PD-AAW-181

PREFEASIBILITY STUDY OF COAL USE IN COSTA RICA

ISN = 57180

Report on Tasks 3, 4, 5 & 6

Prepared for

USAID/Washington
Contract No. LAC-5724-C-005126-000

and

Refinadora Costarricense de Petroleo (RECOPE)
Government of the Republic of Costa Rica

by

Bechtel National, Inc.
San Francisco, California, USA

March 1987

PREFEASIBILITY STUDY
OF
COAL USE
IN
COSTA RICA

COAL USE IN CEMENT PLANTS

REPORT ON TASK 3

PREPARED BY

BECHTEL NATIONAL INC.
SAN FRANCISCO

MARCH 1987

v

Table of Contents

		Page
1.0	Purpose	1
2.0	National Cement Industries	1
	2.1 Existing Plant and Operation	1
	2.2 Conversion to Coal-Firing	2
3.0	Pacific Cement	4
	3.1 Existing Plant and Operation	4
	3.2 Conversion to Coal-Firing	4
4.0	Conclusions and Recommendations	4

Drawing: No. SK-M-07

TASK NO. 3

COAL USE IN CEMENT PLANTS

1.0 Purpose

The purpose of this task is to comment on the feasibility of coal substitution for Bunker C oil in National Cement Industries at Kartago and Pacific Cement located on the West Coast of Costa Rica. The following is a summary of Bechtel comments. These comments are based on the review of the information gathered by Bechtel Engineer who visited these cement plants in April, 1986.

2.0 National Cement Industries

2.1 Existing Plant and Operation

National Cement Industries (NCI) has two cement kilns with a total clinker production capacity of 1350 tonnes per day. This capacity will be increased to 1800 tonnes per day by the end of 1986. The No. 2 kiln will be taken out of service because of excessive energy consumption. Only No. 1 kiln will be upgraded. The plant uses a dry process.

Currently, the plant uses Bunker C oil. Petroleum coke from Texas was used to substitute 55% of current fuel oil consumption. The plant also substituted local solid waste fuels up to 25% of the fuel consumption. Thus, currently the plant has the capability to use petroleum coke upto 55% or solid waste fuels upto 25%.

Average consumption of energy per kilogram of clinker is about 850 Kcal. The current clinker production rate is about 870 tonnes (about 65% of the capacity) per day. Annual consumption of Bunker C oil is about 23,000 cubic meters based on 100% oil firing.

4

2.2 Conversion to Coal-Firing

At the current level of production, about 50,000 tonnes per day of Uatsi coal with an average calorific value of 4224 Kcal/kg will be required to replace 100% of the Bunker C oil consumption. An order of magnitude cost estimate shows that about 2.5 to 3.0 million dollar investment is required to convert to 100% coal firing. There is ample room on the site for providing coal receiving, storage, reclaim, preparation and coal firing equipment. Because of the high moisture content in the coal, it appears that the plant may have to use an indirect-fired system with pneumatic transport of pulverized coal to a cyclone separator and then to the kiln. A conceptual configuration of the system required for coal handling, storage and preparation is shown on Drawing No. SK-M-07.

There is no question of the technical feasibility of converting NCI to coal use, such conversion are common around the world and this site imposes no technical obstacles. The only uncertainty is the economics, and that depends entirely upon the delivered costs of oil versus coal. Another factor that should be considered is the transportation of coal from the mine to the plant covering a distance of approximately 180-200 KM one way.

It should be noted that conversion to coal-firing will increase operating and maintenance costs of the plant because of the following:

1. Additional manpower required for coal handling.

2. Additional energy consumption for coal handling and preparation.

3. Additional power required to handle increased flue gas flows.

Further, coal-firing has the following undesirable aspects on the plant and personnel:

5

1. Increased plant dust.

2. Increased plant fire hazard.

3. Increased operators reluctance to work in a dusty environment.

Conversion to coal-firing of the cement plant is not only one of the least cost coal use alternatives but also an environmentally acceptable way of burning coal. The coal ash becomes part of cement and therefore does not present a solid waste disposal problem. The sulfur in coal is absorbed by the product and therefore becomes minimal environmental problem. Therefore, the economics of this alternative along with coal transportation possibilities should be thoroughly explored. NCI is willing to convert to coal-firing if production cost savings are significant.

Private industries generally require short pay-back periods for their investment. The investment for conversion to coal-firing will be at risk if the difference between delivered oil prices and coal prices decrease significantly because of market forces or government regulations. The government may have to provide appropriate safeguards to minimize this risk.

Table 1 below is intended to illustrate the variation of maximum prices for the delivered coal the company can pay if the Bunker C oil prices change. It assumes an investment of 2.5 million dollars with 5 year pay back period and 12% interest per year. It assumes no increase in operating and maintenance costs.

Table 1

1.	Bunker C Oil Price/litre	4 Colones	6 Colones
2.	Assumed Pay Back Period	5 years	5 years
3.	Maximum permissible coal cost $/tonne at the plant (see Note below)	$18	$35

Note: Based on 2.5 million dollar investment at the plant for coal conversion. Assumes 50,000 tonnes coal consumption per year with no increase in operating and maintenance costs due to coal-firing.

3.0 Pacific Cement

3.1 Existing Plant and Operation

Pacific Cement has one kiln with total production capacity of 1250 tonnes clinker per day. Bunker C oil consumption is about 100 tonnes per day. The current production rate is about 60% of its capacity. The plant uses dry system. It has not made any studies on conversion to coal-firing. The plant personnel stated that they can use up to 10% coal with less than 5 million colones investment. The plant has done some studies to use charcoal as fuel.

3.2 Conversion to Coal-Firing

There is no major technical barrier to use 40 to 50 thousand tonnes of coal per year. The equipment and investment required will be similar to that of NCI as described in paragraph 2.2 above.

The major problems expected are coal transportation and the overall economics of cement production. A separate study should be made to address these issues.

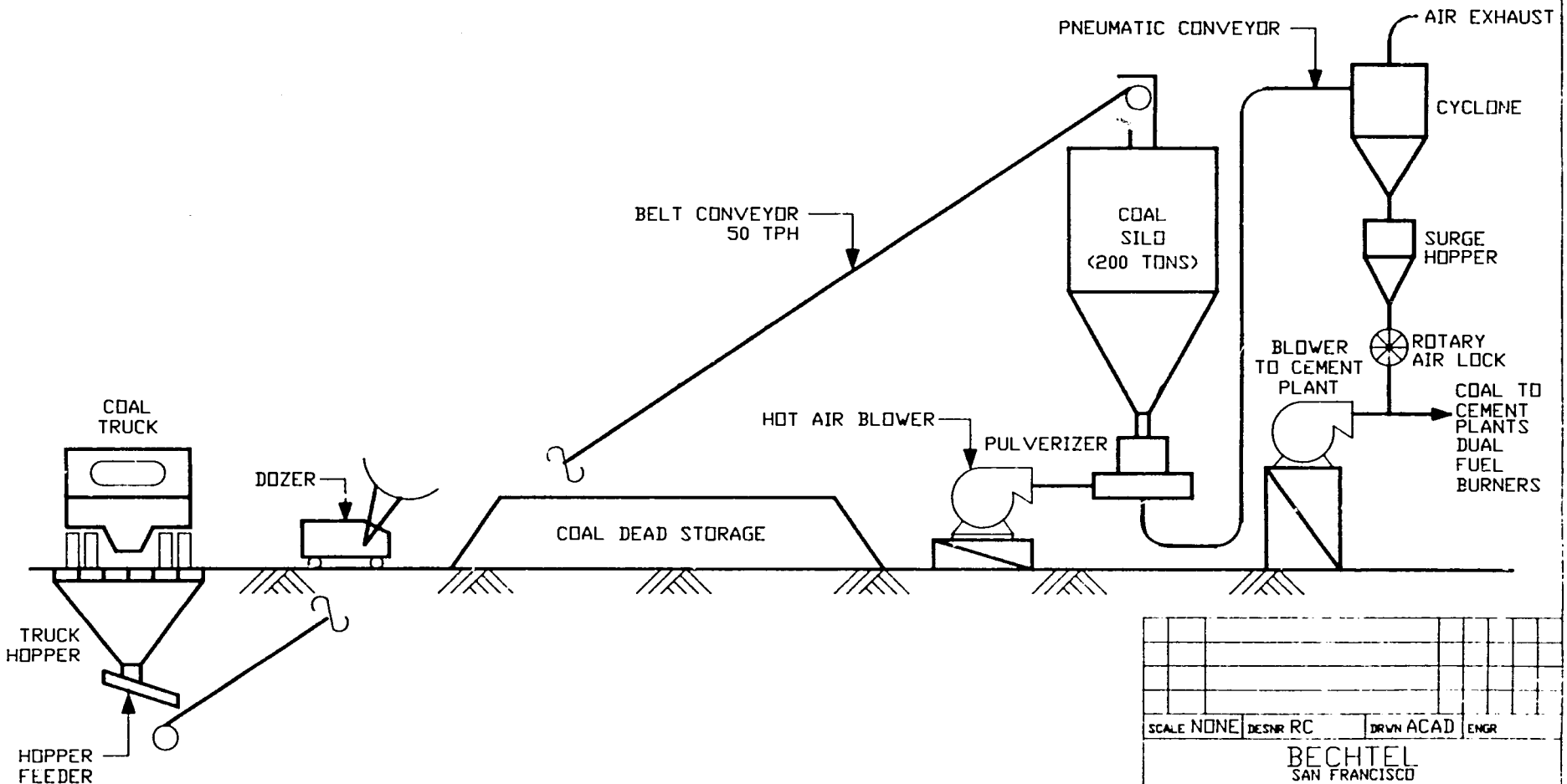
4.0 Conclusions and Recommendations

4.1 This preliminary review concludes that there is no major technical barrier to convert both the cement plants to coal-firing to replace nearly 100% of the Bunker C oil. Each plant has the potential to use about 40 to 50 thousand tonnes of Uatsi coal.

4.2 These cement plants appear to be the most attractive options for coal use in Costa Rica. Coal use in cement plants is environmentally acceptable with low hazard to human health. The capital investments required in the cement plants for coal conversion is relatively low compared to that of a coal-fired power plant using same amount of coal.

4.3 This review does not cover the economics of conversion to coal firing due to lack of data on coal prices as delivered to this plant, reliable estimates of investments required for coal conversion and the economic parameters such as debts, interest rates, operating costs, payback periods, etc. applicable to these plants.

4.4 It should be noted that the investments made for coal conversion will have to be recovered during the pay back period by differential price between oil and coal. Currently this differential appears to be low. It is clear that the cost of coal as delivered to the plant should be reduced by using better mining methods, planning more coal production to reduce fixed charges per tonne of coal and economic modes of transportation. In addition, government incentives such as subsidies, interest free or low interest loans, tax benefits etc. will be required to induce the private cement industry to use coal.



SCALE NONE	DESNR RC	DRWN ACAD	ENGR

BECHTEL
SAN FRANCISCO

CEMENT PLANTS

CONVERSION TO COAL FIRING

JOB NO.	DRAWING NO.	REV.
17958	SK-M-07	0

PREFEASIBILITY STUDY
OF
COAL USE
IN
COSTA RICA

COAL USE IN THERMAL POWER PLANTS

REPORT ON TASK 4

PREPARED BY

BECHTEL NATIONAL INC
SAN FRANCISCO

MARCH 1987

10

Table of Contents

	Page
1.0 Purpose	1
2.0 Moin Thermal Power Plant	1
2.1 Existing Plant Description	1
2.2 Conversion to Coal-Firing	1
3.0 Colima Thermal Power Plant	2
3.1 Conversion to Coal-Firing	2
4.0 Baranca Thermal Power Plant	2
4.1 Conversion to Coal-Firing	2
5.0 San Antonio Steam Power Plant	2
5.1 Existing Plant Description	2
5.2 Conversion to Coal-Firing	3
5.3 Pulverized Coal-Firing	3
5.4 Stoker Firing	5
5.5 Coal-Oil Mixture (COM) or Coal-Water Mixture (CWM) Firing	6
5.6 Coal Gasification and Coal Gas Firing	7
5.7 New Coal-Fired Boilers	9
6.0 Conclusions and Recommendations	9
Attachment A	10
Attachment B	11

TASK NO. 4

COAL USE IN THERMAL POWER PLANTS

1.0 Purpose

The purpose of this task is to comment on the feasibility of coal substitution for Bunker C oil at Moin, Colima, and San Antonio Thermal Power Stations. The following is a summary of Bechtel comments. These comments are based on the review of the information gathered by Bechtel engineer in April 1986.

2.0 Moin Thermal Power Plant

2.1 Existing Plant Description

The Moin Thermal Power Plant is about 10 years old and consists of four diesel generators, each rated at 8 MW. These generators use Bunker C oil. The plant is connected to a 138 KV double circuit transmission line which connects Kachi to Limon. The generation voltage is 13.8 KV (60 Hz). The plant is used only for emergency services for a few hours in a year.

2.2 Conversion to Coal-Firing

Coal cannot be used in diesel engines burning Bunker C oil. The possible technical approaches for coal use in a diesel engine would be to convert coal into clean fuels such as Medium Btu Gases (LBG) or liquids. These approaches are very expensive and cannot be economically justified for this plant. Bechtel recommends that conversion of Moin Thermal Power Plant to coal-firing should not be pursued further.

12

3.0 Colima Thermal Power Plant

3.1 Conversion to Coal-Firing

The Colima Thermal Plant includes diesel generators and is rated approximately 20 MW. As discussed for Moin Station coal cannot be used in the diesel generators of Colima Station. Bechtel recommends that conversion of Colima Thermal Power Plant to coal-firing should not be pursued further.

4.0 Barranca Thermal Power Plant

4.1 Converstion to Coal-Firing

The Barranca plant has gas turbine set and is rated at about 40 MW. Coal can be used in gas turbines after gasification. Coal gasification technology for power production in gas turbines is currently in the demonstration stage in the United States and is relatively expensive. Coal gasification is described in the subsequent sections of this report. Coal gasification technology for power production in gas turbines will not be economical for this plant. Therefore, Bechtel recommends not to pursue conversion of this plant to coal-firing.

5.0 San Antonio Steam Power Plant

5.1 Existing Plant Description

The plant consists of two 5 MW units. It has GE turbine-generators and CE VU-50 type oil fired boilers (see Attachment A). The plant is about 32 years old and has low efficiency (see Attachment B). The plant is operated for emergency use only because of its low efficiency.

13

5.2 Conversion to Coal-Firing.

Technically, there are four possible ways coal can be used in this plant. They are:

a. Modify the existing boilers for pulverized coal (PC) firing or Stoker firing. Provide new baghouse, ash handling and coal handling systems.

b. Modify the existing boilers for coal-oil mixture (COM) or coal-water mixture (CWM) firing. Provide baghouse, ash handling and coal handling systems and fuel-oil mixture or coal-water mixture handling systems.

c. Modify the existing boilers to fire gas from coal gasification.

d. Provide new coal-fired boilers for each of the units with baghouse, chimney, ash handling systems and coal handling systems.

5.3 Pulverized Coal-Firing

The boilers can be converted to pulverized coal-firing. However, the furnaces will require modification to accommodate hopper bottom for ash removal. In general, the capacity for pulverized coal-firing will be limited to a greater degree by actual furnace size - volume, and effective projected radiant surface area (EPRS) - and to a lesser degree by the furnace plan area.

Comparison of oil-fired units converted to pulverized coal-firing shows that the capacity obtained with pulverized coal-firing will be about 25 to 30% lower than that of oil fired units.

In general, conversion to PC firing requires the following modifications:

a. Modify the furnace bottom pressure parts to accommodate a hopper bottom for furnace ash collection and removal.

b. Provide space for a dropped (excavated) furnace bottom, ash hopper, and ash removal system.

c. Modify the windboxes to accommodate coal nozzles and ignition equipment.

d. Add pulverizers and their associated coal piping (space adjacent to the boiler will be required).

e. Add soot blowers to the furnace walls, the superheater, and the boiler bank to keep heating surfaces clean.

f. Modify the superheater to obtain the desired tube spacings.

g. Modify the air heater, as required for acceptable heating surfaces for coal firing, to prevent air heater plugging. Add a primary flow air heater if a higher coal pulverizing mill air inlet temperature is required because of coal moisture content.

h. Install new foundations, supporting steel, platforms and ductwork as required.

i. Modify the combustion and safety controls.

j. Add an ID fan for balanced draft operation.

k. Modify the furnace buckstays and add ductwork stiffeners as required for balanced draft operation.

l. Install a baghouse type of flue gas particulate removal system.

m. Modify the ductwork to the stack.

Conversion of the existing boilers to pulverized coal firing results in down rating of the boiler capacity which in turn results in the down rating of the unit capacity. In addition to the obvious complexity and expense, the extensive modifications will require each

unit to be shut down for an extensive period. Considering the foregoing, Bechtel concludes that conversion of these existing boiler to pulverized coal-firing should not be further considered.

5.4 Stoker Firing

The furnace bottom of the boiler can be modified so that the difference in elevation between the lower side wall headers and any lower drum supports does not present a differential expansion problem with Stoker firing.

Comparison between oil-fired units and the oil-fired units converted to spreader stoker coal firing indicates that the capacity will be reduced by as much as 30 to 35%.

In general, conversion to Stoker or grate firing requires the following modifications:

a. Modify the furnace bottom pressure parts to accommodate a spreader stoker and an overfire air system.

b. Provide space for a dropped furnace bottom, ash hopper, and ash removal system.

c. Add superheater surface to maintain design steam temperature.

d. Add additional soot blowers to keep convection surfaces clean.

e. Add hoppers for gas pass fly ash collection and reinjection to minimize carbon loss.

f. Modify the air heater to limit air temperature to the grate, and install an economizer to regain the heat recovery lost by the air heater modification.

g. Install a gas pass dust collector ahead of the air heater to prevent air heater plugging.

h. Install new foundations, supporting steel, platforms and ductwork as required.

i. Modify the combustion and safety controls.

j. Add an ID fan for balanced draft operation.

k. Modify the furnace buckstays and add ductwork stiffeners as required for balanced draft operation.

l. Install a baghouse type of flue gas particulate removal system.

m. Modify ductwork to stack.

5.5 Coal-Oil Mixture (COM) or Coal-Water Mixture (CWM) Firing

COM, a 50 percent (weight) mixture of pulverized coal in oil, behaves similarly to oil in its handling and storage characteristics. COM has been extensively studied and tested as a boiler fuel particularly in the U.S.A. and Japan. However, to Bechtel's knowledge, no permanent conversion of a utility boiler from oil to COM fuel has been made. COM firing technology is relatively old compared to CWM firing technology.

CWM is a concentrated mixture of 65 to 75 percent pulverized coal (by weight) suspended in 35 to 25 percent water with about one percent chemical additives to control flow properties and improve storage ability. Over the last several years CWM has been produced as a test product, and fired in ever larger quantities. However, we are not aware of any permanent conversion of a utility boiler from oil to CWM.

The principal reasons for not converting utility boilers from oil to COM or CWM are:

17

a. A large investment is needed for the coal and ash handling systems and for many of the same boiler modifications needed for 100 percent pulverized coal firing, as described in the foregoing.

b. Firing COM containing 50 percent coal or CWM containing 65 to 75 percent coal can cause furnace slagging problems as serious as those encountered when firing 100 percent coal. The results, ultimately, is a significant derating of boiler capacity.

In early 1982 Bechtel and a large boiler manufacturer completed a comprehensive study for the U.S. Electric Power Research Institute (EPRI) on the effects of converting various utility boiler types from oil to COM ("Coil-Oil Mixture as a Utility Boiler Fuel, Volume 1: Conversion Guidelines Handbook," EPRI CS-2309, March 1982). Depending on the specific boiler design, the predicted deratings ranged from 20 percent to 58 percent. All of the boilers considered were large enough (e.g., 600 MW) to obtain economies of scale with respect to the $/kW cost of conversion. However, the overall economic analysis in the EPRI study indicated that the economic advantage of conversion to COM was "marginal, at best..."

Recently Bechtel and a large boiler manufacturer completed a study for EPRI on the effects of firing CWM in boilers designed for oil firing. The results of these studies show that the boiler derating of 25 to 50 percent is required depending on the type of coal used.

Considering the age of the units, investment required for the modifications, Bechtel has concluded that these alternatives should not be further considered.

5.6 Coal Gasification and Coal Gas Firing

Coal gasification involves the production of a clean-burning gaseous fuel from coal. It is accomplished by partial oxidation of solid coal using either air or oxygen as the oxidant. If air is used as the oxidant, the high concentration of inert nitrogen in air will

18

severely dilute the heating value of the gaseous fuel produced, yielding a low-Btu gas (LBG) with a heating value typically on the order of 890 Kcal/m^3 [100 Btu per standard cubic foot]. Using oxygen as an oxidant will yield a medium-Btu gas (MBG) with a typical heating value of 2670 Kcal/m^3 [300 Btu/SCF]. By comparison, the heating value of natural gas is 950 to 1000 Btu/SCF.

The most important aspect of possible firing of LBG or MBG in the existing oil-fired San Antonio boilers is the increase in fuel weight (and volume) which must be admitted to the furnace and the resultant increase in total combustion products which will flow over the heat absorbing surfaces. This change in total combustion gas flow will increase gas velocities and shift heat absorption patterns within the components of the steam generating unit.

In 1975 EPRI reported a study by Combustion Engineering, Inc. ("Retrofit of Gasified Coal Fuels to Steam Generators," EPRI 265-1, December 1975) which examined the effects of firing LBG and MBG in various existing boiler designs. The smallest boiler size considered was 250 MW. It was concluded that with only minor modifications to windboxes and firing system equipment, the resulting derating in oil-fired boiler capacity when using MBG would be zero and for LBG would be 50 percent. It was estimated that with further and more major boiler modification the derating for LBG could be reduced to 40 percent. Use of LBG in an existing boiler thus introduces the same capacity loss problem encountered with COM or CWM, and use of MBG would seem to be the preferred route. Production of MBG, however, requires additional capital and operating costs for an air separation plant to provide oxygen to the coal gasification process.

Both LBG and MBG production will require coal receiving, storage, preparation facilities, ash handling systems, and particulate emission control systems, in addition to the gasifiers and auxiliaries associated with the gasifiers. The total system costs for coal gasification, including boiler modification, could be about the same as for construction of a new coal-fired boiler to supply steam to the existing turbine/generator, and overall efficiency would

be less. This is the primary reason that, to Bechtel's knowledge, no permanent conversion of an existing oil-fired utility boiler to a coal gasification fuel has been made anywhere in the world. With this observation Bechtel has concluded that this alternative should not be considered.

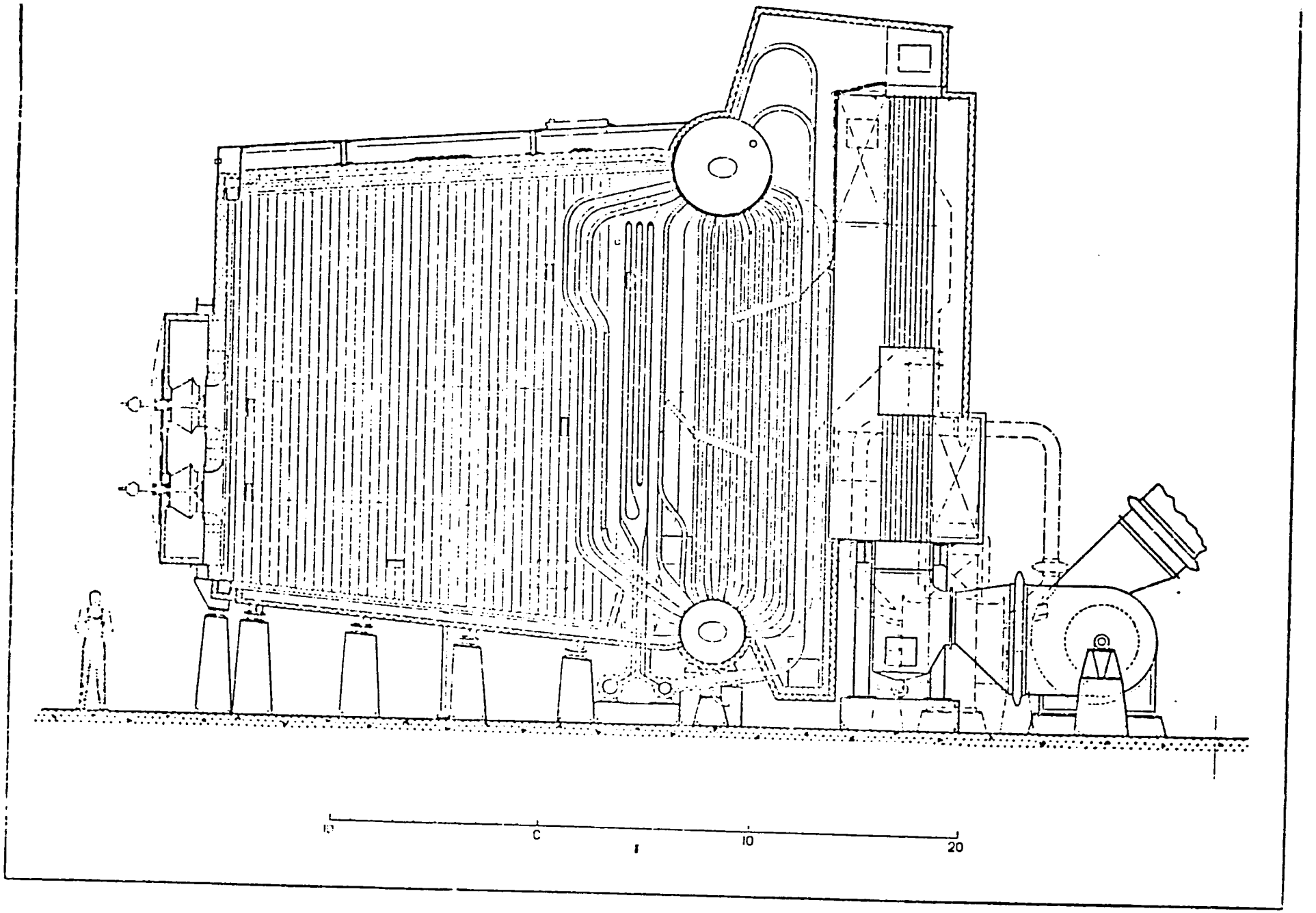
5.7 New Coal Fired Boilers

New Stoker fired or pulverized coal-fired boilers can be used in place of the existing boilers without affecting the capacity of the existing units. The new installation will include baghouses, ash handling systems, coal handling systems and new stacks.

Considering the age, capital investment and efficiency of the plant, Bechtel has concluded that the alternative should not be further considered.

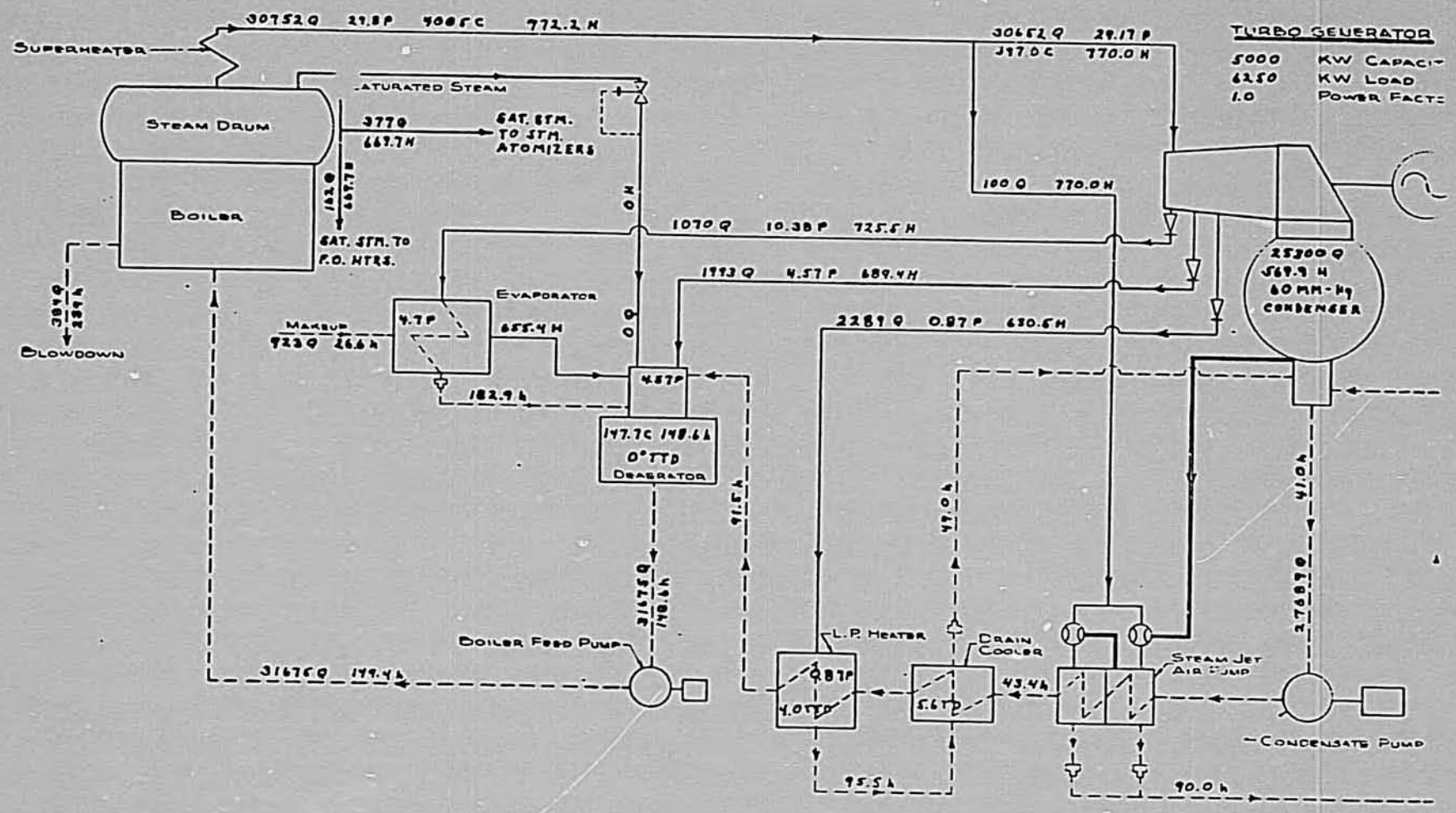
6.0 Conclusions and Recommendations

Conversion to coal-firing is considered for Moin, Colima, Barranca, and San Antonio Power Plants. It is concluded that these power plants should not be converted to coal-firing because of the technical and economical reasons such as poor plant performance, high cost of conversion, low remaining useful life, etc. It is recommended to discontinue all studies on converting these Thermal Power Plants to coal-firing.



ATTACHMENT A

ATTACHMENT B



PERFORMANCE

GENERATION	TO AUXILIARIES	NET OUTPUT
6250 KW	280 KW	5970 KW

BOILER EFFICIENCY	KG. CAL. PER KW HR. NET OUTPUT
85%	3842
83%	3934

LEGEND

SYMBOL	TERM	UNITS
Q	FLOW	KG/HR.
P	PRESSURE	KG/SQ.CM. ABS
C	TEMPERATURE	DEGREES CENTIGRADE
H	ENTHALPY OF STEAM	KG. CAL./KG
h	ENTHALPY OF LIQUID	KG. CAL./KG

——— STEAM
– – – – WATER
——— AIR

CIA NATIONAL DE FUERZA Y LUZ
SAN ANTONIO S.E. STATION
1953-2-5000 KW INSTALLATIONS
HEAT BALANCE - SHEET NO. 1

EBASCO INTERNATIONAL CORPORATION

22

PREFEASIBILITY STUDY
OF
COAL USE
IN
COSTA RICA

LIST OF POSSIBLE COAL USES

REPORT ON TASK 5

PREPARED BY

BECHTEL NATIONAL INC.
SAN FRANCISCO

MARCH 1987

23

Table of Contents

		Page
1.0	Purpose	1
2.0	Coal Uses	1
2.1	Steam and Electricity Generation	3
2.2	Steam and Hot Water Generation	4
2.3	Furnaces, Kilns and Ovens	4
2.4	Coal-Derived Gases and Liquids	6
2.5	Conclusions	7
	Attachment 1	8
	Attachment 2	9

TASK NO. 5

LIST OF POSSIBLE COAL USES

1.0 Purpose

The purpose of this task is to prepare a list of uses for coal in general. The following sections discuss the use of coal for various purposes.

2.0 Coal Uses

Coal can be substituted directly for oil in many instances. The major opportunity for such substitution is generally found in the energy-intensive industries which use bulk heat or heat and power. For example, coal can be substituted for oil in cement industry where ash and sulfur become part of cement resulting in minimum environmental problems. Similarly coal can be burned in the wood burning boilers of paper mills. It can be used in the steam generating boilers of aluminum, textile, chemical, food industries, etc.

While the most obvious way of displacing oil with coal is to use coal directly for bulk heat applications, it is possible to displace more specialized uses of oil through end use substitution in the form of electricity or gas. If natural gas is highly priced or limited in supply, coal can be converted to Substitute Natural Gas (SNG) or Medium or Low calorie gas on site The gas burns clean with controlled flame. If economics can justify coal can be subjected to liquefaction to produce, gasoline, diesel or methanol.

Attachment 1 shows U.S. coal consumption by End-Use Sectors during 1950 - 1995. Attachment 2 shows coal consumption at Manufacturing Plants during 1980 - 1984.

Table 1 shows the possible methods of coal use in the following areas:

25

TABLE 1

POSSIBLE USES FOR COAL

AREAS OF FUEL USE	METHODS OF FUEL USE			
	Coal/Coke	Coal-Oil/Water Mixtures	Coal-Derived Gases	Coal-Derived Liquids
A. Steam and Electricity	Utility Boilers	Utility Boilers	Gas Turbine and Boilers	
B. Steam and Hot Water	Industrial Boilers	Industrial Boilers		
C. Furnaces, Kilns and Ovens				
1. Iron and Steel	Coke Oven/ Blast Furnace	Blast Furnace		
2. Cement	Kilns	Kilns		
3. Brick and Tiles	Kilns/Ovens	Kilns/Ovens		
4. Glass, Pottery, and Ceramics	Ovens	Ovens		
5. Food and Other Industries	Ovens	Ovens		
6. Briquettes	Industrial & Home Ovens	Industrial & Home Ovens		
D. Chemical Feed Stock				
1. Coal-Derived Gases			Low/Med/Hi Btu gases	
2. Coal-Derived Liquids				Gasoline/ Diesel/ Methanol

a. Steam and electricity
b. Steam and hot water
c. Furnaces, kilns and ovens
d. Coal-derived gases and liquids.

The following sections briefly discuss these uses and point out some of the major constraints to the use of coal:

2.1 Steam and Electricity Generation

Most of the World's coal is used for steam and electricity generation. The electric utilities are the major consumers for coal in the United States. See Attachment 1.

Electric Utilities purchase about two-thirds of the coal on the basis of long term contracts and about one-third in the spot markets. They receive coal in bulk quantities, store it, prepare it and burn it in large steam generators to raise high pressure steam for driving turbine-generators. These utilities are required to meet the stringent environmental regulations applicable to coal burning facilities in U.S.A.

With the increasing fuel oil costs, coal-oil mixtures (COM) have been prepared successfully for burning in the existing oil fired boilers. However, COM is still in the development phase. COM is a liquid product consisting of up to 50% of ground coal blended with fuel oil. Boilers, designed for fuel oil burning, will require about 20-30% derating while burning COM. With decreasing oil prices use of COM is very much limited in the utility industry.

COM firing technology is relatively old compared to coal-water mixture (CWM) firing technology. CWM firing is still in development phase. CWM is a concentrated mixture of 65 to 75 percent pulverized coal (by weight) suspended in 35 to 25 percent water with about one percent chemical additives to improve storage and flow properties. Use of CWM in boilers, designed for oil firing, requires significant derating.

27

Demonstration plants have been built to gasify coal. The low/medium calorie gases obtained from these gasifiers can be used in gas turbines to generate electricity and process steam. Because of the high cost of production, coal gasification has not gone beyond the demonstration stage for power production.

2.2 Steam and Hot Water Generation

Many industries such as food industries need steam for drying or heating. These industries generally have steam or hot water boilers. In addition they may also generate some electric power. Coal can be used in these type of industries. However, existing industries using oil will be required to make substantial investment to convert from oil to coal.

Instead of coal, coal-oil mixtures or coal-water mixtures can be used if economically attractive, in the existing oil fired boilers. However, these boilers will require significant derating.

2.3 Furnaces, Kilns and Ovens

Furnaces, kilns and ovens cover a wide range of industries, each with its own technical requirements. The special feature of coal use in furnaces, kilns and ovens is that heat is transferred directly to the product. Therefore, cleanliness and controllability are big factors in certain processes and may out weigh fuel cost considerations. For example, sulfur may have a deleterious effect on lime or glass. Furnaces, kilns and ovens cover the following industries.

a. Iron and Steel
b. Cement
c. Bricks and Tiles
d. Glass, Pottery, and Ceramics
e. Food and Other Industries

One of the major uses of coal is in the iron and steel industry. Energy is required for reduction of iron ore and various finishing

processes. Coal is converted to coke in coke ovens and the resulting coke is used in the blast furnaces to produce steel.

Items b, c, and d above use high temperature (above 600°C) for direct heating. Cement industry uses rotary furnaces or kilns for direct heating. Large number of cement kilns in USA and U.K. use coal as fuel. Converting oil fired kilns to coal firing is relatively cheap involving only change of burner and provisions for coal storage, handling and preparation systems. The coal ash becomes part of the product as does the sulfur. Thus the ash handling and environmental problems are minimized. Costa Rica has two large cement plants. These two plants can use a total of about 100,000 tons of coal per year.

Direct use of coal in firing bricks and tiles is practicable. In the United Kingdom, coal provides substantial energy for brick making.

Direct firing of coal in glass, pottery and ceramics manufacture is not generally suitable due to the effect of sulfur and ash. However, pulverized coal is used for dolomite firing in rotary kilns.

Low temperature heating (below 600C) is used for drying in food and textile industries. Coal's ability to substitute for these uses is less clear. Direct heating of food and textiles by coal combustion may not be acceptable due to likelihood of contamination. In such cases indirect heating may be required. Indirect heating will require significant modifications to the existing heating/drying systems.

Coal can be converted to briquettes and can be used for domestic cooking and heating. This can displace use of kerosene, diesel oil or natural gas. Briquettes can be used in industrial ovens.

In each case, the economics of the alternatives for fuel uses should be studied carefully.

2.4 Coal-Derived Gases and Liquids

Coal can be used locally to produce coal-derived gases or liquid fuels produced in large central plants. It should be noted that these alternatives have high cost of production and are rarely used. Coal gasificiation is generally done locally because gas transportation is expensive. On the other hand coal-derived liquids are manufactured in large central plants to obtain economy of scale. Coal-derived gases can be classified as follows:

a. Substitute Natural Gas (SNG). The Gas consists mostly of methane and has about 35-38 MJ/m^3 calorific value. It can be directly substituted for natural gas.

b. Medium Calorific Value Gas (MCG). The gas is called medium Btu gas or Synthesis gas and has a calorific value of 9-13 MJ/m^3. It consists of carbon monoxide and hydrogen. It can be used directly for heating or it can be converted to SNG, hydrogen or liquid fuels and chemicals. The gas can also be used for the manufacture of ammonia and methanol.

c. Low Calorific Value Gas (LCG). This is also known as low Btu gas, producer gas or fuel gas. It contains carbon monoxide and hydrogen but is diluted with nitrogen. The calorific value is about 2.5-7 MJ/m^3. This is mainly used for local consumption.

Coal can be used in the production of liquid fuels. However, this route is very expensive. There are two fundamentally different approaches to the production of liquid fuels from coal.

a. Synthesis Method: In this method coal structure is completely destroyed by reaction with steam and oxygen to produce a mixture of carbon monoxide and hydrogen. Under controlled conditions in the presence of a catalyst, the gas mixture is converted to gasoline, diesel oil or methanol.

b. Hydrogenation Method: Involves a breakdown of the coal structure using heat and hydrogen. These processes are complex and can produce gasoline, diesel oil, benzene, toluene, and xylene for use in chemical industry.

It should be noted that coal uses in the above industries are subject to many constraints. The following critical elements should be examined:

a. A large amount of investment is generally committed in existing oil and gas-fired boilers, kilns and furnaces. The capital required to convert these existing facilities to use coal is substantial. Therefore, the need to achieve greater energy independence or security in the long term and the wide price difference between coal and oil are the essential elements for coal conversion.

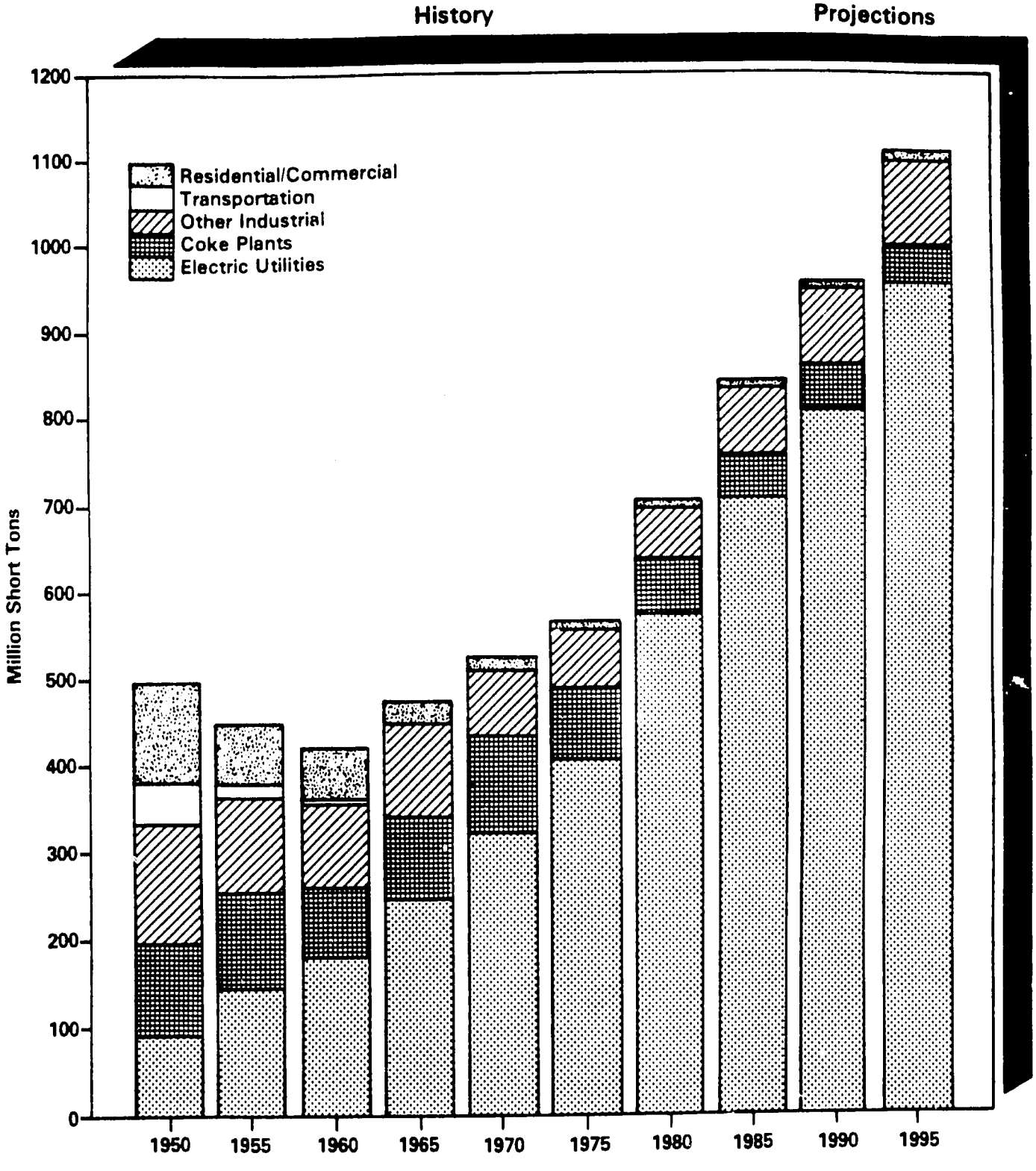
b. A decision to convert from oil to coal depends on balance between substantial capital expenditure and fuel costs and operating costs.

c. The government regulations have crucial effect on the financial decisions of the industry. This may involve use of government subsidies, tax concessions, and low interest loans to encourage conversion. It may also involve impact of environmental and planning restrictions.

2.5 Conclusions

Coal is mainly used by the Utilities for electricity and steam generation. Smaller industries use coal for power production, steam production, and hot water production. Coal is used in steel plants in coke ovens and blast furnaces. Coal is also used for bulk heat generation in kilns and ovens. Coal derived gases can be used in gas turbines and boilers. Coal derived liquids are used in chemical industries.

U.S. Coal Consumption by End-Use Sector, 1950-1995
(Million Short Tons)



Sources ● 1950-1983: Energy Information Administration, *Annual Energy Review 1984* (1985) ● 1984: Energy Information Administration, *Quarterly Coal Report* (April 1985) ● 1985-1995: Energy Information Administration, *Annual Energy Outlook 1984* (1985)

Coal Consumption at Manufacturing Plants by Standard Industrial Classification (SIC) Code, 1980-1984

(Thousand Short Tons)

SIC Code	Year				
	1980	1981	1982	1983	1984
20 Food and Kindred Products	4,179	4,677	4,845	4,692	5,084
21 Tobacco Products	340	360	368	347	365
22 Textile Mill Products	1,629	2,264	2,129	1,633	1,719
23 Apparel, Other Textile Products	W	W	W	W	W
24 Lumber and Wood Products	475	461	404	144	144
25 Furniture and Fixtures	335	394	295	84	83
26 Paper and Allied Products	8,699	8,880	9,009	9,823	11,058
27 Printing and Publishing	W	W	W	W	W
28 Chemicals, Allied Products	13,237	14,412	14,250	14,318	15,798
29 Petroleum and Coal Products	100	137	267	291	2,213
30 Rubber, Misc. Plastic Products	556	529	575	575	624
31 Leather, Leather Products	78	54	33	28	36
32 Stone, Clay, Glass Products	12,178	12,952	11,393	12,234	14,847
33 Primary Metal Industries[2]	5,844	7,392	7,865	7,071	7,930
34 Fabricated Metal Products	354	397	414	439	516
35 Machinery, Except Electric	782	750	708	617	685
36 Electric, Electronic Equipment	326	318	360	485	457
37 Transportation Equipment	2,548	2,551	1,995	1,956	2,034
38 Instruments, Related Products	W	W	W	W	W
39 Misc. Manufacturing Industries	W	W	W	W	W
U.S. Total	**52,470**	**57,356**	**55,781**	**55,845**	**64,706**

[1] Preliminary

[2] Excludes coke plants

W Withheld to avoid disclosure of individual company data

Note: Totals may not equal sum of components due to independent rounding

Source: ● 1980 U.S. Department of Energy, Energy Information Administration, Form EIA-3, "Quarterly Coal Consumption Report - Manufacturing Plants" ● 1981-1984 Energy Information Administration, *Quarterly Coal Report*, DOE/EIA-0121(82/4Q), (83/4Q), and (84/4Q)

ATTACHMENT 2

PREFEASIBILITY STUDY
OF
COAL USE
IN
COSTA RICA

COMPARATIVE FUEL COSTS

REPORT ON TASK 6

PREPARED BY

BECHTEL NATIONAL INC.
SAN FRANCISCO

MARCH 1987

Table of Contents

	Page
1.0 Purpose	1
2.0 Fuel Cost Variations	1
2.1 Electric Utility Insdustry Data Base	2
2.2 Comparative Fuel Costs per Million Btu	3
3.0 Conclusion	5
Attachment 1	6
Attachment 2	7

TASK 6

COMPARATIVE FUEL COSTS

1.0 Purpose

The purpose of Task 6 is to develop comparative fuel costs per million Btu for coal, Bunker C Oil (No. 6 Fuel Oil), Diesel Oil (No. 2 Fuel Oil), Biomass and cost of hydroelectric power per million Btu. These costs area discussed in the following sections.

2.0 Fuel Cost Variations

Fuel costs as delivered to end-users vary significantly with fuel quality, transportation, type of contract, market segment, etc. For example, Table 1 below shows the variations of costs of fuels (coal, residual fuel oil, distillate fuel oil and electricity) as delivered to electric utility, industrial, transportation and residential and commercial sectors in the United States for the period 1980 to 1982.

Table 1

Delivered Costs of Fuels and Electricity to End-User Sectors 1980-1982*

Sectors	Fuel Cost-Dollars per Million Btu (Excluding Taxes)											
	Coal			Residual Fuel Oil			Distillate Fuel Oil			Electricity		
	1980	1981	1982	1980	1981	1982	1980	1981	1982	1980	1981	1982
A. Electric Utility	1.32	1.53	1.65	4.25	5.32	4.85	5.80	7.05	6.68	--	--	--
B. Industrial	1.81	1.98	2.03	3.71	4.50	4.36	5.63	6.64	6.41	10.81	12.46	14.42
C. Transport	--	--	--	3.18	4.11	3.85	7.12	8.46	8.14	12.12	13.32	15.28
D. Residential and Commercial	2.72	3.33	3.33	4.44	5.48	4.87	7.04	8.72	8.53	15.73	18.18	19.93

*Source: Annual Energy Review 1984, Energy Information Administration.

Most of the coal produced in the United States is consumed by the Electric Utilities. Coal use by residential and commercial, transportation and industrial sectors is relatively small. See Attachment 1.

2.1 Electric Utility Industry Data Base

This report is based on the data available for the Electric Utility industry in the United States. The main source of cost information for this report is the Energy Information Administration's report "Cost and Quality of Fuels for Electric Utility Plants 1985."

Electric Utilities have long-term contracts for coal. They also purchase from spot market. Approximately two-thirds of the coal supply is based on long term contracts and one-third is from the spot market. Table 2 shows contract, spot and average costs of coal at Electric Utilities from 1981 to 1985.

Table 2

Contract and Spot Coal Costs at Electric Utilities
(Steam Plants 50 MW or Larger 1981 - 1985)

	Cost in US Dollars Per Tonne of Coal				
Year	1981	1982	1983	1984	1985
Type of Purchases					
Contract	34.55	38.16	38.80	38.64	38.16
Spot	42.75	41.43	36.74	39.11	37.17
Average	35.62	38.47	38.56	38.70	38.05

Costs vary with the quality of coal. Table 3 below shows average costs of various types of coal and fuel oils at the Electric Utilities during 1985:

Table 3

Average Cost of Fuels by Quality at Electric Utilities
(Steam Plants 50 MW or Larger)
1985

Fuel Type	U.S. $/Tonne	Cents/10^6 Btu
Bituminous	45.52	173.3
Subbituminous	30.70	156.7
Lignite	13.96	99.0
Anthracite	15.94	86.1
Wyoming Subbituminous (Sulfur 1% or less)	32.20	169.3
Illinois Bituminous (Sulfur 3% or more)	38.64	163.5

	U.S. $/Barrel	Cents/10^6 Btu
No. 2 Fuel Oil	33.64	578.2
No. 6 Fuel Oil	26.71	424.1

2.2 Comparative Fuel Costs per Million Btu

Table 4 below shows comparative fuel costs (excluding taxes) per million Btu at the U.S. Electric Utility steam plants of 50 MW or larger capacity. The general quality and the available analyses of the fuels used for developing fuel costs in Table 4 are shown on Attachment 2.

Table 4 includes average U.S. coal, high sulfur U.S. coal, low sulfur U.S. coal and Colombian low sulfur coal. The average U.S. coal represents the average of all coals received at the U.S. Electric Utility Steam Station with more than 50MW capacity. It has an approximate average calorific value of 5860 Kcal/kg (10,550 Btu/lb). The high sulfur U.S. coal is assumed to be Illinois bituminous coal with a calorific value of 5610 Kcal/kg (10,100 Btu/lb) with more than 3% sulfur. The low sulfur U.S. coal is assumed to be Wyoming subbituminous coal with a calorific value of 4456 Kcal/kg (8020 Btu/lb) with less than 1% sulfur.

Table 4

Comparative Fuel Costs Per Million BTU

(excluding Taxes)

	Cost in U.S. Cents*								Colones
Year	Diesel Oil	Bunker C Oil	Average U.S. Coal	U.S. High Sulfur Coal	U.S. Low Sulfur Coal	Colombian Coal	Biomass	Electricity U.S.	Electricity Costa Rica
1980	580.1	348.7	135.1				180.0	1081	132
1981	705.7	448.7	153.2				124.0	1257	191
1982	668.1	407.3	164.7	150.1	164.8		143.0	1450	316
1983	585.8	407.3	165.6	154.9	167.9			1453	586
1984	583.7	439.3	166.4					1477	
1985	559.6	389.3	164.8	163.5	169.3			1515	
1986-J	553.9	352.7	159.5				169.0	1512	
-F	436.2	284.7	161.1					1500	
-M	363.1	238.0	161.7					1500	1026***
-A	344.0	200.7	163.6					1494	
-M	329.1	178.7	162.3					1480	
-J	297.9	178.7	159.2					1471	
Average*	387.4	238.9	161.2					1493	
1987	350	200	158	157	162		165	1490	
(Predicted)	to	to	to	to	to	140.2	to	to	1026***
	450	300	160	159	164		170	1525	

*Average of 6 months, 1986

**As delivered to U.S. Steam Electric Utility Plants

***Based on 3.5 calones/KWH obtained from National Cement Factory in April 1986

The price per tonne of Colombian low sulfur coal is obtained by telephone from Exxon Coal USA Inc., partners of Carbocol of the Cerrajon coal mine in Colombia. The cost of Colombian coal is based on the delivery at U.S. harbor and is assumed to be the same as for delivery at Limon. The cost is $34/tonne including $4/tonne shipping charges. The coal has a calorific value of 6111 Kcal/kg (11,000 Btu/lb). The cost per million Btu is 140.2 U.S. cents.

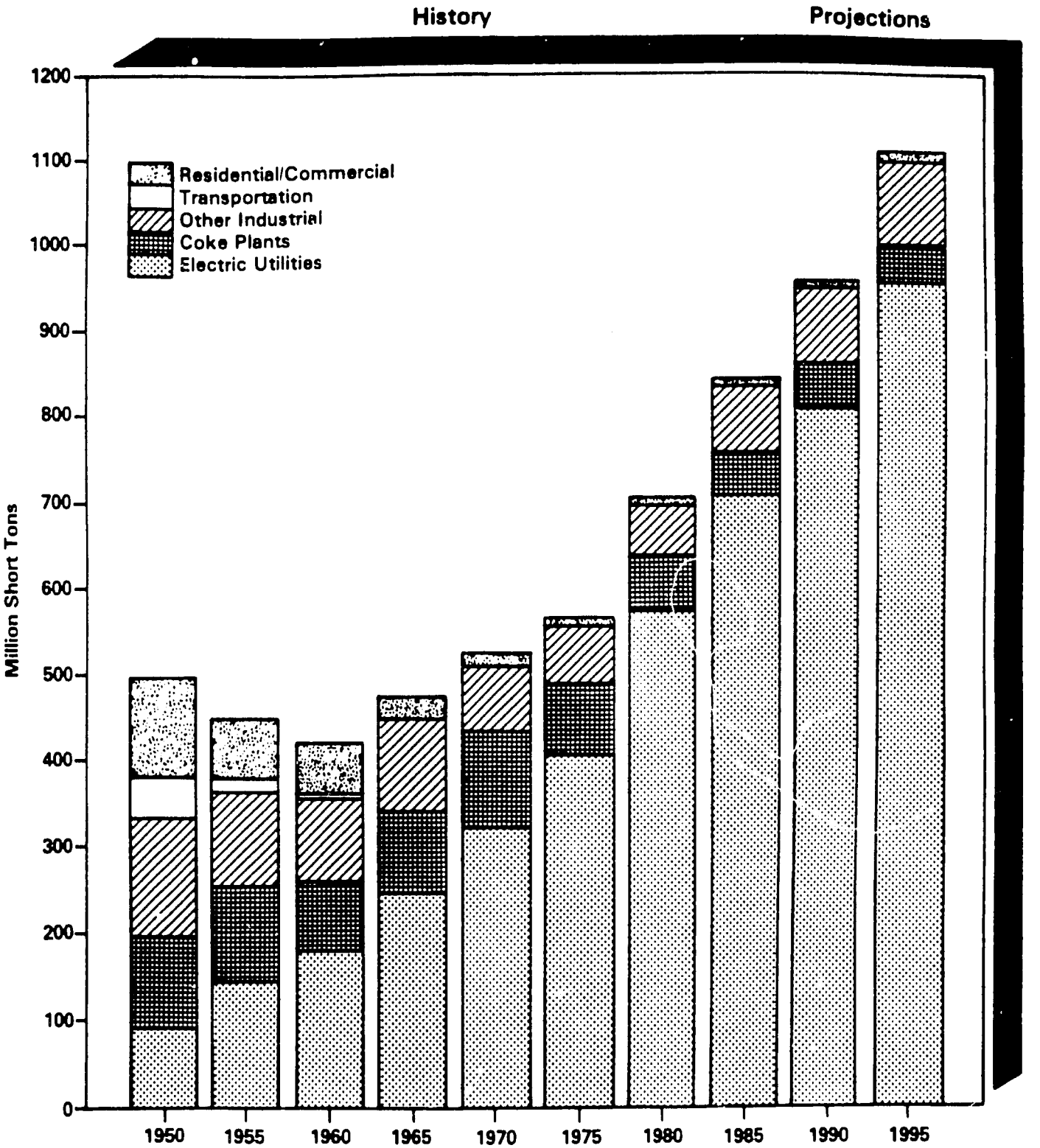
The cost of biomass fuel for 1980 - 1982 is based on published data in U.S. However, the cost of 169 cents/million Btu is based on a recent Bechtel biomass project.

Cost of electricity is given both for U.S. and Costa Rica. The cost of electricity is at user-end point and includes cost of generation, transmission, and distribution. The costs of electricity in calones for Costa Rica from 1980 - 1983 are based on the information furnished to Bechtel by Instituto Costarricense de Electricidad (ICE). Cost information is not available to Bechtel from ICE for the period after 1983. The cost of electricity is estimated to be 1026 calones in March 1986 based on 3.5 calones/KWH as indicated by Costa Rican Cement Factory. This needs to be verified with ICE.

3.0 Conclusion

The fuel costs vary with quality, types of contracts, transportation methods, market segments, etc. Fuel costs as delivered at the U.S. Electric Utility Steam Plants of 50 MW or greater capacity are assembled for a period from 1980 through mid 1986. These costs are listed in Table 4. The predicted range of fuel costs for 1987 are based on these data.

U.S. Coal Consumption by End-Use Sector, 1950-1995
(Million Short Tons)



Sources ● 1950-1983 Energy Information Administration. *Annual Energy Review 1984* (1985) ● 1984 Energy Information Administration *Quarterly Coal Report* (April 1985) ● 1985-1995 Energy Information Administration *Annual Energy Outlook 1984* (1985)

Attachment 2

Fuel Analysis

Fuels

Constituents	Diesel Oil	Bunker C Oil	Uatsi Coal	Colombian Coal	High Sulfur Illinois Bit. Coal	Low Sulfur Wyoming Subbit. Coal	Biomass (Wood)
A. Proximate Analysis %							
1. Moisture			26.85	N/A	12.00	30.40	
2. Ash			12.53	N/A	16.00	6.40	
3. Volatiles			27.83	N/A	33.00	31.10	
4. Fixed Carbon			32.79	N/A	39.00	32.10	
			100.00		100.00	100.00	
B. Ultimate Analysis %							
1. Moisture	Trace	2.0 (max)	26.85	N/A	12.00	30.40	46.85
2. Ash	Trace	0.08	9.21	10.0	16.00	6.40	0.80
3. Volatiles	86.40	87.70	31.90	N/A	57.60	47.87	27.3
4. Fixed Carbon	12.70	10.50	3.23	N/A	3.70	3.40	3.20
5. Sulfur	0.4-0.7	2.8 (max)	0.64	0.7	4.00	0.48	---
6. Oxygen	0.2	.92	27.66	N/A	5.80	10.83	21.80
7. Nitrogen			0.51	N/A	0.90	0.62	0.05
			100.00		100.00	100.00	100.00
C. Specific Gravity	0.8654	0.9861	---	---	---	---	---
D. Higher Heating Value							
BTU/LB			7657	11,000	10,100	8020	4700
BTU/GALLON	141,000	150,000					