90	1	90	81.8	8000	93.5%	36.1%	236,225
Compressor	KD3600T	1	110	1	110	100.0	8000	93.5%	36.1%	288,720
Compressor	KD3800T	1	132	1	132	119.4	8000	94.0%	36.1%	344,621
Totals:		**473**	**11,015**	**473**						**33,658,658**

Notes for table 8.1:

1. Quantity of motors installed for this application.
2. Sum of all rated motor KW installed.

3. Number of motors in
simultaneous operation.
4. Nameplate rated KW for
each individual motor.
5. Electrical demand (KW) draw of each motor adjusted for motor load and
efficiency.
6. Annual run time of motors.
7. Motor load correction factor to normalize assumed motor electrical energy use with actual electric
energy use.
8. Total annual electric energy consumption of
operating motors.

8.2 POTENTIAL MOTOR REPLACEMENTS

Potential Motor Replacements

	Model #	Quan. (1)	Installed KW (2)	Number of Motors in Operation (3)	Rated KW (4)	Actual KW (5)	Annual Operating Time (Hour) (6)	Motor Load Correction Factor (7)	Existing Efficiency % (8)	Proposed Efficiency % (9)	Savings KW (10)	Savings KWh (11)	Savings rmb (12)	Motor Cost rmb (13)	Simple Payback (yrs) (14)
#6 Mist Machine	Y280M-4	1	90	1	90	76.5	8000	36.1%	93.5%	95.0%	0.5	3,730	3,175	15,300	4.8
#6 Smoke Exhaust	Y280S-4	1	75	1	75	63.8	8000	36.1%	92.7%	94.7%	0.5	4,193	3,569	12,750	3.6
#6 Heat Exhaust	Y225M-4	1	45	1	45	38.3	8000	36.1%	92.3%	94.1%	0.3	2,289	1,948	7,650	3.9
#6 Quick Cooling	Y200L2-4	1	37	1	37	31.5	8000	36.1%	92.2%	93.5%	0.2	1,369	1,165	5,100	4.4
#6 Indirect Cooling	Y180M-4	1	22	1	22	18.7	8000	36.1%	91.5%	93.2%	0.1	1,076	916	3,740	4.1
#6 Burner Fan	Y225M-4	1	45	1	45	38.3	8000	36.1%	92.3%	94.1%	0.3	2,289	1,948	7,650	3.9

	Model #	Quan. (1)	Installed KW (2)	Number of Motors in Operation (3)	Rated KW (4)	Actual KW (5)	Annual Operating Time (Hour) (6)	Motor Load Correction Factor (7)	Existing Efficiency % (8)	Proposed Efficiency % (9)	Savings KW (10)	Savings KWh (11)	Savings rmb (12)	Motor Cost rmb (13)	Simple Payback (yrs) (14)
#6 Dry Cooling	Y160M-4	1	11	1	11	9.4	8000	36.1%	87.8%	91.1%	0.1	1,115	949	1,870	2.0
#6 Dry Heat Exhaust	Y160L-4	1	15	1	15	12.8	8000	36.1%	88.5%	91.8%	0.2	1,495	1,273	2,550	2.0
#6 Dry Moisture Exhaust	Y225M-4	1	45	1	45	38.3	8000	36.1%	92.3%	94.1%	0.3	2,289	1,948	7,650	3.9
#5 Burner Fan	Y200L-4	1	37	1	37	31.5	8000	36.1%	92.2%	93.5%	0.2	1,369	1,165	5,100	4.4
#5 Heat Exhaust	Y225M-4	1	45	1	45	38.3	8000	36.1%	92.3%	94.1%	0.3	2,289	1,948	7,650	3.9
#5 Indirect Cooling		1	22	1	22	18.7	8000	36.1%	91.5%	93.2%	0.1	1,076	916	3,740	4.1
Unreadable		1	45	1	45	38.3	8000	36.1%	92.3%	94.1%	0.3	2,289	1,948	7,650	3.9
Unreadable		1	15	1	15	12.8	8000	36.1%	88.5%	91.8%	0.2	1,495	1,273	2,550	2.0
#5 Dry Moisture Exhaust	Y225M-4	1	45	1	45	38.3	8000	36.1%	92.3%	94.1%	0.3	2,289	1,948	7,650	3.9

	Model #	Quan. (1)	Installed KW (2)	Number of Motors in Operation (3)	Rated KW (4)	Actual KW (5)	Annual Operating Time (Hour) (6)	Motor Load Correction Factor (7)	Existing Efficiency % (8)	Proposed Efficiency % (9)	Savings KW (10)	Savings KWh (11)	Savings rmb (12)	Motor Cost rmb (13)	Simple Payback (yrs) (14)
#5 Ventilation Fan	Y160L-4	1	15	1	15	12.8	8000	36.1%	88.5%	91.8%	0.2	1,495	1,273	2,550	2.0
# 3 & 4 Mist Machine	Y280S-4	1	75	1	75	63.8	8000	36.1%	92.7%	94.7%	0.5	4,193	3,569	12,750	3.6
#3 Smoke Exhaust	Y200L-4	1	30	1	30	25.5	8000	36.1%	92.2%	93.5%	0.1	1,110	945	5,100	5.4
#3 Dry Moisture Exhaust	Y200L-4	1	30	1	30	25.5	8000	36.1%	92.2%	93.5%	0.1	1,110	945	5,100	5.4
#3 Burner Fan	Y180M-4	1	22	1	22	18.7	8000	36.1%	91.5%	93.2%	0.1	1,076	916	3,740	4.1
#3 Indirect Cooling	Y180L-4	1	22	1	22	18.7	8000	36.1%	91.5%	93.2%	0.1	1,076	916	3,740	4.1
#3 Heat Exhaust	Y180M-4	1	18.5	1	18.5	15.7	8000	36.1%	91.0%	93.0%	0.1	1,073	913	3,145	3.4
#3 Quick Cooling	Y160M-4	1	15	1	15	12.8	8000	36.1%	88.5%	91.8%	0.2	1,495	1,273	2,550	2.0
#4 Smoke Exhaust	Y225M-4	1	45	1	45	38.3	8000	36.1%	92.3%	94.1%	0.3	2,289	1,948	7,650	3.9

	Model #	Quan. (1)	Installed KW (2)	Number of Motors in Operation (3)	Rated KW (4)	Actual KW (5)	Annual Operating Time (Hour) (6)	Motor Load Correction Factor (7)	Existing Efficiency % (8)	Proposed Efficiency % (9)	Savings KW (10)	Savings KWh (11)	Savings rmb (12)	Motor Cost rmb (13)	Simple Payback (yrs) (14)
#4 Dry Moisture Exhaust	Y200L-4	1	30	1	30	25.5	8000	36.1%	92.2%	93.5%	0.1	1,110	945	5,100	5.4
#4 Burner Fan	Y200L-4	1	30	1	30	25.5	8000	36.1%	92.2%	93.5%	0.1	1,110	945	5,100	5.4
#4 Indirect Cooling	Y180L-4	1	22	1	22	18.7	8000	36.1%	91.5%	93.2%	0.1	1,076	916	3,740	4.1
#4 Quick Cooling	Y160M-4	1	15	1	15	12.8	8000	36.1%	88.5%	91.8%	0.2	1,495	1,273	2,550	2.0
#4 Heat Exhaust	Y180M-4	1	18.5	1	18.5	15.7	8000	36.1%	91.0%	93.0%	0.1	1,073	913	3,145	3.4
Oil Storage	YB180M-4	1	18.5	1	18.5	15.7	8000	36.1%	91.0%	93.0%	0.1	1,073	913	3,145	3.4
Ventilation Blower	Y250M-2	1	55	1	55	46.8	8000	36.1%	92.6%	94.5%	0.4	2,931	2,494	9,350	3.7
Ventilation Blower	Y225M-2	1	45	1	45	38.3	8000	36.1%	92.3%	94.1%	0.3	2,289	1,948	7,650	3.9
Pressure Pump	YB2-280M-2	1	90	1	90	76.5	8000	36.1%	93.5%	95.0%	0.5	3,730	3,175	15,300	4.8

	Model #	Quan. (1)	Installed KW (2)	Number of Motors in Operation (3)	Rated KW (4)	Actual KW (5)	Annual Operating Time (Hour) (6)	Motor Load Correction Factor (7)	Existing Efficiency % (8)	Proposed Efficiency % (9)	Savings KW (10)	Savings KWh (11)	Savings rmb (12)	Motor Cost rmb (13)	Simple Payback (yrs) (14)
Deep Water Pump	R95-MA-10	1	5.5	1	5.5	4.7	8000	36.1%	84.5%	88.3%	0.1	687	585	680	1.2
Waste Water Pump	Y200L-4	1	30	1	30	25.5	8000	36.1%	92.2%	93.5%	0.1	1,110	945	5,100	5.4
Waste Water Pump	Y225M-4	1	45	1	45	38.3	8000	36.1%	92.3%	94.1%	0.3	2,289	1,948	7,650	3.9
Tile Planing Machine	Y160L-4	133	15	133	15	12.8	8000	51.1%	88.5%	91.8%	35.2	281,634	239,716	339,150	1.4
Tile Polishing Machine	Y160M-4	133	11	133	11	9.4	8000	51.1%	87.8%	91.1%	26.3	210,013	178,755	248,710	1.4
Tile Rough Polishing Machine	Y180M-4	133	18.5	133	18.5	15.7	8000	51.1%	91.0%	93.0%	25.3	202,090	172,011	418,285	2.4
Ball Mill	QMP3200*4650-18T	6	540	6	90	459.0	5100	36.1%	93.5%	95.0%	16.8	85,601	72,860	91,800	1.3
Ball Mill	XQM-23T	6	540	6	90	459.0	5100	36.1%	93.5%	95.0%	16.8	85,601	72,860	91,800	1.3
Ball Mill	XQM-40T	14	1848	14	132	1570.8	5100	36.1%	94.0%	95.8%	158.6	809,068	688,646	314,160	0.5

	Model #	Quan. (1)	Installed KW (2)	Number of Motors in Operation (3)	Rated KW (4)	Actual KW (5)	Annual Operating Time (Hour) (6)	Motor Load Correction Factor (7)	Existing Efficiency % (8)	Proposed Efficiency % (9)	Savings KW (10)	Savings KWh (11)	Savings rmb (12)	Motor Cost rmb (13)	Simple Payback (yrs) (14)
Stirring Mixer	Y160M-4	1	11	1	11	9.4	8000	36.1%	87.8%	91.1%	0.1	1,115	949	1,870	2.0
Stirring Mixer	Y100L-4	1	2.2	1	2.2	1.9	8000	36.1%	81.0%	86.3%	0.1	409	348	374	1.1
Ventilation Blower	Y315M3-6	1	132	1	132	112.2	8000	36.1%	94.0%	95.8%	0.8	6,475	5,511	22,440	4.1
Ventilation Blower	Y315M1-6	1	90	1	90	76.5	8000	36.1%	93.5%	95.0%	0.5	3,730	3,175	15,300	4.8
Ventilation Blower	Y280M-4	1	90	1	90	76.5	8000	36.1%	93.5%	95.0%	0.5	3,730	3,175	15,300	4.8
Air Compressor	SA55	1	55	1	55	46.8	8000	36.1%	92.6%	94.5%	0.4	2,931	2,494	9,350	3.7
Air Compressor	L55-7	1	55	1	55	46.8	8000	36.1%	92.6%	94.5%	0.4	2,931	2,494	9,350	3.7
Air Compressor	GA55P	1	55	1	55	46.8	8000	36.1%	92.6%	94.5%	0.4	2,931	2,494	9,350	3.7
Air Compressor	GA75+AP-7.5	1	75	1	75	63.8	8000	36.1%	92.7%	94.7%	0.5	4,193	3,569	12,750	3.6

	Model #	Quan. (1)	Installed KW (2)	Number of Motors in Operation (3)	Rated KW (4)	Actual KW (5)	Annual Operating Time (Hour) (6)	Motor Load Correction Factor (7)	Existing Efficiency % (8)	Proposed Efficiency % (9)	Savings KW (10)	Savings KWh (11)	Savings rmb (12)	Motor Cost rmb (13)	Simple Payback (yrs) (14)
Compressor	KD3200T	1	90	1	90	76.5	8000	36.1%	93.5%	95.0%	0.5	3,730	3,175	15,300	4.8
Compressor	KD3600T	1	110	1	110	93.5	8000	36.1%	93.5%	94.5%	0.4	3,055	2,600	18,700	7.2
Compressor	KD3800T	1	132	1	132	112.2	8000	36.1%	94.0%	95.8%	0.8	6,475	5,511	22,440	4.1
Totals:		**473**									**292.3**	**1,781,255**	**1,516,133**	**1,869,864**	**1.2**

Notes For Table 8.2:

1. Quantity of motors installed for this application.
2. Sum of rated KW of all motors installed.
3. Number of motors operating at any one time.
4. Rated nameplate KW of each of the separate motors installed.
5. Electrical demand (KW) draw of each motor adjusted for motor load and efficiency.
6. Annual run time of motors as reported by the facility.
7. Motor load correction factor to normalize assumed motor electrical energy use with actual electric energy use.
8. Existing motor efficiency assuming Y-series motors.

9. Proposed motor efficiency assuming YX-series motor replacements.

10. Demand Savings KW = (# of motors) x (KW draw) x [(1/Existing eff.) - (1/Proposed eff.)] x (Motor correction factor).

11. Annual Energy Savings KWh = (Annual hours of operation) x (Demand Savings).

12. Annual Cost Savings RMB = (Annual energy savings) x (0.85112 rmb/KWh).

13. Motor Replacement Cost RMB = (Installed KW of motors) x (170 rmb/KW)

14. Simple Payback Years = (motor replacement cost) / (Annual cost savings).

8.3 VARIABLE FREQUENCY DRIVE MEASURES

Variable Frequency Drive Measures

	Model #	Quan. (1)	Installed KW (2)	Number of Motors in Operation (3)	Rated KW (4)	Actual KW (5)	Annual Operating Time (Hour) (6)	Proposed Motor Efficiency (7)	Average Seasonal Load (8)	Base Demand KW (9)	Reduced Demand KW (10)	Energy Savings KWh (11)	Annual Cost Savings rmb (12)	Installed Cost rmb (13)	Simple Payback Years (14)
#6 Smoke Exhaust	Y280S-4	1	75	1	75	67.3	8000	94.7%	36.1%	71.1	3.3	178,506	151,937	75,000	0.5
#6 Heat Exhaust	Y225M-4	1	45	1	45	40.6	8000	94.1%	36.1%	43.2	2.0	108,474	92,328	45,000	0.5
#6 Quick Cooling	Y200L2-4	1	37	1	37	33.6	8000	93.5%	36.1%	36.0	1.7	90,338	76,892	37,000	0.5
#6 Indirect Cooling	Y180M-4	1	22	1	22	20.1	8000	93.2%	36.1%	21.5	1.0	54,061	46,014	22,000	0.5
#6 Dry Cooling	Y160M-4	1	11	1	11	10.3	8000	91.1%	36.1%	11.3	0.5	28,322	24,107	11,000	0.5
#6 Dry Heat Exhaust	Y160L-4	1	15	1	15	13.9	8000	91.8%	36.1%	15.1	0.7	37,992	32,338	15,000	0.5
#6 Dry Moisture Exhaust	Y225M-4	1	45	1	45	40.6	8000	94.1%	36.1%	43.2	2.0	108,474	92,328	45,000	0.5
#5 Heat Exhaust	Y225M-4	1	45	1	45	40.6	8000	94.1%	36.1%	43.2	2.0	108,474	92,328	45,000	0.5
#5 Indirect Cooling		1	22	1	22	20.1	8000	93.2%	36.1%	21.5	1.0	54,061	46,014	22,000	0.5
#5 Dry Moisture Exhaust	Y225M-4	1	45	1	45	40.6	8000	94.1%	36.1%	43.2	2.0	108,474	92,328	45,000	0.5

	Model #	Quan. (1)	Installed KW (2)	Number of Motors in Operation (3)	Rated KW (4)	Actual KW (5)	Annual Operating Time (Hour) (6)	Proposed Motor Efficiency (7)	Average Seasonal Load (8)	Base Demand KW (9)	Reduced Demand KW (10)	Energy Savings KWh (11)	Annual Cost Savings rmb (12)	Installed Cost rmb (13)	Simple Payback Years (14)
#5 Ventilation Fan	Y160L-4	1	15	1	15	13.9	8000	91.8%	36.1%	15.1	0.7	37,992	32,338	15,000	0.5
#3 Smoke Exhaust	Y200L-4	1	30	1	30	27.3	8000	93.5%	36.1%	29.2	1.4	73,247	62,345	30,000	0.5
#3 Dry Moisture Exhaust	Y200L-4	1	30	1	30	27.3	8000	93.5%	36.1%	29.2	1.4	73,247	62,345	30,000	0.5
#3 Indirect Cooling	Y180L-4	1	22	1	22	20.1	8000	93.2%	36.1%	21.5	1.0	54,061	46,014	22,000	0.5
#3 Heat Exhaust	Y180M-4	1	18.5	1	18.5	16.9	8000	93.0%	36.1%	18.2	0.9	45,656	38,860	18,500	0.5
#3 Quick Cooling	Y160M-4	1	15	1	15	13.9	8000	91.8%	36.1%	15.1	0.7	37,992	32,338	15,000	0.5
#4 Smoke Exhaust	Y225M-4	1	45	1	45	40.6	8000	94.1%	36.1%	43.2	2.0	108,474	92,328	45,000	0.5
#4 Dry Moisture Exhaust	Y200L-4	1	30	1	30	27.3	8000	93.5%	36.1%	29.2	1.4	73,247	62,345	30,000	0.5
#4 Indirect Cooling	Y180L-4	1	22	1	22	20.1	8000	93.2%	36.1%	21.5	1.0	54,061	46,014	22,000	0.5
#4 Quick Cooling	Y160M-4	1	15	1	15	13.9	8000	91.8%	36.1%	15.1	0.7	37,992	32,338	15,000	0.5
#4 Heat Exhaust	Y180M-4	1	18.5	1	18.5	16.9	8000	93.0%	36.1%	18.2	0.9	45,656	38,860	18,500	0.5
Ventilation Blower	Y250M-2	1	55	1	55	49.5	8000	94.5%	36.1%	52.4	2.5	131,459	111,893	55,000	0.5
Ventilation Blower	Y225M-2	1	45	1	45	40.6	8000	94.1%	36.1%	43.2	2.0	108,474	92,328	45,000	0.5

	Model #	Quan. (1)	Installed KW (2)	Number of Motors in Operation (3)	Rated KW (4)	Actual KW (5)	Annual Operating Time (Hour) (6)	Proposed Motor Efficiency (7)	Average Seasonal Load (8)	Base Demand KW (9)	Reduced Demand KW (10)	Energy Savings KWh (11)	Annual Cost Savings rmb (12)	Installed Cost rmb (13)	Simple Payback Years (14)
Ball Mill	QMP3200*4650-18T	6	540	6	90	483.2	5100	95.0%	36.1%	508.6	91.8	468,050	398,386	540,000	1.4
Ball Mill	XQM-23T	6	540	6	90	483.2	5100	95.0%	36.1%	508.6	91.8	468,050	398,386	540,000	1.4
Ball Mill	XQM-40T	14	1848	14	132	1639.7	5100	95.8%	36.1%	1,711.6	308.8	1,575,132	1,340,689	1,848,000	1.4
Stirring Mixer	Y160M-4	1	11	1	11	10.3	8000	91.1%	36.1%	11.3	1.5	20,811	17,714	11,000	0.6
Stirring Mixer	Y100L-4	1	2.2	1	2.2	2.2	8000	86.3%	36.1%	2.5	0.3	4,633	3,943	2,200	0.6
Ventilation Blower	Y315M3-6	1	132	1	132	117.1	8000	95.8%	36.1%	122.3	5.7	306,997	261,303	132,000	0.5
Ventilation Blower	Y315M1-6	1	90	1	90	80.5	8000	95.0%	36.1%	84.8	4.0	212,856	181,175	90,000	0.5
Ventilation Blower	Y280M-4	1	90	1	90	80.5	8000	95.0%	36.1%	84.8	4.0	212,856	181,175	90,000	0.5
Totals:		**54**	**3,976.2**	**54**						**3,735**	**540.8**	**5,028,116**	**4,279,732**	**3,976,200**	**0.9**

Notes For Table 8.3

1. Quantity of motors installed.
2. Sum of all rated motor KW installed.
3. Number of motors in simultaneous operation.
4. Nameplate rated KW for each individual motor.

5. Electrical demand (KW) draw of each motor adjusted for motor load and efficiency.

6. Annual run time of motors.

7. Motor efficiency assuming motors up-graded to premium efficiency YX motors.

8. Average motor load based on actual electric energy use and seasonal variation.

9. Calculated motor load in KW.

10. Average reduced demand:

KW = (calculated load) x (average load percent^3) for centrifugal loads such as fans and pumps where energy consumption varies as the cube of speed,

KW = (calculated load) x (average load percent^2) for variable torque loads such as Mixers where energy consumption varies as athe square of speed.

KW = (calculated load) x (average load percent) for constant torque loads such as the ball mills where energy consumption varies linearly with speed.

11. Total annual electric energy savings KWh = (annual hours of operation x average load factor) x (Base load demand KW - Average reduced demand KW)

12. Annual Cost Savings RMB = (Annual energy savings) x (0.85116 rmb/KWh)

13. Installed measure cost RMB = (Installed KW of motors) x (1000 rmb/KW), 850 rmb/KW for the drive, 150 rmb/KW for installation.

14. Simple Payback Years = (Total measure cost) / (Annual cost savings).

8.4 Synchronous and Cogged Belt Measures

Synchronous and Cogged Belt Measures

	Quan. (1)	Connected Load KW (2)	Number of Motors in Operation (3)	Rated KW (4)	Annual Operating Time (Hour) (5)	Motor Load Correction Factor (6)	Assumed Motor Efficiency % (7)	Demand Savings KW (8)	Energy Savings KWh (9)	Cost Savings rmb per year (10)	Measure Cost rmb (11)	Simple Payback years (12)
#6 Mist Machine	1	90	1	90	8000	36.1%	0.95	2.3	18,203	15,493	46,530	3.0
#6 Smoke Exhaust	1	75	1	75	8000	36.1%	0.947	1.9	15,217	12,952	38,775	3.0
#6 Heat Exhaust	1	45	1	45	8000	36.1%	0.941	1.1	9,188	7,821	23,265	3.0
#6 Quick Cooling	1	37	1	37	8000	36.1%	0.935	1.0	7,603	6,472	19,129	3.0
#6 Indirect Cooling	1	22	1	22	8000	36.1%	0.932	0.6	4,535	3,860	11,374	2.9
#6 Burner Fan	1	45	1	45	8000	36.1%	0.941	1.1	9,188	7,821	23,265	3.0
#6 Dry Cooling	1	11	1	11	8000	36.1%	0.903	0.3	2,341	1,992	5,687	2.9
#6 Dry Heat Exhaust	1	15	1	15	8000	36.1%	0.918	0.4	3,140	2,672	7,755	2.9
#6 Dry Moisture Exhaust	1	45	1	45	8000	36.1%	0.941	1.1	9,188	7,821	23,265	3.0
#5 Burner Fan	1	37	1	37	8000	36.1%	0.935	1.0	7,603	6,472	19,129	3.0
#5 Heat Exhaust	1	45	1	45	8000	36.1%	0.941	1.1	9,188	7,821	23,265	3.0
#5 Indirect Cooling	1	22	1	22	8000	36.1%	0.932	0.6	4,535	3,860	11,374	2.9
Unreadable	1	45	1	45	8000	36.1%	0.941	1.1	9,188	7,821	23,265	3.0
Unreadable	1	15	1	15	8000	36.1%	0.918	0.4	3,140	2,672	7,755	2.9
#5 Dry Moisture Exhaust	1	45	1	45	8000	36.1%	0.941	1.1	9,188	7,821	23,265	3.0

	Quan. (1)	Connected Load KW (2)	Number of Motors in Operation (3)	Rated KW (4)	Annual Operating Time (Hour) (5)	Motor Load Correction Factor (6)	Assumed Motor Efficiency % (7)	Demand Savings KW (8)	Energy Savings KWh (9)	Cost Savings rmb per year (10)	Measure Cost rmb (11)	Simple Payback years (12)
#5 Ventilation Fan	1	15	1	15	8000	36.1%	0.918	0.4	3,140	2,672	7,755	2.9
# 3 & 4 Mist Machine	1	75	1	75	8000	36.1%	0.947	1.9	15,217	12,952	38,775	3.0
#3 Smoke Exhaust	1	30	1	30	8000	36.1%	0.935	0.8	6,165	5,247	15,510	3.0
#3 Dry Moisture Exhaust	1	30	1	30	8000	36.1%	0.935	0.8	6,165	5,247	15,510	3.0
#3 Burner Fan	1	22	1	22	8000	36.1%	0.932	0.6	4,535	3,860	11,374	2.9
#3 Indirect Cooling	1	22	1	22	8000	36.1%	0.932	0.6	4,535	3,860	11,374	2.9
#3 Heat Exhaust	1	18.5	1	18.5	8000	36.1%	0.93	0.5	3,822	3,253	9,565	2.9
#3 Quick Cooling	1	15	1	15	8000	36.1%	0.918	0.4	3,140	2,672	7,755	2.9
#4 Smoke Exhaust	1	45	1	45	8000	36.1%	0.941	1.1	9,188	7,821	23,265	3.0
#4 Dry Moisture Exhaust	1	30	1	30	8000	36.1%	0.935	0.8	6,165	5,247	15,510	3.0
#4 Burner Fan	1	30	1	30	8000	36.1%	0.935	0.8	6,165	5,247	15,510	3.0
#4 Indirect Cooling	1	22	1	22	8000	36.1%	0.932	0.6	4,535	3,860	11,374	2.9
#4 Quick Cooling	1	15	1	15	8000	36.1%	0.918	0.4	3,140	2,672	7,755	2.9
#4 Heat Exhaust	1	18.5	1	18.5	8000	36.1%	0.93	0.5	3,822	3,253	9,565	2.9
Ventilation Blower	1	55	1	55	8000	36.1%	0.945	1.4	11,183	9,518	28,435	3.0
Ventilation Blower	1	45	1	45	8000	36.1%	0.941	1.1	9,188	7,821	23,265	3.0
Ball Mill	6	540	6	90	5100	36.1%	0.95	7.0	35,912	30,567	224,520	7.3
Ball Mill	6	540	6	90	5100	36.1%	0.95	7.0	35,912	30,567	224,520	7.3
Ball Mill	14	1848	14	132	5100	36.1%	0.958	23.9	121,872	103,732	523,880	5.1
Ventilation Blower	1	132	1	132	8000	36.1%	0.958	3.3	26,474	22,534	68,244	3.0
Ventilation Blower	1	90	1	90	8000	36.1%	0.95	2.3	18,203	15,493	46,530	3.0

	Quan. (1)	Connected Load KW (2)	Number of Motors in Operation (3)	Rated KW (4)	Annual Operating Time (Hour) (5)	Motor Load Correction Factor (6)	Assumed Motor Efficiency % (7)	Demand Savings KW (8)	Energy Savings KWh (9)	Cost Savings rmb per year (10)	Measure Cost rmb (11)	Simple Payback years (12)
Ventilation Blower	1	90	1	90	8000	36.1%	0.95	2.3	18,203	15,493	46,530	3.0
Totals:	**60**	**4,322**						**73.5**	**478,126**	**406,962**	**1,693,618**	**4.2**

Notes For Table 8.4:

1. Quantity of motors installed for this application.
2. Rated KW of all motors installed.
3. Number of motors operating at any one time.
4. Rated KW of each of the separate motors installed.
5. Annual run time of motors as reported by the facility.
6. Motor load correction factor adjusting load for actual plant electricity consumption.
7. Motor efficiency assuming units have been up-graded to YX-series motors.
8. Demand Savings KW = (# of motors) x (rated KW) x (Motor Load Factor) x ([(1/0.92)-(1/proposed drive efficiency)] / (motor efficiency).
   a. It is assumed that most of the motors/drives have been supplied with synchronous sprockets and belts with a drive efficiency of 98%.
   b. It is assumed that the ball mills have been supplied with cogged v-belts with a drive efficiency of 95%.
9. Annual Energy Savings KWh = (Annual hours of operation) x (Demand Savings).
10. Annual Cost Savings RMB = (Annual energy savings) x (0.85116 rmb/KWh).
11. Estimated measure cost in rmb. This assumed United States prices for drive systems. Costs in China may be significantly less.
12. Simple Payback Years = (motor replacement cost) / (Annual cost savings).