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**A PRELIMINARY FEASIBILITY STUDY OF A
GRID-CONNECTED INTEGRATED COMMUNITY ENERGY
SYSTEM AT CLARK UNIVERSITY**

Volume I

Executive Summary

July 1977

Work Performed Under Contract No. EC-77-C-02-4211

**Clark University
Worcester, Massachusetts 01610**

**ENERGY RESEARCH AND
DEVELOPMENT ADMINISTRATION**

Division of Buildings and Community Systems

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July, 1977

Prepared for ERDA under Contract #EC77-C-02-4211

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INTRODUCTION

We have made a four month study of the feasibility of grid-connected cogeneration at Clark University. We present here a summary of our results.

Summary of Task Accomplishments of Phase I

Energy and economic analysis. Clark's energy need and use profiles were compared with theoretical and actual grid-connected cogeneration systems. We concluded that the most useful system for Clark would be an ebulliently cooled diesel of 1500 kw, burning #6 oil, and supplemented by Clark's existing boilers. The most favorable production model found to date is a Fairbanks-Morse 1500 kw diesel burning #2 oil, costing \$800,000 installed, and giving oil savings of 19% a year and an internal rate of return of 18% a year.

Institutional problems. We have been assured by officials responsible for enforcing environmental, zoning, building, and other codes and regulations that the proposed ICES poses no serious problems and will probably proceed to approval without delay once final design is available. We have also investigated the restrictions of the University Charter and, though some problems remain to be resolved, we do not anticipate any difficulty.

Conceptual design. We have considered two possible locations for the cogeneration system, one in an existing building that now houses the university's boiler, the other in an external addition to this building. Both sites appear feasible. We have also made process flow diagrams and system schematics for the principal components of candidate ICES systems and have uncovered no fundamental difficulties in linking with the existing heat distribution system of the university.

Firming up commitments. The New England Electric System has agreed to purchase electricity from Clark for a price closely approximating the marginal cost of displaced fuel. This is currently about 2.4¢/kwh on weekdays and 2.0¢/kwh on weeknights and weekends. When we import power we will pay the present posted rate of about 4.2 to 4.5¢/kwh. There will be no restriction on interchange.

The most attractive financing would be a federally guaranteed low interest loan like the 3% loans in HUD programs for energy conservation

in academic institutions. If President Carter's energy program goes into effect there will be other loans of this type, and there may even be some matching grants. HEFA bond issues also offer a good possibility. Because of restricted standard lines of credit, we are reluctant to borrow against our limited endowment.

The Trustees of Clark University have passed a resolution affirming their enthusiasm for and intention of following through with the demonstration project and directing the Treasurer and Dean to make the necessary arrangements.

Work management plan. We have made detailed estimates for the effort required, the cost, and the duration of tasks in remaining phases of the demonstration program. We expect that Phase II, detailed feasibility and preliminary design, will last about 9 months including reporting requirements and will cost about \$219,000. We then anticipate a two-year period before startup during which the greater part of program costs will be borne by the University. ERDA will be asked to support design and procurement of equipment for the grid-connection and monitoring, as well as the continuing evaluation of the program and the associated information program.

Recommendation: Request for Continuation of Clark
as Demonstration Community

Clark University is attractive for an ICES demonstration.

Clark University is willing and able to proceed with the development of an ICES demonstration.

The Fairbanks-Morse Colt 4 cyl. 2160 BHP 1530 kw diesel generator fills nearly all the objectives set for an ICES project at Clark at a cost of less than \$1,000,000.

Therefore we recommend that Clark University be chosen to continue this study into Phase II. Here are some additional reasons.

Transferability of results. Clark is typical of a large number of Northeast communities, both in size and energy use. Clark also represents a typical example of retro-fitting. Since retro-fitting is the only way ICES can become widespread in the U.S. in the next ten years, Clark's experience should be of maximum benefit as a model.

Monitoring, evaluation and training. Clark is a center for energy

studies and has resources in faculty and students and staff with appropriate experience for long-term monitoring and evaluation of the proposed ICES system. From Clark's point of view, our selection as a demonstration site will give a boost to our energy-related studies by providing a full-scale laboratory for students and faculty.

Dissemination of results. Clark faculty members customarily present research results in technical publications and conferences and are experienced in the art of such communication. We are therefore able to offer a substantial information program in connection with the proposed ICES demonstration. This program will include press releases, site visits by the general public, performance data sheets for technical audiences, a planning workbook for potential new ICES users, publication of system evaluation in standard journals and at scientific conferences, and intimate links to a Massachusetts State Planning study on cogeneration. Two papers on the project have already been accepted for presentation at national and international conferences.

Grid connection. We have successfully negotiated a very favorable preliminary agreement for electric interchange with the New England Electric System, as noted above.

Economic viability. Candidate ICES offer internal rates of return of 15-25% compared with Clark's conventional energy system. The range is due to difference between engine makes and models as well as uncertainties in final costs.

Cost to ERDA. Because the expected rates of return are sufficiently high for Clark to finance the basic system itself, we plan to ask ERDA support for only those costs listed in the original request for proposals.

Energy savings. The proposed ICES will reduce by approximately 25% Clark's direct and indirect consumption of energy. This large saving is due to the planned use of diesels, and is especially significant because New England depends almost wholly on foreign oil for its energy supply.

Firmness of commitment. The Trustees of Clark University, who are ultimately responsible for the operation of the University, have recently passed the following resolution:

As Trustees of Clark University we have reviewed the

proposed cogeneration demonstration project. We expect that the demonstration project will involve an investment of approximately \$1 million with a projected internal rate of return of about 20%. We also recognize that the project offers Clark an unusual opportunity to strengthen energy-related academic studies and thus to achieve prominence in the field of energy innovation. We are therefore enthusiastic about the proposed demonstration program and are prepared to follow through on the project to become a demonstration community. Our decision assumes Phase I results will be confirmed in Phase II, and that suitable financing can be arranged. We therefore instruct the Treasurer, Mr. Landry, and the Dean of Academic Affairs, Mr. Puffer, to initiate application for Phase II of the Program, and to make the necessary preliminary contractual arrangements.

1. PRELIMINARY ENERGY AND ECONOMIC ANALYSIS

1.0 Introduction

The goal of this section is the identification of candidate ICES which are economically attractive and energy saving. In Section 1.1 we consider those site characteristics that affect the integration of the ICES into the existing energy plant. In Section 1.2 we report the scope and results of a monitoring program through which we have defined heat and electric demand profiles for Clark University. In Section 1.3 we mention the projected growth of the university. In Section 1.4 we describe the economic aspects of the existing energy system, and emphasize the great uncertainties that prevail in the area of oil prices and electricity rate structure. In Section 1.5 we conduct energy and economic comparisons of 14 candidate ICES, and arrive at the conclusion that the system of choice is an ebulliently cooled diesel, burning #6 oil, and rated at approximately 1500 kW. For economic comparisons we use a ten-parameter evaluation model which specifies annual savings for each of the candidate systems, and also characterizes each in terms of an internal rate of return. For energy comparisons we utilize detailed heat and electric specifications as supplied by the manufacturers.

1.1 Site Characteristics

Clark University has the character of a mixed commercial and residential facility. Major building uses include housing, academics, administration, dining, theatre, student activities and stores. Except for a small amount of electric heating where temperature control is critical, heat for the entire Clark campus is supplied by a central boiler plant through a steam distribution system. Distribution steam pressures range from 15 to 125 psig, as shown in Fig. 1.1-1. Electrical power for the campus is supplied at 13.8 kV at one point (Goddard Library), and is distributed and transformed at voltages ranging from 13,800 to 208 V.

The single access point for utility power will make a potential grid connection a straightforward matter. In contrast, the range of pressures used for steam distribution raises certain problems in the design of an appropriate ICES as summarized in Table 1.1-1. From this we

Table 1.1-1. Form of by-product heat and end use

Form of by-product heat	Source of heat	End use
125 psig steam	steam turbine gas turbine exhaust of diesel	End use is unlimited without modification of distribution system
15 psig steam	jacket of certain diesels	End use limited to present 15 psig lines, having steam load in range of 2500 lb/hr.
180°F water	jacket of certain diesels	End use not possible without distribution system modification.

come to a three-part analysis of the heat-matching problem, as follows.

(1) Steam and gas turbines present no problems since the use of 125 psig steam is essentially unlimited. Heat recovery from diesel exhaust presents no problems for the same reason.

(2) The use of 15 psig steam from diesel jackets is limited by the

- 125 psig steam lines
- 40 psig steam lines
- 15 psig steam lines

Fig. 1.1-1. Steam distribution system at Clark University. Steam lines in all cases include both steam supply and condensate return.

presently available 15 psig distribution network. If significant heat waste is to be avoided, this places a size limit on candidate diesel ICES.

(3) Use of 180° water from diesel jackets requires modifications of the distribution system in all cases. These are excessively costly, which makes diesels with low temperature cooling unattractive.

1.2 Energy Profiles

In this section we report on the results of our monitoring program, and the aggregate heat and electric demand profiles derived from them.

1.2.1 Extent of monitoring effort

To refine our understanding of fuel and electric usage at Clark University we began a monitoring program. Its principal aspects are described in Table 1.2.1-1. Although serious delays were caused by late instrument delivery and failure of water flow gauges, we were able to obtain significant results as follows.

(1) The efficiency of the largest of our existing boilers was measured under varying load conditions.

(2) The University heat use as a function of degree days was measured.

(3) An average temperature difference of $\sim 4^{\circ}\text{F}$ between Clark and Worcester Airport Weather Station was determined.

(4) Typical diurnal variation of total electric demand was recorded.
(See Fig. 1.2.1-1)

(5) During periods when the entire university was supplied by the #3 boiler typical diurnal variation of total heat demand was recorded.
(See Fig. 1.2.1-2)

1.2.2 Aggregate electric demand profile

Using results from the monitoring program we developed an electric load distribution curve covering the period of one year, Fig. 1.2.2-1. This curve is adjusted to take into account three sources of load increase which will come into effect before installation of the proposed ICES: (a) lighting and ventilation in the new student activities center; (b) use of supplementary electric heat pumps in the new student activities

Table I.2.1-1. Summary of energy monitoring effort

Variable monitored	Method	Sampling frequency	Accuracy	Period of Survey	Comments
University fuel consumption	manually read oil tank float	3/day	250 gal.	Nov. 30, 1976-Present	
University electric consumption	automatically recording KW-meter	continuous	10 kW	Sept. 1974-Present	
Local weather	automatically recording thermometer *	6/hr	0.1°C	April 8, 1977-Present	Experienced late instrument delivery
#3 boiler oil consumption	automatically recording oil flow meter *	1/hr	10 gal.	March 14-Present	
#3 boiler steam production	automatically recording make-up water meter *	1/hr	250 lbs.	March 14-Present	Experienced repeated equipment failure

* Equipment purchased with ERDA funds

Fig. 1.2.1-1: Typical diurnal variation of electric demand

Fig. 1.2.1-2: Typical diurnal variation of oil demand and outside temperature

Fig. 1.2.2-1: Electric Load Distribution

ANNUAL HOURS AT POWER LEVEL P OR GREATER

center; (c) an anticipated increase in summer use of the campus, leading to increased air conditioning. Our estimate is that these effects will increase electric consumption by 15%.

1.2.3 Aggregate heat demand profile

Compared to the electric case, extracting heat demand profiles from the monitoring data is somewhat more complex and consisted of four steps as follows.

(1) Using the measured average boiler efficiency of 0.75, the data on fuel use was converted to steam demand vs. degree days. In this a distinction was made between regular session weekdays, regular session weekends, vacation weekdays, and vacation weekends.

(2) Using 30-year-average weather data, demand profiles were generated for each of the four conditions defined above. These were, of course, limited to the heating season.

(3) Using monthly gas and oil consumption for the summer, a boiler efficiency of 0.75, and estimated variations in daily summer steam demand, approximate demand profiles were generated for the summer. (The absence of monitoring data for the summer made this estimate necessary.)

(4) The results of (2) and (3) were aggregated to obtain a yearly steam demand profile. To account for the new student activities center and anticipated increased summer usage of the campus, this profile was increased point by point by 15%. The result appears in Fig. 1.2.3-1.

1.3 Projected Growth

No significant growth in Clark facilities or in energy demands is anticipated after completion of the gymnasium and augmentation of the summer schedule. Both of these effects were estimated in 1.2 since they will precede installation of the ICES.

We have concluded that it is neither feasible nor desirable for Clark to try to sell heat to its neighbors. The distribution system would be prohibitively expensive, it would not improve our load factors, and there are serious political problems.

1.4 The Conventional Energy System

Heating and Cooling. Clark's existing space and hot water conditioning

system is largely powered by a boiler plant producing steam in the range of 15 - 125 psig pressure. The plant burns #6 fuel oil and can burn gas when available. End use equipment includes steam radiators, pressurized hot water radiators, hot water, and absorption air conditioning. Current steam demand, as already indicated, peaks at 32,000 lbs of steam per hour; average fuel use is 1.2×10^{11} Btu/yr.

Electric Power. Clark currently buys power from Massachusetts Electric Company, part of the New England Electric System. A single utility line enters the campus at a voltage of 13,800 volts. After metering, power is distributed by Clark-owned transformers and lines to the campus. Major electric end-use equipment includes lighting, ventilation and cooking. Peak electric demand is about 1.3 - 1.5 MW; average annual use is 6.6×10^5 kwh/year.

1.4.1 Present prices

Since our original proposal there have been no significant changes in the provisions under which Clark buys fuel and electricity; however prices have changed markedly, as shown in Table 1.4.1-1. Price increases are largely traceable to recent increases in the price of oil and imply an added \$117,000 in Clark's annual energy bill.

Table 1.4.1-1. Energy prices at Clark University

Commodity	Price (11/76)	Price (5/77)
Electricity	3.6¢/kwh average	4.2¢/kwh average
#6 Fuel Oil	\$1.87/10 ⁶ Btu	\$2.50/10 ⁶ Btu
#2 Fuel Oil	\$2.35/10 ⁶ Btu	\$3.00/10 ⁶ Btu
Natural Gas		
Contract basis	\$2.55/10 ⁶ Btu	\$2.62/10 ⁶ Btu
Interruptible	\$1.48/10 ⁶ Btu	\$1.92/10 ⁶ Btu

1.4.2 Projected prices

Projected prices of heating oil and electric power at Clark depend significantly on future prices of oil, the extent of nuclear power development by the utility, and the electric rate structure mandated by regulatory agencies. It is beyond the scope of this report to make a

detailed analysis of these factors. We therefore limit ourselves to the following observations.

Oil prices. The historical record shows very rapid changes which discourages projections. A belief in the stability of world trade and politics over the next ten years leads to the estimate that oil will escalate no less than general inflation, which we judge to be 6% per year.

Rate structure. The historical record, shown in Fig. 1.4.2-1 indicates a declining ratio between Clark electric costs and utility wholesale costs. This might be expected in a situation in which fuel costs dominate generating costs. At the same time, Clark's rate structure factor is far removed from the one applied to small consumers and considerably below a rate structure factor applicable in the case of flat rates. Given

Fig. 1.4.2-1. Historical record and base case projections of wholesale distribution costs and the retail rate structure for Clark. Also shown are the retail rate structure factor for the small consumer and the retail rate structure factor for the proposed flat rate structure.

present consumer campaigns and Presidential efforts in the direction of flatter rate structures, we think that conservative planning leads us to expect an increase in the rate structure factor for Clark, leading to correspondingly increased prices independent of escalation.

Utility generating costs. The historical record shows rapid change because of the domination of oil fired generation in New England. In the future, utility costs will include increasingly large contributions from nuclear power, especially in the form of capital costs. In a separate study conducted prior to the present contract (STS Review, Vol. 2, #4, Clark University, 1976), we have shown that the installation schedule for nuclear power anticipated by NEES will not significantly reduce the escalation of electricity prices even though oil burning plants are in part replaced. We therefore have good reason to project electric utility generating costs at least at the general inflation rate.

To summarize, Clark can expect to experience energy prices that escalate at 6% or faster. We have found no credible mechanisms by which increases would be less rapid than general inflation.

1.5 Candidate ICES: Energy and Economic Comparisons

In this section we indicate how we arrive at our system of choice: a single, ebulliently cooled diesel having a maximum electrical output of 1500 kw, and satisfying about 1/3 of Clark's average steam demand. Though our analysis was quantitative throughout, a qualitative summary follows.

(1) At the outset, we considered three general types of systems: steam turbines, gas turbines and diesels. Gas turbines could be eliminated in all cases because of low electric efficiency, high maintenance cost, and expensive fuel.

(2) Next, we considered steam turbine and diesel systems that can in principle meet all of Clark's steam demand. Because steam demand is sharply peaked, and because it is impractical to export excess steam, all such systems would run most of the time at half capacity or less (see Fig. 1.2.3-1). This ruled out steam turbines because they produce essentially no electricity at half capacity, and it also ruled out diesels because of unused capital investment.

(3) Next we considered steam turbines and diesel systems that were sized at half or less of Clark's steam demand, and which would require backup by Clark's existing boiler facility. In this case, the problem of underutilized capacity is avoided, but steam turbines of this size have such small electric output that they failed on economic grounds. Diesels, on the other hand, showed reasonably large returns, especially if their size was reduced to a point that no significant dumping of heat was required during periods of low university heat demand. The size range for which this is true roughly defines the system of choice: a 1500 kw diesel. The requirement that this diesel be ebulliently cooled arises from the fact that, as indicated earlier, the university has no way of utilizing hot water without large modifications in the distribution system.

It is interesting that our system of choice also has rather handsome fuel savings when compared to steam turbines of various kinds. This is again because steam turbines that are compatible with our steam demand profile produce negligible amounts of electricity.

In the following sections we provide details that support the qualitative arguments we have made.

1.5.1 Economic evaluation model

In order to obtain an estimate of the economic merits for a given ICES we used a simple algebraic model that describes the savings attainable with a given system when compared to the conventional system. The model assumes that the time dependence of all quantities is exponential. Our base assumptions for the key parameters are given next.

1.5.2 Base case assumptions

Certain parameters, such as the price of oil, recur in evaluation of all ICES. We therefore held these constant throughout our comparison of candidate systems, and summarize their assumed values in Table 1.5.2-1 below. In a later section, after our initial choice of system has been determined, we indicate the effect of varying these (and other) parameters in order to determine the sensitivity of system returns to such change.

Table 1.5.2-1. Base case assumptions

Variable	Variable name	Value
Rate of inflation	y	6%/yr
Price of fuel (current)		
#2 oil		\$3.00/MBtu
#6 oil		\$2.50/MBtu
Prices of electricity (current)		
Purchased by Clark	$u_r(0)$	4.2¢/kwh
Sold by Clark, Weekdays 7 A.M.-11 P.M.	$u_s(0)$	2.4¢/kwh
Sold by Clark, other	$u_s(0)$	2.0¢/kwh
Standby charge	Z(0)	\$25,000/yr
Rate structure factor	p	1.2
Plant lifetime	-	20 years
Clark electric demand	Q_t	6.6×10^6 kwh/yr
Conventional boiler efficiency	-	85%*

* This value used only in initial system comparisons. Clark boiler efficiency is actually 75%.

1.5.3 Initial comparison of 14 candidate ICES

We begin our analysis by comparing 14 systems listed in Table 1.5.3-1. This list includes single and multiple diesels, gas turbines and steam turbines. For this initial comparison we used the base case parameters listed in the previous section and capital costs and other parameters as provided by the manufacturers. For each case, an internal rate of return was obtained.

Table 1.5.3-2 summarizes the principal features of the 14 systems. Examination of the table shows that only three systems meet our initial selection criterion of an internal rate of return greater than 10%. These are systems IV, IVB, and IX. All are single diesels, ebulliently cooled.

1.5.4 Diesel size and fuel

Systems IV and IVB are identical except for fuel: System IVB has a better rate of return because it is fueled by #6 oil. Systems IVB and

IX are very similar except for size: System IVB has a better rate of return because it is smaller. We conclude that the best system appears to be a single, #6 oil-fueled diesel that is not too large--in the range of 1500 kw electrical output. We also conclude that steam turbines are, as our previous qualitative arguments indicated, out of the question.

Table 1.5.3-1. Candidate ICES - Initial List

Case

- I Two 870 kw, 1200 BHP, 750 RPM, 8 cylinder diesels, G-M Model S-8E4G with waste heat boiler.
- II One 2210 kw, 3055 BHP, 20 cylinder diesel, 750 RPM, G-M Model S20E4G with waste heat boiler.
- III One 1780 kw, 2460 BHP, 16 cylinder diesel, 750 RPM, G-M Model S-16E4 with waste heat boiler.
- IV One 1530 kw, 2160 BHP, 720 RPM, 9 cylinder diesel, Colt Fairbanks-Morse Model 38TD8-1/8 with waste heat boiler.
- V Two 850 kw, 1200 BHP, 900 RPM, 6 cylinder diesels, Colt-Fairbanks Morse Model 38D8-1/8 with waste heat boiler.
- VI Two 780 kw, 1100 BHP, 6 cylinder diesels, 750 RPM, Sulzer Model No. ASL25/30 with waste heat boiler.
- VI-B Three 700 kw, 16 cylinder diesels, 1200 RPM, Caterpillar Model 399 including a waste heat boiler for each unit.
- VII One Colt Pielstick 4550 kw, 6420 BHP, 514 RPM, 12 cylinder diesel, Colt Pielstick Model No. 12PC2V with waste heat boiler.
- VIII One DeLaval Enterprise 2591 kw, 3656 BHP, 450 RPM, 6 cylinder diesel. Enterprise Model No. R-46 with waste heat boiler.
- IX One Sulzer 3030 kw, 4200 BHP, 514 RPM, 6 cylinder diesel, Sulzer Model No. Z40 with waste heat boiler.
- X One noncondensing steam turbine, 904 kw, 600 psig, 700°F, 125 psig back pressure.
- X-B Same as X but 365 kw.
- XI One condensing extraction steam turbine plus boiler, 600 psig, 700°F, 125 psig extraction, various outputs.
- XII Two International Harvester 800 kw solar gas turbines.

TABLE 1.5.3-2

ECONOMIC COMPARISON OF ENGINE ALTERNATIVES (LOCATED INSIDE JONAS CLARK)

A-489

Case No.	Description	Fuel Type	Total Capital Costs		Rated Electrical Load kW	kWh Generated by Clark 10 ⁶ kWh	kWh Used by Clark 10 ⁶ kWh	kWh Sold to NEES 10 ⁶ kWh	Incremental Fuel Cost \$/kWh	Revenue		Fuel Cost \$	Maintenance \$	Standing Charge (9 Months) \$	First Year Net Cash Flow \$	First Year Payback Years	Internal Rate of Return %	First Year Profitability \$/yr
			\$	\$/kW						\$	\$							
I.	2 GM Diesel** 870 kW	Distillate	1,108,000	640	1,740	12.63	6.47	6.65	0.02407	271,700	141,900	316,100	50,500	25,200	23,800	46.6	<6.0	-6,400
II.	1 GM Diesel** 2210 kW	Distillate	980,000	440	2,210	16.05	6.47	9.87	0.02308	271,700	217,100	382,600	64,100	25,200	16,900	58.3	<6.0	-16,200
III.	1 GM Diesel** 1780 kW	Distillate	862,000	495	1,780	12.92	6.47	6.74	0.02367	271,700	148,300	305,900	51,700	25,200	27,200	23.7	4.9	13,200
IV.	1 FM OP Diesel* 1531 kW	Distillate	820,000	535	1,531	11.17	6.47	4.96	0.02139	271,700	108,700	238,900	46,700	25,200	71,600	11.9	12.9	60,300
IVb.	1 Diesel 1531 kW	Residual	826,000	585	1,531	11.17	6.47	4.96	0.01609	271,700	108,700	184,200	55,900	25,200	115,100	7.7	18.0	91,000
V.	2 FM OP Diesel* 850 kW	Distillate	1,221,000	700	1,700	12.34	6.47	6.16	0.02318	271,700	135,500	288,000	61,700	25,200	26,300	35.0	<5.0	1,600
VI.	2 Salsor Diesel** 788 kW	Distillate	1,149,000	740	1,560	11.33	6.47	5.15	0.026	271,700	112,300	271,900	45,300	25,200	62,600	27.0	<5.0	11,300
VIIb.	3 Caterpillar* 700 kW	Distillate	956,000	680	1,600	10.17	6.47	3.99	0.02161	271,700	87,800	219,000	81,600	25,200	33,100	28.9	<5.0	7,100
VII.	1 Colt Pleistick* 4550 kW	Residual	2,455,000	940	4,550	29.49	6.47	23.02	0.01609	271,700	506,600	698,000	118,000	25,200	236,900	18.0	7.0	78,600
VIII.	1 Enterprise** 2591 kW	Residual	1,892,000	730	2,591	18.81	6.47	12.63	0.01898	271,700	277,900	397,100	73,300	25,200	92,000	20.6	5.9	40,500
IX.	1 Salsor* 3030 kW	Residual	1,932,000	640	3,030	22.96	6.47	16.49	0.01630	271,700	362,900	372,000	91,000	25,200	262,300	19.3	10.5	92,900
X.	1 Steam Turbine Noncondensing	Residual	978,400	3,100	365	1.87	1.87	0	0.0188	78,500	0	39,200	2,500	0	40,500	24.2	4.9	13,900
			1,139,000	1,260	904	1.49	1.49	0	0.01840	60,100	0	26,300	2,100	0	31,700	36	<6.0	700
XI.	2 Steam Turbine Extraction/Condensing	Residual	1,605,000	Not considered in detail. Economics worse than noncondensing steam turbine. See text for explanation.														
XII.	2 Solar Gas Turbine 800 kW	Distillate	922,000	580	1,600	11.87	6.47	5.4*	0.0258	271,700	116,800	302,700	71,200	25,200	-6,600	-	0	0

* Efficiently Cooled Diesel Engine (12 psig)

** Water Cooled Jacketed Diesel Engine (160-180°F)

- Base Conditions: A. Value of Power Used by Clark - \$0.042/kWh
 B. Value of Power Sold - \$0.022/kWh
 C. Fuel, Power and Maintenance Escalated at 6%/yr
 D. Life of Equipment - 20 years
 E. Efficiency of Conventional Boiler - 85%

Maintenance Costs: Diesel 1200 RPM, No. 2 Oil - \$0.002/kWh
 900 RPM, No. 2 Oil - \$0.004/kWh
 720 RPM, No. 2 Oil - \$0.004/kWh
 720 RPM, No. 6 Oil - \$0.004/kWh
 450-514 RPM, No. 6 Oil - \$0.004/kWh
 Steam Turbine - \$0.0015/kWh
 Gas Turbine - \$0.004/kWh

1.5.5 Sensitivity Analysis

In order to see to what extent economic benefits vary with changes in key parameters, we have conducted a sensitivity analysis. Parameters varied are specified in Table 1.5.5-1. The base case for four engines (including one added since the original 14-system survey) is shown in Fig. 1.5.5-1. Sensitivity plots for the FM 1530 kw machine fueled by #6 oil are shown in Fig. 1.5.5-2.

Table 1.5.5-1. Key parameters for sensitivity analysis

Key Parameters	Base Values	Variation
Efficiency of Clark boiler	.75	.85
Interest rate on loan	.03	.06
Retail electricity rate multiplier	1.2	1.35 (flat rate is 1.5)
Rate of fuel price escalation	.06	0 - 1.2
Credit for electric capacity	0	.6¢/kwh
Underestimate of capital costs	0	\$200,000

Our conclusions are as follow:

(1) Changing the boiler efficiency from 75% to 85% (by purchasing economizers) reduces ICES savings by about 8%.

(2) Going from 3% to 6% interest in financing reduces ICES savings by about 30%.

(3) Increasing the rate structure multiplier from 1.2 to 1.35 nearly doubles the ICES savings.

(4) Varying oil price escalation from 0 to 12% has an effect on ICES savings that lies largely in the future; the former leads to slightly declining savings, the latter produces annual savings in the 10th year that are nearly double the base case.

(5) Giving an average 0.6¢/kwh credit for capital in the case of electricity sold to the utility increases savings by over 50%.

(6) Assuming a \$200,000 capital cost overrun reduces annual savings by an average of 15%.

(7) Assuming the random occurrence of all of the above effects produces savings variations that range from 0.6 to 1.5 times the base case. Even the lower limit of this range has a minimum saving of \$40,000/year.

It is therefore clear that even quite large deviation from the base

Fig. 1.5.5-1: Base case savings for four engines

Fig. 1.5.5-2: Sensitivity of savings for the Fairbanks Morse engine burning #6 oil. Base case is shown as solid line, variation by dotted line. The variation used is defined in Table 1.5.5-1

case produces no unacceptable loss in savings, and may provide in certain not implausible circumstances a substantial increase over the base case.

1.5.6 Energy Savings of ICES

We show the mechanical and thermal efficiencies of our candidate systems in Table 1.5.6-1. For comparison, we include gas turbines and steam turbines. We also show the amount of oil saved in the total demonstration system. The total demonstration system is compared to the conventional system which supplies Clark's electricity and heat, plus the electricity that Clark's exports would replace. Diesels would save 20-40% of the fuel presently used at Clark.

Table 1.5.6-1. ICES efficiencies

ICES	Electric Efficiencies	Thermal Efficiencies	Energy Saved 10 ⁹ Btu
Fairbanks-Morse	35%	33%	44
Superior	35%	35%	36
Sulzer	35%	35%	98
Gas Turbine (Solar)	21%	40%	38
Steam Turbine	≤7%	≤78%	9

In Fig. 1.5.6-1 we show these savings graphically. All of the diesels save large amounts of energy, and the steam turbine saves a negligible amount. The particularly poor savings of this steam turbine comes about in part because its small size gives poor performance, but it is still quite generally true that for any ICES heat load, a steam turbine, because of its low electric efficiency, gives a much smaller total fuel savings than a diesel.

1.5.7 Summary of energy and economic comparisons

We have shown that an ebulliently cooled single diesel with an electrical output of about 1500 kw and residual fuel capability is the system of choice. Such a system can be expected to have an internal rate of return of about 20%; it will save about 25% in fuel compared to a conventional system. Savings to Clark after financing costs are likely

Fig. 1.5.6-1: Energy Savings

to be \$50,000 or higher in the first year. We have arrived at this conclusion after analyzing 14 candidate ICES systems and making detailed cost and energy comparisons.

At present we are unable to identify an "off the shelf" diesel of the exact type we desire. Existing machines which come close to desired requirements are summarized in Table 1.5.7-1. All appear to be acceptable.

Table 1.5.7-1. Summary of the most favorable diesel ICES

Manufac- turer	Elec- trical power ^a (MW)	fuel oil type	oil savings ^b (%)	Internal rate of return ^c (%/yr)	Capital cost ^d (\$1000)	Availability
Fairbanks Morse	1.5	#2	19	18	800	Production model
	1.3	#6	22	25	850	not confirmed
Superior	1.0	#6	17	20	950	Modified pro- duction model, confirmed Appendix 1C
Sulzer	3.0	#6	50	15	2,000	Modified pro- duction model, confirmed Appendix 1C

a. Stated power level is maximum steady power level that can be produced by a given engine. Most engines can be run at about half of the stated level without serious loss of efficiency.

b. Oil savings represent oil not needed at Clark or at the utility oil-fired power plants as a result of the proposed ICES. Percent savings are based on Clark's anticipated annual use of 30,000 bbls/yr.

c. Internal rate of return gives payback realized before financing charges. It is based on the assumption that oil prices and all other prices escalate at 6% per year.

d. Capital costs include engine price, engineering design, installation, and interconnect costs for heat recovery; they do not include costs of the grid connection.

2. PRELIMINARY INSTITUTIONAL ASSESSMENT

We have examined five areas important to Clark's relationship with the outside community. These are: 1) statutes and codes; 2) community relations; 3) information dissemination; 4) legal problems, and 5) restrictions posed by the University charter. In general, the Worcester community and state and local officials have been gratifyingly receptive to Clark's plans for an ICES and most helpful in overcoming the various problems encountered.

2.1 Statutes and Codes

Four areas of regulation have major relevance to the Clark University ICES system. These are: (a) reciprocal zoning regulations; (b) municipal and state building and equipment codes; (c) state and federal air pollution regulations; and (d) state and federal environmental regulations. (This section will deal with each of these four areas individually.)

2.1.1 City of Worcester Zoning Ordinance

The City of Worcester Zoning Ordinance defines the permissible uses in a residential district. The use of the Clark ICES installation was discussed with Mr. Norton S. Remmer, Commissioner, City of Worcester, Department of Code Inspection. The Commissioner has stated that the proposed project would not violate existing zoning.

2.1.2 State Building Code

Commissioner Remmer has stated that compliance with all requirements of Article 11 of the building code can be achieved with standard design and construction techniques. The provisions of Chapter 146 require approval of certain boilers and pressure vessels by the Board of Boiler Rules of the State Department of Public Safety. Such approval can be obtained only after detailed designs and specifications are submitted.

2.1.3 Air Pollution Regulations

Federal and state air pollution regulations are practically identical. Discussions with personnel concerned with air quality in EPA Region I (Boston) confirmed that existing state requirements would satisfy federal requirements. There are no EPA standards for

diesel engine emission. Issue of such standards is expected in February, 1978 and there are indications that these standards will be met by most existing diesel engines. Massachusetts standards for fossil fuel utilizing facilities with a fuel input of less than 250×10^6 Btu/hr can be met by the most likely unit, the F.M. Colt 1530 kW diesel, with ease, and other candidate units will also meet these standards. Following our presentation of the material relating to air pollution to Mr. Edward G. Benoit, Chief, Air Quality Control Section, Central Massachusetts Air Pollution Control District, Mr. Benoit stated that, in the opinion of his office and based on presently available data, the project would not be in violation of existing air pollution regulations and standards.

2.1.4 Environmental Impact

We have made an Environmental Evaluation Report to provide a preliminary environmental impact assessment based on the present plan for the Clark ICES plant and the most likely configuration. The overall conclusion is that environmental impacts are insignificant except as follows: (1) Compared to the present system there would be an approximate doubling in NO_x emission; (2) Compared to the present system, there would be a 20-25% reduction in oil use. At this stage of evaluation, the increase in NO_x emission is not a serious problem, because NO_x is a critical pollutant only as a contributor to photochemical smog, and this occurs only rarely in Worcester. In contrast, the decrease in oil consumption is viewed as being of major importance, especially if the ICES concept is extended to other sites.

Whether the state will require an environmental impact assessment is questionable and will depend on the degree of involvement of the Commonwealth in the ICES project.

2.2 Community Relations

Clark University is located in an older residential neighborhood about 1.2 miles south of the city center. While the relations of the University with its surrounding neighborhood are generally good, some conflicts exist, stemming from student parking, student competition for housing, and University expansion. New parking recently construc-

ted and more under construction, as well as the announcement by the University that no further expansion is contemplated, have significantly mitigated these conflicts. There is no neighborhood association that speaks for the community. The Worcester Redevelopment Authority, an agency that operates in the vicinity of Clark University, was contacted. It stated that it could not foresee any objections to an ICES at Clark.

Relations of the University with the City of Worcester as a whole are very good. The University contributes significantly to the city through economic value of students and staff and through direct assistance by faculty and student interns to city functions. Informal discussions with city staffs have uniformly produced positive reactions towards the implementation of an ICES at Clark.

2.3 Information Dissemination

Because Clark is an academic institution with a substantial record in the study of technology and environmental impact assessment, we are in a unique position to provide a comprehensive information program for the proposed Demonstration ICES. Written material will be prepared by the Program on Science, Technology and Society; site visits will be organized through the Office of the Physical Plant and the Office of Public Relations. Specifically, we envision six activities to inform the public and technical audiences about the project.

(1) Occasional press releases. Addressed to the general public, largely in the local community, these will indicate progress on the project, describe the general implications of cogeneration for the nation, and indicate the local impacts. In the post-construction stages, these releases will be used to invite the general public to visit the site and learn about its functioning. (See below.)

(2) Site visits. Provided for the general education of the public in the local area, these visits will allow touring of the facility. To make them meaningful, we will provide museum-like posters indicating principal functions and benefits, and we will arrange for student guides as needed.

(3) Performance data sheets. We will make available brief technical reports on operations performance characteristics of the Clark ICES as the project progresses. These will be addressed to technical

audiences with an interest in cogeneration.

(4) Planning Workbook. For potential planners of other ICES we shall prepare a workbook that details the planning experience at Clark. It is our hope that by describing our experience, our evaluation models, and the institutional problems we have faced and solved, we will help to initiate projects with considerably reduced effort. The workbook will be based on the major tasks of Phases I-III, and it is expected that a draft of it will be available at the end of Phase IV.

(5) Publication in journals and presentation at conferences. We have carried on general studies of cogeneration for some years; we expect to continue as the Clark Demonstration ICES matures, using information from it as additional input. We shall attend conferences and publish in technical and semi-technical journals (Environment, Technology Review, Bulletin of the Atomic Scientists, etc.), describing how cogeneration is evaluated in regional and national terms, and how the Clark demonstration and other related projects illustrate this evaluation. Based on Phase I work we have already submitted two papers to be read and published in conference proceedings.

(6) Consultation with the Massachusetts State Energy Policy Office. Because of our continuing connection with the State Energy Policy Office we expect that information generated at Clark will have significant impact on the State's efforts in the cogeneration area. Thus we expect to be called on to give testimony on our planning process, on the institutional problems we have faced and solved, and on the performance of our system. We will work closely with the newly formed Massachusetts Commission Studying Cogeneration.

2.4 Legal Problems

A preliminary analysis of legal problems relating to the proposed ICES at Clark University has been provided by Richard Mirick, Counselor at Law and legal counsel to the University. Based on this and our own assessment, we have identified only one source of legal problems in addition to the statutes and codes and the restrictions in the University charter. This is regulation by the State Department of Public Utilities (DPU).

The manufacture and sale of electricity by Clark places the Uni-

versity under their jurisdiction, and requires conformance with applicable rules of that department. Appropriate discussions with NEES and the DPU on the implications of these rules are in progress. We have assurances that there will be no significant restrictions.

2.5 The University Charter

A preliminary analysis of problems relating to the University Charter has been given by Richard Mirick, legal counsel for the University. With their actual and/or potential resolution, these problems are as follows.

2.5.1 University Ownership of the Plant

Mirick states: "although the University has no express power to engage in the generation of electric power, I am satisfied that it has the implied power to do so for its own internal use." We therefore do not anticipate any problems with the ownership of the plant per se and conclude that such problems as there are arise from the sale of electricity, as discussed below.

2.5.2 Corporate Power to Sell Electricity

In Mirick's opinion, the University may not at present have the power to sell electricity. Mirick suggests that, given the limited nature and purposes of the project and the national interest in energy conservation, the problem can probably be solved by special legislation. With the support of the Governor and the State Energy Policy Office, we do not anticipate difficulty in this solution. An alternative would be for the University to establish a separate corporation, for electricity sales.

2.5.3 Federal Tax-Exempt Status

In Mirick's opinion, the sale of electricity by Clark could be construed as unrelated business income and subject to federal taxation. A ruling from the Internal Revenue Service could be requested if ERDA desires. Such a ruling would be more meaningful near the end of Phase II, when preliminary design is completed. In the meantime we do not consider taxation for sold electricity as a problem, since the system is not likely to show any taxable profit.

2.5.4 Local Tax-Exempt Status

In Mirick's opinion, the sale of electricity by Clark may lead to consideration of real estate and equipment as subject to local real estate and property tax. If necessary, we plan to seek remedy via state legislation that specifically exempts the ICES from such taxation. We do not believe it advisable, however, to engage in such action until the issue of taxation is raised by local authorities.

3. CONCEPTUAL DESIGN

The purposes of the conceptual design presented here are: (1) to identify the major components of the selected system; (2) to serve as a basis for preliminary cost estimates; and (3) to show that the components can be fitted into the site available.

3.0 System and Plant Description

In Section 1.5 we gave the reasons for our selection of the Fairbanks Morse 9 cylinder Model 38TD diesel producing 2160 bhp at 720 rpm with a 3 phase generator with a nameplate rating of 1531 kilowatts. Fig. 3.0-1 identifies the major components of the system. It should be noted that the fuel oil storage tanks shown are those already in existence at Clark, and that the centrifuge in the fuel line is only needed should #6 oil be used.

Major components and auxiliary equipment will be installed adjacent to the existing boiler room in one of two locations: (1) the biology laboratories in the basement of Jonas Clark Hall, or (2) a new building to be erected adjacent to Jonas Clark Hall.

To illustrate, we show in Fig. 3.0-2 a possible plant layout in the first of the above sites. Though the exact location of all components is not shown, the sketch demonstrates that there is ample space for the equipment within the building. The space required for layout is 65' x 40'; the required headroom is 12'5". In order to remove inside load-bearing walls, it is necessary to take up building loads with steel beams. The waste heat boiler will be oriented in the building before the diesel generator is skidded into position. The diesel generator will be skidded into the building through a permanent access door. The unit will require inlet and exhaust silencers as shown and, for the alignment shown, will require a new stack.

The layout for a plant adjacent to Jonas Clark Hall is similar. The choice between these two configurations will be made in Phase II, based on economic, aesthetic and risk considerations.

3.1 Process Diagram

We have made process diagrams for five subsystems: air cooling; air supply; fuel; lubrication; and steam, feedwater and condensate.

Fig. 3.0-I: System Schematic

Fig. 3.0-2: Central Plant Layout

The first four are integral parts of the diesel engine, and are shown in the main report.

Figure 3.1-1 shows the steam, feedwater and condensate circuits. The deaerator (water softener) and condensate return tank, condensate return pump, and feedpumps are existing equipment in the existing boiler plant. The waste heat boiler has evaporation and economizer sections, both consisting of spirally wound, finned tubes. The boiler will deliver saturated steam. The diesel engine jackets will be ebulliently cooled using an ebullient boiler. The system consists essentially of an elevated steam and water drum reservoir. The water head will keep sufficient pressure on the jacket water to prevent boiling in the jacket. Ebullient condensers will control the pressure and, with pressure control, the steam from the jacket system will be condensed and returned to the condensate return tank. A cooling tower will provide cooling water for the ebullient boiler condensers when the heating load is not sufficient.

3.2 Cost and Performance Estimates

Cost estimates for the Fairbanks Morse 1531 kW diesel system are presented in Table 3.2-1, with separate results for each of the two sites. The construction of a new building adds about \$186,000 to the project cost. A new building may nevertheless be desirable, both for reducing the risk involved in modifying an existing building, and for aesthetic reasons.

Performance data for the Fairbanks Morse 1531 kW diesel system are presented in Table 3.2-2.

Fig. 3.1-1: Steam System

Table 3.2-1. Cost Analysis for the FM 1531 KW Diesel System

Item	Cost (units of \$1,000)	
	Jonas Clark	New building
<u>Equipment</u>		
Engine, generator and switchgear	369	369
Boiler	32	32
Ebullient boiler	9	9
Cooling tower	2	2
Crane	10	10
Water softener	6	6
Freight	21	21
<u>Civil work</u>		
New building		228
Miscellaneous alterations	47	
Engine foundation	14	14
Boiler foundation	3	3
Accoustical	18	
Fire proofing	5	
Remove #1 boiler	5	
<u>Mechanical and electrical work</u>		
Rig engine	9	9
Rig in boiler	4	4
Align engine	2	2
Install ducts	13	13
Piping, hangers, valves	31	31
Heating alterations	37	37
Electrical work	15	15
Instrumentation	8	8
Ventilation	12	12
<u>Engineering cost</u>	148	181
<u>Total Project Cost</u>		
Equipment	449	449
Civil Work	92	245
Mechanical and electrical work	131	131
Engineering cost	148	181
PROJECT TOTAL	820	1006

Table 3.2-2. Performance Data for FM 1531 KW Diesel System

Fuel oil	#2
Electrical output (maximum)	1531 KW
Steam generation	
low pressure	979 lbs/hr
high pressure	2983 lbs/hr
Incremental heat use	6596 Btu/kwh
Fuel cost	2.1¢/kwh
Electric-steam ratio	
generated	0.38 kwh/lb., 0.33 kwh/1000 Btu
used	0.38 kwh/lb., 0.33 kwh/1000 Btu
Heat balance	
fuel	6555 Btu/bhp
power	2545 Btu/bhp
jacket	465 Btu/bhp
exhaust	2230 Btu/bhp
lube oil	775 Btu/bhp
air cooler	400 Btu/bhp
radiation	140 Btu/bhp
Exhaust specifications	
NO _x	9 gm/bhp/hr
CO	1 gm/bhp/hr
HC	0.4 gm/bhp/hr
particulates	0.125 gm/bhp/hr
SO ₂	1.66 gm/bhp/hr

4. FIRMING OF COMMITMENTS

4.0 Firming of Commitments

We have made the commitments necessary for continuation of the demonstration program. These commitments are as firm as is feasible or desirable at our present stage of planning. We have preliminary contractual agreements for design and construction of the ICBS and we have made a mutually acceptable preliminary agreement with the New England Electric System on terms of interconnection.

There are two areas in which "as firm as feasible" is still not very firm. One is financing. The best mode of financing would be a federally subsidized loan for energy conservation. However, such loans are only now becoming available, and it is still uncertain what regulations will apply. Hence it is too early for us to settle a detailed financing arrangement. The second is the acquisition of permits. While we have been assured that, given our present plans, there will be no problems in obtaining permits, actual permits can only be given based on final design.

4.1 Financing

For Phase I we have investigated four alternative methods of financing the ICES demonstration: 1) borrowing from the endowment, (2) a commercial loan, (3) a Health and Education Facilities Authority (HEFA) bond issue, and (4) long-term borrowing under one or more federal loan programs. We anticipate a total system cost of approximately one million dollars. This is a substantial investment for Clark University. Because it will be at rates of return permitting full pay-back only after a number of years, the short-term financing options (1) and (2) would be unacceptable as the major source of funds. HEFA bond issues or federal loans would permit long-term financing. We have explored the possibility of an HEFA bond issue for financing the ICES while making arrangements for issuing bonds to finance our new gymnasium. We have uncovered a number of difficulties with an HEFA bond issue. The most serious of these is that it will be necessary to secure the loan, and the plant itself would not be adequate security. This could seriously limit Clark's borrowing capability.

Though we are not ruling out an HEFA bond issue at this time, we would strongly prefer to secure our major financing through a federally subsidized loan for purposes of energy conservation. At present we are investigating two programs. One, to be administered by Housing and Urban Development (HUD), will provide bonds at 3% for energy conservation in dormitories and dining areas. We will submit an application as soon as the final regulations are published. The second is authorized by the Higher Education Facilities Act. It will provide for loans and some matching grants for investments in academic buildings for the purpose of saving energy. Again, we will apply once final regulations are published. Further financing possibilities exist in other bills presently before Congress and in President Carter's energy program. We expect that all of these possibilities will be sufficiently clarified so that we can decide on the mode of financing by the end of Phase II.

4.2 Fuel Availability

Since the ICES will burn fuels similar to what we now use, and since we will retain our existing boilers, we will have no additional difficulties with fuel availability. Despite its energy savings, the ICES may not improve our priority for fuel allocation since Clark is too small to have a specific allocation under present regulations.

4.3 Ownership

Clark University will own and operate the demonstration ICES. We have made tentative agreements with Thermo Electron Corporation for design and construction of the ICES, with Fitzmeyer and Tocci for modification to the existing heating system, and with the New England Electric System for design of the grid interconnection.

4.4 Terms of Grid-Connection

We have made a preliminary agreement with NEES for interchange. The agreement is mutually acceptable as a basis for final negotiation. Under the agreement there would be no restrictions on interchange. Clark would purchase electricity at published rates. These rates include a standby provision under which Clark must agree to pay at least a certain minimum which depends on the peak demand Clark might put on

the system. At present, all purchases would be at one of the standard rates, provided the minimum charge is passed. However, NEES has notified us that they expect to request the Department of Public Utilities for permission to have a standby charge independent of purchases. Clark will respond to this proposal when we learn the proposed terms. Clark purchases will be made only for demand in excess of what the ICES provides at any given time.

Clark will sell the excess electricity when local demand is smaller than the ICES output. NEES will purchase this excess at a price closely approximating the cost of the oil Clark's export displaces. The price will be calculated by multiplying the New England Power average fuel price (including hydro and nuclear) by a factor which depends on time of day and which is designed to convert average fuel price to the displaced oil cost.

5. DETAILED WORK MANAGEMENT PLAN

5.1 Task Definitions and Schedules

In this section we describe the work management plan required for completion of the ICES demonstration program at Clark University. The plan is divided into Phases II-VI. Phase I, just completed, concludes that the optimum ICES would be an ebulliently cooled diesel with electrical output of 1-3 MW, with average load factor of 85%, and with approximately 25-70% of the generated electricity fed to the utility grid.

Phase II focuses on the final selection of the engine and its fuel, completion of the institutional assessment, preliminary design, and a final decision by the Clark Trustees to implement or not to implement construction of the plant.

Phase III is concerned with final design of the demonstration system, specification of operation and maintenance procedures; completion of the negotiations with NEES, completion of the financing and legal requirements, and revision of the energy-economic analysis, if necessary.

Phase IV is concerned with construction and installation of the demonstration system, including management, procurement and reporting thereon.

Phase V involves starting and testing the demonstration system.

Phase VI involves long-term evaluation of the system, largely in terms of energy-economic characteristics.

The essential tasks for each phase, with our proposed schedule for them, are shown in Figures 5.1-1 to 5.1-5.

5.2 Project Costs

We have made estimates of the manpower and equipment required for phases II through VI. From these estimates we have made projections for the total cost of the project. These projections are shown in Table 5.2-1. The costs shown include equipment, construction and engineering costs, certain first-of-a-kind engineering and institutional costs as well as costs directly attributable to the demonstration process per se. They are therefore greater than the costs to Clark shown in Table 3.2-1.

TASK DESCRIPTION

MONTHS

[illegible]

REPORT ON PHASE II TO ERDA

Task 1: Engine System Design

- A. Design analysis, engine plant
- B. Flow diagram
- C. Detailed engine system layout and construction working drawings
- D. Detailed distribution system, building design and work drawings
- E. Mockup and models
- F. Procurement specifications
- G. Construction specifications
- H. Construction cost budget

- A. Design analysis, monitoring system
- B. Monitoring system layout and working drawing
- C. Procurement specifications
- D. Installation specifications
- E. Cost budget

A. Specifications of procedures
B. Operations and maintenance manual

- A. Final resolution of legal issues relating to the Clark University Charter
- B. Final resolution of issues relating to code compliance, environmental impact
- C. Final resolution of financing issues

- A. Final resolution of legal issues relating to the grid connection
- B. Final agreement on grid connection
- C. Design of grid connection

- A. Detailed work plan for subsequent phases
- B. Update cost estimates for subsequent phases

- A. Prepare technical reports detailing regional and national implications of Phases I and II
- B. Prepare draft planning workbook on the Clark planning experience

A. Summary of tasks 1-8
B. Application of support for subsequent phases

Fig. 5.1-3

PHASE IV: CONSTRUCTION

TASK DESCRIPTION	MONTHS																			
	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Task 1: Construction Management Plan																				
Task 2: Engine System Construction																				
A. Building modification and site preparation																				
B. Equipment purchase and procurement																				
C. Component fabrication																				
D. Install engine system																				
Task 3: Monitoring System Installation																				
A. Equipment purchase and procurement																				
B. Equipment installation																				
Task 4: Grid Connection Installation																				
A. Equipment purchase procurement																				
B. Component fabrication																				
C. Equipment installation																				
Task 5: Construction Reports																				
A. Records and reports of deliveries																				
B. Records of installation and construction systems																				
C. Changes in drawings																				
D. Daily construction log and photos																				
Task 6: Demonstration Information Program																				
A. Prepare press release informing local community of construction and implications																				
B. Prepare technical report on regional and national implications of final design adopted.																				
C. Final draft, planning workbook																				
Task 7: Detailed Work Plan																				
A. Detailed work plan, subsequent phases																				
B. Update cost estimates for subsequent phases																				
Task 8: Report to ERDA on Phase IV																				
A. Summary of tasks 1-7																				
B. Application for support in subsequent phases																				

Fig. 5.I-4

PHASE V: STARTUP AND PERFORMANCE TESTS

TASK DESCRIPTION	MONTHS																	
	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Task 1: Demonstration System Installation Test																		
A. Engine system installation test																		
B. Monitoring system installation test																		
C. Report to ERDA on installation tests																		
Task 2: Startup Tests																		
A. Engine system startup tests																		
B. Monitoring system startup test																		
C. Report to ERDA on startup tests																		
Task 3: Performance Tests																		
A. Engine system performance test																		
B. Monitoring system performance test																		
C. Report to ERDA on performance tests																		
Task 4: Demonstration Information Program																		
A. Provide display facilities for demonstration system site visits by general public																		
B. Issue press release informing local community of system startup, availability of site visits																		
C. Publish technical report on monitoring and performance test, indicate implications of this on a regional and national basis. State results in terms of energy-economic models																		

Fig. 5.1-5

PHASE VI: LONG-TERM OPERATION AND EVALUATION

TASK DESCRIPTION

YEARS

	1	2	3	4	5
Task 1: Engine System Operation and Maintenance.					
Task 2: Monitoring system operation and maintenance.					
Task 3: Periodic reports to ERDA on engine system operation and maintenance.					
Task 4: Periodic reports to ERDA on monitoring system results.					
Task 5: Evaluation of Engine System operation and monitoring, report of same to ERDA.					
Task 6: Demonstration Information Program					
A. Issue periodic press releases to inform local community of demonstration system evaluation.					
B. Prepare technical publications for journals and conferences, indicating regional and local impact of system evaluation, state results in terms of energy-economic models.					
C. Update planning workbook.					
D. Continue site visit program as needed.					

Table 5.2-1: Total Costs

Phase	THOUSANDS OF DOLLARS				TOTAL
	Clark	TECO	Fitz	NEES	
II	65	79	37	4	185
III	54	109	51	3	217
IV	36	107	42	2	187
V	58	53	12	3	126
VI	139	64			203
Equipment					449
Civil work					92
Mech & Elec					131
Grid connect.					50
Monitoring					30
TOTAL					1,670

5.3 Replication Costs

We have asked: "What would be the cost, given that a Clark demonstration program exists, for a similar institution to design and install a similar power plant?" The question can not be answered by simply using the task definitions of the demonstration program phase schedules. The reason is that these tasks and phase schedules are explicitly designed to permit maximum control and intervention by ERDA in the direction of the demonstration program, and for this reason they include many activities that would not be engaged in by a replicating institution, including some outright repetition of activities. We have therefore made a new task description with corresponding man-hours which shows that for the FM 1531 KW diesel replication costs would be \$934,000. This analysis is shown in Table 5.3-1. Similar analysis was also performed for the other three candidate systems included in our summary table, 1.5.7-1. Results, with corresponding rates of return, are given a revised summary table which appears as Table 5.3-2.

5.4 Demonstration and First-of-a-Kind costs

Beyond the basic replication cost, full implementation of the R.F.P. involves two distinct aspects as follows.

(1) Demonstration costs. These are costs related to documenting actions taken, evaluating these actions, and reporting on this to ERDA and the general public. They include extensive monitoring, testing, evaluative report writing, and public information efforts. As shown in Table 5.4-1, these tasks account for \$470,000, nearly half of which would be expended in Phase VI: long term operation and evaluation.

(2) First-of-a-kind costs. These costs are related to engineering and institutional problems in constructing a first ICES. They are the most difficult to quantify explicitly in terms of phase schedules. We therefore obtain them by subtracting as follows.

First of a kind costs	Full R.F.P. = implementation	-	Replication costs	-	Demonstration costs
	= \$1,670,000	-	\$934,000	-	\$470,000
	= \$ 266,000				

Table 5.3-1. Replication Cost Analysis

	MAN MONTHS		
	Engineering	Design	Supervision
1.0 Engineering and economic feasibility			
2.0 Detailed Engineering Study	1.0		
Detailed layouts	0.5	1.0	
Detailed cost analysis	0.7		
Grid connection	0.3		
Site and civil engineering	1.5	1.0	
Environmental engineering	0.8		
TOTAL	<u>3.8</u>	<u>2.0</u>	
3.0 Final Design			
General arrangement drawings	1.0	2.0	
Flow diagrams	1.0	1.5	
Electrical drawings and layout	1.0	1.0	
Thermal distribution system drawings & design	0.2	0.1	
Heating and ventilation drawings and design	0.2	0.1	
Structural and acoustics drawings and design	1.0	1.0	
Engine system specifications	1.5		
Electrical specifications	0.5		
Structural and acoustics specifications	1.0	0.7	
Heat and ventilation specifications	0.5		
Thermal distribution system specifications	0.2		
Project purchases, schedules and construction plan	1.5		
Construction cost budget	0.5		
TOTAL	<u>10.1</u>	<u>6.4</u>	
4.0 Installation			
Engine installation			1.5
Electrical installation			0.4
Civil and architectural installation			1.5
Heat and ventilation installation	1.0		0.2
Thermal distribution installation			0.2
Drawing changes	0.5	1.0	0.2
TOTAL	<u>1.5</u>	<u>1.0</u>	<u>4.0</u>
5.0 Test and Startup	0.5		0.5
GRAND TOTAL	15.9	9.4	4.5
Total Engineering Cost		\$183,000	

REPLICATION COST ANALYSIS FOR CLARK ICES

Equipment and construction	\$672,000
Grid connection	50,000
Engineering	183,000
Lawyers, site evaluation	20,000
Instrumentation	10,000
TOTAL REPLICATION COST	<u>\$935,000</u>

TABLE 5.3-2
SUMMARY OF REPLICATION COSTS OF REPRESENTATIVE ICES

Manufac- turer	Elec- trical power ^a (MW)	Fuel oil type	Oil savings ^b (%)	Internal rate of return ^c (%/yr)	Capital cost ^d (\$1000)	Availability
Fairbanks Morse	1.5	#2	19	16	930	Production model
		#6	22	22	970	Hypothetical mo- del, not confirmed
Superior	1.0	#6	17	18	1080	Modified production model, confirmed
Sulzer	3.0	#6	50	15	1955	Modified production model, confirmed

- a. Stated power level is maximum steady power level that can be produced by a given engine. Most engines can be run at about half of the stated level without serious loss of efficiency.
- b. Oil savings represent oil not needed at Clark or at the utility oil-fired power plants as a result of the proposed ICES. Percent savings are based on Clark's anticipated annual use of 30,000 bbls/yr.
- c. Internal rate of return gives payback realized before financing charges. It is based on the assumption that oil prices and all other prices escalate at 6% per year.
- d. Capital costs include engine price, engineering design, installation, and interconnect costs for heat recovery and grid connection. A new building would cost about \$180,000 more.

5.5 Cost Summary

CLARK CONTRIBUTION

Engine system, including construction, installation, engineering, as outlined in Table 3.2-1. \$820,000

ERDA CONTRIBUTION

Grid connection, system testing, explicitly stated as ERDA-supported in R.F.P. (When added to the Clark contribution, above, the result is the replication cost of the Clark ICES.) 114,000

First-of-a-kind costs as outlined in Section 5.4 266,000

Demonstration costs, as outlined in Section 5.4 470,000

Total ERDA contribution, all phases \$850,000

Table 5.4-1. Demonstration levels of effort

Phase	M A N M O N T H S		
	Evaluation & Reporting	Monitoring & Testing	Public Information
ii	4.5		
iii	3.0	1.3	5.0
iv	5.8	2.5	2.7
v	3.7	13.6	4.2
vi	12.5	16.5	9.5
Totals	29.5	33.9	21.4
Total cost	\$164,000	\$190,000	\$116,000
<hr/>			
All demonstration aspects	\$470,000		