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ECONOMIC FEASIBILITY ANALYSIS
OF DISTRIBUTED ELECTRIC POWER
GENERATION BASED UPON THE
NATURAL GAS FIRED FUEL CELL

Draft and Final Progress Report for the Period May 1, 1993 - July 31, 1993

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For:
U.S. Department of Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By:
Manes Associates, Inc.
Huntington Beach, California

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5th Quarterly Report

of Progress on

Cooperative Agreement DE-FC21-92MC29227

for the Period

May 1, 1993 to July 30, 1993

Submitted

to

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INTRODUCTION

This report is an account of the work performed from May 1, 1993 to July 30, 1993, under a cooperative agreement No. DE-FC21-92MC29227, among the US Department of Energy, Fossil Energy, Morgantown Energy Technology Center, The Southern California Gas Company, The Brooklyn Union Gas Company and the Manes Associates, Incorporated. The participants are sponsoring an investigation by the Manes Associates, of the "Economic Feasibility of Distributed Electric Power Generation Based Upon the Natural Gas-Fired Fuel Cell."

The Cooperative Agreement formally began on May 15, 1992, although some work was begun in anticipation of the award. Because of funding delays, the model was not complete by May 15, 1993, and a six month extension to the project was approved by Southern California Gas Company, Brooklyn Union and the Department of Energy. The forecast completion of the project is October 15, 1993.

ECONOMIC FEASIBILITY ANALYSIS OVERVIEW

The "*Economic Feasibility Analysis of Distributed Electric Power Generation Based upon the Natural Gas-Fired Fuel Cell*" is comprised of a survey of energy users, the development of numeric models of an energy distribution system and a central plant utilities system that includes a fuel cell. A model of the capital cost of the hardware elements is combined with a series of ownership scenarios and an operations model that provide the necessary input for a model of the cost of ownership of a fuel cell-based power generation system. The relationship among these elements of the project is represented by Figure No. 1.

Figure No. 1
Elements of An Economic Feasibility Analysis
of Fuel Cell-Based Power Generation

The model development tasks are complete the associated reports are complete and submitted in draft form.

The Combined Use Energy Survey- is a survey of the extensive literature on energy consumption among a variety of user classes was conducted to establish the consumption rates and the relationship between consumption of thermal and electrical energy. The literature survey is supplemented with data on consumption history contributed by 15 industrial energy users in the Southern California area. The data are organized into demand profiles by industry and end-use which are used to model the fuel cell-based utility plant that could satisfy the users energy demands.

The Thermal Energy Distribution System - defines the types of thermal energy distribution systems that are suitable for the distribution of thermal energy to multiple points of use. The primary conclusion drawn from the work is that a four-pipe, hydronic distribution system is most suitable for adaptation of the fuel cell based central plant.

The Central Plant Utility Model- defines The central plant model sizes a fuel cell for one of several user-chosen electrical demand profiles. The thermal energy produced is a dependent variable of the electric energy computed by a model of fuel cell performance and gas consumption. The model computes the thermal energy required for space conditioning and other uses to size an absorption chillier, boiler, thermal accumulator tank and system pumps.

The Ownership Scenarios - define the treatment of revenues, expenses and incentives considered by the economic analysis. The *Ownership Scenarios* are dependent on the owner's contractual and regulatory status with respect to the utility companies in the service area and the owner's customers for the energy produced by the fuel cell. The capital recovery period and the requisite return on investment will also vary by the class of owner, their industry and regulation.

Operations Model - The business operations model computes both the operational cost and the revenue derived from distributed fuel cell operations. The Operations model combines the results of the Operations Scenarios with the Operating Expense Compilation (Task 7), The operating Cost Model (Task 8) and the Cost Recovery Scenario Model (Task 9). The Operations Model bases the fuel cell operating expenses upon gas price forecasts or an input parameter. The maintenance expenses include periodic fuel cell stack refurbishment and the purchase of back up electric power and additional boiler fuel for space heating while the cell is out of service. The revenue stream is imputed from the avoided cost of purchasing electric and thermal energy at rates that are appropriate to the ownership class, time of day and season. The power and thermal energy production rates are computed by the Central Utility Plant Model. An additional revenue stream is derived from investment credit, utility displacement credits or RECLAIM permit sales. In some cases the enabling legislation to support the incentives does not exist. Provision have been included in the operations model to enable the prospective owner to account for this possible source of revenue.

The Cost of Ownership Model is the final product of the series of models represented in Figure No. 1. The model combines the product of the capital cost model, ownership scenarios and the operations model cash flows to compute the cost of ownership. The form of the output is selected from a menu that includes cash flow curves, net present value as a function of capital cost and fuel cost or the internal rate of return on investment. The variety of output forms has been chosen to accommodate the expected interests of the variety of industries that will evaluate the

Economic Feasibility of Distributed Electric Power Generation Based on the Natural Gas-Fired Fuel Cell.

MANAGEMENT ACTIVITIES

The primary model development tasks are complete. The remaining study emphasis is to perform an economic analysis of varied ownership scenarios using the model. The results of these analytical efforts are to be the basis for the final report, due on October 15, 1993. The following paragraphs outline the progress through July 30, 1993.

TASK 1- ANALYTICAL PLAN The *Analytical Plan* was completed during the first reporting period and issued for comment to each of the sponsors. As of this date, no suggestions for additions have been received.

TASK 2- COMBINED USE ENERGY SURVEY - The *Combined Use Energy Survey* was issued for comment during the second quarter of the project. No suggestions for additions or modifications have been received as of this date. The results of the Combined Use Energy Survey are incorporated into the standard plant configuration of the *Central Utility Plan Model*.

TASK 3- DISTRIBUTION SYSTEM MODEL -The *Distribution System Model* is complete. The model contains analytical expressions of equipment size as a function of heat transfer capacity employed by the Central Utility Plant Model to define the most likely plant thermal storage and distribution configurations.

TASK 4 - END-USER EQUIPMENT SELECTION- The *End User Equipment Selection* results have been combined into the distributed energy system employing a fuel cell. The end-user equipment selection identified the major cooling, space conditioning, thermal storage and distribution equipment components to be included with the fuel cell. The equipment chosen are convection circulated "baseboard" heaters and a fan-coil cooling heat exchanger. Potable hot water will be provided by a liquid/liquid heat exchanger.

TASK 5 - CENTRAL PLANT MODEL - The model of the Central Utility Plan is complete. The Central Utility Plan Model report describes the Central Utility Plan configuration and its relationship to the other elements of the project. The central plan model sizes a fuel cell for one of the several user-chosen electrical demand profiles. The thermal energy produced is a

dependent variable of the electric energy computed by a model of fuel cell performance and gas consumption. The model computes the thermal energy required for space conditioning and other uses to size an absorption chiller, boiler, thermal accumulator tank and systems pumps.

TASK 6 - CAPITAL COST MODEL - The Capital Cost Model is complete. The cost of ancillary equipment is forecast by scaling cost data with a series of multiple variable linear regression expressions. The capacity of each element of the central utility plant varies as a variable of the demand profile and the user defined space conditioning requirements. Capital cost varies with manufacture's learning. **TASKS 7 and 8- OPERATIONS MODEL**- The operating cost model is complete. The model provides a choice of natural gas price forecasts. The model includes a forecast of the cost of natural gas fuel, backup electricity, operating personnel and failure (reliability costs).

TASK 9- COST RECOVERY SCENARIO- Cost recovery scenarios are being evaluated for potential fuel cell users including ownership by a natural gas distribution utility. The results of the recovery scenarios will form the basis for the conclusions of the final report.

TASK 10- COST OF OWNERSHIP MODEL - The initial cost of ownership model is completed and test cases described under Task 9 are being prepared. Each scenario provides a cost and revenue or benefits profile for the fuel cell installation. The economic analysis of distributed fuel cells is based upon a comparison of revenue and benefits to cost under defined conditions. In several instances, the fuel cell operating costs per KW are being compared to the cost of Identified Deferrable Resources (IDR's), such as solar and geothermal. This is the method being used to bid and award electric power sales agreements in California under the current emissions legislation. The comparison will indicate those instances or scenarios in which the fuel cell application would provide energy at commercially competitive rate per kilowatt.

TASK 11- FINAL REPORT. The final report is being prepared at this time. Attachment 1 is a working draft outline of the final report to be submitted on October 15, 1993.

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