



NASA TM-79213

DOE/NASA/1062-79/2
NASA TM-79213

NASA-TM-79213 19790019494

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AUG 6 1979

Work performed for
U.S. DEPARTMENT OF ENERGY
Energy Technology
Fossil Fuel Utilization Division

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HAMPTON, VIRGINIA



NF00512

Prepared for
Terrestrial Energy System Conference
Orlando, Florida, June 4-6, 1979

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ENERGY AND COST SAVINGS RESULTS FOR ADVANCED
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SUMMARY

This paper presents an overview of the organization and methodology and a summary of selected results to date of the Cogeneration Technology Alternatives Study (CTAS). The CTAS is being performed by NASA for the Division of Fossil Fuel Utilization of the Department of Energy (DOE). The effort is being carried out via study contracts with industry supported by NASA in-house analyses at the Lewis Research Center and the Jet Propulsion Laboratory. The objectives of the study are to identify the most attractive advanced energy conversion systems for industrial co-generation applications in the 1985-2000 time period and to assess the advantages of advanced technology systems compared to those systems commercially available today. Advanced systems being studied include steam turbines, open and closed cycle gas turbines, combined cycles, diesel engines, Stirling engines, phosphoric acid and molten carbonate fuel cells and thermionics. Steam turbines, open cycle gas turbines, combined cycles, and diesel engines are also being analyzed in versions typical of today's commercially available technology to provide a base against which to measure the advanced systems. Cogeneration applications in the major energy consuming manufacturing industries are being considered. Results of the study in terms of plant level energy savings, annual energy cost savings and economic attractiveness are presented for the various energy conversion systems considered. Sensitivity of the results to variations in assumed study groundrules such as fuel prices and the price of purchased electricity and the potential effect of regional characteristics are discussed.

BACKGROUND AND INTRODUCTION

Cogeneration can be broadly defined as the generation of electricity or shaft power by an energy conversion system and the concurrent use of the rejected thermal energy from the conversion system which might otherwise be wasted. The cogeneration concept offers the potential for significant energy conservation through improved overall energy

efficiency. In recent years, cogeneration has seen relatively limited use in the United States. However, in the light of diminishing oil reserves and rising fuel and electricity prices, the application of cogeneration concepts may have the potential for significant national benefits in the future, especially if coal or alternative fuels can be utilized.

The Department of Energy (DOE) is responsible for the advancement of cogeneration technology using energy conversion systems with both today's commercially available technology and advanced technology. In line with the latter responsibility, the DOE Division of Fossil Fuel Utilization is sponsoring a study called the Cogeneration Technology Alternatives Study (CTAS). The CTAS is being performed for DOE by NASA using two parallel contracts with industry, supported by in-house analysis at two NASA centers, the Lewis Research Center (LeRC) and the Jet Propulsion Laboratory (JPL). The organization of the study is shown in figure 1. LeRC is responsible for the management of the overall effort, management of the two industrial contracts, providing in-house analysis of the energy conversion systems and evaluation of the results. JPL support to LeRC in CTAS includes providing an independent source of information on industrial process plant characteristics and requirements, industrial economics, and providing regional data and assisting in the interpretation of regional influences which might impact the relative attractiveness of the various energy conversion systems. The majority of the data in CTAS are being obtained through two independent parallel study contracts with industry. The contracted studies are being performed by two teams led by the General Electric Company and the United Technologies Corporation. The major participants on the two teams are shown in table 1. The use of two parallel contractor studies enables the government to obtain two independent sets of results with the opportunity for differing design approaches and philosophies and to get the benefit of different viewpoints as to the technology advancements which could be achieved and made commercially available by the 1985-2000 time period. NASA will compare and evaluate the results from the two contracted studies and where differences exist the reasons for the differences will be identified and reconciled. The combined results of the total CTAS effort will then be examined by NASA to assess the relative attractiveness of the various advanced energy conversion systems for application to industrial cogeneration.

The NASA CTAS efforts began in October 1977. The two contracts were awarded in March of 1978 and the technical efforts under those contracts will have been completed by the time this paper is published. The total CTAS effort will be completed in 1979. This paper provides an overview of the study scope and methodology and a summary of the preliminary results available at the time of its writing in terms of potential fuel energy savings and annual energy cost savings, along with an indication of the economic attractive-

ness of the advanced energy conversion systems in industrial cogeneration applications. The sensitivity of study results to the basic study assumptions and ground rules is also addressed and examples of ways in which regional characteristics might affect the relative attractiveness of various systems are discussed.

CTAS OBJECTIVES AND SCOPE

The primary objectives of the CATS effort are to:

- (1) Identify and evaluate the most attractive advanced energy conversion systems for implementation in industrial cogeneration systems for the 1985-2000 time period which permit the increased use of coal or coal-derived fuels.
- (2) Quantify and assess the advantages of using advanced technology conversion systems in industrial cogeneration as compared to today's commercially available technology.

As indicated by the above objectives, the focus of CTAS is on the comparison of advanced energy conversion systems in industrial cogeneration applications. Residential and commercial cogeneration or total energy systems, while under the responsibility of DOE, are not included in CTAS. Additionally, while a limited number of state-of-the-art conversion systems are being carried along in CTAS for purposes of comparison, the optimization of industrial cogeneration systems using currently available conversion system technology was not within the scope of CTAS. The above efforts are being covered in other studies under DOE sponsorship.

The advanced energy conversion systems which are included in the CTAS are listed in table 2. Each of the systems listed is being considered in one or more versions representing the technology levels which the contractors feel could be made commercially available in the 1985-2000 time period. The specific technology advances being considered will not be detailed here. The steam turbines, gas turbines, combined cycles and diesel engines are also being examined at conditions representing today's commercially available technology in order that the benefits of advancements in technology can be assessed.

The fuels being considered in the study are shown in table 3. Emphasis of the study is on the use of high sulfur coal and coal-derived fuels, with petroleum derived residual oil (characteristics similar to a heavy no. 5 boiler grade fuel) also being considered as a step toward the use of the heavy coal-derived liquid fuels. In general, when distillate grade liquid fuel (similar to no. 2 diesel fuel) was used in an advanced energy conversion system, coal-derived distillate was assumed. Except for the advanced low temperature fuel cell analyzed by UTC, the use of petroleum-based distillate fuel was limited to

state-of-the-art systems. Natural gas and high BTU gas from coal were originally included among the fuels for consideration in the study. However, none of the system designs selected burn either natural gas or HBTU gas from coal. The low BTU gas from coal was obtained through integrated on-site gasification.

The various energy conversion systems are being examined for application in industrial plants belonging to the manufacturing sector of U.S. industry. Emphasis is on representative plants selected from the six major industry groups listed in table 4. These six major industry groups accounted for approximately 80 percent of the energy consumption in the U.S. manufacturing industries in 1974. The specific plants included in the study were selected from a variety of subclassifications within the groups listed and have a wide range of thermal and electrical requirements. The sizes, electrical and thermal requirements and other factors for the representative plants have been projected to the 1985-2000 time period by the CTAS contractors. In the projections, consideration was given to the reduction in energy demand which could result from conservation measures which are likely to be implemented by that time.

While the benefits of cogeneration itself are of much interest, the purpose of CTAS is to provide a comparative evaluation of the various advanced energy conversion systems rather than to determine the merits of cogeneration. To that end, this study has concentrated on the technical and economic aspects of the advanced cogeneration systems rather than institutional, regulatory and policy type barriers which may confront widespread application of industrial cogeneration.

METHODOLOGY

A schematic representation of a typical industrial process plant operating in a non-cogeneration mode is shown in figure 2. The electrical needs of the plant are fulfilled by purchasing electricity from a utility and process heat requirements are satisfied by an on-site furnace. The results presented in this paper have been generated assuming that the utility fuel is coal. However, a utility fuel mix consistent with projections for utility base-load power generation in the 1985-2000 time period will be incorporated into estimates of fuel savings by type on a national basis in the final results of the study.

The non-cogeneration case shown in figure 2 serves as the base point for the calculation of energy savings, cost savings, emissions savings and measures of economic attractiveness for cogeneration systems using both current technology and advanced technology energy conversion systems. The fuel assumed for the on-site furnace in the non-cogeneration case can have a dramatic impact on the results obtained. This is an area where the two CTAS contractors made different assumptions. UTC assumed that a residual

grade liquid fuel (either petroleum or coal-derived) was used to fire the non-cogeneration furnace. GE's basic assumption was that coal would be used where feasible, based on the size of the plant. GE also calculated results assuming the residual grade liquid fuel was used in the non-cogeneration furnace. Preliminary results showing the effect of this difference in assumptions will be presented later in this paper.

Two basic cogeneration options are being considered in CTAS, topping and bottoming. These options are illustrated in figure 3. In the topping application, fuel is input to the energy conversion system which generates electricity. Waste heat from the conversion system is used to provide heat to the process. In the bottoming application fuel is burned to provide the high temperature process heat required and the waste heat from the process is used as thermal input to the energy conversion system which generates electricity. Emphasis in CTAS is on the topping application and results will be presented in this paper for that option only.

Two basic strategies for matching conversion systems with industrial process requirements have been considered for the topping cycle configuration. In the first, called the "Match E" or match electric strategy, the energy conversion system is sized to meet the electrical requirement of the process plant. If the heat output from the conversion system is insufficient to fulfill the process heat requirement, a supplementary furnace is used to make up the deficit. In the second basic strategy, the "Match Q" or match heat strategy, the conversion system is sized to meet the heat needs of the process plant. In this strategy electricity is purchased from a utility if the on-site system does not provide enough electricity to meet the plant needs or electricity is sold to the utility if the on-site system generates excess electricity.

In addition to the two basic strategies described above, UTC examined a third strategy for matching cogeneration systems with industrial plants. This strategy maximizes the energy savings for cases where two or more process heat streams are provided to a plant.

The block diagram in figure 4 illustrates the methodology being employed in CTAS. The first step consists of collecting data on the industry process requirements and screening that data to ensure that the plants selected cover a wide range in the parameters important to the study (e. g., ratio of electrical power to process heat, plant size, form and temperature of process heat required, etc.). Concurrently, the values of energy conversion system parameters appropriate for each system in the time period under consideration are selected and screened for their applicability to cogeneration. The conversion system capabilities are then matched with the process requirements according to the strategies discussed earlier. Auxiliary equipment such as fuel and

waste handling equipment, auxiliary furnace, where necessary, and other balance of plant equipment is added to form complete cogeneration systems. Those cases which are obvious mismatches of conversion system capability and process requirement are screened out. Capital costs, fuel consumption by type (both on-site and at the electric utility), fuel costs, operation and maintenance costs, costs for purchased electricity, and revenues received from the sale of electricity to the grid where applicable are then determined for the non-cogeneration and cogeneration cases on a plant basis. From this data, fuel energy savings, annual energy cost savings and emissions savings are calculated for the cogeneration system as compared to the non-cogeneration base case. In CTAS each contractor has considered approximately 3000 cogeneration system cases through this point of the study. Based primarily on energy savings and energy cost savings, the number of cases was reduced to 120 to 150 per contractor at this point. These selected cases were then analyzed in greater detail in an economic comparison based on parameters such as rate of return on investment (ROI) and payback period. This paper will summarize selected results through this point of the study.

The next task in the study consists of aggregating the results obtained on a plant basis to an industry-wide and then a nation-wide basis in order to estimate maximum potential national benefits in terms of energy, costs and emissions savings. The final task is to fulfill the primary objectives of the study by comparing and evaluating the quantitative results obtained in earlier tasks and factoring in qualitative factors which might affect the attractiveness of one system relative to another. The results for the advanced systems are then compared with the results for the cases with today's commercially available energy conversion systems to determine the benefits, if any, of advanced technology.

DISCUSSION OF PRELIMINARY RESULTS

As indicated earlier, at the writing of this paper, the CTAS contracted studies were not yet complete and final results were not available. However, some preliminary results in the form of fuel energy savings and annual energy cost savings will be discussed here. The values for the savings in both energy and energy costs are plant level savings, in per cent, when a cogeneration case is compared to the non-cogeneration case. The calculation of fuel energy savings takes into account the combined utility and on-site fuel energy necessary to satisfy the plant electrical and thermal requirements. The energy costs are calculated on a levelized basis and include on-site capital costs, on-site fuel costs, on-site operation and maintenance costs and cost of purchased electricity where required. Revenues from electricity sold to the grid are also accounted for, where applicable.

Figure 5 summarizes the contractors' results for fuel energy and energy cost savings. The results indicate significant energy and energy cost savings from the use of advanced technology. The differences between GE and UTC results can be attributed to a variety of causes, including differences in analytical procedures, differences in assumptions made in the treatment of the various systems and process plants, the system configurations studied and design choices made and differences in the estimates of the capital costs of the equipment. NASA is currently engaged in identifying the probable contributors to these differences and examining their significance. It is expected that the indicated differences may be reduced when the results are put on a comparable basis by the NASA evaluation. One of the major causes contributing to the differences in the envelopes in figure 5 is the GE basic assumption for the non-cogeneration case to burn coal in the on-site industrial furnace whenever feasible, while on-site furnaces in the UTC non-cogeneration cases always burned a residual grade liquid fuel. (Both contractors assumed that the utility fuel displaced was coal as indicated in fig. 2.) As mentioned earlier, GE also ran all of their cases for a liquid-fired non-cogeneration furnace. The GE results for the two different non-cogeneration fuel assumptions are compared in figure 6. Note that while the level of energy savings did not change significantly, energy cost savings increased markedly when the base case assumption was changed to liquid-fired furnaces. The increase in energy cost savings is directly due to the higher cost of fuel in the non-cogeneration case. Obviously, the fuel assumed for the non-cogeneration case will also have a major effect on the estimates of potential national oil savings.

Tables 5 and 6 present some specific selected cogeneration results calculated by the two CTAS contractors for advanced energy conversion systems burning solid coal and coal-derived residual grade liquid fuel, respectively. Two sets of cases are shown, those with the highest fuel energy savings and those with the greatest levelized annual energy cost savings. In many cases several processes are shown because they are all near the top of the typical range shown for the parameter which served as the basis for the selection. For several of the energy conversion systems the highest energy savings and the maximum energy cost savings were achieved for the same process so the same process appears in both columns. The column after the process names show the value of the non-selecting parameter and the estimated return on investment (ROI). The ROI is the after-tax discounted rate of return on the difference between the capital investment required for the cogeneration system and the capital investment required for the non-cogeneration system. This parameter gives an indication of the economic attractiveness of such an investment to the industrial user. The ROI values shown are inflation-free and as such are considered conservative.

The data shown in tables 5 and 6 for both contractors are based on residual liquid-fired non-cogeneration systems so as to offer comparable results. In general, the GE results based on a coal-fired non-cogeneration system exhibit similar energy savings but lower cost savings, as indicated earlier in the discussion of figure 6. In tables 5 and 6 the coal-fired and liquid-fired advanced cogeneration systems show comparable fuel energy savings results ranging, in general, from 15 to 40 percent. The range of levelized annual energy cost savings is, in general, higher for the coal-fired systems than for the liquid-fired systems, due primarily to the difference in fuel prices. The greater annual cost savings of the coal-fired systems is counterbalanced by the smaller capital investment typically required for the liquid fired systems. When the different advanced systems are considered in their best applications, the result is that liquid-fueled and coal-fueled systems yield similar ranges of return on the incremental investment required for cogeneration.

The results displayed in tables 5 and 6 indicate that cogeneration with advanced energy conversion systems offers a potential for significant overall fuel energy savings, compared to non-cogeneration, for the nation and reduced annual energy costs and attractive returns on investment for industrial users in a wide range of industrial processes. Emissions savings were also calculated for the cogeneration systems compared to the non-cogeneration case, however, they are not shown here. Large emissions savings (in many cases over 50 percent) are possible when area-wide (utility plus process plant) emissions are considered. Except for the advanced fuel cell systems, total on-site emissions are generally increased when the advanced cogeneration systems are compared to the non-cogeneration on-site boiler due to the increase in fuel consumed on site.

The results discussed above illustrate the potential energy and cost savings for cogeneration using advanced technology conversion systems when compared to non-cogeneration. These results provide some information which can be used in making comparisons among advanced technology conversion systems. Relatively attractive energy and cost savings compared to non-cogeneration have also been estimated for the current technology cogeneration systems included in CTAS. A detailed comparison of the merits of advanced technology vs. current technology has not yet been completed.

Fuel energy savings, energy cost savings and economic attractiveness, for which quantitative results have been shown, are just three of a number of criteria which are being included in the CTAS comparison of advanced energy conversion systems for industrial cogeneration applications. These criteria are listed in table 7 along with several other important factors which are also being considered. All of these factors will impact the final assessment of the relative attractiveness of the various systems.

SENSITIVITY OF RESULTS TO STUDY ASSUMPTIONS

In CTAS, ground rules were established by NASA in cooperation with DOE in order to assure that the contractors results could be compared on a common basis and that differences which occurred would not be caused by differences in the basic study assumptions used in each contractor effort. Table 8 identifies the areas where common ground rules were established for the study.

One area which can have a significant effect on the results and where considerable uncertainty exists is the area of future prices for fuel and electricity. The values for fuel prices and electricity prices selected as base values for the study are shown in tables 9 and 10, respectively. These values are based on projections for the 1985-2000 time period which were developed by the Energy Information Administration and which were provided to NASA by DOE for use in the study. The coal-derived liquid fuels prices were assumed to be equal to the petroleum fuel prices of the same grade.

In order to illustrate the sensitivity of the economic results to changes in the basic fuel and electricity price assumptions, two examples which have been analyzed by NASA will be considered. In each case a sample industry was selected for which ROI had been calculated by the contractors for a number of advanced energy conversion systems based on the baseline fuel and electricity price assumptions given in tables 9 and 10. The examples shown are based on a residual oil-fired non-cogeneration case. The match electric strategy is assumed, therefore, no electricity is imported or exported in the cogeneration case. For the first case, shown in figure 7, the price of liquid fuel is increased up to 50 percent while the prices of coal and electricity are held constant. As the liquid fuel price is increased the liquid-fired cogeneration systems become less attractive economically because more liquid fuel is burned on-site in the cogeneration case than in the non-cogeneration case. At the same time the coal-fired systems show increased returns on investment as the liquid fuel price is raised because of the increasing difference between the price of coal and residual oil. Therefore, as the ratio of liquid fuel price to coal price is varied, we note that the relative economic attractiveness of the liquid-fired and coal-fired systems is affected greatly.

A second example of the sensitivity of result to study assumptions is shown in figure 8. In this case the fuel prices were all held constant and the purchase price of electricity was varied. Note that as the electricity price is increased the returns on investment of all cogeneration systems, both liquid-fired and coal-fired, improved. While the slope of the lines differ somewhat, the relative economics of the systems do not change significantly.

The two examples discussed briefly above illustrate the type of sensitivity analysis being performed in CTAS. The sensitivity of the study results to many of the basic study ground rules and assumptions are being analyzed and will be reported with the final results.

POTENTIAL EFFECTS OF REGIONAL CHARACTERISTICS

In the previous section on sensitivities, a variation of one fuel price relative to another was shown to have a significant impact on the relative comparison of advanced systems. The fuel prices provided by DOE for use in the basic CTAS analysis were representative prices based on projected national averages. However, the relative prices of oil and coal, for example, vary throughout the United States as indicated in figure 9. The cross-hatched areas in the figure indicate those areas where the ratio of residual oil price to coal price differs by greater than 10 percent from that used as a baseline in CTAS. Many U.S. industries are concentrated in particular locations in the country for various reasons such as the availability of raw materials, the price of power, convenience of transportation, etc. The regions where the paper and pulp industry is concentrated in the U.S. are overlaid on the map of fuel price variations in figure 10. Note that in general the areas where this industry is concentrated have fuel price ratios similar to CTAS. However, in the far northeast and in the South Atlantic States, the ratio of residual oil price to coal price is lower than that used in CTAS and, hence, in those areas the energy cost savings results for the liquid-fueled systems would look somewhat better relative to the coal-fueled systems than the estimates made using the baseline fuel prices.

The Jet Propulsion Laboratory (JPL) has gathered regional concentration data on over 20 of the industries considered in CTAS. They have also gathered regional characteristics on environmental regulations and a number of other factors which could affect the comparison of the advanced systems. NASA (JPL and LeRC) will examine the results from the CTAS contractors in the light of these regional characteristics in order to assess the impact of regional factors on the attractiveness of the various advanced energy conversion systems for industrial cogeneration applications.

CONCLUDING REMARKS

The CTAS effort is aimed at providing data which will assist DOE in establishing R&D funding priorities for advanced energy conversion system technology for industrial cogeneration. It is a broad study focusing on the technical and economic issues important to comparisons of the various advanced technology systems being examined.

Based on early outputs from the study, advanced technology energy conversion systems appear to offer favorable economics and significant energy savings and energy cost savings advantages compared to the use of today's commercially available technology. The sensitivity of study results to the basic ground rules and assumptions used in CTAS and the potential effects of regional characteristics on the relative comparisons are being analyzed.

TABLE 1
CTAS CONTRACTOR TEAMS

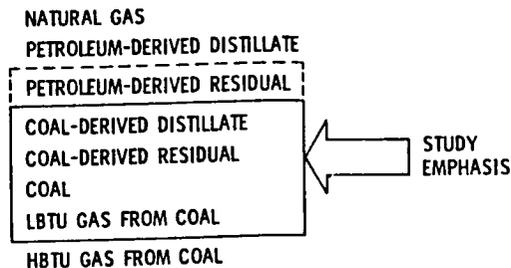
	GENERAL ELECTRIC	UNITED TECHNOLOGIES
PROGRAM MANAGEMENT	G. E. - ENERGY TECH OPERATIONS	UTC - POWER SYSTEMS DIV
ENERGY CONVERSION SYSTEMS	G. E. INTERNAL DIVS DELAVAL, INC INST OF GAS TECH NORTH AMERICAN PHILLIPS CORP	UTC INTERNAL DIVS AEROJET ENERGY CONVERSION CO BECHTEL, INC CUMMINS ENGINE CO, INC DELAVAL, INC DR PHILLIP MYERS, CONSULTANT MECH TECH, INC RASOR ASSOC SULZER BROS., INC WESTINGHOUSE ELEC CORP
INDUSTRIAL PROCESSES	G. E. INTERNAL DIVS DOW CHEM CO GENERAL ENERGY ASSOC KAISER ENGINEERS, INC J. E. SIRRINE	GORDIAN ASSOC

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TABLE 2
ADVANCED TECHNOLOGY CONVERSION
SYSTEM CANDIDATES

STEAM TURBINE
OPEN CYCLE GAS TURBINE
COMBINED GAS TURBINE/STEAM TURBINE CYCLES
CLOSED CYCLE GAS TURBINE
DIESEL ENGINE
STIRLING ENGINE
PHOSPHORIC ACID FUEL CELL
MOLTEN CARBONATE FUEL CELL
THERMIONICS

TABLE 3
CTAS FUELS



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TABLE 4
CANDIDATE INDUSTRY GROUPS

~80% OF US INDUSTRIAL ENERGY CONSUMPTION	}	CHEMICALS & ALLIED PRODUCTS
		PRIMARY METALS INDUSTRIES
		PETROLEUM REFINING
		PAPER & ALLIED PRODUCTS
		STONE, CLAY, & GLASS PRODUCTS
		FOOD & KINDRED PRODUCTS
		OTHERS

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TABLE 5
PRELIMINARY REPRESENTATIVE CTAS RESULTS FOR COAL FIRED ADVANCED SYSTEMS

ADVANCED SYSTEMS	CONTR	FUEL ENERGY SAVINGS, (FES), %				LEVELIZED COST SAVINGS, (LECS), %			
		TYP RANGE	INDUSTRIES WITH HIGHEST FESR'S	LECS, %	ROI, %	TYP RANGE	INDUSTRIES WITH HIGHEST LECS'S	FES, %	ROI, %
STEAM-AFB	GE	14-28	CORN MILLING (EX)	43	38	32-43	CORN MILLING (EX) UNBLEACHED KRAFT CHEMICAL PLANT (EX)	28 22 20	38 57 52
STEAM-PFB	UTC GE	22 22-29	CORRUGATED PAPER CORN MILLING (33)(EX)	29 40	24 23	29 34-42	CORRUGATED PAPER CORN MILLING (EX) UNBLEACHED KRAFT (EX) WRITING PAPER (EX)	22 33 29 29	24 23 33 33
GT-GASIFIER	UTC	21, 33	WRITING PAPER	37	19	27, 37	WRITING PAPER	33	19
GT-AFB	UTC	35-44	WRITING PAPER	38	18	34-38	WRITING PAPER BOX BOARD	44 39	18 19
GT-PFB	UTC	30, 34	NEWSPRINT	37	18	31, 37	PETROLEUM	30	17
CLOSED GT-AFB	GE UTC	7-15 16-38	CHLORINE WRITING PAPER BOX BOARD	7 35 39	7 18 23	7-23 19-39	CHEMICAL PLANT BOX BOARD	11 36	15 23
STIRLING-FGD	GE	12-25	PARTICLE BOARD CARBON BLACK	20 15	13 12	4-20	PARTICLE BOARD	25	13
-AFB	UTC	17-21	MEAT PACKING	15	10	15-30	CORRUGATED PAPER	17	23
MOLTEN CARB, FC-	GE	34	CHEMICAL PLANT (EX)	33	16	33	CHEMICAL PLANT (EX)	34	16
GASIFIER	UTC	38	NEWSPRINT	30	13	30	NEWSPRINT	38	13
THERMIONICS-FGD	GE	14-16	CHEMICAL PLANT	4	6	3-4	CHEMICAL PLANT	16	6

(EX) INDICATES CASE WHICH EXPORTS ELECTRICITY

TABLE 6
PRELIMINARY REPRESENTATIVE CTAS RESULTS FOR ADVANCED SYSTEMS USING
COAL-DERIVED LIQUID FUELS

ADVANCED SYSTEM	CONTR	FUEL ENERGY SAVINGS, (FES), %				LEVELIZED ENERGY COST SAVINGS, (LECS), %			
		TYP RANGE	INDUSTRIES WITH HIGHEST FESR'S	LECS, %	ROI, %	TYP RANGE	INDUSTRIES WITH HIGHEST LECS'S	FES, %	ROI, %
GT-RESIDUAL	GE	19-31	NEWSPRINT	20	23	15-27	COPPER	30	19
	UTC	26-38	STYRENE BUTADIENE MALT BEVERAGES (EX) CHLORINE	18 12 26	18 14 41	12-27	PVC CHLORINE	37 35	37 41
COMB CYCLE-RESID	GE	17-35	PVC COPPER NEWSPRINT (EX)	27 18 22	37 17 22	10-24	STEEL NEWSPRINT (EX) CHLORINE	33 35 31	28 22 30
	UTC	31-39	CHLORINE	27	30	7-27	CHLORINE	39	30
DIESEL, MS-RESID	GE	23-29	NYLON	6	8	3-6	NYLON	29	8
	UTC	29-32	NEWSPRINT	10	10	5-10	NEWSPRINT	32	10
LS-RESID	UTC	22-30	TEXTILE MILL	3	--	0-3	TEXTILE MILL	41	--
	GE	12-35	CHLORINE	NEG	--	NEG	-----	--	--
MOLTEN CARB FC-DISTILLATE	UTC	26-41	CHLORINE	15	17	3-15	CHLORINE	41	17
	GE	13-29	STYRENE BUTADIENE	NEG	--	NEG	-----	--	--
PHOS. ACID FC-DISTILLATE	GE	15-40	WRITING PAPER (EX) BOX BOARD (EX)	6 4	9 10	2-6	WRITING PAPER (EX)	40	9
	UTC	15-40	WRITING PAPER (EX) BOX BOARD (EX)	4 4	10 10	2-6	WRITING PAPER (EX)	40	9
THERMIONICS-RESID	GE	15-18	UNBLEACHED KRAFT	NEG	1	NEG	-----	--	--
	UTC	10-25	CORRUGATED PAPER	8	10	0-8	CORRUGATED PAPER	25	10

(EX) INDICATES CASE WHICH EXPORTS ELECTRICITY

TABLE 7
MAJOR FACTORS FOR COMPARISON OF
ADVANCED ENERGY CONVERSION SYSTEMS

- POTENTIAL FOR OIL & GAS SAVINGS
- POTENTIAL FOR INCREASED OVERALL ENERGY EFFICIENCY
- POTENTIAL FOR ANNUAL ENERGY COST SAVINGS
- ENVIRONMENTAL CHARACTERISTICS
- ECONOMIC ATTRACTIVENESS TO INDUSTRIAL USERS
- ABILITY TO ACCOMMODATE A TRANSITION FROM PRESENT FUELS TO HEAVY OILS, COAL, & COAL-DERIVED FUELS
- FUEL FLEXIBILITY

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TABLE 8
AREAS WHERE GROUND RULES HAVE
BEEN SPECIFIED BY NASA

FUEL CHARACTERISTICS
 UTILITY CHARACTERISTICS
 FUEL & ELECTRICITY PRICES
 EMISSION GUIDELINES
 CAPITAL COSTING APPROACH & ECONOMIC METHODOLOGY
 OTHER

CS-79-940

TABLE 9
FUEL PRICES**
BASED ON DOE INPUT

FUEL	1985 BASE YR PRICE (1978 \$/MMBTU)	ESCALATION OF PRICE ABOVE INFLATION (%/YR)
DISTILLATE OIL*	3.80	1.0
RESIDUAL OIL*	3.10	1.0
COAL	1.80	1.0
NATURAL GAS	2.40	4.6 (1985-2000) 1.0 (>2000)

*PRICES FOR PETROLEUM & COAL-DERIVED LIQUID FUELS OF
 SIMILAR GRADES ARE ASSUMED TO BE THE SAME.
 **SENSITIVITY OF RESULTS TO FUEL PRICES WILL BE EXAMINED.

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TABLE 10
ELECTRICITY PRICES

PURCHASE PRICE FOR UTILITY ELECTRICITY IN 1985 IS 3.3¢/kWhr.*

ELECTRICITY PURCHASE PRICE ESCALATES AT 1% ABOVE INFLATION.*

PRICE RECEIVED BY COGENERATOR FOR ELECTRICITY EXPORTED TO THE
 GRID IS 60% OF THE PURCHASE PRICE DEFINED ABOVE.

SENSITIVITY OF RESULTS TO THE PRICE OF BOTH PURCHASED &
 EXPORTED ELECTRICITY WILL BE EXAMINED.

*BASED ON DOE INPUT.

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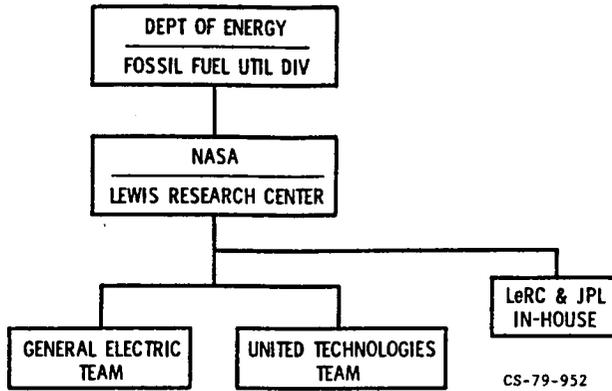


Figure 1. - CTAS organization.

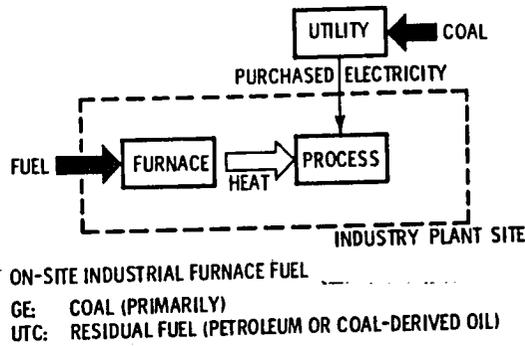


Figure 2. - CTAS noncogeneration case.

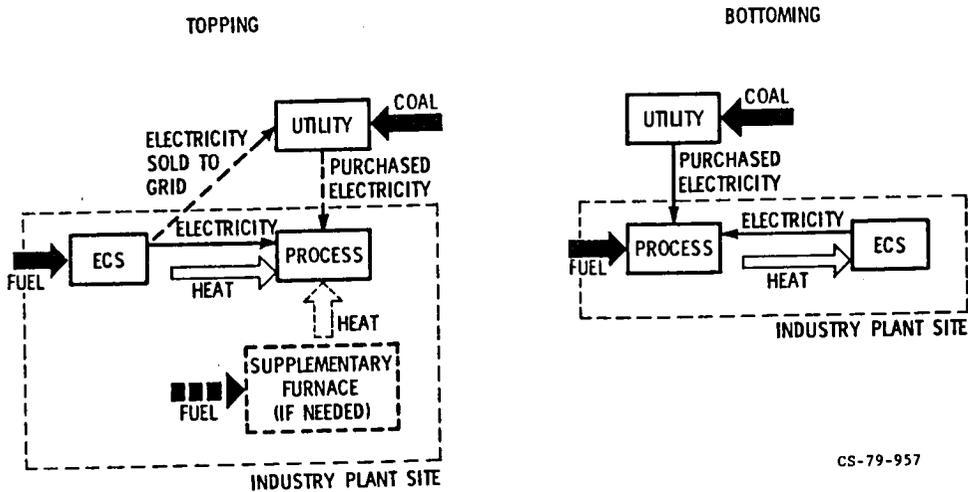


Figure 3. - CTAS cogeneration options.

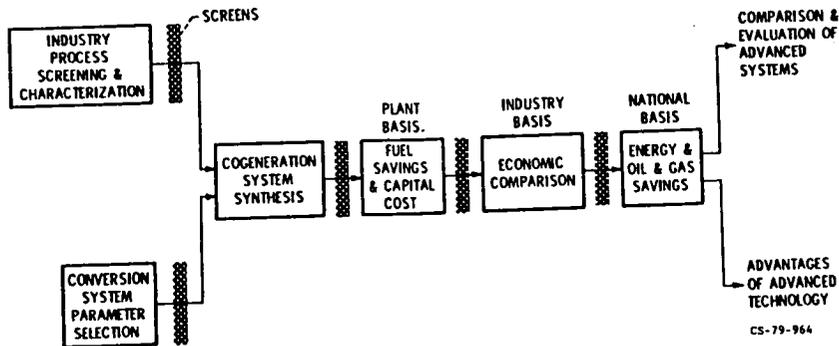


Figure 4. - Illustration of CTAS methodology.

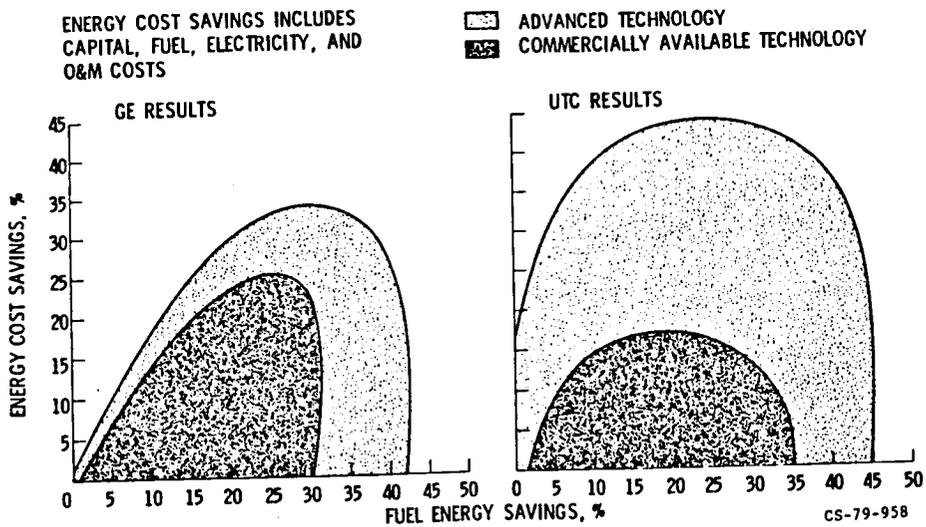


Figure 5. - Preliminary comparison of CTAS contractor results. Envelopes of attractive cases.

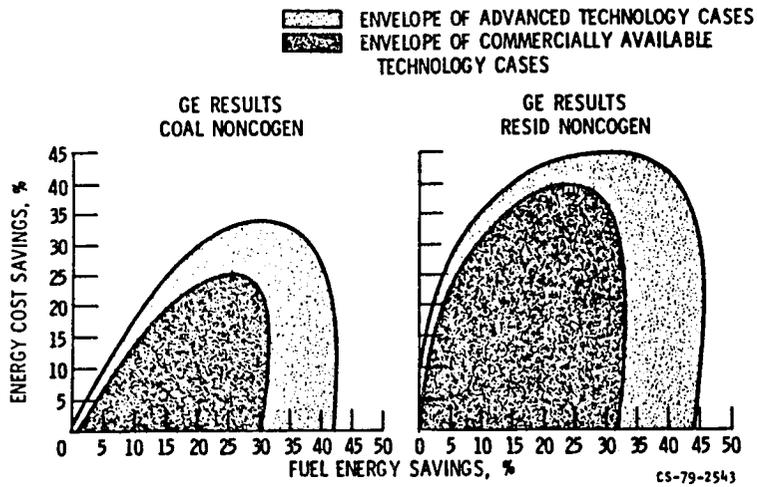


Figure 6. - Preliminary comparison of GE results for different noncogeneration fuels.

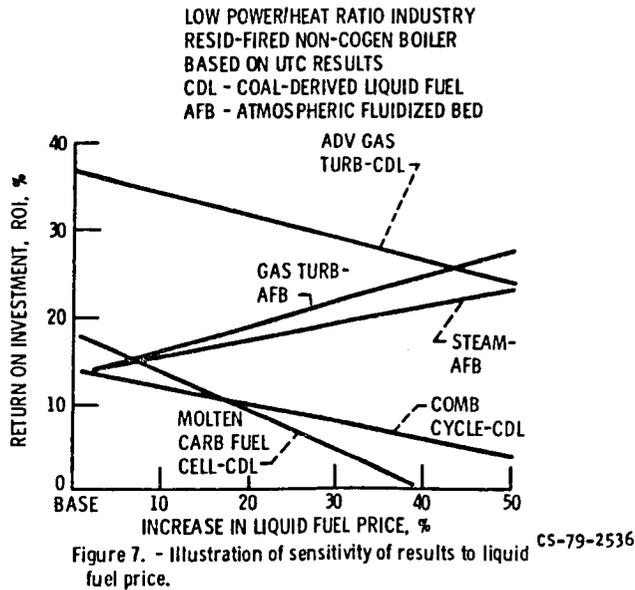


Figure 7. - Illustration of sensitivity of results to liquid fuel price.

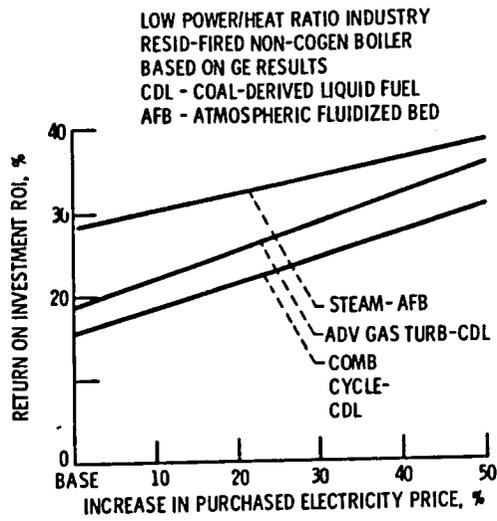
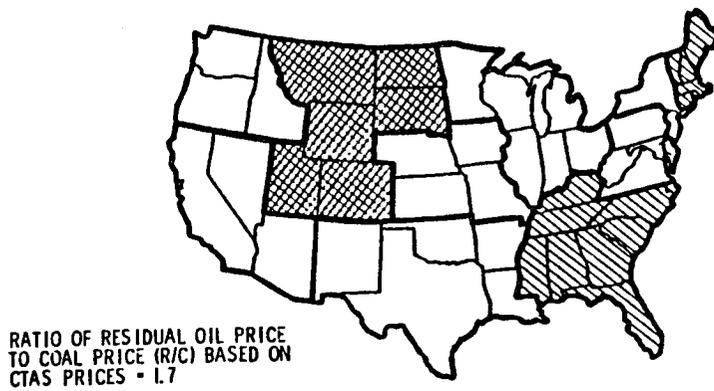
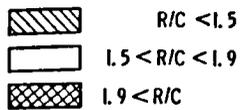


Figure 8. - Illustration of sensitivity of results to purchased electricity price.

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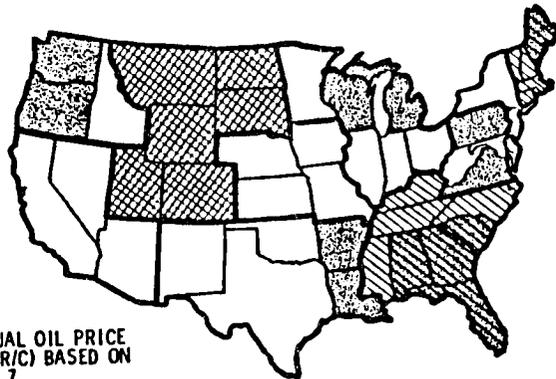


RATIO OF RESIDUAL OIL PRICE
TO COAL PRICE (R/C) BASED ON
CTAS PRICES - 1.7



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Figure 9. - Regional oil and coal price variations based on DOE input.



RATIO OF RESIDUAL OIL PRICE
TO COAL PRICE (R/C) BASED ON
CTAS PRICES - 1.7



 REGIONS WHERE PAPER AND PULP
INDUSTRY IS CONCENTRATED

CS-79-2542

Figure 10. - Regional concentrations of paper and pulp industry overlaid on regional oil and coal price variations.

1. Report No. NASA TM-79213		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle ENERGY AND COST SAVINGS RESULTS FOR ADVANCED TECHNOLOGY SYSTEMS FROM THE COGENER- ATION TECHNOLOGY ALTERNATIVES STUDY (CTAS)				5. Report Date	
				6. Performing Organization Code	
7. Author(s) G. D. Sagerman, G. J. Barna, and R. K. Burns				8. Performing Organization Report No.	
9. Performing Organization Name and Address National Aeronautics and Space Administration Lewis Research Center Cleveland, Ohio 44135				10. Work Unit No.	
				11. Contract or Grant No.	
				13. Type of Report and Period Covered	
12. Sponsoring Agency Name and Address U. S. Department of Energy Fossil Fuel Utilization Division Washington, D. C. 20545				14. Sponsoring Agency Code	
15. Supplementary Notes Prepared under Interagency Agreement EC-77-A-31-1062. Prepared for AIAA Terrestrial Energy Systems Conference, Orlando, Florida, June 4-6, 1979.					
16. Abstract This paper presents an overview of the organization and methodology and a summary of selected results to date of the Cogeneration Technology Alternatives Study (CTAS). The CTAS is being performed by NASA for the Division of Fossil Fuel Utilization of the Department of Energy (DOE). The effort is being carried out via study contracts with industry supported by NASA in-house analyses at the Lewis Research Center and the Jet Propulsion Laboratory. The objectives of the study are to identify the most attractive advanced energy conversion systems for industrial cogeneration applications in the 1985-2000 time period and to assess the advantages of advanced technology systems compared to those systems commercially available today. Advanced systems being studied include steam turbines, open and closed cycle gas turbines, combined cycles, diesel engines, Stirling engines, phosphoric acid and molten carbonate fuel cells and thermionics. Steam turbines, open cycle gas turbines, combined cycles, and diesel engines are also being analyzed in versions typical of today's commercially available technology to provide a base against which to measure the advanced systems. Cogeneration applications in the major energy consuming manufacturing industries are being considered. Results of the study in terms of plant level energy savings, annual energy cost savings and economic attractiveness are presented for the various energy conversion systems considered. Sensitivity of the results to variations in assumed study groundrules such as fuel prices and the price of purchased electricity and the potential effect of regional characteristics are discussed.					
17. Key Words (Suggested by Author(s)) Cogeneration Energy Conversion System CTAS Energy Conservation			18. Distribution Statement Unclassified - unlimited STAR Category 44 DOE Category UC-95f		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages	22. Price*

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