HARNESSING THE SUN FOR DEVELOPMENT

DRAFT

Actions for consideration by the international community at the U.N. Conference on New and Renewable Sources of Energy for promoting the use of renewable energy in developing countries.

August 1981

By

David J. Jhirad
Vinod Mubayi
Brookhaven National Laboratory

and

Jerome Weingart
Lawrence Berkeley Laboratory and Teknekron Research Inc.

with major contributions from

Charles Case
Lawrence Berkeley Laboratory

Edward Kahn
Lawrence Berkeley Laboratory

Mohammed Massoudi
Teknekron Research, Inc.

Gerald Miller
Teknekron Research, Inc.

Elliot Taubman
Institute for Study of Human Issues

Harry Davitian
Entek Research, Inc.

Richard Leigh
Brookhaven National Laboratory

Marshal Merriam
University of California, Berkeley

Jayant Sathaye
Lawrence Berkeley Laboratory

Prepared by

Brookhaven National Laboratory and Teknekron Research, Inc.
for the United States Agency for International Development
under RSSA No. 16 DOE 1-78 with the U.S. Department of Energy

HARNESSING THE SUN FOR DEVELOPMENT

Actions for consideration by the international community at the U.N. Conference on New and Renewable Sources of Energy for promoting the use of renewable energy in developing countries.

August 1981

By

David J. Jhirad
Vinod Mubayi
Brookhaven National Laboratory

and

Jerome Weingart
Lawrence Berkeley Laboratory and Teknekron Research Inc.

with major contributions from

Charles Case
Lawrence Berkeley Laboratory

Edward Kahn
Lawrence Berkeley Laboratory

Mohammed Massoudi
Teknekron Research, Inc.

Gerald Miller
Teknekron Research, Inc.

Elliot Taubman
Institute for Study of Human Issues

Harry Davitian
Entek Research, Inc.

Richard Leigh
Brookhaven National Laboratory

Marshal Merriam
University of California, Berkeley

Jayant Sathaye
Lawrence Berkeley Laboratory

Prepared by

Brookhaven National Laboratory and Teknekron Research, Inc.
for the United States Agency for International Development
under RSSA No. 16 DOE 1-78 with the U.S. Department of Energy

ACKNOWLEDGEMENTS

We would like to thank our colleagues and professional associates in the Secretariat of the U.N. Conference on New and Renewable Sources of Energy, the World Bank, U.S. AID Office of Energy as well as Brookhaven National Laboratory and Lawrence Berkeley Laboratory for many insights which are reflected in the pages that follow. In particular, we would like to thank Dr. Robert Nathans of the Institute of Energy Research, State University of New York, Stony Brook for providing the initial impetus to many of the ideas embodied in this paper and Mr. William Eilers of the Office of Energy, US AID for his unfailing help and advice in all phases of the project.

To Patricia Miller, who, in a very real sense, is responsible for the production of this paper, no praise can be too high for her tireless and unstinting efforts.

EXECUTIVE SUMMARY

PURPOSE

The purpose of this paper is to provide a set of concrete actions for consideration by the international community present at the United Nations Conference on New and Renewable Sources of Energy (UNCNRSE). The content of the paper is a discussion of the opportunities, barriers, and remedies associated with the introduction and large scale use of renewable energy technologies, particularly in the developing world. To focus the discussion, we have chosen solar industrial process heat as an example of a potentially significant technology for displacing oil in a number of low temperature industrial applications in developing countries. The actual commercial use of such technology on a significant scale throughout both the industrialized and developing regions must be preceded by a number of actions, many of which are nontechnical and common to a wide host of renewable energy technologies or increased energy efficiency technologies. While many of the needed actions must be taken at the national or even local level, there is a set of important initiatives which can be conducted best at the international level, by specialized agencies of the United Nations, by other international organizations such as the World Bank, and through bilateral and multilateral programs involving UN member governments. In particular, there are important opportunities for innovative action by the international financial community.

THE PROBLEM

It is commonplace that the rapid recent increases in the prices of oil and other commercial fuels have created enormous balance of payments problems for oil-importing developing countries. It is also well recognized that any substantial improvements in their living standards will require significant increases in the existing low per capita energy consumption and the efficiency with which this energy is utilized. This difficult situation has in part been responsible for much of the resurgence in interest in the use of renewable sources of energy, including the direct use of solar radiation and the harnessing of the winds, biomass, and thermal gradients in the tropical oceans. While all mankind must ultimately make the transition to primary reliance on some mixture of fission, fusion, and renewable sources of energy for the production of fuels, electricity, and heat, this transition will

almost certainly require the better part of a century. Yet many of the energy related problems developing nations face require resolution over the time scale of the coming few decades.

All of this is further complicated by the dual nature of the energy dilemma of the LDC's. The modern sectors of their economies, in common with the developed world, have to confront the very high and rapidly rising prices of conventional fossil fuels. At the same time, rural communities, in which over half the world's population lives, are experiencing increasing difficulties in obtaining the traditional fuels -- firewood, agricultural residues, and animal dung -- required primarily for cooking. The present scale of firewood consumption in which wood is essentially mined rather than farmed, has led to widespread deforestation, massive erosion of topsoil, increased severity of flooding in many regions, and, in some areas, to desertification. In both cases, renewable energy technologies supplemented by a much greater emphasis on proper energy planning and resource management have important but very different kinds of contributions to make.

The effective mobilization of renewable energy resources to meet these diverse needs continues to elude us. The difficulties are only partly technical, and there is persuasive evidence that the remaining technical problems are likely to be the first to be solved. Much more difficult are the problems associated with the financial, political, and institutional environments in which these technologies will eventually be used.

This United Nations conference provides a special opportunity to initiate a process to identify and resolve the financial and institutional barriers which will continue to inhibit the widespread use of new and renewable energy resources, even after the technologies themselves are essentially proven.

APPROACH

In order to formulate concrete and workable proposals for action, we have drawn extensively on the experience of a diverse group of people in a number of countries. They include government officials, planners, economists, scientists and engineers, manufacturers, industrial and utility professionals, educators and members of the international financial community. Our experiences with countries including Brazil, Peru, the Dominican Republic, Portugal, the Pacific Trust Territories, India, Thailand,

Indonesia, Singapore, Taiwan, Jamaica, Kenya, and others, along with manufacturers of renewable energy technologies in the United States formed the basis for much of the discussion and recommendations in this paper. Each of the authors has had extensive professional experience working with one or more of these countries on problems of energy and development, and most are also expert in one or more of the renewable energy technologies being considered at the Conference.

We have chosen a specific solar energy application, the provision of industrial process heat, as a vehicle to examine the technical, financial, and institutional barriers to the use of renewable energy technologies in the modern industrial sector in developing countries, and to identify various measures to minimize or remove these barriers. In making our choice, we had several criteria in mind. These included picking a renewable energy application where a substantial amount of oil could be displaced, for which the technical components were in a relatively mature stage of commercial development, and for which most or all of the required components could be manufactured within many developing countries over the coming decade. Moreover, consideration of this particular application makes explicit the very important role of increased energy end-use efficiency in saving strategic amounts of oil over the next ten years.

We prefer the term "energy efficiency" to that of "conservation," since energy conservation implies to some people the notion of curtailment or sacrifice. By contrast, we mean doing more with less, and NOT the cutting back of energy-related services. Viewed in this way, increasing the efficiency with which energy is used in industrial, commercial, and transport sectors is an essential component of any energy strategy designed to displace oil as rapidly as technically and economically possible. The use of renewable sources of energy through what is almost always capital intensive technologies, demands that we use energy with as great an efficiency as possible, since the available techniques for increasing energy efficiency are generally more cost effective than new energy supplies, whether conventional or renewable.

SOLAR INDUSTRIAL PROCESS HEAT

To highlight the potential impact of solar industrial process heat technology in a number of the industrializing countries, Figure ES-1 shows the fraction of oil going to industrial process heat and the percentage of that

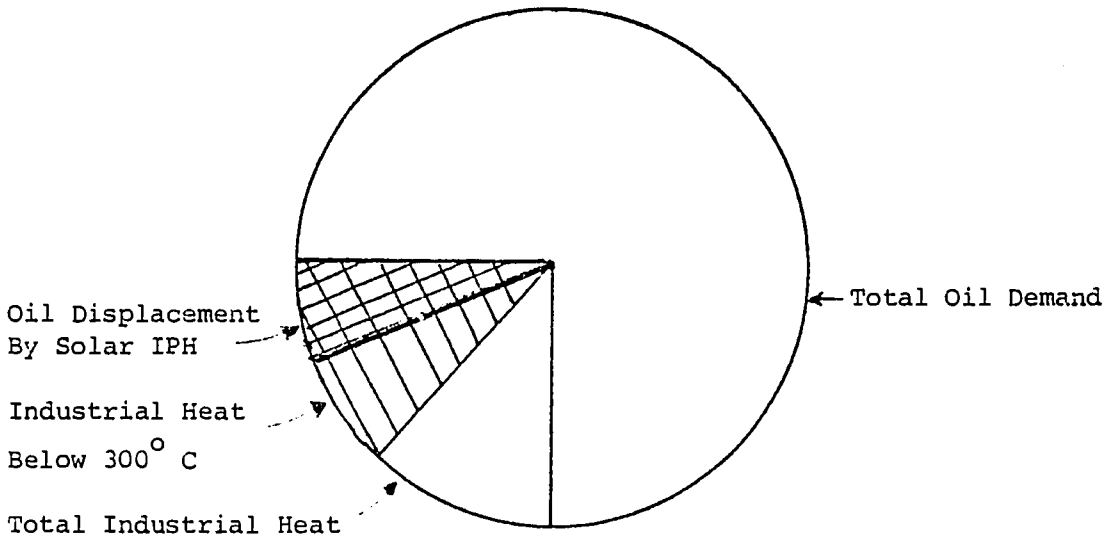


Figure ES-1. Oil Consumed in Industrial Proces Heat
(Average for 7 Developing Countries)

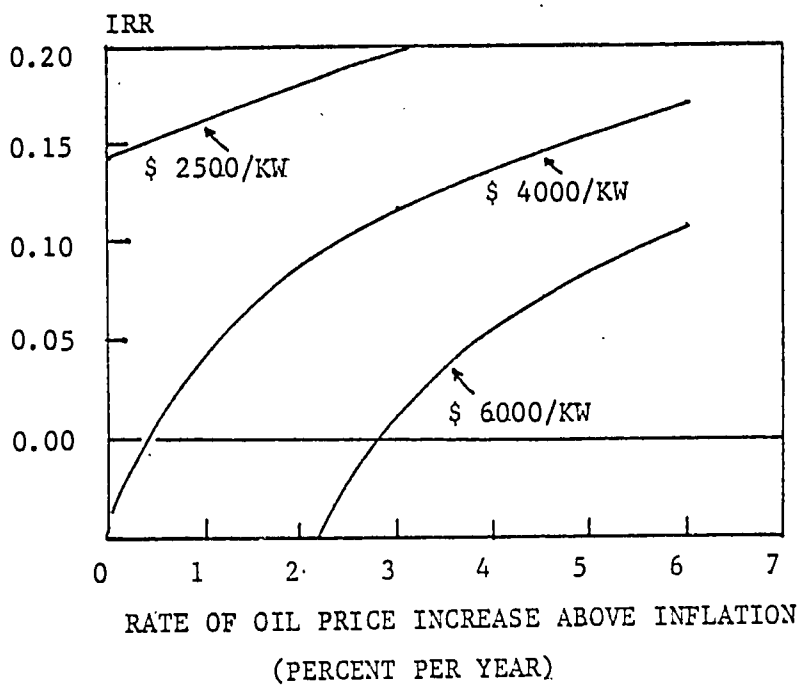


Figure ES-2. IRR vs Oil Price Increase

used at temperatures below 300 °C where current solar technology is proven and available. About a quarter of oil consumption in a number of developing countries goes to heating water or raising steam at temperatures <300 °C. Much of this can be replaced by utilizing various types of solar equipment, flat plate or concentrating collectors, solar ponds, etc. discussed in detail in the main body of the paper.

The economic rationale for this substitution is illustrated in Figures ES-2, ES-3, and ES-4 which show the internal rates of return (IRR) on an investment in a solar IPH facility under various assumptions of capital cost, increase in oil prices, and financial policy parameters. (The IRR is frequently used by international financial institutions as a criteria for project evaluation.)

Figures ES-3 and ES-4 display the significant impact that financial policy variables such as investment tax credits and debt interest rates have on the IRR for a solar IPH investment. Since a project IRR greater than 10% is generally regarded in a favorable light by development banks, it is clear that SIPH systems can already be regarded as acceptable investments in many instances. Changes in the financial policy variables can create incentives on the part of end users to install such systems with a net benefit to the national economy in saving on imported oil.

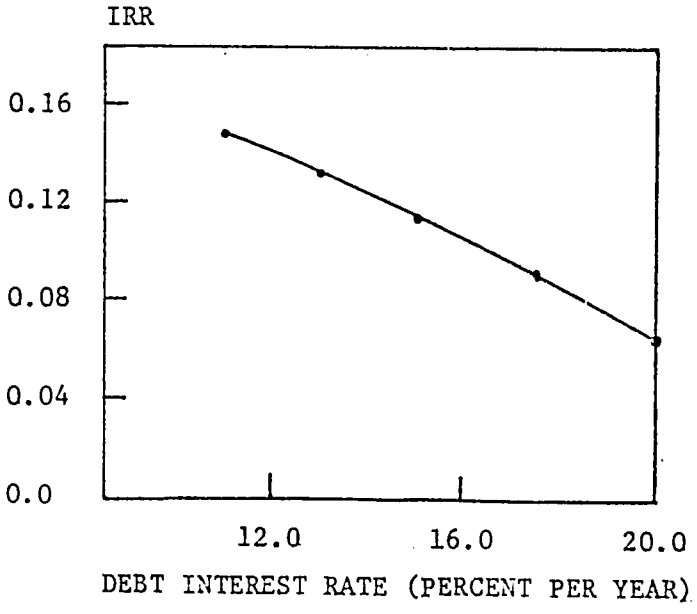


Figure ES-3. IRR vs Debt Interest Rate

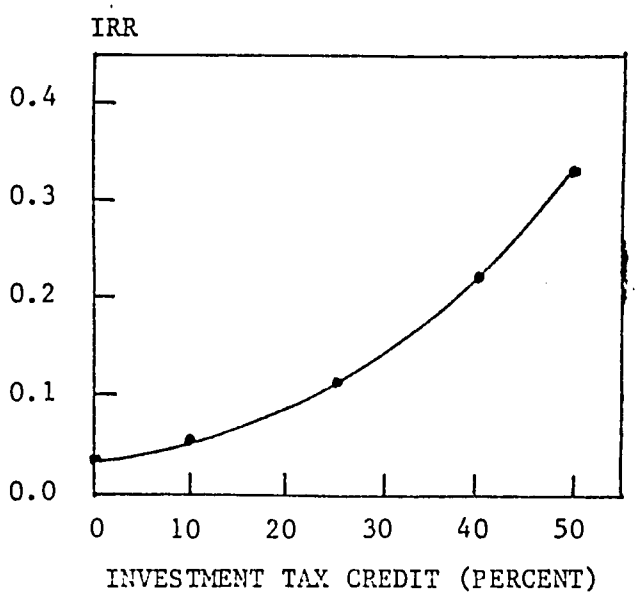


Figure ES-4. IRR vs Investment Tax Credit

Among the major barriers to implementation of renewable energy technologies are:

- Lack of availability of capital and financing
- Deficient financial criteria for investment in capital-intensive systems
- Inadequate mechanisms for technology transfer to the developing countries
- Regulatory laws and procedures
- Absence of accepted test and certification procedures for products.

In suggesting and discussing remedies to the above barriers mentioned, we focus on specific actions that can be taken by the international community through the UNCNRSE to reduce or eliminate these barriers.

- The UN should strongly encourage its member nations and the development banks to allocate a small fraction of their total investment in urban, industrial, and agricultural development projects to a fund for exploring the potential role of renewable energy systems in specific projects.

- The UN should urge the development banks and donor agencies (both national and United Nations affiliated) to adopt economic and financial accounting procdures that permit clear and consistent comparisons between the costs and benefits of renewable and conventional energy technologies.

- The UN should encourage the World Bank and other regional development banks, donor agencies, and member governments to adopt investment criteria and tax structures to reduce the annualized costs of capital intensive energy systems if the benefits of such systems are found to be superior to those of fuel-intensive energy systems performing equivalent tasks and matched to similar applications. Schemes to offer economic incentives to investors in renewable technologies that displace oil should be created and adopted.

- The UN should ensure that commercialization activities in LDC's of manufacturers from advanced industrial countries are accompanied by assistance in research, development, and training in order that the technology transfer process is open and dynamic. Such assistance should help to alleviate legitimate concerns in LDC's about being locked into obsolete technologies and new forms of technological dependence.

- The UN should help to provide the international financial institutions and all donor agencies with complete, consistent, and up-to-date information on the costs, performance, and

commercial availability of a wide range of energy technologies in a variety of climatic and financial settings. Such an international data base should be continually updated, and should contain country-specific information on capital costs, labor costs, materials availability, and technology import requirements. All member nations and donor agencies sould have cost effective access to the energy technology data base.

- The UN should urge its member nations to examine carefully their respective regulatory structures with a view to creating a symmetrical and favorable economic environment for renewable energy technologies that use scarce fossil fuels with greater efficiency. Regulatory obstacles affecting the production of decentralized power or the export of electricity to central grids from cogenerators and small power producers should be removed.

- Decision-makers, whether they are development banks, private investors, companies, government agencies, utilities, or others require accurate and comprehensive information on the technical characteristics and performance of renewable energy equipment. The UN Conference could help in coordinating actions at the international, national, and regional level to accelerate the widespread development and use of procedures and standards to test, evaluate, and certify a variety of renewable energy products. Such actions could be taken in concert with the International Solar Energy Society and a network of national and regional institutions.

- Training programs in the assembly, operation and maintenance of renewable energy technologies need to be offered on a much wider and expanded basis. The UN could coordinate such programs on a systematic basis at an international level through one of its specialized agencies or other appropriate body that may be set up by the UNCNRSE.

CONCLUSIONS

There are very substantial opportunities for the use of renewable sources of energy on a strategically important scale. But there is also an array of technical, financial, and institutional barriers to the commerical development and implementation of these technologies. In many cases, the non-technical barriers should be subject to change through governmental policy actions. We have concluded that there is a real opportunity for the United Nations and the international community to act to resolve the nontechnical problems inhibiting the use of renewable energy sources. These actions can also help to speed up the pace of technical development as the other constraints to widespread use are removed.

TABLE OF CONTENTS

1 Introduction 1

2 Industrial Process Heat Use in Developing Countries 5
2.1 Portugal 5
2.2 Dominican Republic 7
2.3 Thailand 8
2.4 Korea 9

3 Solar Industrial Process Heat 11
3.1 Potential Markets and Applications 11
3.2 Solar Thermal Technology: Flat Plate, Evacuated Tube, and Parabolic Trough Collectors 14
3.3 Solar Thermal Technology: Solar Ponds 16
3.4 Preliminary Results from U.S. Solar Pond Installations 23
3.5 Preliminary Results from U.S. Low-Temperature Industrial Process Heat Field Tests 25
3.6 Solar Industrial Process Heat: Some U.S. Case Examples 29
3.6.1 Campbell Soup Solar Hot Water System, Sacramento, CA 33
3.6.2 Johnson & Johnson Solar Low Pressure Steam, Sherman, TX 35
3.6.3 Solar Heating and Cooling, CDC World Distribution Center, St. Paul, MN 37
3.7 Solar Industrial Process Heat and Energy-Efficient Technologies 39

4 Solar Industrial Process Heat -- Financial and Economic Analysis 45
4.1 Introduction 45
4.2 The Internal Rate of Return as an Instrument for Investment Decisions 46
4.3 Financial Analysis Procedures for Renewable Energy Systems 48
4.3.1 Introduction 48
4.3.2 Computer-Based Financial Analysis for Solar Industrial Process Heat 48
4.4 Economic Considerations and Uncertainties in Solar IPH Financial Analysis 49

5 Investment Analysis of Solar Industrial Process Heat Systems 55
5.1 Introduction 55
5.2 Solar Industrial Process Heat for a Brewery in Zimbabwe 55
5.2.1 Introduction 55
5.2.2 The Solar Brewery 56
5.2.3 Parametric Financial Analysis for the Zimbabwe Brewery 57
5.2.4 Conclusions 64
5.3 Influence of Policy-Controlled Financial Variables and Technology-Dominated Economic Factors on the Internal Rate of Return for Solar Industrial Process Heat 69
5.3.1 The Basis of the Financial Analysis 69
5.3.2 The Variable Parameters 71
5.3.4 Case Study Examples 75
5.4 Conclusions 81

6 Barriers and Remedies..... 83
6.1 Generic Barriers to Implementation..... 83
6.2 Role of International Financial Institutions..... 83
6.3 Remedies to Generic Barriers..... 85
6.4 Development of Procedures and Mechanisms for Test and Certification of Renewable Energy Technologies and Products..... 88

References..... 93

Appendix A: Creating Incentive Schemes for Renewable Energy Projects in Developing Countries

Appendix B: Regulatory Developments to Encourage Renewable Resource Development and Efficiency: Implications of Recent Experience in the United States

Appendix C: Renewable Energy Institutions for the Developing World: The Potential Relevance of Recent U.S. Regulatory, Legal, and Institutional Experience

Appendix D: Small-Scale Energy Technology Projects in the Pacific Territories: A Case Study Review

Appendix E: Industrial Process Heat Applications and Annual Requirements in the United States (1974)

LIST OF TABLES

Table 2.1 Industrial Process Heat in Portugal..... 5

Table 2.2 Process Heat Demand by Major Industry in Portugal..... 6

Table 2.3 Fuels Used to Produce Industrial Process Heat, 1977..... 6

Table 2.4 Industrial Energy Consumption in the Dominican Republic..... 7

Table 2.5 Industrial Energy Consumption in Thailand by Fuel Type..... 8

Table 2.6 Industrial Process Heat in Korea..... 9

Table 2.7 Sectoral Breakdown of Industrial Process Heat in Korea..... 10

Table 3.1 Potential Contributions of Solar Industrial Process Heat by the Year 2000 in the United States and in an LDC..... 12

Table 3.2 Industries With a Significant Portion of Energy Use at Or Below 290 °C..... 13

Table 3.3 17

Table 3.4 19

Table 3.5 24

Table 3.6 Solar-Augmented Application in Industry..... 26

Table 3.7 System Performance of IPH Field Tests..... 30

Table 3.8 System Performance of IPH Field Tests..... 31

Table 3.9 Costs of the Low-Temperature IPH Field Tests..... 32

Table 3.10 Capital Costs of Competing Technologies for Low Temperature Industrial Applications..... 43

Table 4.1 Economic and Financial Factors Used to Compute the Internal Rate of Return for a SIPH System Investment..... 49

Table 4.2 Characteristics of Solar Radiation as an Energy Source..... 52

Table 4.3 Factors Contributing to the Average Capital Cost of a Solar Industrial Process Heat Facility..... 53

Table 5.1 Summary of Specifications for Solar IPH System for Zimbabwe... 56

Table 5.2 Economic and Financial Parameters for the Zimbabwe SIPH Example..... 57

LIST OF TABLES (Continued)

Table 5.3 Economic and Financial Parameters Used in the Financial Analysis of the Zimbabwe Solar Industrial Process System..... 58

Table 5.4 Independent Variables and Parametric Variables for Solar IPH Internal Rate of Return Calculations..... 69

Table 5.5 Parameters and Values Chosen for Sensivity Analysis..... 70

Table 5.6 Economic and Financial Parameters for the Base Case..... 70

Table 5.7 Various Estimates of Increases in Real World Oil Price..... 72

Table 5.8 Internal Rate of Return for the Base Case, as a Function of Rate of Oil Price Increases and Capital Costs..... 75

Table 5.9 Internal Rate of Return for the Base Case as a Function of System Capital Cost and Oil Prices..... 77

Table 5.10 Internal Rate of Return as a Function of Investment Tax Credit for the Base Case..... 77

Table 5.11 Internal Rate of Return as a Function of Percent Equity, for the Base Case..... 80

Table 5.12 Internal Rate of Return as a Function of Debt Interest Rate, for the Base Case..... 80

LIST OF FIGURES

Figure 3.1 15

Figure 3.2 Campbell Soup Solar Hot Water System Schematic..... 34

Figure 3.3 Simplied Schematic of Johnson & Johnson Solar Steam Supply System..... 36

Figure 3.4 Integrated Solar System CDC World Distribution Center..... 38

Figure 3.5 Cost Trends in Trough IPH Projects.....39

Figure 3.6 Capital Cost vs Technology..... 43

Figure 4.1 Determination of Internal Rate of Return for a Solar Industrial Process Heat System..... 50

Figure 5.1 Internal Rate of Return as a Function of System Cost Zimbabwe Solar Industrial Process Heat Case Example..... 59

Figure 5.2 Internal Rate of Return as a Function of Fuel Cost for Zimbabwe Solar Industrial Process Heat Case Example..... 60

Figure 5.3 Internal Rate of Return as a Function of Investment Tax Credit for the Zimbabwe Solar Industrial Process Heat Case Example... 61

Figure 5.4 Internal Rate of Return as a Function of System Life for the Zimbabwe Solar Industrial Process Heat Case Example..... 62

Figure 5.5 Internal Rate of Return as a Function of Debt Interest Rate for the Zimbabwe Solar Industrial Process Heat Case Example... 63

Figure 5.6 Internal Rate of Return as a Function of Percent Equity for the Zimbabwe Solar Industrial Process Heat Case Example..... 65

Figure 5.7 Internal Rate of Return as a Function of Fuel Escalation Rate for the Zimbabwe Solar Industrial Process Heat Case Example... 66

Figure 5.8 Internal Rate of Return as a Function of Operation, Maintenance, Property Tax, and Insurance for the Zimbabwe Solar Industrial Process Heat Case Example..... 67

Figure 5.9 Internal Rate of Return as a Function of Straight Line Depreciation Period for the Zimbabwe Solar Industrial Process Heat Case Example..... 68

Figure 5.10 Internal Rate of Return as a Function of the Rate of Increase in Oil Prices and of SIPH Capital Cost, for the Base Case System..... 76

Figure 5.11 Internal Rate of Return as a Function of Capital Cost and Oil Prices for the Base Case SIPH System..... 76

LIST OF FIGURES (Continued)

Figure 5.12 Internal Rate of Return as a Function of Investment Tax Credit for the Base Case SIPH System..... 78

Figure 5.13 Internal Rate of Return as a Function of Percent Equity, For the Base Case SIPH System..... 79

Figure 5.14 Internal Rate of Return as a Function of Debt Interest Rate, for the Base Case SIPH System..... 79

1 INTRODUCTION

The technical feasibility of generating heat, mechanical or electric energy by using renewable energy sources such as solar or wind has long been demonstrated. However, the economic feasibility of using renewable energy equipment in industrial, agricultural, or residential applications is still viewed with considerable skepticism by policymakers and planners responsible for making investment and other energy policy decisions. Part of this skepticism is, no doubt, well founded since economic competitiveness for a number of solar technologies in comparison with conventional alternatives still lies somewhere in the future. However, some of the skepticism needs correction since it is either based on lack of knowledge about the actual performance of solar equipment or on the practice of making overly facile economic comparisons with fossil-fuel systems.

This paper reviews the technical and economic evidence for one particular solar application, solar industrial process heat (IPH), which, in the authors' opinion, is already near-competitive with existing oil-based systems and which appears to offer the largest near-term potential for saving oil. Our analysis highlights the fact that financial parameters, such as tax credits and depreciation allowances, play a very large role in determining the economic competitiveness of solar investments. This is to be expected for systems which are completely dominated by front-end capital requirements in sharp contrast with oil-based systems where the running costs of fuel will usually predominate over the system's lifetime.

It is well-known that the rise in oil prices over the last decade has put oil-importing developing countries in a very severe balance-of-payments problem where the choice confronting many countries has become, in the words of the UNCNRSE Synthesis Paper, "oil or food or (other) essential imports." This paper analyzes the energy and oil consumed in providing industrial process heat in a number of developing countries. Our choice of solar IPH as a case study is dictated in part by our belief that solar IPH systems can lead to substantial near-term oil savings in a large number of developing countries particularly in their food processing, textile, and other industries which require large amounts of low to medium temperature hot water and steam. We also feel that the relevant policy actions on the part of national

governments, international lending institutions, and other policy- and decision-makers which will play a significant role in stimulating the developing of solar options are probably a great deal easier to implement within the organized industrial sector. However, the choice of solar IPH is primarily intended as an example of a case study of one particular application. We do not mean to downplay the potentially very important role renewable energy can play in meeting other essential energy needs pertaining to economic and social development in the developing countries such as, for example, the energy needs of rural households and food production.

The plan of this paper is as follows:

(i) Introduction

(ii) The second chapter presents an analysis of the energy (and oil) consumed in providing industrial process heat in a number of selected developing countries where the authors have had access to detailed data. We find from this sample that oil consumption in industries where solar systems can provide an acceptable technical alternative is sufficiently large to merit a detailed analysis.

(iii) The third chapter provides a discussion of solar IPH technology including the operating experience of several demonstration plants in the U.S. We also provide a brief description of solar ponds which appear to be very promising and low-cost alternatives to the more conventional collector systems.

(iv) The fourth chapter describes financial and economic analysis of solar IPH systems under different assumptions on future oil prices, and various financial parameters such as tax credits, depreciation allowances, etc. We find that the financial parameters, most of which are amenable to policy changes, can have a major impact on the economic feasibility of solar IPH systems.

(v) The fifth chapter summarizes financial analyses for a solar IPH retrofit of a brewery in Zimbabwe, and a high efficiency system operating in financial conditions typical of the United States and a number of other industrialized nations. In both cases, a parameteric analysis of the impact of changes in the financial parameters on the internal rate of return for the systems is conducted. The chapter concludes with a set of recommended policy

17

actions for countries wishing to enhance the commercial feasibility of renewable energy technologies in the commercial/industrial sector.

(vi) The concluding chapter discusses various barriers and remedies to development of solar IPH including the potential role of international financial institutions such as the World Bank and the regional development banks. The issues of test and certification procedures for solar equipment, establishment of standards, and the training of personnel are analyzed.

2 INDUSTRIAL PROCESS HEAT USE IN DEVELOPING COUNTRIES

The rapid growth of oil consumption in the developing countries has been attributed to two major determinants of energy use - industrialization and urbanization. The underlying sectors of energy consumption that have grown most rapidly are industrial energy consumption and transportation.

Industrial energy consumption can be broken down into three major categories: 1) non-energy or feedstock uses of energy products, such as coking coal for steel production and oil or natural gas for ammonia/urea production, 2) industrial process heat, and 3) non-substitutable uses of electricity, such as electric drive and electrolysis.

We have compiled data on current and projected process heat demands in industry from a number of country studies. The level of detailed data that were available varied somewhat between countries.

2.1 PORTUGAL

Data for Portugal are based on a study of energy-economy interactions performed at Brookhaven National Laboratory for the U.S. Department of Energy.[1] The base year selected for this study was 1977 and projections were made for the year 1990, 2000, and 2010 based on mid- and long-term sectoral economic growth rates provided by the government of Portugal. Sectoral demand for energy services, such as process heat, motive power, feedstocks, in contrast to demand for fuels alone, were developed through an energy input-output representation of the economy in which fuels, energy services, and the non-energy sectors were linked in an interindustry accounting table.

Table 2.1 shows the demand for industrial process heat in 1977 and as projected for the year 1990 and 2000 under two scenarios (I = high growth and II = low growth) of sectoral economic growth.

Table 2.1
Industrial Process Heat in Portugal
(10^{15} joules)

	Projected			
	1990		2000	
Actual 1977	Scenario I	Scenario II	Scenario I	Scenario II
49.7	124.4	100.3	213.4	162.5

19

Table 2.2
Process Heat Demand by Major Industry in Portugal
(% Total)

	Actual	Projected			
		1990		2000	
	1977	Scenario I	Scenario II	Scenario I	Scenario II
Cement	24.4	23.4	24.6	22.1	26.0
Pulp & Paper	13.3	11.7	16.4	13.1	17.8
Food & Beverages	15.4	11.6	13.6	12.2	12.3
Chemicals	8.9	10.8	12.3	11.0	13.6
Nonmetallic Minerals	9.4	9.3	9.9	10.5	9.5
Textiles	9.1	6.1	5.6	5.3	2.4
Glass	4.9	8.8	5.2	10.3	4.3
Other	14.6	18.3	12.4	14.5	14.1

In 1977, industrial process heat accounted for about 31% of total energy service demand (net of losses in production, conversion, and end use). Table 2.2 shows the percentage breakdown of process heat by major industry. It is seen that food and beverages and the textile industry together account for almost 25% of industrial process heat. These are the industries which have temperature ranges of greatest interest from the point of view of solar devices to produce low temperature process hot water or steam.

Table 2.3 provides a breakdown of the fuels utilized to produce industrial process heat in 1977. Because of the way the data were collected and analyzed, electricity used for process heat is excluded from this breakdown; it is included instead in the service demand for electricity.

Excluding electricity, almost 30% of which in Portugal is generated by oil-fired plants, we see that oil accounted for almost 90% of industrial process heat demand in 1977. It should be recalled that all of Portugal's oil is imported, either as crude or refined products and that oil accounted for about 70% of Portugal's total energy consumption. Since oil imports

Table 2.3
Fuels Used to Produce Industrial Process Heat, 1977

	10^{15} joules	% Total
Coal	1.6	2.1
Oil Products	69.0	88.5
Biomass	6.9	8.8
City Gas	0.5	0.6

20

contribute very significantly to Portugal's trade deficits, a situation which is expected to worsen considerably under a "business-as-usual" scenario, reduction of oil consumption by indigeneous renewable resources, coupled with increased efficiency in industrial energy use, can play a significant and important role in Portugal's energy planning.

2.2 DOMINICAN REPUBLIC

Data for industrial energy consumption in the Dominican Republic (D.R.) are based on a study of energy strategies for the D.R. performed by Energy/Development International[2] and on some earlier work done at Brookhaven National Laboratory.[3] Data were not available by type of energy service demand, but only in the form of fuels directly consumed in different industries. However, the consumption of fuel oil, LPG, and wood/charcoal is a close indicator of the demand for process heat. Table 2.4 presents estimated data on fuel consumption in different industries in 1978. Industrial energy consumption in the D.R. is completely dominated by the sugar industry and the use of sugar cane bagasse as a fuel in sugar refining. Bagasse accounts for over half of all industrial energy consumption.

Excluding the sugar industry, the industries with the most potential for low temperature process heat applications consume approximately 10% of the fuel oil and 25% of the diesel used by all industry. A portion of the diesel consumed goes to on-site power generation or to transport within the industry

Table 2.4
Industrial Energy Consumption in the Dominican Republic, 1978
(10^9 Btu)

Industry	Fuel Oil	Diesel	LPG	Wood/ Charcoal	Bagasse	Purchased Electric
Cement	5051	323				653
Mining	7613	1193	3443*			174
Sugar	2472	444		43	29,001	95
Food & Beverages	1285	468	95	970	13	279
Glass	352	6	59			20
Paper	295					49
Petroleum Refining	1537		78**			69
Textiles	67	21				45
Chemicals	47	67				39
Iron and Steel	180	17				225
Total	18,300	2538	3676	1013	29,014	56,788

*Naphtha.
**Refining gas.

and so cannot be counted in terms of replacement by alternative process heat technologies. However, given the extremely serious economic impact of oil imports on the D.R.'s economy where imported oil accounts for more than 50% of all export earnings, replacement of oil consumption in any sector by indigenously available resources can be expected to have a beneficial result in freeing scarce foreign exchange for other essential imports. This is especially so in view of the recent concessional terms offered by Venezuela and Mexico to the Dominican Republic and other Caribbean islands who have been particularly hard hit by the rise in oil prices. Under this arrangement, Venezuela and Mexico, the principal suppliers of oil to the Caribbean, will offer oil at a concessional price whose difference from the world market price will be put into a special fund from which long-term (20 year) loans for energy development projects utilizing indigenous resources will be available at nominal interest rates of two percent. This creates a positive incentive for investments in technologies such as solar IPH designed to replace some oil.

2.3 THAILAND

Table 2.5 is a schematic of the fuel consumption in some major energy consuming industries in Thailand.[4]

It is significant that almost 30% of the total oil consumed in industry takes place in two industries requiring low temperature process heat, textiles and food products. From disaggregated data on type of oil product utilized we estimate that almost 75% of the oil consumed in these industries was fuel oil used to provide process heat. The high fraction of energy used in these industries compared with total industrial energy consumption suggests that a significant role for solar IPH may be possible.

Table 2.5
Industrial Energy Consumption in Thailand by Fuel Type, 1979
(10^{15} joules)

Industry	Oil	Electricity
Mining	3.1	0.4
Food Products	10.3	3.0
Textiles	8.7	4.8
Chemicals	4.8	1.0
Non-Metallic Minerals	29.1	2.1
Construction	3.8	0.1

22

2.4 KOREA

Data for Korea are based on an ongoing study at Brookhaven National Laboratory of energy-economic interactions in Korea for the U.S. Department of Energy.[5] Energy service demands have been calculated and projected through an inter-industry accounting methodology similar to that developed for Portugal. These projections are being driven by a macro-economic model of the Korean economy developed by the Korea Development Institute.

Table 2.6 shows the demand for industrial process heat in Korea in 1975, 1979, and 1986, and the primary fuels used to produce it. The process heat service demands were calculated from the primary fuels use at an average end-use efficiency of 0.49, the actual efficiency estimated for the base year 1975. This rather low efficiency for converting fuels to useful heat actually points to the substantial potential for energy efficiency improvements.

Table 2.6
Industrial Process Heat in Korea
(10^{15} joules)

Year	Coal	Oil	IPH Fuel Demand	IPH Service Demand
1975[1]	24.4	258.2	282.6	139.4
1979[2]	41.8	442.4	484.2	238.9
1986[3]	168.4	1783.3	1951.7	962.7

[1]Actual.
[2]Estimated.
[3]Projected.

On account of the way the data were collected and analyzed, Table 2.6 excludes the use of electricity to produce industrial process heat; such use of electricity is included in the service demand for electricity. The table shows that, excluding electricity, over 90% of IPH demand is met by oil. currently, about 82% of electricity is generated by oil-fired plants although the very ambitious nuclear power plant expansion program will lead to a decrease in this percentage over the next two decades. In addition, oil accounts for over 61% of total primary energy requirements, and, since Korea has no domestic oil production, oil imports impose a staggering burden on the Korean economy. Current energy planning in Korea is dominated by the need to reduce oil dependence.

Table 2.7 shows the breakdown of industrial process by major industry.

Table 2.7
Sectoral Breakdown of Industrial Process Heat in Korea
(10^{15} joules)

Industry	1975	1979	1986
Iron & Steel	12.4	34.7	73.2
Food	7.2	12.5	66.4
Textile	11.1	17.5	106.7
Chemical & Petrochemical	2.5	4.0	29.3
Fertilizer	7.0	9.4	48.2
Rubber & Synthetic Resin	7.2	12.5	59.7
Non-Metallic Minerals	15.8	27.5	70.1
Paper & Printing	2.1	3.8	19.5

The food and textile industries, both of which are potentially good candidates for low and medium temperature solar IPH applications, accounted for about 12% of total IPH service demand in 1979; this is projected to rise above 16% by 1986.

3 SOLAR INDUSTRIAL PROCESS HEAT

3.1 POTENTIAL MARKETS AND APPLICATIONS

Solar energy can be converted to heat and be supplied at any temperature required by industry. Because of the higher cost of high-temperature collection systems, as well as the sensitivity of solar thermal system efficiency to operating temperature, the use of solar energy has been found most cost-effective at process temperatures below about 290 °C. In order to determine the share of industrial process heat that can be supplied by commercially available solar thermal systems, a knowledge of total energy consumed by the industrial sector, and the temperature distribution of industrial process heat (IPH) energy consumption is required.

In the U.S., about 37% of the annual total gross energy demand of 82 EJ is consumed by industry. Approximately half of this industrial demand, or about 16 EJ, is consumed for industrial process heat. Since about 27 percent of industrial process heat requirements are at temperatures below 290 °C, the potential market for solar thermal energy systems is large, about 4 EJ of annual thermal energy production.

Table 3.1 suggests that a goal of 0.3 percent of total U.S. primary energy use might be supplied by solar IPH by the year 2000. This corresponds to energy savings of 42 million barrels of oil equivalent per year, if in the year 2000 the United States used energy at the present rate of 36 million barrels of oil equivalent per day. If oil costs $50 per barrel (1981 dollars) in the year 2000, a very modest assumption given the experience of the past decade, the annual savings would be worth approximately $2 billion. This is certainly a sufficiently interesting market to stimulate a commercial solar IPH industry in the U.S., provided the stream of savings can amortize investments in solar IPH equipment.

In many developing countries, the potential share of total energy which might be provided by SIPH technology could be much higher than in the United States. This is because in many LDC's, the industrial sector constitutes a larger fraction of total commercial energy use than in many industrialized nations, and because a larger fraction of industrial heat use is at temperatures most suitable for SIPH applications. In addition, many LDC's have their industries located in areas with considerable solar energy. In Portugal, as shown in Table 2.2, the food and beverage industry and the

Table 3.1

Potential Contributions of Solar Industrial Process Heat by the Year 2000 in the United States and in an LDC

Energy Sector	Fraction of the Total Energy Sector	
	United States	Possible LDC[1]
Total country	1.0	1.0
All industry[2]	0.3	0.4
Industrial heat[3]	0.6	0.8
Industrial heat below 300 °C [4]	0.25	0.5
Fraction of heat provided by solar IPH[5]	0.4	0.4
Fraction of industrial operations with SIPH	0.20	0.33
Fraction of total national energy provided by solar IPH	0.0036	0.021

[1]These are guesstimates for an LDC with an industrial sector now using a substantial fraction of total imported fuels, primarily petroleum. The assumptions include a sunny environment, a preponderance of lower temperature industrial processes and good physical opportunities for retrofit of solar IPH units to existing industries.

[2]We assume that the industrial sector will be a larger component of total energy demand than in the United States or other industrialized nations.

[3]This is the fraction of the total energy which goes into the industrial sector which is delivered as process heat (as contrasted with thermal requirements for space heating and air conditioning in those industries).

[4]In the hypothetical LDC example, half of the industrial process heat requirements are assumed to be below 300 °C.

[5]This fraction represents an upper limit in most cases. For the majority of solar IPH systems the actual fraction will be lower, in the range 0.2 - 0.35.

textile industry account for one quarter of the industrial energy demand, which in turn is 31% of total energy service demand in the country. If one third of the energy required in these two industries was provided from solar IPH systems, the fraction of total energy service demand in the country available from solar energy would be (0.33 x 0.25 x 0.31 =) 2.7 percent. In Indonesia, 87 percent of commercial energy use is provided by petroleum products. Manufacturing activities require 18 percent of total energy demand, and roughly 30 percent of that is for two industries - food and

26

beverages, and textiles. If one third of the petroleum required for these two industries were supplied by solar IPH systems, about 1.6 percent (0.87 x 0.18 x 0.30 x 0.33) of total commercial energy requirements in Indonesia would be displaced. These two examples correspond fairly well to the hypothetical LDC discussed in Table 3.1.

In our hypothetical LDC example, roughly seven times more energy, as a fraction of total energy, could be provided by solar IPH than in the case of the United States. If this were true, a country using only two percent of the energy used in the United States would still constitute a market of about 300 million dollars per year (oil import savings).

Table 3.2 lists the U.S. industries with a significant portion of energy use at low and intermediate temperatures. Solar thermal applications

Table 3.2

Industries With a Significant Portion of Energy Use at Or Below 290 °C

Industries Below 100 °C	
Meat Packing (2011)	Synthetic Rubber (2822)
Poultry Dressing (2016)	Noncellulosic Fibers (2824-Rayon & Acetate)
Natural Cheese (2022)	Explosives (2892)
Soft Drinks (2086)	Leather Tanning & Finishing (3111)
Finishing Plants (2262)	Concrete Block (3271)
Wooden Furniture (2511)	Ready Mix Concrete (3273)
Upholstered Furniture (2512)	Inorganic Pigments (2816)
Plastic Materials & Resins (2821)	Automobiles & Trucks (3711,3712,713)
Industries Between 100° and 177 °C	
Wet Corn Milling (2046)	Pulp Mills (2611)
Cane Sugar Refining (2062)	Paper Mills (2621)
Beet Sugar (2063)	Paperboard Mills (2631)
Soybean Oil Mills (2075)	Building Paper (2661)
Animal and Marine Fats (2077)	Solid & Corrugated Fiber Boxes (2653)
Shortening & Cooking Oil (2079)	Alkalies and Chlorine (2812)
Malt Beverages (2082)	Cyclic Intermediates (2865)
Cigarettes (2111)	Alumina (28195)
Tobacco Stemming & Redrying (2141)	Pharmaceutical Preparations (2834)
Finishing Plants, Cotton (2261)	Organic Chemicals (2869)
Finishing Plants, Synthetic (2262)	Paving Mixtures (2951)
Sawmills and Planning Mills (2421)	Asphalt felts and coatings (2952)
Plywood (2435)	Tires and Inner Tubes (3011)
Veneer (2435 and 2436)	Gypsum (3275)

SIC codes in parenthesis.

27

currently exist in at least 18 different four digit SIC (Standard Industrial Classification) industries, providing process hot water or steam from temperatures ranging from 60 to 290 °C. A more detailed table of industrial process heat applications and annual requirements in the United States is presented in Appendix E. Extensive data on industrial process temperature requirements in the U.S. are available in References 6 and 7.

3.2 SOLAR THERMAL TECHNOLOGY: FLAT PLATE, EVACUATED TUBE, AND PARABOLIC TROUGH COLLECTORS

Solar energy for process heat can be supplied through hot water, low pressure steam or hot dry air. Hot water may be supplied by directly heating water in the collector absorber tubes and piping this water to the process terminals or a separate fluid may be circulated through the collector and then used to heat water in a heat exchanger. There are several ways to produce low-temperature steam by solar systems such as concentrating collectors and evacuated tubes. Common methods include circulating pressurized water in a collector field and then flashing into steam in a low pressure vessel, or circulating a high-temperature heat transfer fluid in the collector field and then feeding to a steam generator, where the fluid acts as a heat source. Hot air can be supplied either by direct heating in a collector field designed to handle air as the circulating media, or as a liquid is heated in the collector system and pumped through an air heat exchanger.

The major types of collectors readily available for purchase include the flat plate, the evacuated tube, and the parabolic trough concentrating collectors. Parabolic dishes, focusing Fresnel lenses, and focusing heliostat collectors are other techniques available for collecting solar energy; however, with the exception of a few manufacturers prepared to make parabolic dishes in limited numbers, these collectors have been built for research and test purposes only. The flat plate, evacuated tube, and parabolic trough concentrating collectors will be suitable for industrial applications with process temperature requirements in the range of 25° - 290°C. The status of the U.S. technology is sketched in Figure 3.1.

Most flat-plate collectors available today are aimed at the domestic market for low temperature use. Most domestic hot water systems do not need heat above 60 °C; most conventional flat-plate collectors are adequate for heating water to 65 °C. Slightly higher temperatures may be obtained by

using a lithium bromide and water solution. Flat plate systems may find widespread use in industrial applications if they are used to preheat fluids before entering some other type of collector or boiler.

Evacuated tube collectors have a vacuum between the outer cover and the absorber. There are currently two prevalent designs: the first is made of all glass construction and the second uses a metal tube acting as a heat

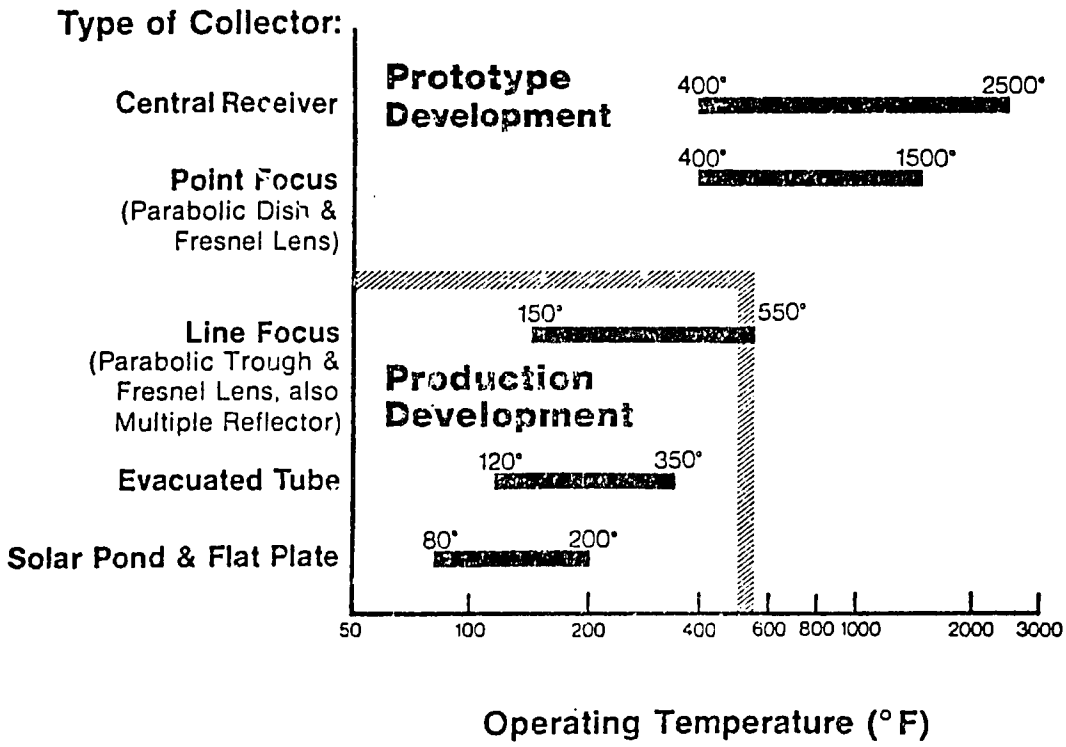


Figure 3.1. (Source: Reference 8.)

exchanger under the absorber. Evacuated tube collectors are technologically ready to be used in low and intermediate temperature applications (50° - 180 °C). Even though evacuated tube collectors can be produced in the United States using existing manufacturing technology, the transfer of this technology to developing countries will require an indigenous capability to fabricate high-vacuum seals and selective surfaces. The installed solar system costs using evacuated tubes is expected to range up to $700/m^2 in 1980 dollars based on manufacturers' estimates.

The parabolic concentrating solar collectors available on the market today have varying designs and operating characteristics, but they are all capable of attaining relatively high thermal fluid temperatures (290 °C). One class of parabolic collectors consists of a single-axis tracking absorber and trough focusing the sun's light onto the absorber. Acurex, Solar Kinetics, and Suntec are the major U.S. manufacturers of such designs. All models use sun-sensing electronic devices to accurately position the troughs and stow them when cloudiness persists for a certain period of time. There are also several other field conditions under which the collectors will automatically be sent to stow position. They include excessively high temperatures in the receiving tube, rain clouds, or nightfall (insolation < 300 W/m^2), high winds (> 30 mph) and loss of fluid flow. A typical current price for concentrating collector systems is about $400 to $600 per square meter, installed. Based on previous experience with other similar industrial products, we believe the parabolic trough concentrators can be reduced in price with cheaper materials and increased production. Acurex, for example, expects to sell glass parabolic trough systems with a variety of reflective coatings in 1982 for $320-$350/m^2 installed.

Concentrating solar energy systems designed to produce either process heat or heat for driving a turbine or heat engine are commercially available or under commercial development in a number of countries, including Austria, India, West Germany, France, Italy, Japan, Switzerland, and the United States. Tables 3.3 and 3.4 summarize the solar thermal collector systems available at present in the United States.

3.3 SOLAR THERMAL TECHNOLOGY: SOLAR PONDS

Since the use of solar ponds as potential sources of process heat in the developing countries is a promising but relatively unfamiliar concept, we review in some detail their theory, performance, and economics, drawing on technical experiences in the United States. Pond performance in equatorial latitudes should often be enhanced over that reported here for temperate climates, and will certainly be more uniform. We will conclude that solar ponds are currently technically and economically viable ways of providing low grade thermal energy to industrial users (< 75°C), especially in equatorial countries with good insolation. For example, Thailand receives around 6.7 GJ/m^2-year and the Dominican Republic about 7.8 GJ/m^2-year, these

30

Table 3.3

Manufacturer	Aperture area (m^2)	Geometric concentration ratio	Application temperature range (°C)	Recommended fluid flow per m^2 of aperture (l/min - m^2)	Receiver Material	Tracking and axis mounting	Notes
Acurex Corp. Mountain View, CA	5.6	35.5:1	90-315	0.41-4.1	SS	SA	Shadow band sensor. Mirrored glass or 3M FEK reflector. Fluid: Therminol 66, Caloria, water. Manufactures reflective materials, tracking systems, framing/substructure.
Alpha Solarco Cincinnati, OH	2.3	18:1	90-230	1.46-3.25	ST or CU	SA N-S	Reflective film. Glass glazed receiver. Fluid: mineral oil.Polar axis tracking system. Manufactures tracking systems, receivers and framing substructure.
Beam Engineering Sunnyvale, CA	1.25	12.6:1	40-120	1.5	CU	SA N-S	Collzak reflector. Tedlar® glazed aperture. Fluid: water.
Energy Harvester San Diego, CA	0.7	10:1	60-150	1.6	CU	SA N-S E-W	Polished aluminum or mirrored glass reflector. Glass glazed receiver. Fluids: water, waterglycol. Non-tracking: E-W mounting. Tracking: N-S mounting.
R.J. Sullivan & Sun Cedar Rapids, IA	1.5	10:1	65-120	9.0	CU	SA N-S	3M scotchtint YS91A reflector. Fluid: water. Glass glazed receiver.
Solar Kinetics, Inc. Dallas, TX	13	34:1	40-315	0.24	ST	SA E-W or N-W	Acrylic film or thin glass reflector. Fluids: treated water, water/glycol, Syltherm, heat transfer oils; pyrex glass glazed receiver.
Sunpower Systems Corporation Tempe, AZ	1.5	22:1	80	0.61	CU	SA DA N-S	3M scotchtint YS-91A reflector. Black chrome coated receiver. Fluid: water, water-propylene glycol.
Suntec Systems Inc. St. Paul, MN	33-100	65:1	90-315	0.57	ST	SA N-S or E-W	FEK 244 or silvered glass reflector. Fluid: water or heat transfer oils. Pyrex glass glazed receiver.
Suntrac Industries, Inc. Oak Ridge, TN	4.6	43:1	120	4.07	CU or SS	SA DA N-S	Scotchcal 5400 reflector. Fluids: water or oils. Manufactures tracking systems and linear receivers.

Table 3.3 (Continued)

Manufacturer	Aperture area (m^2)	Geometric concentration ratio	Application temperature range (°C)	Recommended fluid flow per m^2 of aperture (l/min - m^2)	Receiver Material	Tracking and axis mounting	Notes
Toltec Industries Inc. Clear Lake, IA	1.8	25:1	120-175	1.4	CU	SA DA N-S	Pyrex-glazed receiver. Silver glass reflectors. Fluids: water, water-glycol, heat transfer oil.
Whiteline Inc. Asheville, NC	1.0	12.5:1	104	0.81-2.1	CU	SA N-S	Anodized aluminum reflector. Fluid: water/glycol. Acrylic glazed aperture.

Receiver Material
Var: variable
CU: copper
ST: steel
SS: stainless steel

Axis Mounting
SA: single axis
DA: dual axis
N/A: not applicable

Tracking Orientation
E-W: east-west
N-S: north-south
PC: photo cell

Source: Solar Engineering, "Special Directory, Concentrating Collectors," June 1981, pp. 46-49.

Table 3.4

Manufacturer	Aperture area (m^2)	Geometric concentration ratio	Application temperature range (°C)	Recommended fluid flow per m^2 of aperture (l/min - m^2)	Receiver Material	Tracking and axis mounting	Notes
AAI Corporation Baltimore, MD	36	24:1	120-230	0.41	ST	SA N-S	Slat type concentrator with movable curved reflector blades mounted in base frame. Fixed receiver. Mirrored glass or FEK-244 reflectors. Fluids: water, water/glycol or Therminol-66. Manufactures linear receivers.
Entropy Limited Boulder, CO	1.0	1.3:1	100	Var	CU	N/A E-W	Cylindrical trough. Non-tracking. Anodized aluminum reflector. Double paned glass glazed aperture. Fluids: water. Uses phase change energy (water to steam) for passive, non mechanical energy transport.
E-Systems Dallas, TX	2.8	25:1 36:1	to 150 to 260	2.9-29.0	CU ST	DA N-S	Linear acrylic glass Fresnel lens. Fluids: water-glycol, heat transfer oils. Two models.
Omnium-G Anaheim, CA	29	Up to 5,000:1	150-540		ST	DA N-S	Parabolic dish. Electropolished aluminum reflector. Fluid: water for steam generation. Receiver is Inconel backed with a copper-zinc block. Manufactures tracking systems, reflective panels, and point focus receivers.
Solactor Corp. Alexandria, VA	10.0 81.0	3000:1	135-150		CU	DA PC	Cylindrical Fresnel lens. Modular construction. Molded acrylic Fresnel lens. Fluid: Therminol. Manufactures point focus receivers.
Solar Steam Inc. Fox Island, WA	67	100:1	82-371	0.2	ST	DA PC	Parabolic dish. Glass silvered mirror reflector. Fluid: water for steam generation.

Receiver Material
Var: variable
CU: copper
ST: steel
SS: stainless steel

Axis Mounting
SA: single axis
DA: dual axis
N/A: not applicable

Tracking Orientation
E-W: east-west
N-S: north-south
PC: photo cell

Source: Solar Engineering, "Special Directory, Concentrating Collectors," June 1981, pp. 46-49.

figures are comparable to those for New Mexico in the U.S., but higher average ambient temperatures in Thailand and the D.R. can be expected to enhance pond performance considerably in these countries, and the energy will be more uniformly available throughout the year.

Solar ponds were discovered near the turn of the century by Von Kalecsinsky,[9] who, after explaining why small lakes characterized by a strong salinity gradient were often much hotter at the bottom then at the top, went on to propose their use for heating and industrial purposes. Several other authors have since described solar ponds[10] and suggested their use as sources of thermal energy for electricity production,[11] space conditioning,[12] water desalination,[13] crop drying,[14] and industrial process heat.[15]

A "solar pond" has come to refer to any relatively still mass of water used as the primary collection and storage medium for solar thermal energy. Several configurations are possible.[16] When the storage medium is fresh water in which convection currents will bring warm water to the top and produce temperatures which are relatively uniform throughout the mass of the water, it is referred to as a "convecting" pond.[17] Energy collection may be either direct, with the sun shining on the mass of water, or indirect, with the collection area separated from the bulk storage volume. The collectors may be focussing, tracking devices, or simply the surfaces of shallow ponds.[18,19] In either case, the storage volume must be insulated, at least on the top. These convecting ponds are similar in operation to large scale flat-plate or concentrating solar thermal collectors with storage, and are therefore not discussed here.

We focus instead on ponds in which convection has been prevented. Incident radiation transmitted to the bottom of the ponds raises the water temperature at the bottom, and this thermal energy is trapped there until removed by a heat exchanger. With convection eliminated, conductive and radiative losses are minimal and most losses occur either through premature absorption of incident radiation in the upper layers of the pond or in losses through the walls and bottom. Convection may be eliminated by the use of gels[16] or horizontal layers of plastic,[12] but if salt is available at a reasonable price, the use of a salinity gradient to suppress convection appears to be effective and economical.

Normal convection is induced in fresh water because warmer water (above 4 °C) is less dense than cool water and tends to rise. However, the solubility of salts increases with temperature, and for most common salts one can construct a stable configuration where the mass density of a brine increases with temperature and depth. In such a pond, thermal energy absorbed at the bottom of the pond will heat the lowest ("storage") layer of brine, but the high mass density due to high salinity will outweigh the levitating forces due to thermal expansion of the liquid, and the element of brine will not rise through the less briny "non-convecting" layer to the nearly fresh "convecting" layer at the surface. The result is a nearly stable pond which is hottest at the bottom, with the bulk of its thermal energy well insulated from the air by brine. Actually, there is a slow diffusion of salts towards the surface which must be countered exogenously. In natural lakes, exposed salt on the lake bottom and fresh water flooding in on top perform this function; for artificial solar ponds, the gradient must be re-established regularly.

The "efficiency," or fraction of incident radiant energy available for use, is not high. About one third of incident light penetrates to the storage layer; thermal losses then hold the overall efficiency to between 10 and 20 percent. This low efficiency is, however, offset by the low cost of the ponds, a point we return to later.

On a more detailed level, there are three aspects of performance which must be considered: the total quantity of thermal energy delivered, the temperature at which it is delivered, and the variation of these quantities with load and with time of year. The two week to two month storage capacity of the ponds renders them relatively insensitive to daily variations in insolation or, within limits, to similar variations in load. The peak thermal power output is determined by the size of the heat exchangers. In northern latitudes (40°, for example), the storage temperature can vary from 30 °C in winter to 90 °C in summer, with a 75 °C average. The more uniform insolation nearer the equator should lessen this variation considerably, and even away from the equator, a stationary vertical reflector enhances winter performance considerably, producing a more uniform supply of thermal energy.[18]

Output temperature and storage capacity depend strongly on area, depth, insolation, ambient temperature, and load. The following examples will give

some idea of expected performance: in Los Angeles, with an average temperature of 17 °C and insolation of 6.3 GJ/m^2-year, a 2000 m^2 pond 2.5-3.5 m deep will provide about 0.8 GJ/m^2-year with a peak power of 70 kW, delivered at an average temperature of 75 °C and a minimum of 50 °C. In Miami, the same performance can be expected from a pond only 1.9-2.9 m deep, due largely to the higher (24 °C) ambient temperature.[20] The importance of performing a monthly analysis of energy demand and availability should be stressed. Due to the inflexible nature of most industrial demands, the energy supply may be insufficient or the delivery temperature too low at certain periods of the year; auxiliary fossil fired boilers may be used to compensate for this, but to date we know of no detailed studies of minimum cost mixes of solar ponds and backup fossil fuel systems. Although the above estimates are expressed as energy delivered per square meter of pond area, simply scaling these figures up or down will give only a rough estimate of pond performance. Serious attempts to determine the applicability of solar ponds to a given demand should be based at least on the techniques of Ref. 20, and preferably on more detailed modelling if possible.[10,21]

Construction of the ponds is straightforward: a hole is dug, smoothed and lined with heavy plastic.[22,23] A salinity gradient is established by any of several methods,[22,23] and thermal energy is removed as desired by a heat exchanger, which may either circulate an external heat transfer fluid through pipes on the bottom of the pond or bring hot brine up to an external heat exchanger. Performance will be poor for at least the first year as the ground under the pool rises to nearly the temperature of the brine.

The only serious environmental problem is the possible contamination of fresh water tables by brine; losses associated with tears in the liner can be hard to detect in the presence of evaporation losses, and can result in the loss of much salt, one of the major contributors to system costs.[24,25] Consequently, the implantation of leak detection equipment beneath the pond is imperative. It is also straightforward, since the brine will increase the electrical conductivity of the ground dramatically; a loose mesh of wires beneath the liner will permit easy localization of any leak. For large installations, fields of several moderately sized ponds are probably preferable to one large pond, allowing flexibility in leak repairs, salinity gradient management and temperature control. Also, some ponds can be kept

hotter for topping up output temperatures. For all configurations, operations and maintenance are minimal, consisting of salinity gradient maintenance, debris removal and leak testing.

Capital costs depend on the type of earth being excavated and on how it is excavated (U.S. experience involves earth moving equipment; LDC applications may well involve human labor), the depth and area of the pond, the type of liner and heat exchangers, auxiliary items like reflectors or leak detection equipment and on the cost of salt and the cost of land. Salt is of course available for the shovelling in many locations, but in many others it is not and must be transported from some distance away. Since about 500 kg of salt are typically needed for every square meter of pond surface, transportation expenses can be considerable, and in some cases, fresh water ponds with insulation may be preferable.[16] Current estimates of capital costs in the U.S. are from \$10 to \$40/m^2.[27] Excavation costs may be adapted to reflect hand labor by noting that 2.0 - 3.5 m^3 of earth must be moved for every square meter of area. For life cycle costing it is prudent to use a life of ten years, reflecting current estimates of liner life.

3.4 PRELIMINARY RESULTS FROM U.S. SOLAR POND INSTALLATIONS

In Table 3.5 we present performance and cost data based on experience with two solar pond installations in the U.S.: a small experimental pond at New Mexico University, Albuquerque, suitable for one or two houses,[14] and a large municipally operated pond in Miamisburg, Ohio which heats a public swimming pool and recreation building.[23-26] The Miamisburg cost estimates are based on outlays, but the delivered energy figure is an estimate, based on extrapolation from data on non-optimal operation during an exceptionally poor weather year to expectations of optimal performance during a typical year. The New Mexico performance data is scaled directly from experience, but the cost estimates are projected costs for the second pond based on experiences with the first. The small size of the New Mexico Pond led to large losses owing to the large surface to volume ratio. The resulting poor performance results in high unit energy costs for ponds of this size, indicating that areas measured in thousands of square meters are preferable. The costs of large numbers of ponds or of ponds prepared by experienced engineers and construction crews will certainly drop substantially from those incurred

at the Miamisburg facility as construction technologies are refined and components like liners and heat exchangers are optimized.

Even though the physics of ponds is well-understood, several areas exist where straightforward engineering activity could enhance solar pond capabilities considerably. Detailed design activites, such as optimization of fossil-fuel back-up systems and pond siting are necessary. Other areas where room for improvement exists include leak detection, minimization of heat losses, lessening of wind-induced convection and mixing and maintenance of salinity gradients. Leak detection can probably be managed through measurement of the electrical conductivity of the soil under the pond by a grid of wires which would permit localization of any leak. Much of the

Table 3.5

	Miamisburg, OH	Albuquerque, NM
Average Ambient Temperature (°C)	10.9	12.6
Insolation (GJ/m^2-year)	4.7	7.6
Pond Area (m^2)	2020	175
Construction Costs (1979\$/m^2)		
Excavation, labor	5.60	8.60
Salt	10.80	13.30
Liner, installation	12.40	14.30
Heat exchanger	3.80	14.30
Miscellaneous	6.50	3.80
TOTAL	39.00	54.30
Performance:		
Delivered Energy (GJ/m^2-year)	0.5-0.7	0.3
Maximum Temperature (°C)	68	93
Minimum Temperature (°C)	28	30

surface heat loss occurs through the latent heat of evaporation; it is possible that both this loss and wind-induced convection could be lessened or eliminated by placing a film of oil or plastic on the surface of the pond, although some early experiments were discouraging,[10] and oil could also conceivably lower the optical reflectivity of the surface. Research activities in all these areas can only enhance operational efficiency, but most

advances will probably result from experience with the first generation of commercial, operational solar ponds.

3.5 PRELIMINARY RESULTS FROM U.S. LOW-TEMPERATURE INDUSTRIAL PROCESS HEAT FIELD TESTS

By the end of October 1980 the U.S. Department of Energy had funded 18 field tests providing hot water, air, and steam for industry. As of June 1981, at least 61 solar thermal facilities have been installed or designed for mining, manufacturing, or commercial and industrial facilities for a variety of thermal end uses.* These end uses include space conditioning, service hot water, and industrial process heat. Of these, barely a dozen were funded entirely from private funds. The rest involved cost-sharing, including a number of DOE-sponsored field test facilities. Table 3.6 lists some solar IPH field tests.

Preliminary operational results of six low temperature solar industrial process heat projects funded by the U.S. Department of Energy are now available.[29] These projects are field tests rather than commercial installations, and, as such, have fulfilled their major objective of providing valuable data and experience in solar system design for industrial applications. Though technically successful in delivering heat at the temperatures desired, these projects have not performed as well as expected, owing to a number of design inadequacies and operational problems.

The projects used flat plate, evacuated tube and line-focus collectors, with array areas from 250 to 2100 m^2. Array efficiencies ranged from 12 to 36 percent and net system efficiencies ranged from 8 to 33 percent. The collector array efficiencies and net system efficiencies were lower than expected, due largely to high thermal losses and high power consumption in the auxiliary equipment used with hot air systems. A further problem that emerged in the field tests was that the solar heat produced by the collector array was not fully utilized by the industrial process. This problem is illustrative of the need for careful systems integration and design to minimize energy losses.

---

*K.C. Brown (1981), "Solar Industrial Process Heat Systems: Cost and Performance Vary Widely," Solar Engineering (June), pp. 22-34.

Table 3.6

Solar-Augmented Application in Industry
Solar Industrial Process Installation in United States -- Year End 1980

Location	Process	Temperature °C	Solar Application	Collector Type	Owner	Status
Sacramento, CA	Can washing	88	Hot water	Flat plate/ parabolic trough	Campbell Soup Co.	Operational, April 1978
Harrisburg, PA	Concrete block curing	82	Hot water	Segmented mirror	York Building Products	Operational, Sept. 1978
LaFrance, SC	Textile drying	88-130	Hot water	Evacuated tube	Reigel Textile Corp.	Operational, June 1978
Redding, CA	Hair care, cosmetic products	70-94	Hot water	Flat plate	Jhirmack Enterprises	Operational, 1979
Auburn, IN	Machine parts, cleaning and coating	55	Hot water	Flat plate	Dana Corporation	Operational
Phoenix, AZ	Vehicle cleaning	—	Hot water	Parabolic troughs	Andy's Solar Truck & Car Wash	Operational, 1976
Waco, TX	Food	—	Hot water	Flat plate	M&M Mars Candy	Operational, 1979
Richmond, VA	Photographic processing	—	Hot water	Flat plate	Easco Photolab	Operational, 1978
Fresno, CA	Laundry	55-70	Hot water	Flat plate	Red Star Industrial Service Laundry	Operational, 1979
Santa Isabel, Puerto Rico	Fruit juice, pasteurization	60-99	Hot water	Evacuated tube	Nestle-Libby Inc.	Design
San Leandro, CA	Tractor parts washing	110	Hot water	Parablic trough	Caterpillar Tractor Co.	Design
Fresno, CA	Fruit drying	66	Hot air	Flat plate	Lamdruzzi & Pantaleo	Operational, 1978
Canton, MS	Kiln drying hardwoods	72	Hot air	Flat plate	LaCourkin Services, Inc.	Operational, 1977

Table 3.6 (Continued)

Location	Process	Temperature °C	Solar Application	Collector Type	Owner	Status
Decator, AL	Soybean drying	60-82	Hot air	Flat plate	Goldkist Soybean	Operational, 1978
Gilroy, CA	Onion drying	70-100	Hot air	Evacuated tube	Gilroy Food	Operational, 1979
Fairfax, AL	Fabric drying	140	Steam	Parabolic trough	Westpoint Pepperell	Operational, 1978
Sherman, TX	Gauze bleaching	180	Steam	Parabolic trough	Johnson & Johnson	Operational, 1980
Pasadena, CA	Laundry	215	Steam	Parabolic trough	Home Cleaning & Laundry	Construction
Bradenton, FL	Fruit juice pasteurization	215	Steam	Parabolic trough	Tropicana Products	Construction
Dalton, GA	Latex production	215-280	Steam	Multiple reflector	Dow Chemical	To be operational, May 1981
Hobbs, NM	Oil refinery	215-280	Steam	Parabolic trough	Southern Union Co.	To be operational, Dec. 1981
San Antonio, TX	Brewery	215-280	Steam	Parabolic trough	Lone Star Brewing Co.	To be operational, May 1981
Ontario, OR	Potato processing	215-280	Steam	Parabolic trough	Ore-Ida Co.	To be operational, May 1981
Haverhill, OH	Polystyrene production	183	Steam	Parabolic trough	U.S.S. Chemical Co.	Design
Fort Worth, TX	Cardboard corrugator	190	Steam	Parabolic trough	Bates Container, Inc.	Design
Jacksonville, FL	Beer pasteurization	70	Hot water	Evacuated tube	Anheiser Busch	Operational, 1977
Youngstown, OH	Aluminum anodizing	75	--	Parabolic trough	General Extrusions, Inc.	Operational, 1978

A positive feature common to all systems was that system availability was uniformly high, indicating that component failure was not a serious problem. Availability in some intermediate temperature (175 °C) systems has also been high. Acurex Corporation[30] has reported that its solar steam plant at the Johnson and Johnson facility in Sherman, Texas, had an availability rating of 97 percent from January through November 1980. The few problems at the plant resulted in only ten days of steam shutdown in 320 days of plant operation.

Capital costs for these first generation demonstration projects are considerably higher than those one might realistically expect for future commercial installations. Total capital costs for the solar installations ranged from about $400/m^2$ to $1400/m^2$ of collector area (1977$), including design and data acquisition costs. Since existing IPH installations are designed to operate with 100 percent fossil-fuel back-up capacity, even when thermal storage is included, the amount of fossil-fuel saved per square meter of collector area is an important indicator of solar system performance. When translated into the capacity to save fossil fuel, the solar system costs ranged from $786/(MBtu/yr) to $2348/(MBtu/yr). If data acquisition and design costs are excluded, the costs of the solar systems range from $250 to $870/m^2$, and from $456/(MBtu/yr) to $1541 (MBtu/yr).[8] Tables 3.7, 3.8, and 3.9 summarize the performance and cost of the solar industrial process heat field tests.

Results of the low temperature field tests reveal that enormous improvements in the efficiency and performance of existing systems are possible. Tables 3.8 shows that the most efficient system performed four times as efficiently as the least efficient one. Even the best net system efficiency of 32.5 percent may be considerably improved, bearing in mind that maximum attainable efficiencies for systems operating below the boiling point of water are about 60 percent.

The installed costs of the systems varied by over a factor of three, a variation that stems largely from the different kinds of collector types utilized and construction requirements for auxiliary systems. Capital costs for complete systems with identical collector types would not be expected to vary by more than a factor of two. Projected reductions in capital costs of collectors and other components may therefore not be as significant as cost

reductions arising from careful systems design and integration. These latter cost reductions are very likely to be attained over the near-term future as more experience is gained with the design of solar industrial process heat installations.

Predictions of future capital costs span a wide range, depending on collector type, solar insolation, and auxiliary system requirements. The Solar Energy Research Institute[8] predicts that the capital costs of complete systems will range from $108/MBtu/yr) to $536(MBtu/yr) in 1980 dollars. In addition, various contractors and manufacturers have projected the cost of systems built in 1982 with 10,000 m^2 of collector assuming that the problems uncovered in the recent field tests can be avoided. These projected costs range from $160/$m^2$ or $157/(MBtu/yr) to $400/$m^2$ or $177/(MBtu/yr) in 1980 dollars.

The economic competitiveness of solar thermal energy in industrial settings will depend on systems performance improvements, on careful integration of technologies with appropriate applications, on component-cost reductions, and on factors such as world oil prices, interest rates and tax credits.

Assuming that the design and operational problems encountered in the first generation field tests are satisfactorily resolved as expected, the financial environment governing investments in solar thermal technology for the industrial sector will be decisive. A combination of factors such as interest rates, tax credits, oil prices and oil price escalation rates can cause the internal rate of return, the levelized cost of energy and the payback period to vary over a wide range. Details of these financial calculations are provided in Chapter 4.

3.6 SOLAR INDUSTRIAL PROCESS HEAT: SOME U.S. CASE EXAMPLES

Brief technical examples of three solar industrial process heat systems are portrayed below. They are:

- Hot water for can washing -- Campbell Soup Co., Sacramento, California
- Steam for gauze bleaching -- Johnson & Johnson, Sherman, Texas
- Heating and cooling -- CDC, Distribution Center, St. Paul, Minnesota.

Table 3.7. System Performance of IPH Field Tests

Project	No. Days Data	Incident Solar Energy[a] (MBtu/day)	Energy Collected (MBtu/day)	Parasitic Energy Use (MBtu/day)	Energy Delivered (MBtu/day)	Energy Delivered/Area (Btu/ft^2 day)	Fuel Displaced
Campbell Soup	62	11.32	3.57	0.15	-	-	Natural gas
Riegel Textile[b]	3	11.0	2.01	0.068	1.07	160	Fuel oil
York Building Products	262	11.05	1.30	0.051	1.09	118	Fuel oil
Gold Kist	290	13.3	3.49	0.31	3.40	260	Fuel oil, Natural gas
LaCour Kiln Services	180	3.22	1.17	0.012	1.08	429	Natural gas
L and P Foods	181	47.8	10.5	1.00	9.49	452	Natural gas

[a]Daily total insulation in the plane of the collector array.
[b]Performance results available for these sites are included for information, but poor statistical basis should be noted.

Source: Kutscher, C. and Davenport, R. (1980), "Performance, Results and Experience of the Operational Industrial Process Heat Field Tests," SERI/7R-632-385, Golden, CO: Solar Energy Research Institute.

Table 3.8. System Performance Of IPH Field Tests

Project	No. Days Data	System Utilization (%)	System Availability (%)	Collector Array Efficiency (%)	Themal System Efficiency (%)	Net System Efficiency (%)	Parasitic[a] Fraction (%)
Campbell Soup	62	81.5	82.0	31.5	-	-	4.2
Riegel Textile[b]	3	97.0	97.6	18.3	9.7	8.1	3.4
York Building Products	262	100.0	91.6	11.7	9.8	8.6	3.9
Gold Kist	290	63.5	100.0	26.2	25.6	19.7	8.7
LaCour Kiln Services	180	100.0	94.0	36.3	33.5	32.5	1.0
L and P Foods	181	41.4	72.2	22.1	19.9	14.2	9.5

[a][Parasitic energy (MBtu) ÷ Energy Collected (MBTU)] x 100%.
[b]Performance results available for these sites are included for information, but poor statistical basis should be noted.

Source: Kutscher, C. and Davenport, R. (1980), "Performance, Results and Experience of the Operational Industrial Process Heat Field Tests," SERI/7R-632-385, Golden, CO: Solar Energy Research Institute.

Table 3.9. Costs of the Low-Temperature IPH Field Tests

Project	Design, Phase 1 ($)	Construction Phase 2 ($)	Total Capital Cost, Phases 1 & 2 ($)	Phase 2 Data Acquisition	Number Days of Data	MBtu/day delivered	Extrapolated MBtu/yr	Extrapolated $/(MBtu/yr)[a]	Extrapolated $/(MBtu/yr)[b]	($/ft^2)[a]	(E/ft^2)[b]
Campbell Soup	204,280	580,870	785,150	549,005	62	-	-	-	-	107.0	74.8
Riegel Textile	258,310	610,350	868,660	568,735	3	1.07	370	2348[c]	1537[c]	130.0	85.1
York Building Products	114,200	449,000	563,200	394,510	262	1.09	364	1547	1084	61.1	42.8
Gold Kist	286,760	747,910	1,034,670	726,160	290	3.40	788	1313	922	79.0	55.4
LaCour Kiln Services	71,300	285,800	357,000	219,555	180	1.08	370	965	593	142.0	87.1
L and P Foods	268,890	545,000	813,890	517,000	181	9.49	1035	786	499	36.8	24.6

[a]Based on total cost.

[b]Based on Phase 2 minus data acquisition cost.

[c]Cost results for this site are included for information, but poor statistical basis should be noted.

Note: In order to put the costs of these first-generation tests in perspective, each contractor was asked to project how much his system would cost if it consisted of 100,000 ft^2 of collector, and were built in 1982, assuming the problems that occurred in these first tests were prevented. Their response based on construction costs only were as follows: Acurex (Campbell Soup) - $121/(MBtu/yr), $36/ft^2; AAI (York) - $270/(MBtu/yr), $30/ft^2; Teledyne-Brown (Gold Kist) - $292/(MBtu/yr), $31/ft^2; Lockheed (LaCour) - $177/(MBtu/yr), $40/ft^2; California Polytechnic State University (L&P) - $157/(MBtu/yr), $16.1/ft^2. These costs are based on 1980 dollars, whereas the costs in the table are in 1977 dollars. No cost estimate was received from General Electric (Riegel) in time for publication.

Source: Kutscher, C. and Davenport, R. (1980), "Performance, Results and Experience of the Operational Industrial Process Heat Field Tests," SERI/7R-632-385, Golden, CO: Solar Energy Research Institute.

46

The CDC Word Distribution Center, though a part of the commercial sector rather than the Industrial sector, deserves attention because of the elaborate and successful system of interfacing solar and nonsolar components and systems.

3.6.1 Campbell Soup Solar Hot Water System, Sacramento, California.

This system is one of the earliest demonstration projects, with preliminary design beginning in March 1976. The capital investment during the period from March 1976 to November 1980 amounted to $1,150,000 including design, construction, evaluation, and extension of field tests.

The solar heated water is used in a can washing operation that is part of the plant's soup production line. A schematic of this system is shown in Figure 2. Well water at 20 °C and 60-90 PSI, enters the flat plate collectors for preheating to 60 °C, passes through the parabolic trough concentrating collector for final heating to 88 °C and is sent to a storage tank. Water passes through the collector field once, without recirculation. From the storage tank, hot water is pumped to the can washer, passing through a steam heat exchanger. If the temperature of water coming from the tank falls below 82 °C, additional heating will be provided in the steam heat exchanger.

The main performance problem with this system is related to the interfacing of solar equipment with the rest of the plant. The solar system is directly connected to either of two can washers. If these can washers do not operate continuously, the solar storage tank will fill and the collector field will shut down early in the day, not achieving its maximum energy delivery. Overall solar collection efficiency would improve if the solar system were connected to the plant hot water system. Other problems related to subsystem performance, including leaking of flat plates, causing corrosion of the absorber surface, have been encountered in the past. The installed system costs per unit collector area was approximately $1600/m^2 (in 1980 dollars).

Major technical data for the system are listed below.

Collectors	414 m^2 flat plate (inclined 25° to south), single glazed-non-reflective coating, 268 m^2 line focus parabolic trough concentrators (E/W orientation). Manufactured by Acurex.
Storage	65,000 liters

47

CAMPBELL SOUP SOLAR HOT WATER SYSTEM SCHEMATIC

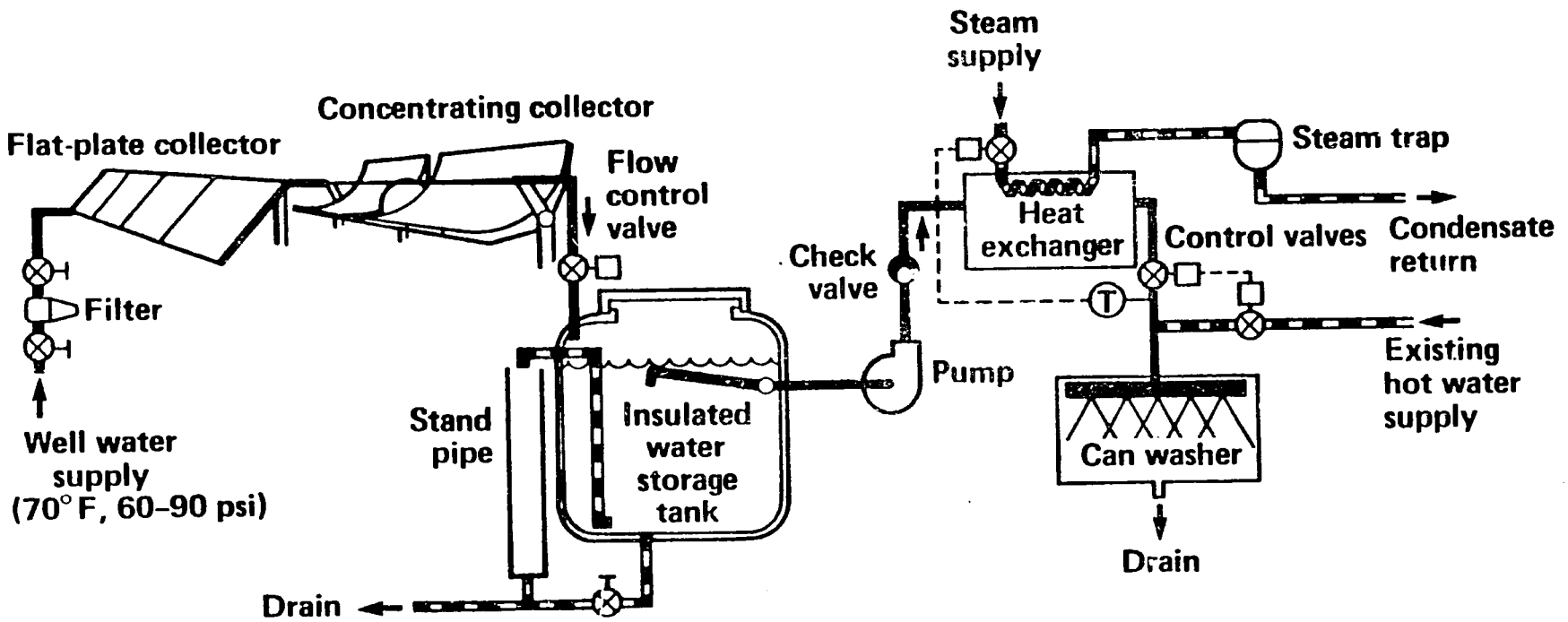


Figure 3.2

Flow Rates	113 l/min collector field flow rate 47 l/min flow rate to can lines
Temperature	82° to 88 °C
Operation Mode	Constant flow rate
Performance	Average daily efficiency is about 40%. During August, 1980, the system generated approximately 4 MBtu daily.

3.6.2 Johnson & Johnson Solar Low Pressure Steam, Sherman, Texas

The design phase of this system started in September 1977 and ended in June 1978. Construction was completed in October 1978, and the system has been in regular operation since January 1980. The total installed cost including design, construction, and evaluation was $2,070,000 or $1880/m^2.

The solar system consists primarily of a parabolic trough collector field (ground installation), a pump, and a flash boiler. The solar system schematic is shown in Figure 3. Pressurized water is circulated directly through the collector field, reaching temperatures as high as 215 °C before flushing into a 19,000 liter insulated flash boiler. Water in the boiler (an ASME-rated pressure vessel) flashes to steam (175 °C) to supply the plant steam main.

This project is technically successful. It has a simple plant interface to allow use of all collected solar energy, and operation is fully automatic, which contributes to low maintenance costs. There have been a few problems. Some instrumentation has required repair, and there has been frequent breakage of flexible hose. The latter can be considered a part of system upkeep.

The relevant technical data are:

Collector	1070 m^2 line focus parabolic trough (axis 45° from north south). Manufactured by Acurex (model 30001)
Storage	19,000 liter insulated flash boiler
Steam Supply Temperature	175 °C
Peak Steam Flow Rate	0.15 kg/sec
Performance	The daily collector field efficiency is about 30 percent. A total of 169 MBtu were delivered to the flash boiler for the month of July.

SIMPLIFIED SCHEMATIC OF JOHNSON AND JOHNSON SOLAR STEAM SUPPLY SYSTEM

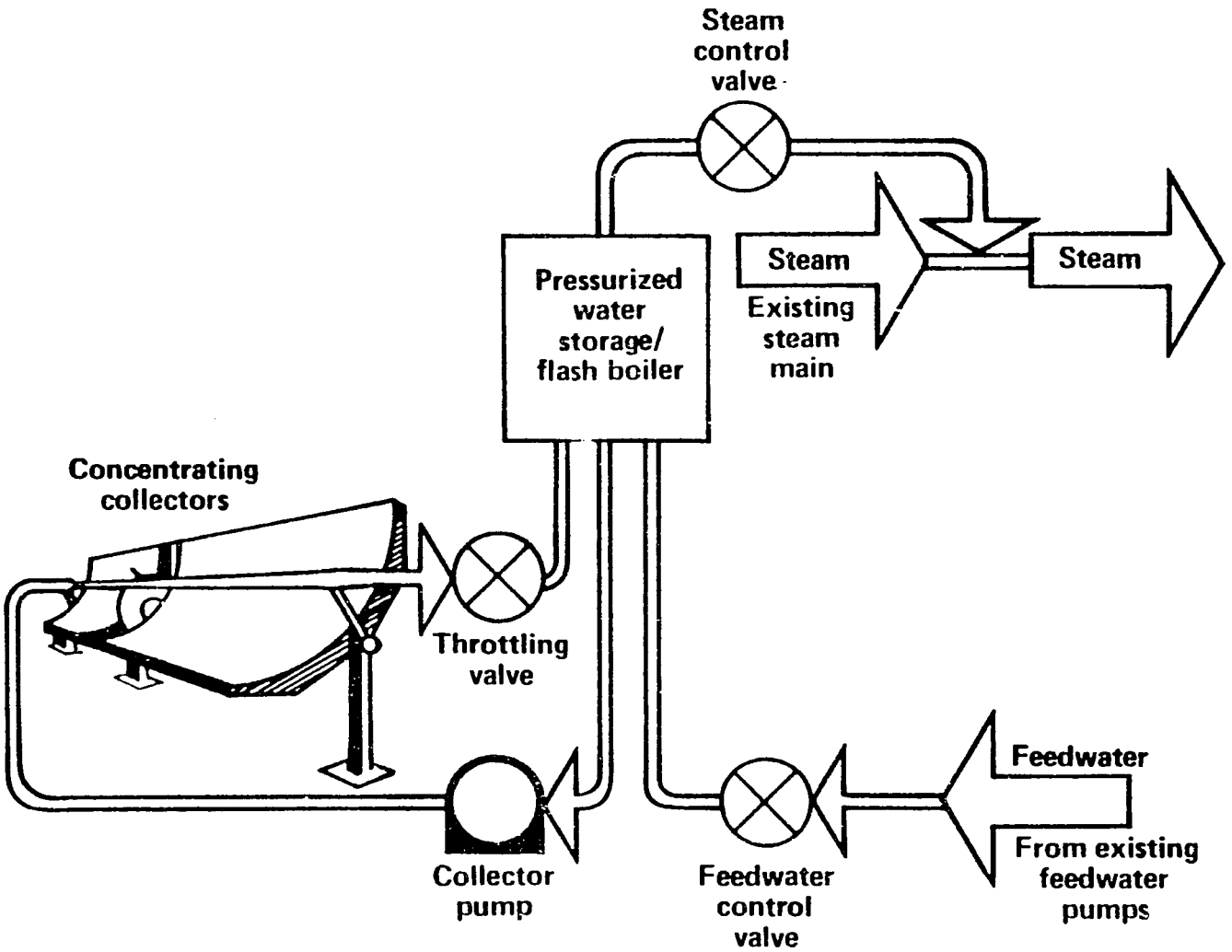


Figure 3.3

50

3.6.3 Solar Heating and Cooling, CDC World Distribution Center, St. Paul, Minnesota

The CDC World Distribution Center is a large building with 24,154 m^2 of floor space. This is divided into 7,432 m^2 of office area and 16,722 m^2 of warehouse and service areas. The annual energy consumption in 1980 was 551 MJ/m^2 (48,577 Btu/ft^2). The schematic of the solar system interfaced with conventional cooling and heating equipment is shown in Figure 4. The solar system contains 2,341 m^2 of parabolic trough collectors and provides both summer cooling, hot water, and winter heating.

A synthetic oil is circulated through the collector field and then used to heat water via a heat exchanger. The hot water circuit is demonstrated in Figure 4. It passes through an absorption air conditioner, residual oil-fired boiler, dock heaters, perimeter heaters, storage tanks, and hot water heaters, depending on the heating or cooling requirement of the building. Summer cooling is provided by 121°C water to run a 200 ton Trane absorption air conditioner. Two 75 ton Trane heat pumps provide cooling in the summer when no solar energy is available. These are used for heating and cooling during the spring and fall. The building is designed to be heated with 52°C hot water. Four (75,700 liter) steel storage tanks are used for storing solar heated water, or for storing chilled water generated off peak for next-day cooling. This system is incorporated in the building design. This is why the interfacing is elaborate and sophisticated. The building was completed in January, 1979, and the solar system was operational in June, 1980. Automatic operation of the system simplifies the demands made on the building operator. There have been a few problems. An AC motor needed to be changed. The collector surface is made up of FEK244 tape which can't be wiped off without damaging or causing deterioration of the surface. The total installed cost has not been disclosed, but the installed system cost per unit area is above $1000/$m^2$ (in 1980 dollars).

Relevant technical data are listed below.

Collectors	2341 m^2, parabolic trough, concentrator line focusing, single axis tracking, 9 ft. aperture, 80 ft. long rows. Manufactured by Suntec.
Storage	302 m^3
Flow Rates	16 /sec

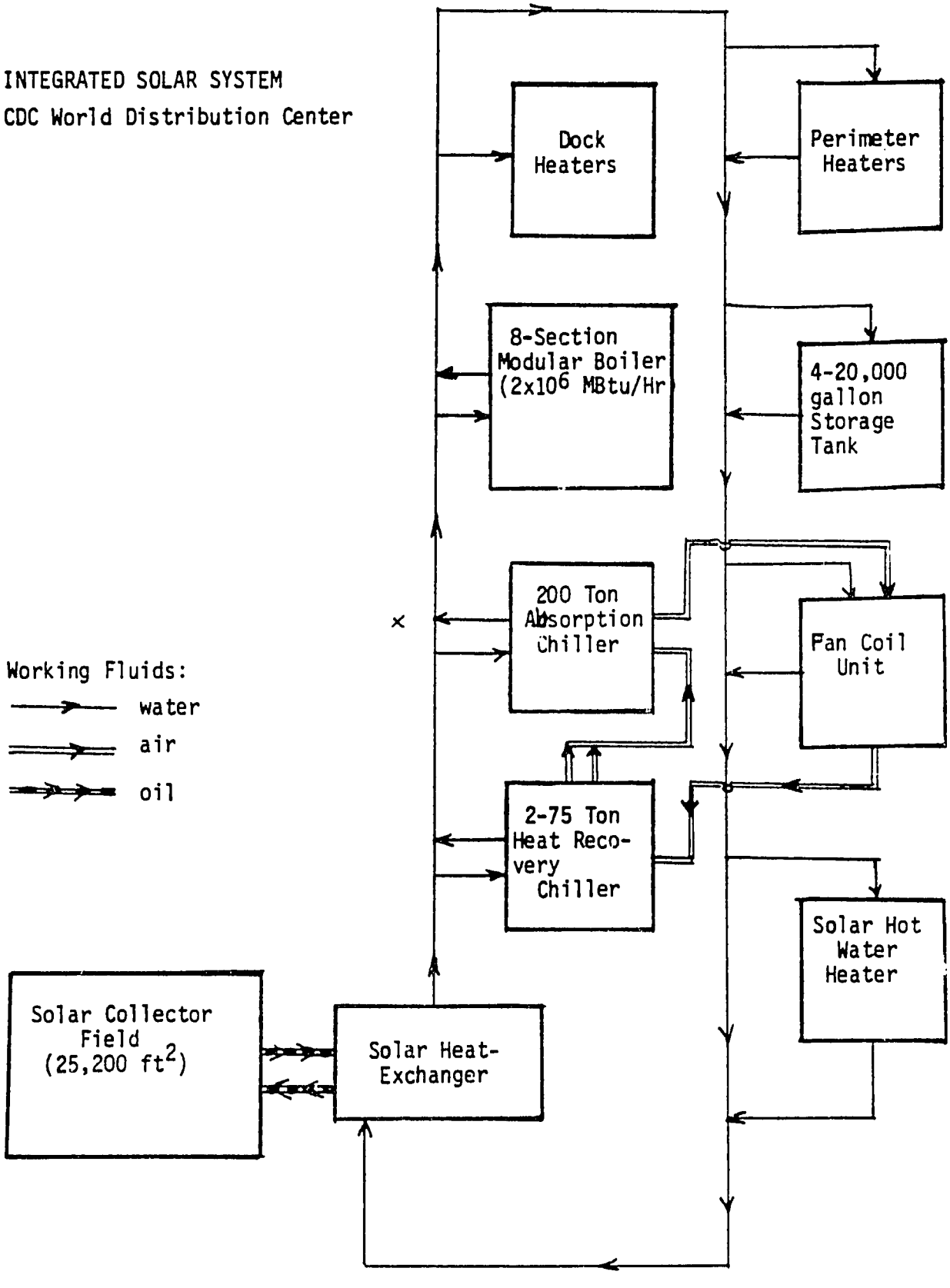


Figure 3.4. Integrated Solar System CDC World Distribution Center

52

Temperature	285°F
Operation Mode	Variable flow rate.

At this stage, it is difficult to measure the economic success of these IPH demonstration projects, but the trend is encouraging. Figure 5 shows the installed system costs per unit collector area for all the parabolic trough collector projects funded for construction. The reduction in costs has been achieved because of reduction of collector costs due to design improvement and manufacturing, and economies of scale.

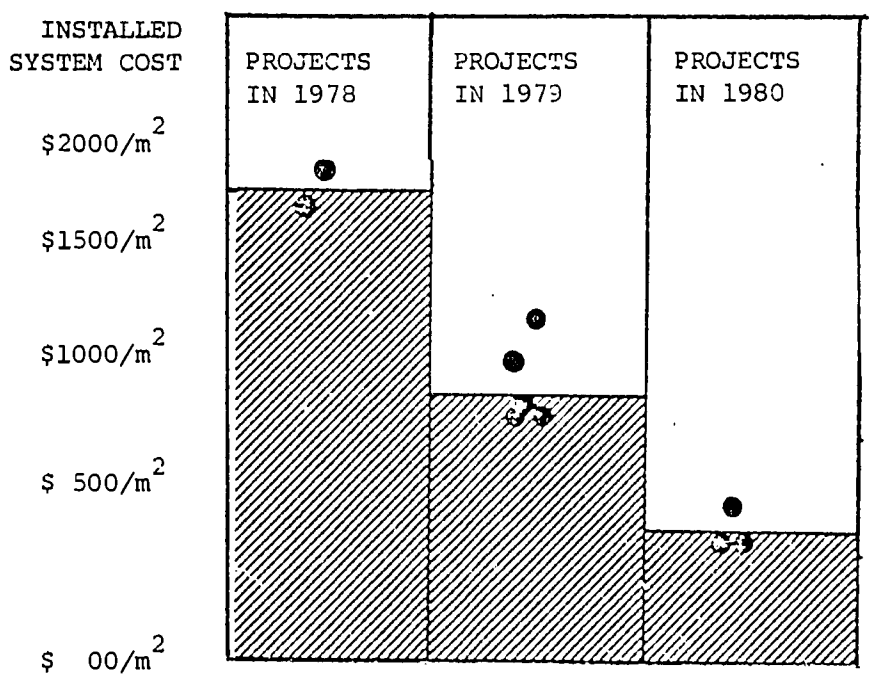


Figure 3.5. Cost Trends in Trough IPH Projects.

3.7 SOLAR INDUSTRIAL PROCESS HEAT AND ENERGY-EFFICIENT TECHNOLOGIES

A decision to use solar industrial process heat systems in an industrial environment cannot be separated from decisions regarding capital investment in alternative energy sources or systems, or indeed, from decisions involving a company's total investment strategy. Merely to optimize the costs, performance and financial environment for solar industrial process heat systems is to run the risk of ignoring other more immediate and cost-effective opportunities.

52

In general, there will be a sequence of economically attractive energy-efficient measures and technologies that should precede the installation of a solar thermal system. Many industrial plants will obtain a far greater return on their investment from installing energy-efficient equipment such as heat recuperators and heat pumps than they will from deriving part of their heat supply from solar.

Many U.S. manufacturers have already identified or implemented "housekeeping" or "leak-plugging" changes that require little or no capital investment. True gains in efficiency, however, require a substantial capital investment. Such investment should be promoted to the point where the cost of additional efficiency measures is equal to the marginal cost of new supply.

A large number of technical studies and papers have identified a vast potential for improvements in the efficiency of energy use throughout the U.S. economy. Stressing that society must continue to develop and utilize new energy sources, these studies argue that an important, indispensable ingredient is required -- the use of energy efficient technologies to make more productive use of fuel and capital.

The vast potential for improvements in energy efficiency can be traced to the fact that the efficiency of energy utilization in most industrial societies economy is extremely low when considered from the perspective of the second law of thermodynamics. In the U.S. for example, the average efficiency is about 8 percent of the maximum efficiency permitted by the second law of thermodynamics. Real devices and processes are unlikely to approach an energy efficiency of 100 percent, but this abysmally low efficiency indicates an enormous opportunity for improving the effectiveness of energy use. The industrial sector in the U.S. operates at an average efficiency of 13 percent, and it is likely that low efficiencies of this magnitude are also characteristics of the industrial sector in developing countries.

Some typical second law efficiencies estimated for various sectors ofthe U.S. economy are shown below:

Sector	Second-law Efficiency (Percent)
Residential & Commercial Space Heating	5
Residential & Commercial Water Heating	3
Air Conditioning	4.5
Refrigeration	4
Automobile Transportation	9
Steel Production	23
Aluminium Production	13
Petroleum Refining	9
Paper Production	<1
Cement Manufacturing	10
Electric Power Generation & Process Steam Production	33

Source: American Physical Society, 1975[32]; Widmer and Gyftopoulous, 1977.[33]

Even an improvement in average efficiency from 8 to 10 percent would be highly significant -- this would save a quarter of the energy consumed in the United States, or about the amount of energy consumed annually by the entire U.S. transportation system.

Such dramatic savings are not merely of academic interest. Focusing on the industrial sector, one important study[31] indicates that the equivalent of 4.5 million barrels of oil per day could be saved over the next 5-7 years through measures that would cost less than the equivalent cost of new supply. Writing in the Harvard Business Review in 1978, the authors of the study state

> "We estimate that cost-effective investments (in which the total cost of the energy saved is equal to or less than the replacement cost of the fuel or the electricity saved) could save about 25 percent of the industrial energy that will be in demand by 1985 and thereby do much to offset higher energy costs. Available technology could be used, and no curtailment in production would be necessary. The energy saved would be huge -- equivalent to the energy consumed by all the automobiles in the United States today."

To place these improvements in perspective, consider that a ton of coal now yields 8 times as much as electricity as it did in 1900, and that in the period 1947-1969, the average fuel requirements to produce a ton of raw steel in the United States fell from 33.5 to 24.6 Btus per ton.

Major generic sources of inefficiency in industrial operations arise from the loss of high-temperature waste heat to the environment, and from the combustion of high flame temperature fuels to provide heat for low-temperature applications. In addition, specific manufacturing processes may be highly inefficient. Technologies to improve industrial energy utilization efficiency include:

- Cogeneration of electricity with process steam
- Low temperature hot-water heat pumps
- Waste heat recuperators
- Improved A-C motor efficiency
- Computer and microprocessor systems
- Industrial process modifications.

All of the technologies and measures mentioned are likely to be cheaper than solar IPH, and investments in such technologies should therefore precede, or be simultaneous with, investments in solar IPH. Table 3.10compares the cost of solar industrial process heat equipment with various energy-efficient technologies. Figure 6 illustrates the sequence of technologies in order of increasing capital cost.

Table 3.10
Capital Costs of Competing Technologies for
Low Temperature Industrial Applications

System	Capital Cost 1980$/GJ/year delivered
Energy efficient technologies[a]	2-50
Solar flat plate Solar Evacuated tube Solar parabolic trough	100-600
Solar ponds	20-150

[a]Figures in Reference 34 have been adjusted for inflation.

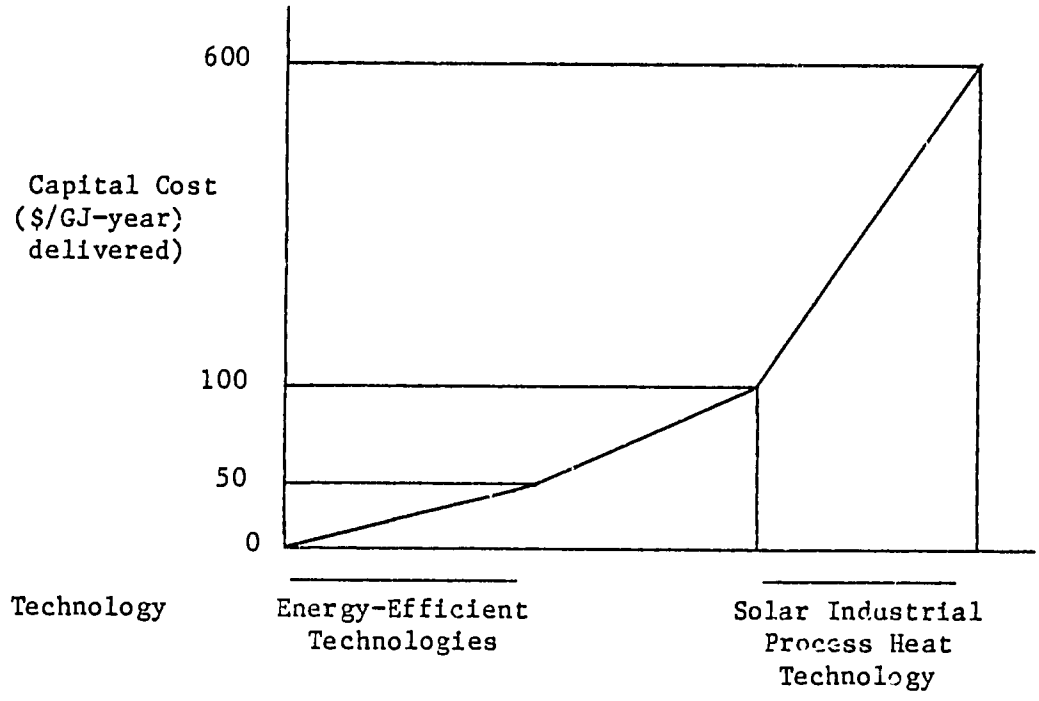


Figure 3.6. Capital Cost vs Technology.

51

4 SOLAR INDUSTRIAL PROCESS HEAT -- FINANCIAL AND ECONOMIC ANALYSIS

4.1 INTRODUCTION

In the report of the UNCNRSE Synthesis Group[35] the economic characteristics of various new and renewable energy systems are compressed into a single parameter, a cost per kW-hr of generated energy. A single fixed charge rate of 20% is used to convert capital costs into levelized energy prices. While some range of energy costs is given for many of the technologies, there is only limited discussion of the factors which contribute most significantly to this range, although recognition of the complexity in carrying out a financial analysis of many renewable energy technologies is reflected in the Report:

> "46. As with conventional energy technologies, many new and renewable energy technologies are capital-intensive. Cost comparisons are therefore critically dependent on the cost of capital, including depreciation. In the comparisons used in this chapter, capital and maintenance costs have been assumed to represent an effective fixed charge rate of 20 percent annually. In practice, however, fixed charges vary widely from country to country, and may even vary markedly within one country."
>
> "142. Financial inventives, for example subsidies, tax rebates, etc. may be necessary to stimulate user and producer interest in new and renewable sources of energy, especially where energy from conventional sources is not priced at economic levels."

In this report we explore the complexities of investment analysis for renewable energy systems, using solar industrial process heat as the case example. Using well established cash flow procedures, we show the relative importance of various technical, economic, and financial parameters in determining the final rate of return on an investment in a renewable energy technology. This analysis also indicates how certain financial parameters can be modified through policy incentives, to accelerate the pace of development and commercial diffusion of these technologies. We believe this analysis supports the view that a combination of enlightened financial policy and sound engineering using available solar products can produce attractive investments in fuel saving SIPH systems throughout much of the developing world.

58

4.2 THE INTERNAL RATE OF RETURN AS AN INSTRUMENT FOR INVESTMENT DECISIONS

Of the various measures which can be used to evaluate the economic and financial attractiveness of an investment in a renewable energy system, the internal rate of return (IRR) is often the preferred instrument. Other indicators include both simple and discounted payback periods and the levelized value of the energy produced (e.g., solar-derived heat). While simple payback is the easiest financial measure to calculate, it is useful only in rough estimates, and for ranking investment alternatives. If the simple payback period is a few years or less, more detailed financial analysis is usually not required to conclude that the investment is attractive. And, if the simple payback period is quite long -- 30 years, for instance -- more analysis is not required to conclude that this is probably not a very good investment. However, when the simple payback period is in the range of roughly five to twenty years, more sophisticated financial analysis is usually required to make an investment decision.

Comparison of the cost of delivered energy between renewable and fossil fuel systems is rarely straightforward. The delivery of solar-derived energy is a capital-intensive activity. The unit cost of equipment to transform solar energy to industrial process heat can be as much as ten times the cost of equipment to transform fossil fuels to process heat. But, since solar energy systems use a free energy source, operating costs are very low compared with fossil fuel systems. A central issue is the extent to which fuel savings can amortize the solar equipment investment. To account for the complex financing and tax considerations that are important in a capital-intensive investment, a detailed cash flow analysis is needed to accurately portray the economic position of solar technologies relative to conventional fuel-based technologies.

To evaluate investments in renewable energy systems, government, industry, and international financial institutions such as the World Bank will require detailed calculations of the internal rate of return for the project. In the case of solar industrial process heat systems, it is the rate gained by investing in solar equipment rather than continuing to buy fossil fuels. This rate can also be compared to the rate of return that may be gained by other investments of the same money. An alternative, equivalent treatment of the comparison between solar and fossil-fired systems can be made on the basis of the levelized heat cost, given a specific discount rate.

A variety of factors determine the IRR. With renewable energy technologies many of these factors will vary considerably from one location to another and also over time as these technologies evolve and become widely commercialized. Among these factors are the capital and operating costs of the system, system performance, the financing details of system ownership, tax status and credits, and the rate of increase in the real prices of fossil fuels.

Each solar IPH installation is a unique engineering, economic, and financial venture. Even when two solar IPH installations have identical technical performance and costs, they can have completely different investment characteristics. For instance, the difference between an available 25 percent tax credit for one installation and no tax credit for the other can be the difference between a project with an attractive rate of return and one with a very low or even negative rate of return. We have examined the circumstances under which a solar IPH installation would be an attractive financial investment. Because of the large number and wide ranges of cost and financial variables, there is no unique combination of technical and financial factors which will produce an attractive investment. However, there is a range of realistic financing circumstances, sunlight environments and equipment performance and costs for which an attractive return on investment can be achieved.

We have used a conventional economic cash flow analysis to evaluate a number of solar industrial process heat (SIPH) systems. We assume that the capital investment in solar equipment is amortized strictly by fuel savings.

This analysis reveals the relative importance of various economic and financial parameters and suggests which policy measures will most accelerate or impede the introduction and diffusion of SIPH and other solar energy systems. For instance, the heavy subsidization of diesel fuel and kerosene practiced in many developing countries will inhibit private investors from investment in renewable energy systems. By contrast, investment tax credits, direct rebates, accelerated depreciation and preferred interest rates for renewable energy systems will help accelerate the pace of commercial development and use of solar products.*

---

*Examples of policy measures introduced in the United States recently to accelerate the use of renewable energy systems are discussed by Taubman and Weingart in Volume II of this report.

60

4.3 FINANCIAL ANALYSIS PROCEDURES FOR RENEWABLE ENERGY SYSTEMS

4.3.1 Introduction

A number of technical, economic, and financial factors combine to determine the investment characteristics of a renewable energy system. These factors can be combined in a computerized discounted cash flow analysis to yield the internal rate of return, discounted payback period, and levelized energy cost for the system.

Some of the economic factors are technical or environmental in nature, such as the installed cost per square meter of solar collector or the available solar energy. Other economic factors are policy-related, such as the local price of fuels and the rate of increase in fuel prices. Important financial factors, subject to some degree of policy control, include the debt interest rate, depreciation life and method, investment tax credits, and effective rates of protection accorded to specific industries and products. The economic and financial factors used to compute the internal rate of return for the renewable energy systems considered in this report, solar IPH technology, are listed in Table 4.1.

4.3.2 Computer-Based Financial Analysis for Solar Industrial Process Heat

A number of computer programs, some quite complex, have been designed to analyze the effects of these factors on the rate of return. The Solar Energy Research Institute (SERI) has developed PROSYS/ECONMAT[36] to simulate SIPH system performance on an hour-by-hour basis and to calculate the resulting energy costs. These programs require detailed insolation data,[37] and run on a main-frame computer. Such programs are extremely useful in assessing the actual performance of a proposed system on an hour-by-hour basis over the course of a year. They can provide good estimates of the requirements for backup fuels during the year, indicate the best (least disruptive) periods for scheduled maintenance of the solar energy components of the system, and so forth. However, such a detailed analysis is not required in order to determine the relative impacts of system costs, performance, and economic factors on the levelized cost of solar-derived heat or on the internal rate of return.

The analysis described in this paper was conducted using a computer program designed for use on a personal sized computer, using simple insolation[38,39] and performance algorithms to examine the important variables in

61

Table 4.1
Economic and Financial Factors Used to Compute the Internal Rate of Return for a SIPH System Investment

Economic Factors (System-Related)

- System cost per m^2 of aperture
- Available insolation
- Net system efficiency (solar)
- Average capital cost ($\$/kW_{th}$)
- Overhead and Maintenance Costs

Economic Factors (Policy-Related or Political)

- Prices of competitive fuels
- Rate of increase in real fuel prices (including changes in the dollar exchange rate of local currencies)

Financial Factors (Subject to Policy Controls)

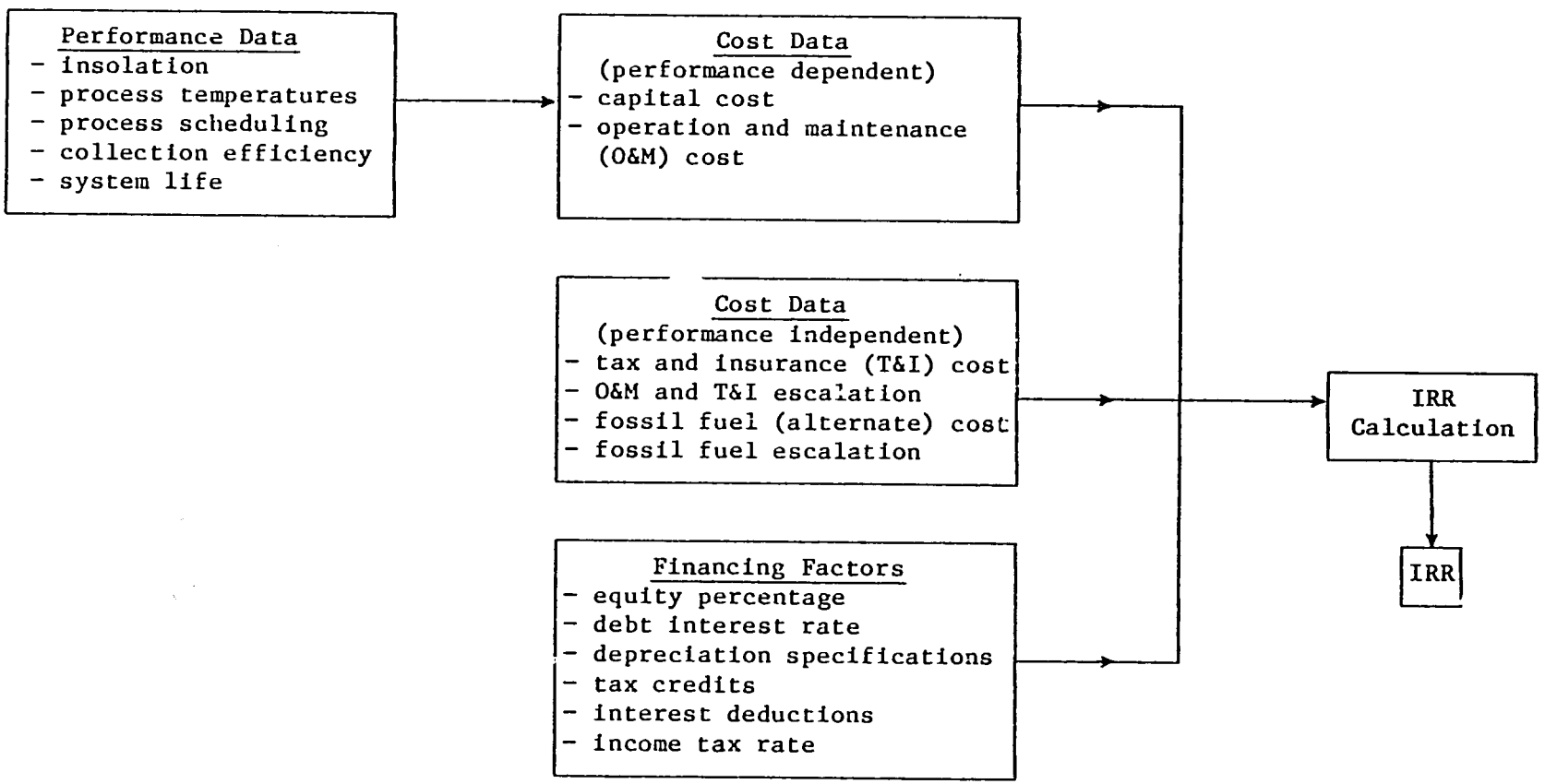
- Percent equity
- Debt interest rate
- Investment life
- Taxes and insurance
- Property tax escalation rate
- Percent of initial investment allowed for depreciation
- Salvage value at end of plant life
- Depreciation life
- Method of tax depreciation (DDB, SYD, straight line)
- Marginal tax rate
- Investment tax credits
- Sinking fund interest rate
- Negative cash flow accounting method

SIPH economics. The program, originally developed at Teknekron Research, Inc., was modified at BNL to run on a mainframe computer, permitting rapid examination of a large number of combinations of financial and economic parameters. The main ingredients (input parameters and computed output) are shown in Figure 4.1.

4.4 ECONOMIC CONSIDERATIONS AND UNCERTAINTIES IN SOLAR IPH FINANCIAL ANALYSIS

This section discusses the technical, environmental, economic, and financial factors which determine the investment characteristics of a solar energy system. The technical factors include the system's solar energy collection, conversion, and thermal exchange efficiencies. These in turn are affected by the industrial process scheduling and process temperature requirements for the complete IPH installation. System and component

Figure 4.1
Determination of Internal Rate of Return for a Solar Industrial Process Heat System



lifetimes and requirements for maintenance will a;sp affect the system costs. Environmental factors affecting performance include the availability of direct and diffuse solar radiation as a function of time, and environmental stresses such as wind loading amd moisture, salt, and other corrosive elements in the atmosphere. The environmental stresses can decrease the life of some of the SIPH system components.

There is no simple generalization which can be made about the costs of SIPH systems. This is because the economics of the hardware and the financial investment environment for such an installation can vary enormously from one region to another. For instance, the capital cost per average kW(th) of delivered heat will depend on the patterns of available solar energy, the specific engineering design[40] of the solar energy collection, conversion and heat transfer subsystems, the requirements of the industrial process[41] and the manner in which the entire system is operated. Installed costs of SIPH systems, per square meter of system aperture, can easily range from $500 - $2000, with projected costs for some systems declining to perhaps $200. (All costs are in current 1981 dollars.) While the net efficiency of conversion from incident solar radiation to useful process heat can in principle be as high as 0.35 (annual average), many currently operating commercial prototype SIPH systems are experiencing annual efficiencies in the range of 0.10 to 0.30. Available solar radiation can range from 2.0 to 6.0 kWh/sq. m-day (annual average) for global insolation, and from perhaps 3.0 to 8.0 kWh/sq. m-day for the tracked, direct beam (focusable) solar radiation. The range of available solar radiation is summarized in Table 4.2.

As a baseline case, we assume a concentrating and tracking solar collection system, operating in an insolation environment of 6 kWh/sq. m-day, a net efficiency of 0.3 and an installed system cost of $300 per sq. meter, which yield a capital cost of $4000/kW(th). This could be achieved with careful system design and operation in an LDC environment with widely encountered solar radiation patterns, and with local government policies which would minimize duty, delays and other factors which can increase costs.

In this case we are assuming that the technology has become fully mature, that the information and experience required to design and operate SIPH systems with something close to the maximum attainable efficiency is widely available, and that policies are in effect to encourage both local

Table 4.2
Characteristics of Solar Radiation As an Energy Source[42]

The Solar Constant	1353 W/m^2
Effective Radiation Temperature of the Sun	5760 K
Maximum Direct Beam Irradiation at Sea Level	1000 W/m^2

Region, Irradiance		kWh/m^2-Day	W/m^2 (Average)
Tropics deserts		5 - 6	210 - 250
Temperate zones	(Annual average horizontal)	3 - 5	130 - 210
Less sunny regions (e.g., northern Europe)		2 - 3	80 - 130
Average annual direct beam irradiance in sunny regions		7 - 8	290 - 330
Monthly average direct beam radiation in sunny, arid regions		5 - 10	210 - 420

manufacture and use of imported hardware, as appropriate, to harness renewable energy flows. Based on previous experience with the emergence of a commercial industry for solar water heating in the US, Japan and Europe, such a process will take the better part of this decade, at least.

While solar energy systems for production of process heat above 100 °C are unlikely to be used in regions which are not very sunny, there is still a substantial range[43,44] in the available direct and total solar radiation in regions generally considered "sunny."* All of these factors conspire to yield a capital cost range for SIPH systems of $1700 to $20,000 per average thermal kilowatt of delivered process heat (Table 4.3).

If some of the equipment, such as high efficiency tracking solar concentrators, must be imported from outside the country, formal and informal import duties, customs clearance periods and fees, and so forth can widen the capital cost range even further. As an example, pressure from US, Japanese and European manufacturers of photovoltaic arrays, and from their local

*In sunny, arid desert regions, the direct beam component of the solar radiation at the ground can be as high as 85%. In sunny, tropical regions near the equator (West Java, for instance), the direct beam component may be as low as 40% over the year, even though the total sunlight reaching the ground is as much as 85% of that experienced in the sunniest deserts.

Table 4.3
Factors Contributing to the Average Capital Cost of a Solar Industrial Process Heat Facility

Factor	Poor	Fair	Good	Base Case	Superb	
Sunlight	2	3	5	6	8	kWh/m^2-day (annual av.)
System Cost	2000	1000	500	300	200	$\$/m^2$ of aperture, installed
Efficiency	0.10	0.15	0.25	0.30	0.35	Net conversion of incident solar radiation into useful process heat
Capital Cost [$\$10^3/kW(th)$]	240	53	9.6	4.0	1.7	Cost per annual average net thermal capacity

distributors, recently led to one LDC government reclassifying these arrays as electronic equipment. This resulted in a decrease in duty from over 100% to about 5%.

Other uncertainties in SIPH economics are due to:

- Wholesale price variations for similar equipment produced by different manufacturers;
- differences in technical performance of various solar collection, conversion and heat transfer elements;
- uncertainty in the rate with which improvements in technical design, industrial production procedures, and manufacturing scale will reduce the wholesale prices of solar IPH components;
- wide variations in system efficiency due to differences in process requirements for heat as a function of time, availability patterns of solar radiation, engineering sophistication of the complete solar IPH installation, operating procedures for the plant, and time required for routine and non-routine operation and maintenance;
- bid spreads from different engineering firms, even when the wholesale price of the solar and nonsolar components is well-defined; and
- cost overruns due to a lack of widespread international experience with commercial solar IPH components and installations.

66

Variations in the financial factors reflect differences among regions and countries in financial practices, tax credits for solar energy systems, special depreciation and tax status for such systems, prevailing interest rates, availability and price of traditional fuels for IPH facilities, and so forth.

5 INVESTMENT ANALYSIS OF SOLAR INDUSTRIAL PROCESS HEAT SYSTEMS

5.1 INTRODUCTION

We analyzed the investment characteristics of solar industrial process heat systems under a variety of economic and financial circumstances. The first example is a brewery in Zimbabwe in which 25 percent of the process heat is assumed to come from solar energy. In this analysis, financial conditions characteristic of Zimbabwe were used. The impact on the IRR of changes in corporate tax rate, depreciation period, investment tax credit, operation, maintenance, tax and insurance costs, fuel price escalation rate, percent equity, fuel cost, debt interest rate, system cost, and system life were examined. A second analysis was conducted using financial conditions characteristic of the United States. The sensitivity of the internal rate of return to changes in system capital cost, rate of increase of oil prices, investment tax credit, the percent equity, and the debt interest rate was determined for a nominal base case.

In the second example, we have gone into some detail to show how the internal rate of return will change with changes in the controlling economic and financial parameters. In both the Zimbabwe and U.S. examples, the central importance of such financial factors as investment tax credits, fuel prices, rate of fuel price increase, system life, debt/equity ratio, debt interest rate and depreciation period is demonstrated.

5.2 SOLAR INDUSTRIAL PROCESS HEAT FOR A BREWERY IN ZIMBABWE

5.2.1 Introduction

In order to illustrate the calculation of the economic feasibility of investment in a solar industrial process heat system in a developing country, a case was chosen for a brewery in Zimbabwe. Most of the countries in the world produce beer; an even larger number have general food and beverage processing needs which require pasteurization. Because of the widespread need for such processing, we felt that a solar industrial process retrofit to a developing country brewery would be a useful example. In this example we have tried to use reasonable estimates of the factors which determine the rate of return on such an investment. The internal rate of return and its sensitivity to various changes in the important financial and economic factors is calculated.

5.2.2 The Solar Brewery

In our example, a brewery in Zimbabwe, about twenty-five percent of the process heat is assumed to be provided by a solar industrial process heat system. We assume that the brewery produces 14 million cases of beer (84 x 10^6 liters) each year and works around the clock, every day of the year. About one-half of the thermal energy required for the plant is used to pasteurize 14 million cases of beer. This requires about 18,000 GJ of heat energy supplied at 65 °C. To reduce fuel bills substantially while maintaining a fossil-fired back-up in place, one-half of the pasteurization process heat will be supplied with a solar system providing 9,000 GJ of solar-derived heat annually.

The brewery location receives an average of 7.25 GJ of solar radiation per square meter each year on a surface tilted at the angle of the brewery latitude. Since a flat plate collector can deliver 45% of this solar energy as heat at 65 °C, 2760 square meters of collectors are required to supply 9,000 GJ of heat per year. We assume that since this is only half the heat needed for pasteurization and since most of the pasteurization can be scheduled during the day, that all of this heat can be used.

Table 5.1 summarizes the specifications of our example. Table 5.2 summarizes the financial and economic parameters for this analysis. The capital cost is the present optimistic U.S. cost. The oil price represents the

Table 5.1
Summary of Specifications for Solar IPH System for Zimbabwe

Parameter	Specified Value
Insolation	7.5 GJ/m^2-yr on surface tilted at angle of latitude
Process Temperature	65 °C
Process Scheduling	24 hour continuous, with full use of solar system during days, all solar generated heat assumed to be collected and used
Solar Collection and Delivery Efficiency	45% at 65 °C
Required Collector Area	2760 m^2
Installed System Cost	\$225/m^2

Table 5.2
Economic and Financial Parameters for the Zimbabwe SIPH Example

Parameter	Value
Capital Cost	$2200/kW(th)
Percent Equity	50%
Debt Interest Rate	20% per year
Investment Life	20 years
Year 1 Cash Flow	$400 ($60/bbl oil)
Cash Flow Escalation Rate	11% per year
Taxes and Insurance	$44/year (2% of Capital Cost)
Operation and Maintenance	$44/year (2% of Capital Cost)
T&I Escalation Rate	8% per year (equal to inflation)
O&M Escalation Rate	8% per year
% Initial Investment Allowed for Depreciation	100%
Salvage Value	None
Depreciation Life	7 years
Depreciation Method	Straight Line
Marginal Tax Rate	44%
Investment Tax Credit	25%
Cash Flow Method	Conventional (no sinking fund)
Internal Rate of Return	17%

present bulk retail price in Zimbabwe. The financing parameters are typical of industrial investment in Zimbabwe today.[45]

In this example, we have used optimistic but attainable costs for such a flat plate collector solar IPH system. At $225 per square meter of collector for the installed costs of the system, the system capital cost is about $2200 per average kW(th). The average rate of solar thermal energy production over the year is about 286 kW(th). Combining the performance, economic and financial factors for this investment yields an internal rate of return of about 17 percent.

5.2.3 Parametric Financial Analysis for the Zimbabwe Brewery

In calculating the internal rate of return for this application, we examined the effect of changes in a number of financial and economic variables.

Table 5.3
Economic and Financial Parameters Used in the Financial Analysis of the Zimbabwe Solar Industrial Process System

Factor	Range
System Cost ($/m^2	$100 - $350 ($960 - $2880/kW)
Fuel Cost ($/GJ)	$5 - $14
Investment Tax Credit (%)	0 - 50%
System Life (years)	10 - 20
Debt Interest Rate (%/year)	3 - 35
Percent Equity	15 - 100
Fuel Escalation Rate (%/year)	9 - 18
O&M and T&I, combined, as annual percentage of capital cost	2 - 8
Depreciation Period (years)	1 - 10

The factors examined in our sensitivity analysis are shown in Table 5.3. These are listed in roughly the order of importance, in terms of the sensitivity of the IRR to changes in these factors.

The impact of changes in the capital cost on the IRR is substantial (Figure 5.1). The same is clearly true for the dependence of the IRR on the fuel costs (Figure 5.2). Since fuel costs will continue to rise over the long term, the competitive position of SIPH will improve. Figure 5.3 demonstrates the importance of the investment tax credit as a mechanism for encouraging investment in renewable energy systems. Increasing the presently effective ITC in Zimbabwe from 10 percent to 30 percent for solar energy systems would, in this example, increase the IRR from 17 percent to 28 percent, substantially increasing the attractiveness of such an investment. Figure 5.4 shows the impact of assumed system life on the IRR. The importance of this parameter is clear. If investors decide that a maximum of ten years system life can be used, because of the limited experience with certain types of solar energy systems, the IRR will be much less attractive than if a longer life is assumed. For flat plate collectors, presently available hardware can last twenty years or more, but a somewhat more conservative assumption (15 years) has been used in this analysis. Figure 5.5 indicates the impact of a change in the debt interest rate on renewable energy technology

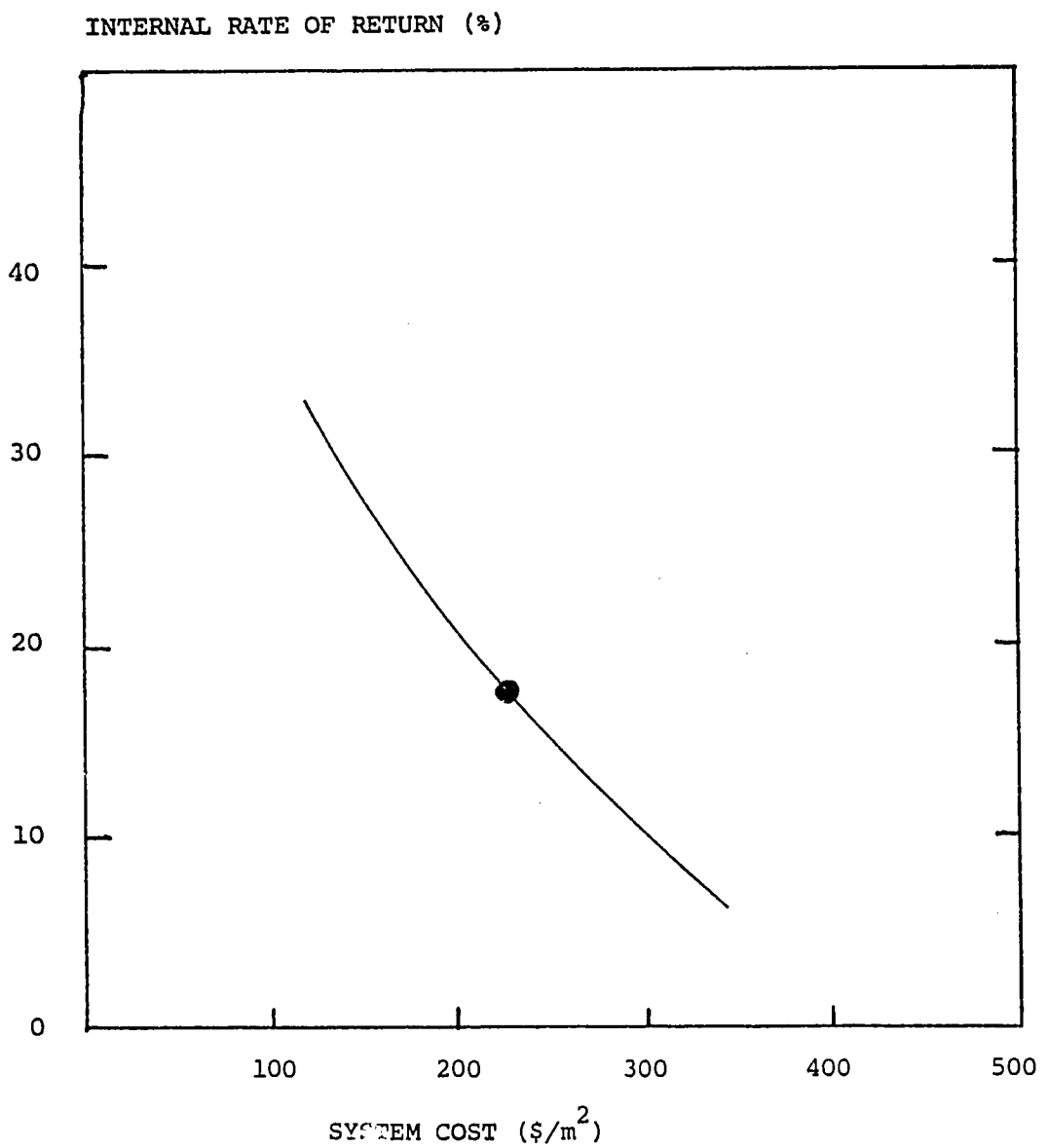


Figure 5.1. Internal Rate of Return as a Function of System Cost Zimbabwe Solar Industrial Process Heat Case Example.

72

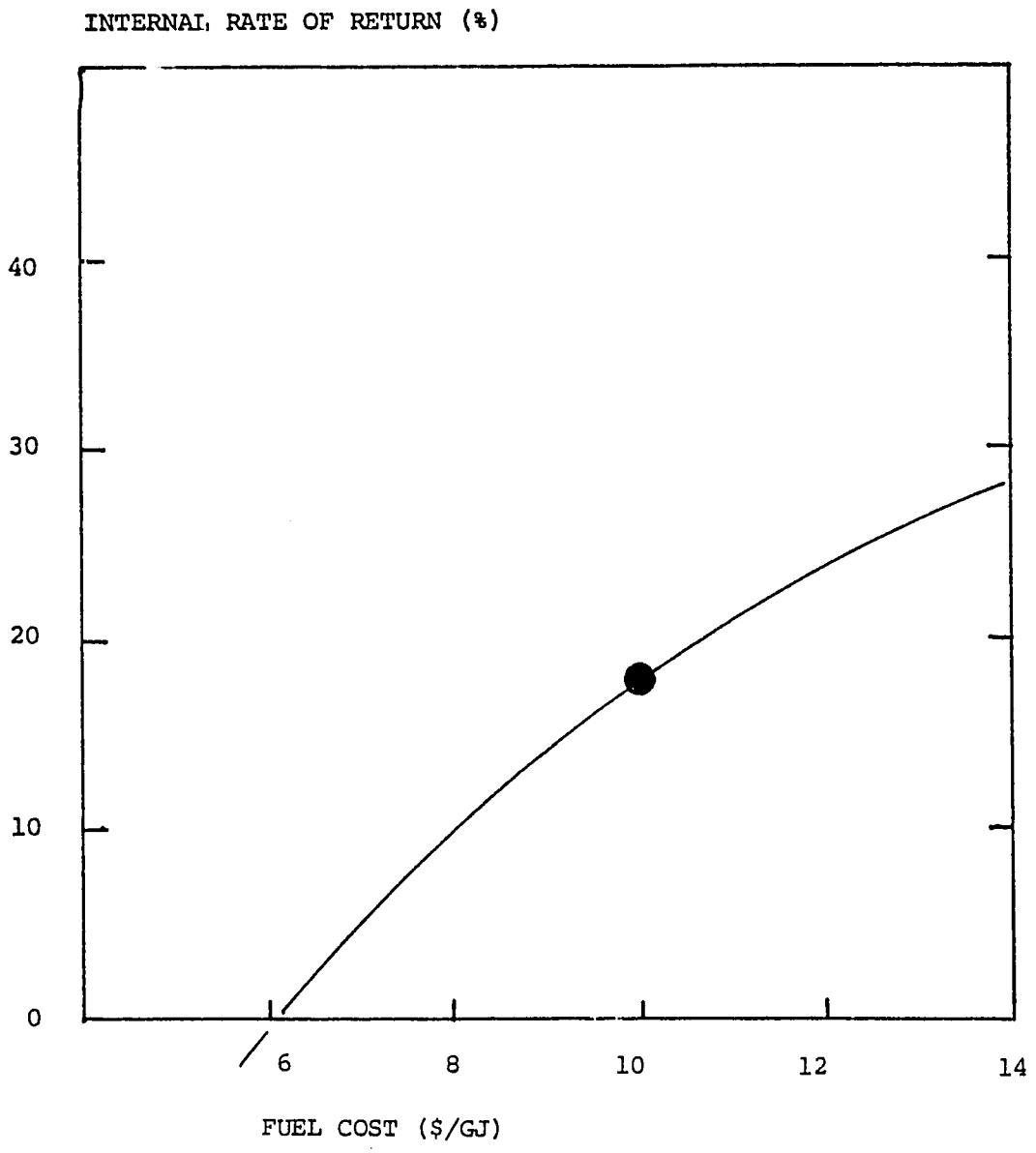


Figure 5.2. Internal Rate of Return as a Function of Fuel Cost for Zimbabwe Solar Industrial Process Heat Case Example.

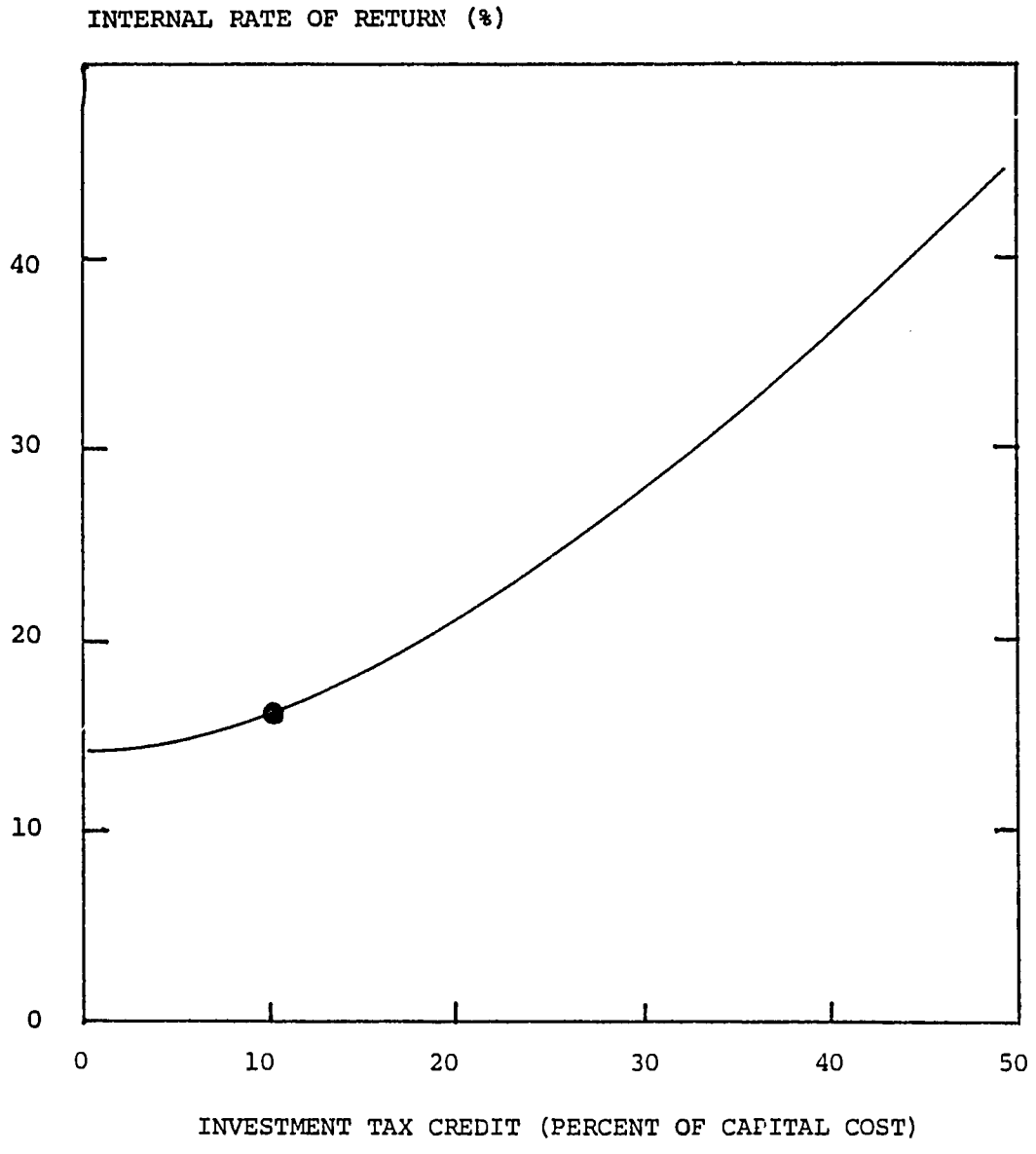


Figure 5.3. Internal Rate of Return as a Function of Investment Tax Credit for the Zimbabwe Solar Industrial Process Heat Case Example.

14

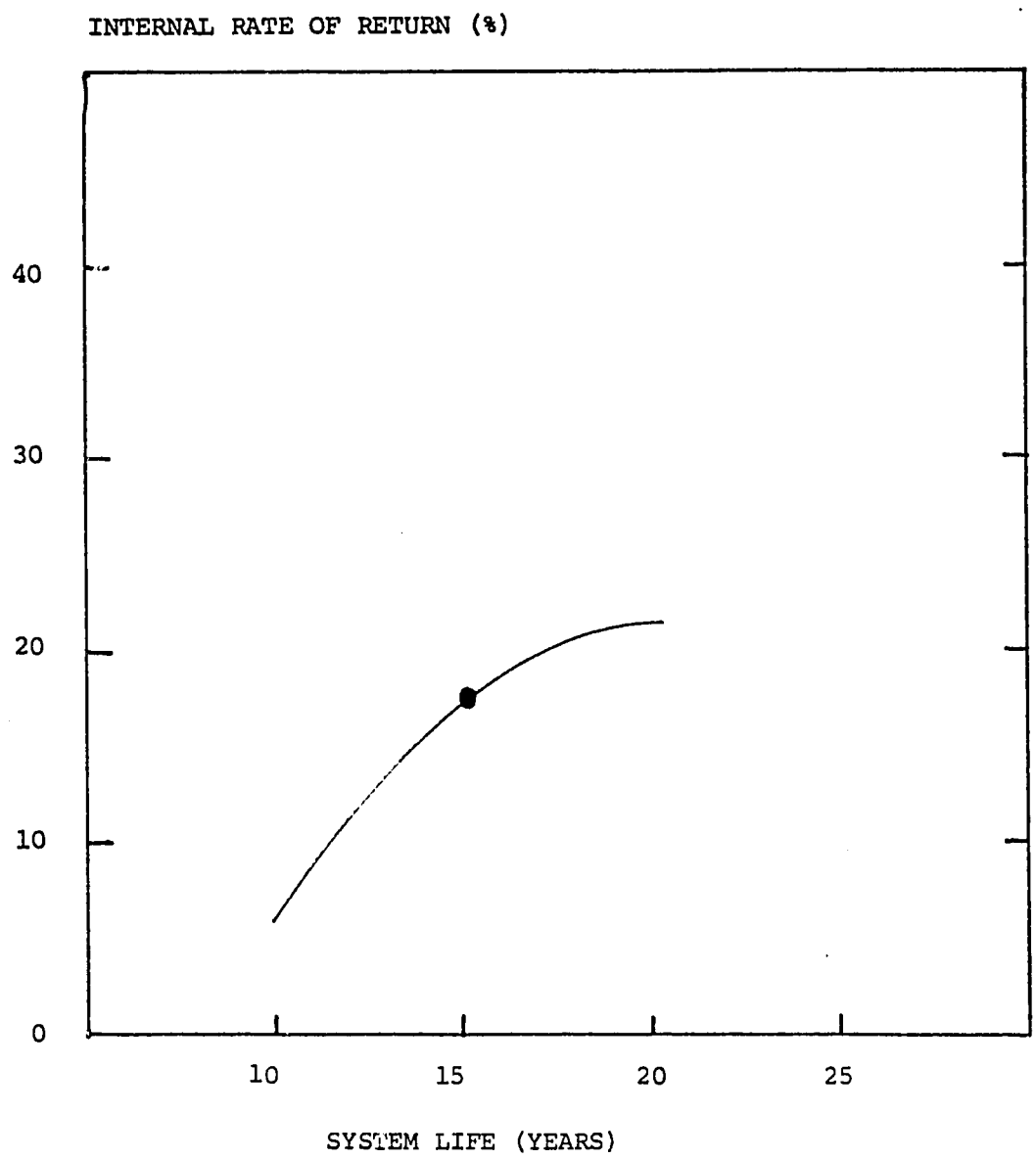


Figure 5.4. Internal Rate of Return as a Function of System Life for the Zimbabwe Solar Industrial Process Heat Case Example.

75

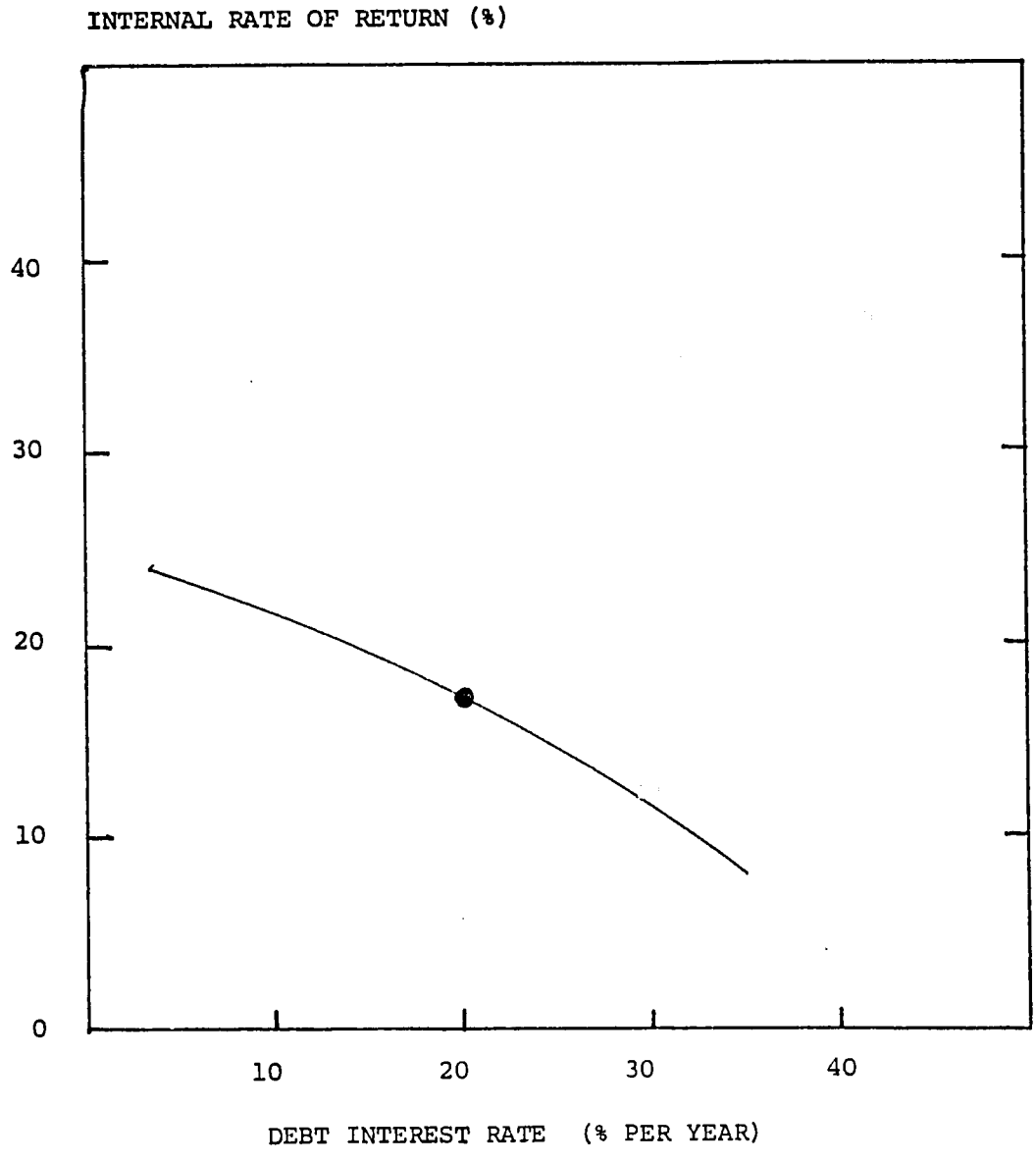


Figure 5.5. Internal Rate of Return as a Function of Debt Interest Rate for the Zimbabwe Solar Industrial Process Heat Case Example.

76

investments in Zimbawe. Establishing a lower effective interest rate (in essence a renewable energy subsidy) would increase the IRR. In this example, lowering the interest rate from about 20 percent to ten percent would increase the IRR from 17 percent to 22 percent, a significant increase. Figure 5.6 indicates the dependence of the IRR on the degree of equity financing. For debt/equity ratios below 50 percent the IRR does not vary very much with increased equity. Figure 5.7 demonstrates for this particular example the impact of different fuel escalation rates on the IRR. This behavior depends strongly on the other elements of the financial analysis. Again, increases in the real price of fuel at rates in excess of 3 percent per year will improve the IRR. A doubling of the fuel increase rate from 3 percent to 6 percent per year will result in an increase of the IRR from 17 percent to 22 percent. Figure 5.8 shows that as O&M and T&I costs increase (as a fraction of total capital cost), the IRR will decline, as expected. Property tax can be an instrument of fiscal and investment policy for a government. Figure 5.9 shows that for depreciation periods below about 7 years (for straight line depreciation) the IRR rises smoothly with declining depreciation. Accelerated depreciation of renewable energy technology investments can also be a powerful tool for creating incentives for the use of such technologies.

5.2.4 Conclusions

These examples demonstrate the substantial range of returns on investment which can occur for a solar industrial process heat system in a developing country. In particular, the importance of the financial factors governing the investment is manifest. Encouragement of solar technologies for displacement of oil for process heat production in Zimbabwe translates directly into policy-mandated shifts in the investment environment for such capital intensive technologies. As we will see, the same is true elsewhere, including the United States, as shown in our next example.

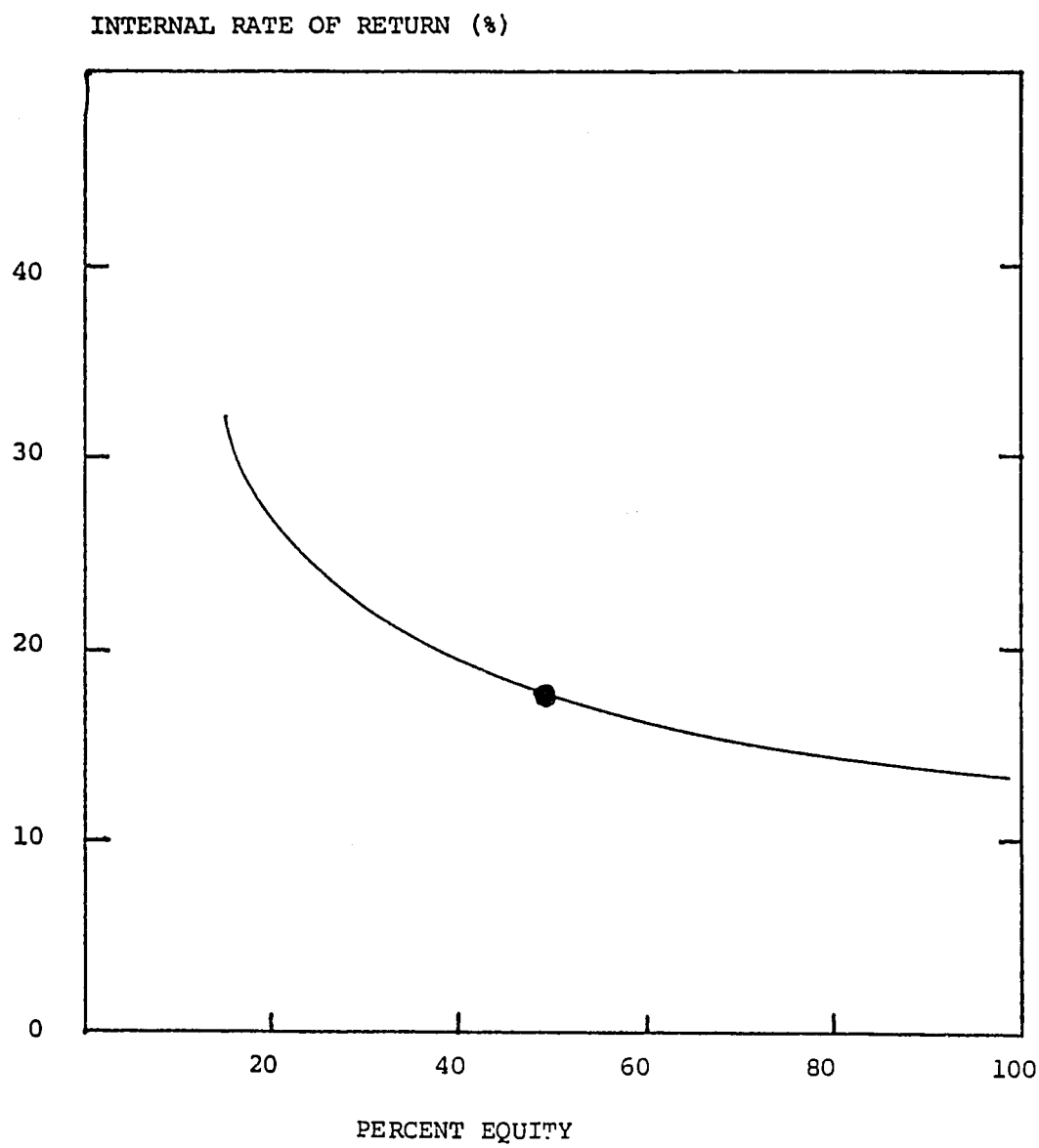


Figure 5.6. Internal Rate of Return as a Function of Percent Equity for the Zimbabwe Solar Industrial Process Heat Case Example.

78

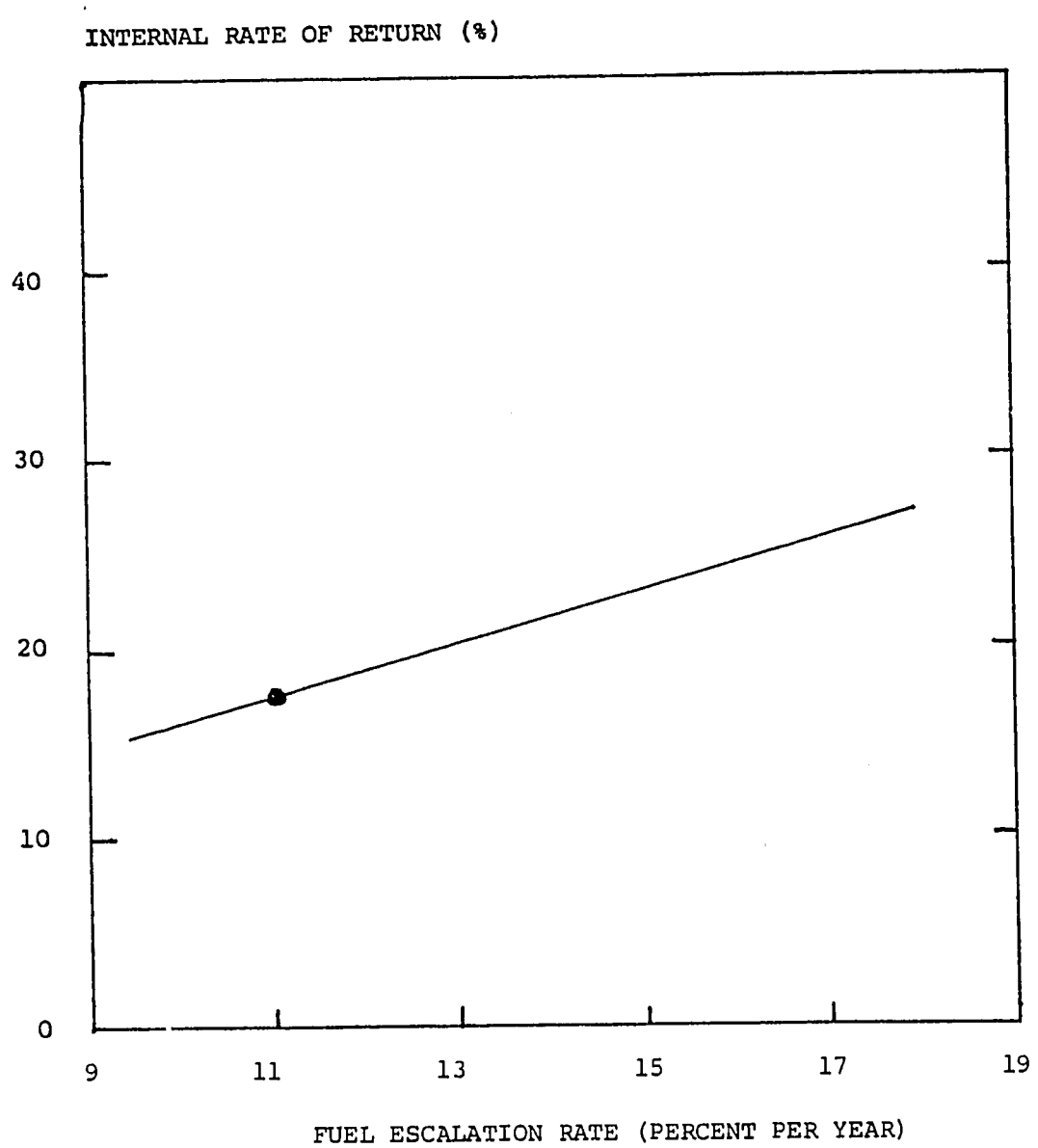


Figure 5.7. Internal Rate of Return as a Function of Fuel Escalation Rate for the Zimbabwe Solar Industrial Process Heat Case Example.

19

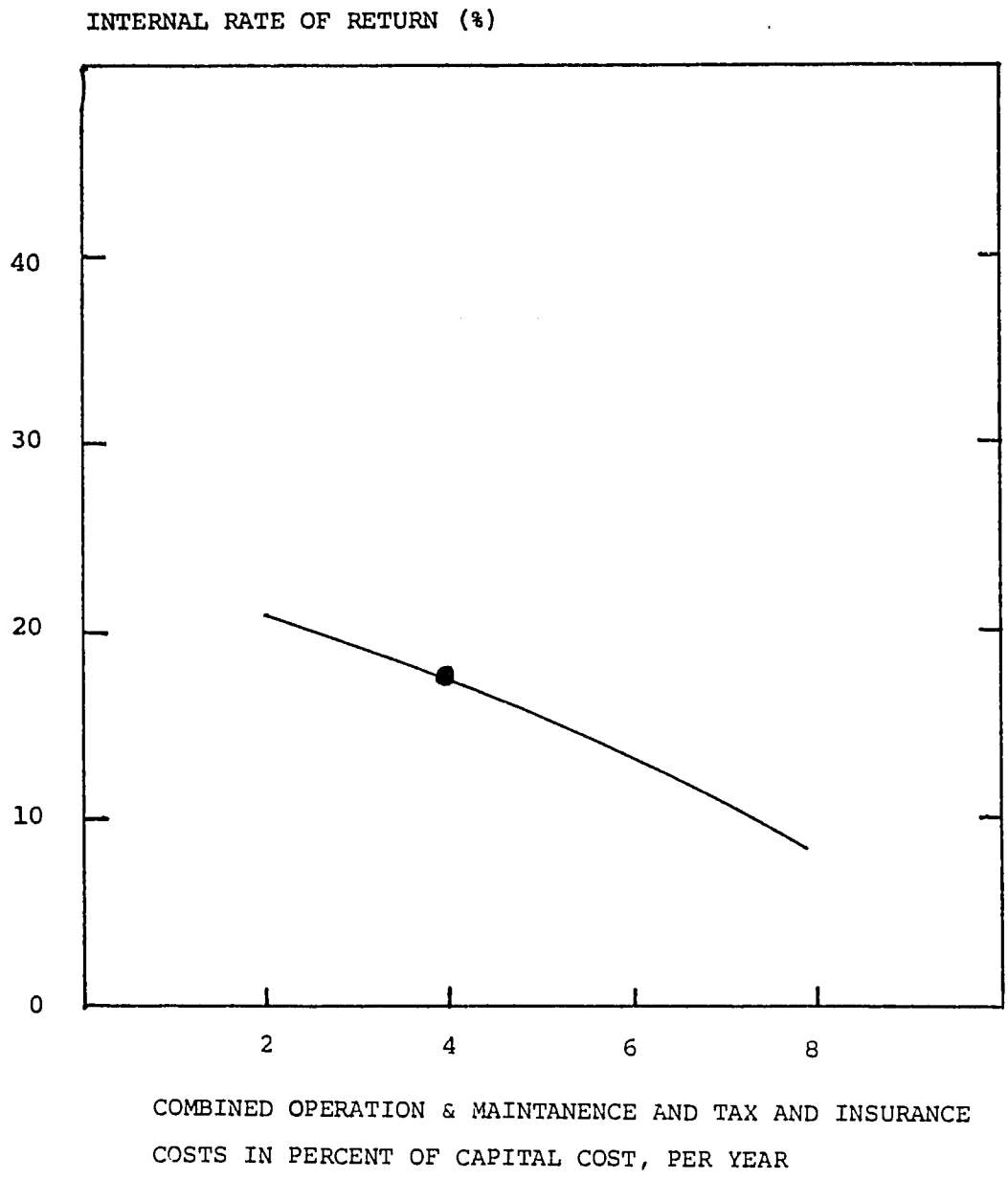


Figure 5.8. Internal Rate of Return as a Function of Operation, Maintenance, Property Tax, and Insurance for the Zimbabwe Solar Industrial Process Heat Case Example.

80

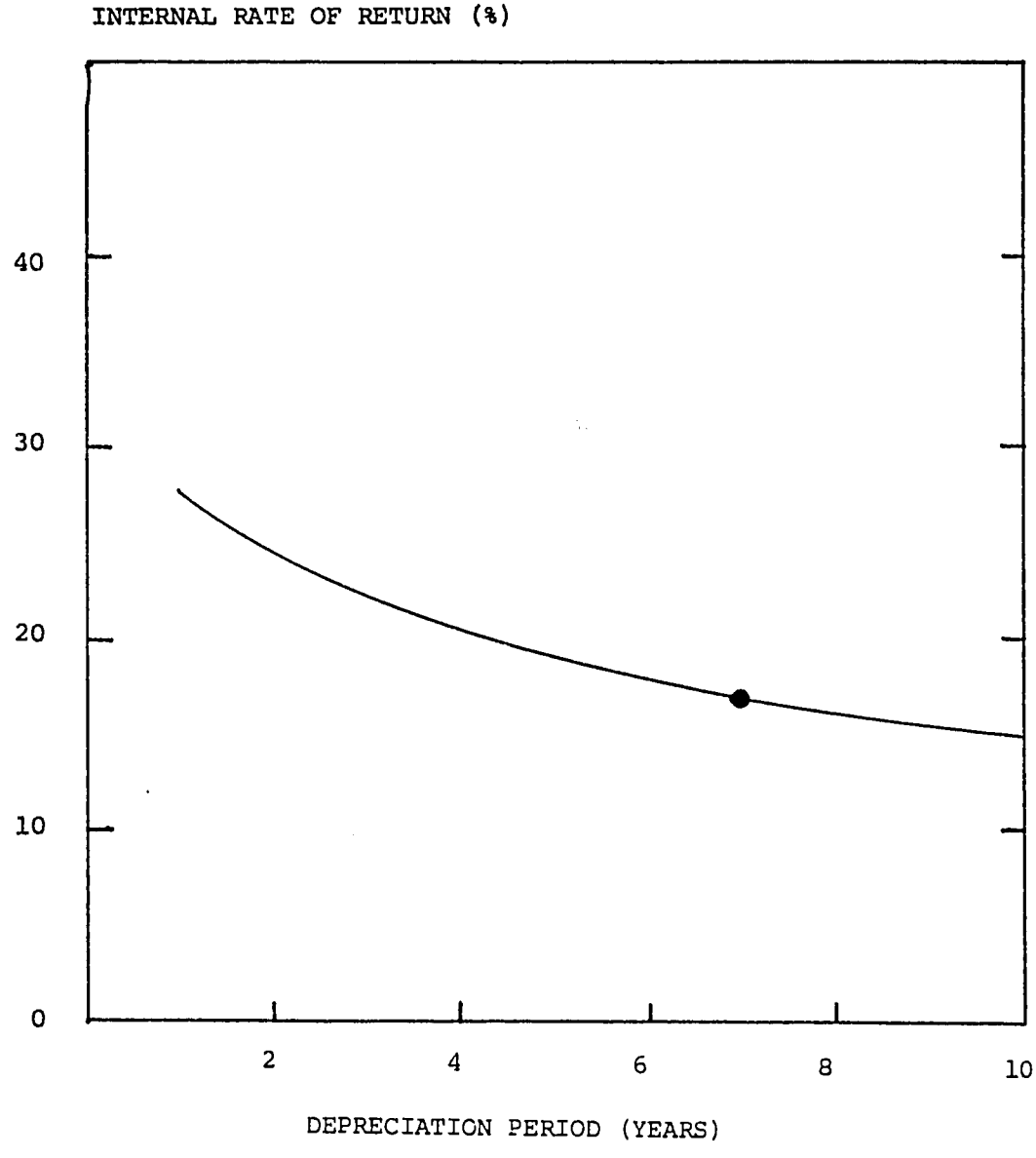


Figure 5.9. Internal Rate of Return as a Function of Straight Line Depreciation Period for the Zimbabwe Solar Industrial Process Heat Case Example.

5.3 INFLUENCE OF POLICY-CONTROLLED FINANCIAL VARIABLES AND TECHNOLOGY-DOMINATED ECONOMIC FACTORS ON THE INTERNAL RATE OF RETURN FOR SOLAR INDUSTRIAL PROCESS HEAT

5.3.1 The Basis of the Financial Analysis

A sensitivity analysis was conducted to explore the relative importance of various economic and financial parameters in the determination of the internal rate of return (IRR) for a solar industrial process heat (SIPH) system investment. Six parameters were initially chosen for variation. These include the capital cost of the SIPH system, the current price of competitive fuels such as oil, gas and coal, the rate of increase in the real price of the competitive fuels, the debt interest rate, the debt/equity ratio, and the investment tax credit. Other parameters were held fixed at the values chosen for the financial base case.

Table 5.4 lists the independent and parametric variables used in the five case examples. This range of analysis is hardly exhaustive, but the results do show the importance of each of the economic and financial parameters which combine to determine the internal rate of return for a renewable energy project. Table 5.5 indicates the range of values used for the variables picked for this analysis.

The financial base case was selected for conditions applicable to the United States. The economic and financial parameters chosen for this case are summarized in Table 5.6. Each of the relevant economic and financial parameters is discussed briefly here, with the range of variation for the five variable parameters and the basis for selection of this range summarized.

Table 5.4
Independent Variables and Parametric Variables for Solar IPH Internal Rate of Return Calculations

Case	Run	Independent Variable	Parametric Variable
1	1-14	Rate of Oil Price Increase	Capital Cost
2	15-28	Capital Cost	Oil Price
3	29-33	Investment Tax Credit	---
4	34-39	Percent Equity	---
5	40-44	Debt Interest Rate	---

Note: All other parameters are the base case values.

92

Table 5.5
Parameters and Values Chosen for Sensitivity Analysis

Parameter	Values Used for Analysis
Capital Cost ($/kW)	2500, 4000, 6000, 8000, 10,000
Oil Price ($/bbl)	30, 45, 60
Rate of Fuel Price Increase	0, 3, & 6% per year
Investment Tax Credit (%)	0, 10, 25, 40, 50
Debt Interest Rate (%/year)	11, 13, 15, 17
Percent Equity	30, 40, 50, 65, 80, 100

Table 5.6
Economic and Financial Parameters for the Base Case

Parameter	Value
Capital Cost	$4000/kW(th)
Percent Equity	50%
Debt Interest Rate	15% per year
Investment Life	20 years
Year 1 Cash Flow[1]	$214 (based on $30/bbl oil)
Cash Flow Escalation Rate[2]	11%/year
Taxes and Insurance[3]	$40/year
Operation and Maintenance[3]	$40/year
T&I Escalation Rate	8%/year
O&M Escalation Rate	8%/year
% Initial Investment Allowed for Depreciation	100%
Salvage Value	None
Depreciation Life	7 years
Depreciation Method	Straight Line (SL)
Marginal Tax Rate	48%
Investment Tax Credit	25%
Cash Flow Method	Conventional (no sinking fund)
IRR	11.6%
Discounted Payback Period	19 years

[1]The first year cash flow is based on displacement of oil costing $30 per barrel and normally converted to process heat with a net efficiency of 70%.

[2]The nominal inflation rate is taken as 8%, with oil prices assumed to rise at 11% per year, or 3% per year above inflation.

[3]O&M costs and T&I costs are each assumed to be one percent per year of the base case capital cost.

This financial analysis is indicative of the various circumstances which will determine the final IRR for a SIPH project. However, many of the fixed values for parameters such as debt interest rate, investment life, marginal tax rate, and tax and insurance costs are representative of conditions in certain industrialized countries, notably the United States. For regions where these parameters take on very different values, the impact of these different values on the IRR will have to be taken into account.

5.3.2 The Variable Parameters

Capital Cost

The wide range of sunlight conditions, installed system cost per square meter of aperture, and net annual average system efficiency all conspire to create a very wide range of possible overall SIPH system costs. For this analysis, we have assumed a range of $2500 to $10,000 per kW(th), with the expectation that the actual installed costs of mature systems, properly engineered and operated in very good sunlight environments will be in this range. At a 20% fixed charge rate this corresponds to a levelized energy cost of $0.057 to $0.23 per kW(th)-hr of delivered useful process heat. Economic competitiveness would be achieved on an annualized basis with alternative fuels (burned at 75% net thermal efficiency) in the range of $70 to $300 per barrel of oil equivalent (boe). Without conducting any sophisticated financial analysis, it is clear that even with very low effective fixed charge rates, (say 10% or less) it will be necessary for SIPH systems to have installed costs well below $10,000 per kW(th).

For cases where the capital cost is taken as fixed, we have picked a base case installed price for the SIPH system of $4000/kW(th) as shown in Table 4.3.

Oil Price/Year 1 Cash Flow

The cash flow is determined by the worth of the process heat delivered by the SIPH system. We consider only the price of the displaced fuels, with no allowance given here for displacement of thermal capacity in the combustion equipment. One kW(th) of average, continuous production will yield 8760 kW(th)-hrs or 29.9 MBtu of useful process heat per year. This will displace 7.14 boe of fuel converted with a net efficiency of 0.70, assuming 6 MBtu per boe. If the oil displaced is worth $30 per barrel, the first year cash flow would be $(7.4 x 30) = $214.

For our analysis, we picked $30, $45, and $60 per boe. While higher values would result in higher values of the IRR, we do not think it is presently meaningful to consider fuel prices above $60/boe (in 1981 dollars) for this analysis.

Cash Flow Escalation Rate/Increase in Oil Prices

The rate with which the cash flow increases depends on the assumed rate of increase of competitive fuels. For our analysis we have chosen a range of zero to six percent per year increase in the real price of oil and other competitive fuels. This spans the range over which most institutions appear to disagree. The World Bank, in its recent report on Indonesia[47] uses a rate of 3.0% per year, the United Nations Secretariat for the Conference on New and Renewable Sources of Energy uses 2.5% per year,[35] and the U.S. Congress has used 3.0% per year in the formulation of some of current U.S. energy policy and legislation. By contrast, some informed observers[46] such as Fesheraki (1980) have suggested that for a least the decade of the 1980's, the real increase in price will be closer to 10% per year. This range is shown in Table 5.7.

Investment Tax Credit

Establishment of investment tax credits for renewable energy technologies and energy technologies which increase the efficiency of energy use can be a powerful incentive for increased investment in such technologies. In the United States a 25% Federal investment tax credit applies to solar IPH equipment (Taubman and Weingart, 1981) and many of the individual states have

Table 5.7
Various Estimates of Increases in Real World Oil Price

Increase (%/yr)	Time Period	Reference
2.5*	1981 - 2000	United Nations (1981)[35]
3.0	1981 - 2000	World Bank (1981)[47]
3.0	1981 - 2000	U.S. Congress
10.0	1980 - 1990	Fesheraki (1980)[46]
0.0-6.0	1981 - 2001	(This study)

*The UN report[35] indicates that 2.5% is extemely conservative and suggests that the actual rate of increase may be much higher.

put additional investment tax credits in place for such technologies. The standard investment tax credit for industry is 10%. We have chosen a range of 0% to 40% (0, 10, 25 and 40 percent) for our analysis. For other analyses done here, we have fixed the value of this parameter at the current U.S. Federal level of 25%.

Percent Equity

For many real projects a mixture of debt and equity financing will be required. We have used a range of 30% to 100% equity financing.

Debt Interest Rate

Corresponding to U.S. conditions in 1981, a value of 6% was chosen, to be used for future analysis of the effect of various debt/equity ratios on the IRR.

Fixed Parameters

Investment Life

An investment life of 20 years was chosen. The IRR does not depend too strongly on this number. For conventional energy technologies a lifetime of 30 years is often assumed, but because of the relative lack of experience with most renewable energy technologies, 20 years seems a better estimate.

Tax and Insurance

These were assumed to be 1.0 percent of the base case capital cost, for an annual charge of $40.00 per kW(th).

Inflation Rate

Eight percent per year is assumed (current U.S. rate).

Operation and Maintenance Costs

For many conventional technologies, this is taken as 2.5% of the initial capital cost. For our analysis we have used 1.0% of initial base case capital cost. This is not entirely satisfactory, since the O&M costs for a solar system will depend on the area of the system but not on the cost per average kW(th). For instance, two identical facilities would be expected to have similar or identical O&M costs. In one case, the facility could be located in a superb insolation environment and be part of a highly efficient industrial process heat system. The other facility might be in only a fair insolation environment, and embedded in an industrial process heat facility

with an average or below average net efficiency. In the latter case, the capital cost PER AVERAGE DELIVERED THERMAL KILOWATT could be as much as four or five times greater than that for the first system. Yet the O&M costs would be virtually the same for the two systems. On the basis of experience with actual systems, we have chosen one percent of the base case capital cost ($4000/kW) per year for the O&M costs.

Again, actual case examples of SIPH systems and their financing is required, and our parametric analysis only suggests those financial and economic parameters which are the most important in determining the IRR for the project.

Property Tax and O&M Escalation Rates

For our initial analyses we have assumed these to be 8%/year, equal to the inflation rate.

Percent Initial Investment Allowed for Depreciation

The entire investment is assumed to be depreciated, with a uniform depreciation life. In many facilities, various components may be assigned different depreciation lifetimes, as in the case of commercial buildings. Because the actual depreciation life has a relatively small impact on the IRR (compared with the other variables chosen), this level of detail is not relevant to our analysis.

Salvage Value

We have assumed NO salvage value for the SIPH facility.

Depreciation Lifetime and Schedule

The depreciation life will generally be shorter than the useful life of the installation. For our financial calculations in the United States, a depreciation life of 7 years, together with straight-line depreciation was used.

Marginal Tax Rate

A marginal tax rate of 48%, applicable to the United States, was chosen. Governments interested in accelerating the use of indigenous renewable sources of energy could consider altering the tax rate for technologies and projects using these sources.

Negative Cash Flow Accounting Procedure

Conventional; no sinking fund.

5.3.4 Case Study Examples

Case 1 -- IRR vs Capital Costs and Rate of Oil Price Increases

In this example (Table 5.8, Figure 5.10), a range of rates of increase for oil prices from 0 to 6 percent per year above inflation is used. Oil is assumed to cost $30/bbl. Three capital costs -- $2500, $4000 (the base case, and $6000 are used. For the least expensive system, the IRR is attractive for all rates of oil price increase. However, for the base case and the more expensive case, this is not so. If a three percent rise in real oil prices is assumed in the financial analysis, the projected IRR is almost 12 percent. If no increase in oil prices (or the prices of the alternative fuels) is assumed, the return on investment is negative. For the most expensive of the systems considered, an annual rate of increase of 6 percent in real oil prices would be required to produce an IRR above ten percent.

Case 2 -- IRR vs Capital Costs and Oil Prices

In this example (Table 5.9, Figure 5.11), the base case cost of $4000 per kW(th) is used, along with a 3 percent per year increase in real oil prices. If $30 per barrel is assumed for the current oil price, the IRR is negative for capital costs above $6000 per kW(th). At $45 per barrel the IRR is positive even at $10,00 per kW(th). For $60 per barrel, the IRR is in excess of 11 percent for capital costs as high as $10,000 per kW(th). In order to secure an IRR in excess of 20 percent, the capital costs must be below $6000 per kW(th) for oil prices of $45 per barrel. The higher oil prices are likely to prevail soon for most countries, and a capital cost of $6000 per kW(th) is not unreasonable for the mid-1980's.

Table 5.8
Internal Rate of Return (percent/year) for the Base Case, as a Function of Rate of Oil Price Increases and Capital Costs

Oil Price Increase (Percent per Year)	Capital Cost ($/kW)		
	2500	4000	6000
0.0	14.0	-4.0	
2.0	18.1	9.1	-6.7
3.0	19.7	11.6	1.6
4.5	21.9	14.5	7.2
6.0	23.9	16.9	10.7

Case 1, Runs 1 - 14.

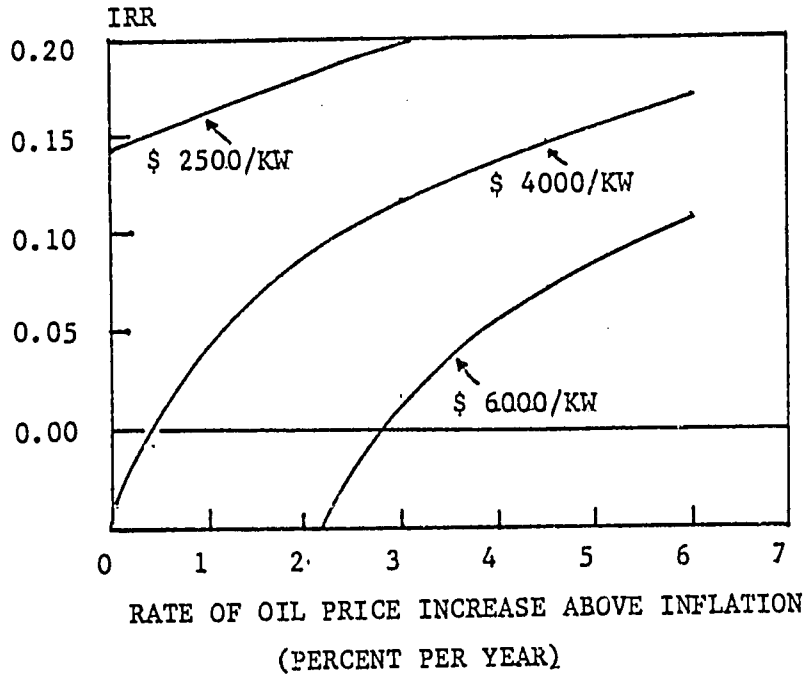


Figure 5.10. Internal Rate of Return (IRR) as a Function of the Rate of Increase in Oil Prices and of SIPH Capital Cost, for the Base Case System.

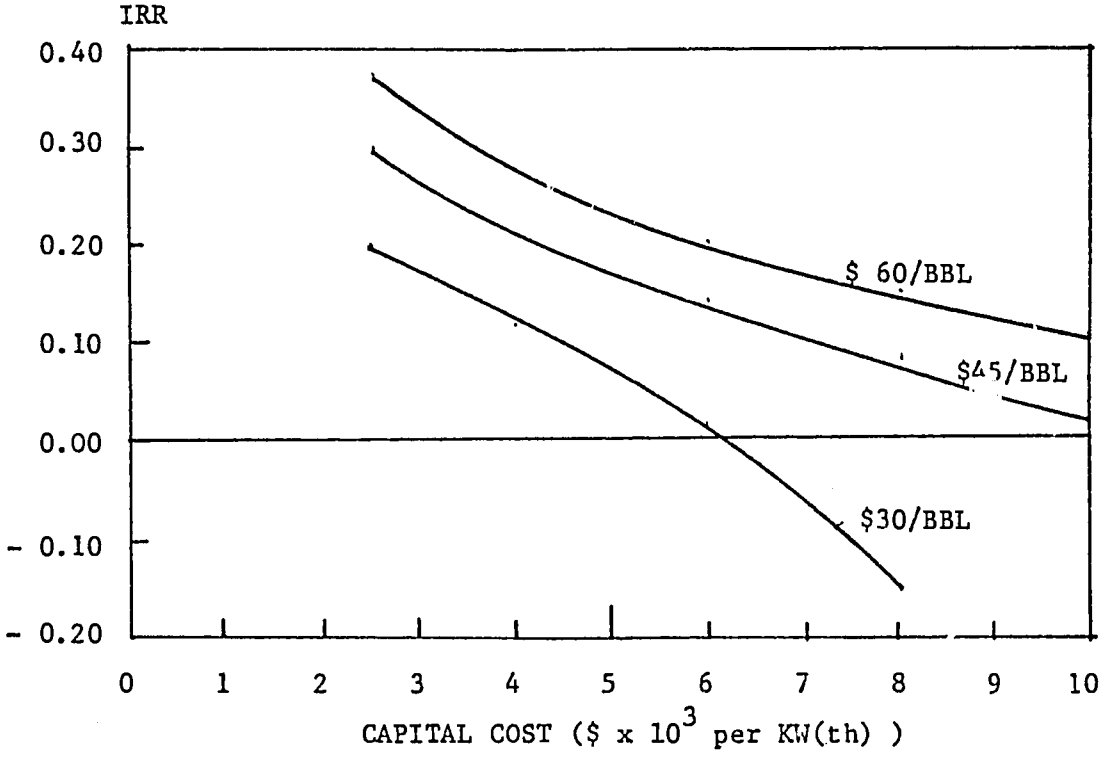


Figure 5.11. Internal Rate of Return (IRR) as a Function of Capital Cost and Oil Prices for the Base Case SIPH System.

84

Table 5.9
Internal Rate of Return (percent/year) for the Base Case as a Function of System Capital Cost and Oil Prices

Capital Cost ($/kW)	Oil Prices ($/bbl) 30	45	60
2,500	19.7	29.6	37.5
4,000	11.6	21.0	27.4
6,000	1.6	14.0	20.1
8,000	-15.5	8.3	15.1
10,000		2.0	10.9

Case 2, Runs 15 - 28.

Case 3 -- IRR vs Investment Tax Credit

In this example, shown in Table 5.10 and Figure 5.12, the IRR for the base case is a strong function of the investment tax credit (ITC). In the case of the United States, the presence of a 15 percent added ITC for certain solar applications, including SIPH, raises the effective IRR from 6.0 percent to 11.6 percent. In some cases, the additional availability of local and state tax credits can raise the effective ITC even further. In the case of a 40 percent ITC, which some countries or regions may wish to implement to stimulate a local solar industry and widespread solar thermal applications, the IRR would be 22 percent, contrasted with under 4 percent with no ITC present. As Figure 5.12 suggests, the ITC is one of the most powerful incentives available to a government to favorably shift the investment environment for solar energy technology investments.

Table 5.10
Internal Rate of Return (percent/year) as a Function of Investment Tax Credit for the Base Case

Internal Rate of Return	Investment Tax Credit
3.6	00%
6.0	10%
11.6	25%
22.0	40%
32.9	50%

Case 3, Runs 29 - 33.

90

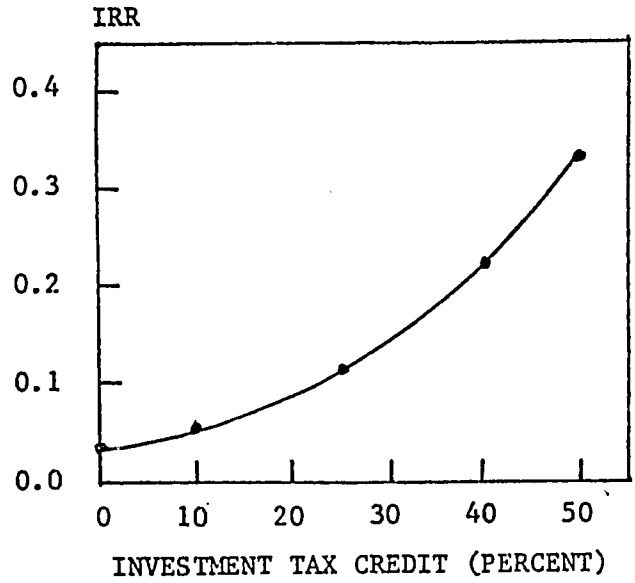


Figure 5.12. Internal Rate of Return (IRR) as a Function of Investment Tax Credit for the Base Case SIPH System

Case 4 -- IRR vs Percent Equity

The debt/equity ratio for an investment in capital intensive solar hardware will determine the IRR as Figure 5.13 and Table 5.11 show. Below about 60 percent equity financing, the IRR increases rapidly. In our base case example, where the debt interest rate is 15 percent per year, the IRR varies from a low of 9.2 percent for 100 percent equity financing to a high of 17.6 percent for 30 percent equity financing. Again, official policies regarding allowable debt/equity ratios will be one of the factors determining the extent to which an investment in solar technologies is attractive.

Case 5 -- IRR vs Debt Interest Rate

As expected, the internal rate of return will decline as the debt interest rate increases (Table 5.12, Figure 5.14). An increase in the interest rate from 11 percent per year to 20 percent per year results in a decline in the IRR from almost 15 percent to 6.4 percent. As with certain other measures, the effective interest rate charged for debt incurred in renewable energy investments will strongly affect the internal rate of return. The use of soft loans for such technologies will clearly result in much more attractive rates of return than conventional financing, for instance.

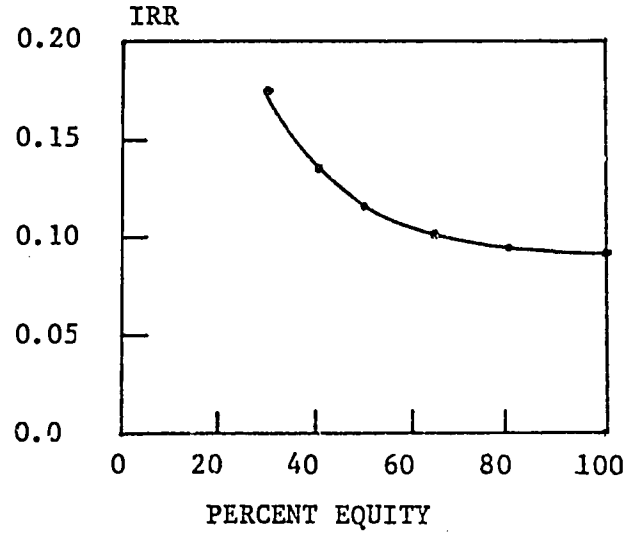


Figure 5.13. Internal Rate of Return (IRR) as a Function of Percent Equity, for the Base Case SIPH System.

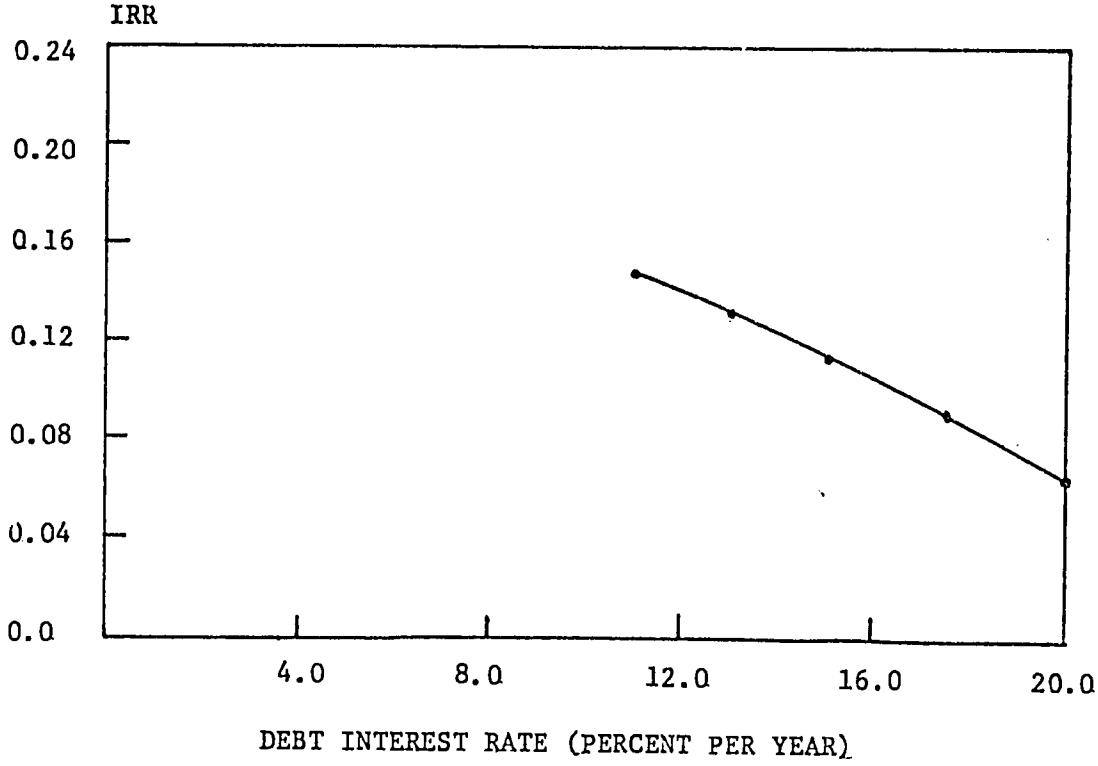


Figure 5.14. Internal Rate of Return (IRR) as a Function of Debt Interest Rate, for the Base Case SIPH System.

Table 5.11
Internal Rate of Return (percent/year) as a Function of Percent Equity, for the Base Case

Percent Equity	Internal Rate of Return
30	17.6
40	13.5
50	11.6
65	10.3
80	9.6
100	9.2

Case 4, Runs 34 - 39.

Table 5.12
Internal Rate of Return as a Function of Debt Interest Rate, for the Base Case

Debt Interest Rate (%/year)	Internal Rate of Return
11.0	14.8
13.0	13.3
15.0	11.6
17.5	9.2
20.0	6.4

Case 5, Runs 40 - 44.

5.4 CONCLUSIONS

A preliminary exploration of the impact of various economic and financial parameters on the viability of an investment in solar industrial process heat to displace fuels was carried out. Our principal conclusions are:

- There is a range of attainable SIPH system costs and performance for which these systems would be competitive with conventional fuels.
- To achieve this competitiveness, a number of actions would be required including:
  - Removal of domestic fuel subsidies,
  - Introduction of investment tax credits for investments in renewable energy technologies,
  - Inclusion of realistic projections of world market prices for oil, the fuel which will remain the pace setter for fossil fuels,
  - Development and diffusion of the engineering and industrial skills to design, install, and operate highly efficient and reliable solar IPH systems in conjunction with industrial process heat facilities,
  - Establishment of special interest rates and conditions for loans for investments in equipment which increases energy efficiency or which makes use of indigenous renewable energy resources,
  - Reduction or removal or property and equipment taxes for energy efficiency and renewable energy technologies,
  - Introduction of accelerated depreciation for renewable energy technology investments.

We have not discussed other factors which could make an investment in such facilities even more attractive than a simple economic analysis would suggest. For instance, if most or all of the SIPH equipment were eventually fabricated within the country using the systems, this would imply an increased indigenous technical, engineering, and industrial capability which could be applied to other aspects of industrial development. For oil importing LDC's, the shadow price of oil, which will remain higher than the world market price for some time, should also encourage governments to provide suitable incentives for the use of indigenous renewable sources of energy. For oil exporting LDC's, renewable energy technologies will free for export oil and gas which would otherwise be required for domestic use.

94

The opportunities for the use of renewable energy technologies such as SIPH are considerable, but it will require imaginative, aggressive, and sustained technical and policy measures to insure that these opportunities are realized on a scale which could contribute to meeting an important portion of energy needs in LDC's around the world.

6 BARRIERS AND REMEDIES

6.1 GENERIC BARRIERS TO IMPLEMENTATION

In previous sections of this report, we have identified major opportunities for saving significant quantities of non-renewable energy through the cost-effective installation of energy-efficient and solar thermal technology in the modern industrial sector of developing countries. In this section, we discuss generic barriers to these opportunities, and suggest remedies for overcoming these barriers.

There are a host of barriers affecting the timely and widespread implementation of energy-efficient and renewable energy technologies in developing countries; and, of these, the financial and institutional barriers are easily the most serious. Major barriers to implementation include:

- Lack of availability of capital and financial incentives for new and renewable energy systems
- Deficient criteria for investment in capital-intensive energy systems
- Inadequate mechanisms for technology transfer to the developing countries
- Inadequate information base on the costs, performance, and availability of NRSE
- Country-specific regulatory requirements
- Lack of widely accepted procedures and mechanisms for test and certification of renewable energy technologies and products
- Uncertainties in the development and cost of new technologies over the next few years.

We concentrate on remedies to the first six barriers, since these are far more susceptible to intervention by the international financial institutions such as the World Bank, donor agencies, and national governments than are the barriers that are unique to each technology.

6.2 ROLE OF INTERNATIONAL FINANCIAL INSTITUTIONS

The international financial institutions such as the World Bank and the regional development banks have played a major role over the last two decades in financing development projects in the less-developed countries. In the energy area, this role has historically taken the form of providing large blocks of investment capital for the expansion of electric grid systems

including construction of new generation capacity and transmission and distribution networks. Only recently, within the last two years, has the World Bank begun to make loans for energy forms other than electricity as a matter of policy.

The issue of financing of renewable energy technologies in developing countries is, as we have discussed earlier, of great importance. Since the component of capital cost in renewable energy systems is much greater than in conventional systems, financial parameters such as tax credits, interest rates, and depreciation allowances have a correspondingly higher impact on the economic and financial viability of renewables. This has been highlighted in our case study of the internal rate of return (IRR) on the investment in solar industrial process heat system in Chapter 5. For the base case assumptions set out in Table 5.6, the IRR rises by almost a factor of 10 from 3.6% to 33% as the investment tax credit increases from zero to 50%. Similarly, the IRR increases from 6% to almost 15% as the annual interest rate on debt is decreased from 20% to 11%. Our preliminary calculations clearly illustrate that there is, with current or near-term available technology of SIPH systems, a considerable area where such systems will show an acceptable rate of return by World Bank project standards provided the financial parameters, which are largely policy variables are appropriated.

The International financial institutions (IFI) already play a significant advisory role in the setting of economic policy in many developing countries. In their lending activities, the IFI are mandated to take into account economic and social development issues in addition to the narrower commercial criteria used for evaluating costs and benefits of investments. To the extent that renewable energy technologies (RET) provide macro-economic benefits such as oil savings to the national economy, or serve necessary social development goals such as energizing a rural health facility, the IFI should be able to factor these effects into their normal project appraisal criteria to provide a more favorable environment for RET.

RET generally have been either ignored or written off as "uneconomic" by the IFI project planners. The World Bank currently has only two areas for funding renewable energy projects, reafforestation for increased fuelwood production and alcohol from crops, despite an oft-articulated commitment

towards developing renewable energy resources. The major reasons why international financial institutions have not utilized renewables to a greater extent can be traced to two of the generic barriers mentioned. These are the lack of operating experience, test and certification procedures, and questionable economic performance in comparison with conventional alternatives, and a lack of information on the part of IFI staff and, as importantly, on the part of project planners in developing countries.

The developments in the world oil situation and the improved technology base for RET has partially changed the situation in regard to the first barrier. and this paper is designed to contribute to the solution of the second.

6.3 REMEDIES TO GENERIC BARRIERS

There are a number of specific actions that can be taken by the UN conference to reduce or eliminate these financial and institutional barriers. For example, the UN should strongly encourage its member nations and the international financial institutions to allocate a small fraction of their total investment in urban, industrial, and agricultural development projects to a fund for assessing the energy consequences of such projects. This fund may be used to explore the potential role of new and renewable energy sources in specific projects.

The UN should also urge the development banks and donor agencies (both national and United Nations affiliated) to adopt economic and financial accounting procedures that permit clear and consistent comparisons between the costs and benefits of new and renewable energy technologies and the costs and benefits of conventional energy technologies. Assuming that new and renewable energy systems are technically proven, we have shown that the financial environment governing the flow of investment capital into capital intensive systems is decisive in evaluating the costs of energy from such systems. The UN should therefore encourage the World Bank and other regional development banks, donor agencies, and member governments to adopt investment criteria and tax incentives to reduce the annualized costs of capital intensive energy systems if the benefits of such systems are found to be superior to those of fuel-intensive energy systems performing equivalent tasks and matched to similar applications.

The UN conference should consider adopting schemes that offer the proper incentives to investors in NRSE equipment. For example, in the proposal discussed in the appendix to our report, the government or the oil import agency of a particular country could offer to pay energy developers who invest in NRSE or energy-efficient technologies the difference between the subsidized price of particular oil products and the country's marginal cost of imported oil for the amount of oil displaced. The central governments of member nations may wish to make such payments with funds that would otherwise go to subsidizing the consumption of imported oil. Such schemes can benefit the end user and provide national economic benefits by reducing the consumption of imported oil.

A major step toward effective technology transfer is the setting up of visible and well-conceived technology demonstration projects. The UN should, therefore, urge international financial institutions to provide financial assistance for developing countries in setting up technology demonstration projects involving new and renewable sources of energy in settings that permit open access to the technology. Properly designed technology demonstration projects should include instrumentation for testing and evaluaton, and this will permit testing and certification of the equipment to be carried out for potential investors, development banks, manufacturers, users, and educational institutions. Technology demonstration projects can also be utilized for education and training in technology research, development, and deployment.

It is important that commercialization activities in LDC's of manufacturers from advanced industrial countries are acompanied by UN and IFI assistance in research, development, and training in order that the technology transfer process is open, dynamic, and permanent. Such assistance should help to alleviate legitimate concerns in LDC's about being locked into obsolete technologies and new forms of technological dependence.

To alleviate the problem of poor information on new and renewable energy systems, the UN should act to provide the international financial institutions and all donor agencies with complete, consistent, and up-to-date information on the costs, peformance, and commercial availability of a wide range of energy technologies in a variety of climatic and financial settings. Such an international data base should be continually updated, and should contain

country-specific information on capital costs, labor costs, materials availability, and technology import requirements. The data base should also contain information on the costs, performance, and financing of specific NRSE projects. The UN should establish mechanisms to ensure that all member nations and donor agencies have cost effective access to the energy technology data base.

The regulatory obstacles affecting the export of electricity to power grids from cogenerators and small power producers have been extensively addressed in the United States under the "Public Utilities Regulatory Policies Act of 1978" (PURPA). Prior to this act, electric utilities were unwilling to purchase power from cogenerators or small power producers, or to provide supplementary and back-up capacity at reasonable rates. The PURPA legislation altered this situation by requiring electric utilities to purchase power from cogenerators and small power producers at the utility's full "avoided costs," or the utility's marginal savings from the reduction in new generating capacity. Utilities are also required to provide standby power at normal rates.

The act is in the process of being implemented by the state public utility commissions, and the ultimate outcome is unclear. In those states which have implemented the provisions of the act, the effect on the economics of cogeneration and small power production has been very favorable.

Accordingly, the UN conference should urge its member nations to examine carefully their respective regulatory structures with a view to creating a symmetrical and favorable economic environment for NRSE or technologies that use scarce fossil fuels with greater efficiency.

The final barrier to implementing new and renewable energy sources in many countries is the lack of well-established procedures for testing and certification of new and renewable technologies.

There are several public and private facilities in the United States for the testing and evaluation of renewable energy systems, such as the Rocky Flats Small Wind Test Facility (for machines less than 100 kW), the Sandia National Laboratories (for solar thermal, photovolatic, and vertical axis wind systems), Wyle Laboratories (for photovoltaic and solar thermal systems) and DSET laboratories. Some of these laboratories, such as Wyle Laboratory, are prepared to provide support in the design and operation of international

100

solar energy test facilities as well as in the development and implementation of international procedures to obtain reliable test results. Procedures for test and certification are discussed at length in Section 6.4.

6.4 DEVELOPMENT OF PROCEDURES AND MECHANISMS FOR TEST AND CERTIFICATION OF RENEWABLE ENERGY TECHNOLOGIES AND PRODUCTS

Decision-makers, whether they are development banks, private investors, companies, government agencies, utilities or others will require accurate and fairly comprehensive information on the technical characteristics and performance of new energy technologies. During the early years of any new technical product many problems can be encountered. Enthusiasm for solar energy conversion systems can result, as it has in some industrialized countries, in products which are not fully tested and are potentially unreliable. Lack of long-term experience with a specific product can breed caution in potential buyers. Lack of standardized comprehensive test and evaluation procedures can make it difficult or impossible to intercompare similar products. The use of products which are not fully tested, certified, and warrantied will be perceived quite legitimately as a potential risk by investors or financing institutions, one which could delay the completion of a large project in which the renewable energy product is only one component. An example could be a solar hot water system for a tourist hotel or a solar industrial process heat system for a food processing plant.

The need for development of test and certification procedures for solar energy technologies has been discussed at various times over the past half century. However, it is only since the early 1970's, with the emergence of commercial solar products on an international scale that such concerns have led to programs in a number of countries to develop standardized test and evaluation methods, as well as procedures for certification of performance and product quality. An example is the procedure adopted by the California Energy Commission for the test and certification of flat plate solar collectors (CEC, 1980).

> "The State of California has an overall goal of encouraging the widespread use of solar energy as an alternate energy resource. In September 1977, the State Legislature passed Assembly Bill 1512 which gave the California Energy Commission (CEC) the authority to set standards that will encourage the use of solar technology."

The Energy Commission has accredited nine independent testing laboratories in the state to test and evaluate flat plate glazed solar collectors. Manufacturers participating in the certification program submit to one of the nine laboratories a collector which has been selected at random from their inventory by a CEC representative. The manufacturer is required to pay a testing fee, and submits a copy of the test report to the Commission for its review. The Commission then uses the test data to determine a product efficiency rating which it assigns to that collector. The collector manufacturer is then authorized by the Commission to label each of its products.

To qualify for an efficiency rating, the collector must pass thermal performance and physical durability standards set by the Commission. For instance, the collector efficiency cannot decrease by more than 10 percent during the testing period, and significant deterioration of the collector materials must not occur. Details of the requirements for passing the various tests are discussed in CEC, 1980.

Analogous test procedures and certification procedures have been developed in the U.S. for concentrating solar collectors suitable for production of industrial process heat, shaft horsepower, and electricity. This program, coordinated by Sandia Laboratories, Albuquerque, New Mexico, involves Sandia and two other laboratories. All three have established fully instrumented test facilities and a common set of test and evaluation procedures. Currently being tested are many of the U.S. produced concentrating linear (trough) collectors and associated equipment.

CONCLUSIONS

As with virtually all other industrial products, solar energy hardware will have to be extensively tested and evaluated, both under laboratory and field conditions, in order to assure the emergence of mature, reliable and efficient technology. Both nationally and internationally recognized and accepted procedures for test, evaluation, and certification of the performance of solar hardware will be essential as a precondition for its widespread use.

POSSIBLE ACTIONS

A number of specific actions can be taken at the international, national, and regional level to accelerate the widespread development and use of procedures and standards to test, evaluate, and certify a variety of new and

102

renewable energy technologies. Specific possible actions include the following:

1. International and regional meetings, facilitated by appropriate UN organizations, to bring together people who are involved in the establishment and use of test, evaluation, and certification procedures for renewable energy technologies. These workshops would bring together those who have been through various aspects of this process with those responsible for initiating similar activities in their own countries.

2. Establishment of permanent technical committees on standards for test, evaluation, and certification of various new energy technologies.

3. Dissemination of available information on test, evaluation, and certification (TEC) programs in various parts of the world, such as the United States, the German Federal Republic, and Japan.

4. Establish a mechanism or forum, such as an international newsletter, which would periodically summarize the performance, costs, and availability of various renewable energy technologies. In order to begin easily and quickly, existing international journals and magazines such as Solar Energy, the International Journal for scientists, engineers, and technologists in solar energy and its applications, and Sunworld could add sections on summarized case examples and working experience. Already some of the national journals and magazines, such as Solar Age and Solar Engineering in the United States and the magazine of the German Solar Energy Society are providing such a service. However, these are generally unavailable or of limited availability in many LDC's. Also, more detailed evaluations of solar installations are required to provide useful data for design engineers, financial institutions, insurance companies, and others interested in using the equipment.

The International Solar Energy Society is perhaps the most appropriate organization to coordinate some of these activities, in cooperation with suitable UN agencies and with a network of national and regional institutions. A specific overall recommendation is that the appropriate agency of the United Nations contact the Directors of the International Solar Energy Society, and initiate a working meeting. The purpose of the meeting would be to identify the needs for test and certification procedures, and the possible role of appropriate technical committees with ISES in carrying this out. Because there are many national branches of ISES throughout both the developing and industrialized regions, with more branches emerging each year, a

mechanism for international information exchange and cooperation in this area to some extent already exists for the United Nations to tap.

As a final suggestion, this topic could be raised in a preliminary manner at the meeting of the International Solar Energy Society in Brighton, England. The meeting takes place this year the week after the start of the Nairobi meeting, and would be an excellent opportunity to present this and other ideas from Nairobi to the largest group of specialists in the renewable field to gather anywhere for the next two years (until the next international ISES meeting).

REFERENCES

1. Scott Rogers, Steve Kyle, Gordon McGranahan, and Vinod Mubayi, "Application of the Brookhaven Energy-Economic Assessment Model in the Portugal-U.S. Cooperative Assessment," BNL 51424, Brookhaven National Laboratory, Upton, NY, June 1981.

2. Energy/Development International, "Energy Strategies for the Dominican Republic: Report of the National Energy Assessment," E/DI, Port Jefferson, NY, September 1980.

3. Gordon McGranahan, Glen Mitchell, Vinod Mubayi, and Robert Stern, "A Preliminary Assessment of Energy Supply and Consumption in the Dominican Republic," BNL 51202, Brookhaven National Laboratory, Upton, NY, November 1979.

4. "Oil and Thailand 1979," National Energy Administration, Bangkok, Thailand, 1980.

5. John Lee, M. K. Lee, Peter Meier, and Vinod Mubayi, "Energy-Economy Interactions in the Republic of Korea," Brookhaven National Laboratory (forthcoming).

6. Analysis of the Economic Potential of Solar Thermal Energy to Provide Industrial Heat, Vols. 1-3, Intertechnology Corp., Warranton, VA, Report COO-2829, February 1977.

7. Survey of the Applications of Solar Thermal Energy Systems to Industrial Process Heat, Vols. 1-3, Battelle Columbus Laboratories, Columbus, OH, for US ERDA, Report #TID27348-1, January 1977.

8. K. Brown, "The Use of Solar Energy to Produce Process Heat for Industry," SERI/TP-731-626, April 1980.

9. Von Kalecsinsky, "Uber die Ungarischen Warmen und Heissen Kochsalzseen als Natuelische Warme Accumulatoren," Annals der Physik, Vol. 4, p. 408 (1902).

10. H. Tabor and Z. Weinberger, "Nonconvecting Solar Ponds," in Solar Energy Handbook, J. Kreider and F. Kreith, Eds., McGraw-Hill, New York, 1981.

11. H. Tabor, "Large Area Solar Collectors for Power Production," Solar Energy, Vol. 7, p. 4, 1963.

12. A. Rabl and C. E. Nielsen, "Solar Ponds for Space Heating," Solar Energy, Vol. 17, p. 1, 1975.

13. H. Tabor, "Solar Ponds as Heat Source for Low Temperature Multi-Effect Distillation Plants," Desalination, Vol. 17, p. 289, 1975.

14. A. Rabl and C. E. Nielsen, op. cit.

15. J. R. Hirschman, "Salt Flats and Solar Heat Collectors for Industrial Purposes," Solar Energy, Vol. 13, p. 4, 1970.

16. T. S. Jayadev, M. Edesess, and J. Henderson, "Solar Pond Concepts: Old and New," Proc. 14th Intersociety Energy Conversion Engineering Conference, Bost, MA, Aug. 1979, or Solar Energy Research Institute, Golden, CO, SERI/TP-35-208.

17. P. Margen, "Economics of Solar District Heating," Sunworld, Vol. 4, p. 128, 1980.

18. A. B. Casamajor and R. E. Parsons, "Design Guide for Shallow Solar Ponds," Lawrence Livermore Laboratory, UCRL-52385 Rev. 1, January 1979.

19. W. C. Dickinson, A. F. Clark, J. A. Day, and L. F. Wonters, "The Shallow Solar Pond Energy Conversion System," Solar Energy, Vol. 18, p. 3, 1976.

20. M. Edesess, J. Henderson, and T. S. Jayadev, "A Simple Design Tool for Sizing Solar Ponds," Solar Energy Research Institute, Golden, CO, SERI/RR-357-347, December 1979.

21. T. S. Jayadev and J. Henderson, "Salt Concentration Gradient Solar Ponds -- Modelling and Optimization," Annual Meeting of the International Solar Energy Society, Atlanta, GA, May 1979, or Solar Energy Research Institute, Golden, CO, SERI/TP-35-277.

22. F. Zangrando and H. C. Bryant, "Solar Ponds for Residential Heating: Heat Extraction from a Salt Gradient Solar Pond," P80-108624, New Mexico University, Albuquerque, NM, 1979.

23. R. S. Bryant and R. P. Bowser, "Construction and Initial Operation of the Miamisburg Salt Gradient Solar Pond," Proceedings of the Annual Meeting of the International Solar Energy Society, Atlanta, BA, May 1979.

24. L. J. Wittenberg and M. J. Harris, "The Miamisburg Salt-Gradient Pond: Mid-1980 Status Report," Monsanto Research Corp., Mound Facility, Miamisburg, OH, 1980.

25. L. J. Wittenberg and M. J. Harris, "Management of a Large Operational Solar Pond," Proc. 15th Intersociety Energy Conversion Conference, Seattle, WA, 1980.

26. L. J. Wittenberg and M. J. Harris, "Performance of a Large Salt-Gradient Solar Pond," Proc. 14th Intersociety Energy Conversion Engineering, American Chemical Society, 1979.

27. T. S. Jayadev and M. Edesess, "Solar Ponds and Their Applications," 7th Energy Technology Conference, Washington, DC, or Solar Energy Research Institute, Golden, CO, SERI/TP-733-617, March 1980.

28. O. J. Löf, J. A. Duffie, and C. O. Smith, "World Distribution of Solar Radiation," Solar Energy Laboratory, The University of Wisconsin, Madison, WI, 1966.

29. C. Kutscher and R. Davenport, "Performance Results and Experience of th Operational Industrial Process Heat Field Tests," SERI/7R-632-385, Golden, CO: Solar Energy Research Institute, 1980.

30. Solar Energy Intelligence Report, May 4, 1981, p. 159.

31. G. N. Hatsopoulos, E. P. Gyftopoulos, R. W. Sant, and T. F. Widmer, "Capital Investment to save Energy," Harvard Business Review, March-April 1978, pp. 111-122.

32. American Physical Society, "Efficient Use of Energy: A Physics Perspective," The American Physical Society, New York, January 1975.

33. T. F. Widmer, and E. P. Gyftopoulos, "Energy Conservation and a Health Economy," Technology Review, June 1977, pp. 31-40.

34. E. P. Gyftopoulos and T. F. Widmer, "Benefit-Cost of Energy Conservation," in Thermodynamics: Second Law Analysis, ed. Richard A. Gaggioli, American Chemical Society, Washington, DC, 1980.

35. United Nations (1981), "Report of the Synthesis Group," Preparatory Committee for the United Nations Conference on New and Renewable Sources of Energy, Third Session, Report 81-06501.

36. S. A. Stadjuhar, "Feasibility Evaluation for Solar Industrial Process Heat Applications, SERI/TP-333-538. Solar Energy Research Institute, Golden, CO, January 1980.

37. E. A. Carter and D. L. Christensen, "NCC Solar Data Project and WERI World Insolation Data," Insolation Resource Assessment Program Contractors Annual FY80 Review. Solar Energy Research Institute, Golden, CO, August 1980.

38. G. O. G. Löf et al., "World Distribution of Solar Radiation," University of Wisconsin, Madison, Wisconsin, July 1966.

39. C. L. Knapp et al., "Insolation Data Manual," SERI/SP-755-789. Solar Energy Research Institute, Golden, CO, October 1980.

40. Collares, Preira, Manual, Rabl, Alei, "Simple Procedures for Predicting Long-Term Average Performance of Nonconcentrating and Concentrating Solar Collectors," ANL-78-67. Argonne National Lab, Argonne, Illinois, June 1978.

41. K. C. Brown, "End Use Matching for Solar Industrial Process Heat," Solar Energy Research Institute, Golden, CO, January 1980.

42. United Nations (1981), "Report of the Synthesis Group," Preparatory Committee for the United Nations Conference on New and Renewable Sources of Energy, Third Session, Report 81-06501.

101

REFERENCES

43. Westfield, J. (1981), "Solar and Wind Assessment: Energy Planning for Development in Indonesia," Report DS-158, Development Sciences Inc., P.O. Box 444, Sagamore, MA 02561 (USA), prepared for Energy/Development International.

44. Parangtopo, A Harsono and Poesposutjipto (1980?), "Correlation of Diffuse Solar Radiation Distribution with Climate Characteristics in Indonesia," Material and Energy Research Institute and Physics Dept., University of Indonesia, Salemba 4, Jakarta, Indonesia. (24 pages)

45. Corporate Taxes in 80 Countries, Price-Waterhouse, New York, NY, 1979.

46. Fesheraki, F. (1980), "Global Petroleum Supplies in the 1980's: Prospects and Problems," presented at the Asia-Pacific Energy Studies Consultative Group Workshop III (APESC), Resource Systems Institute, East-West Center, 1777 East-West Road, Honolulu, HI 96848 (USA).

47. World Bank (1981), "Indonesia Development Prospects and Policy Options," Report No. 3307-IND, p. 19 (distribution limited).

APPENDIX A

CREATING INCENTIVE SCHEMES FOR RENEWABLE ENERGY PROJECTS IN DEVELOPING COUNTRIES

H. Davitian
Entek Research, Inc.
E. Setauket, NY 11733

INTRODUCTION

Most developing countries are burdened with oil import bills they cannot afford. A disproportionate share of foreign exchange earnings is diverted to paying for the import of this one commodity while purchases of capital equipment and of other necessary goods and raw materials are cut back. All too frequently, the oil imports are financed with international loans that increase the LDC's indebtedness without creating productive enterprises which generate income to pay off the loans.

"A recent report provides a revealing analysis of this situation:

> The first round of oil price increases in 1973-74 had a major impact on the economies of the oil importing developing countries. In just one year their oil bill increased by $11 billion, more than the total cost of their food grain imports. The direct and indirect result of the oil price increase was a reduction in their overall economic growth rate by 25 percent and their growth in per capita income by 50 percent (comparing the 1974-79 period with the 1964-74 period)...
>
> The price increases of 1979 and 1980 will cost the oil importing developing countries approximately $30 billion a year. In aggregate, this represents about 10% of their annual investmetn and 15% of their export earnings. In many countries, however, oil imports consume more than 50% of export earnings. In some cases the simple combination of debt service and oil imports payment consumes everything earned through exports..." (Palmedo and Adams; 1981)

Despite the seriousness of the problems created by oil imports, opportunities for short-payback investments in energy conserving and alternative energy supply devices in LDC's are rarely exploited due to a lack of available capital, subsidies which provide improper price signals, and the lack of an investment infrastructure which contains the knowledge and experience to properly judge investment opportunities. In addition, protected industries, which are generally able to pass costs on to customers, have little incentive to make economically efficient investment decisions. As a consequence, the economic and social benefits of subtituting indigenous resources and more efficient energy consuming equipment for oil are foregone and LDC's which might otherwise become substantially more self-reliant with respect to their energy requirements find their economic futures increasingly hostage to debilitating oil import bills.

It is in the mutual interests of the LDC governments, the international banking institutions that finance oil imports, and the consumers of energy

in the LDC's to see to it that investments are made as expeditiously as possible in cost-effective alternative energy technologies.*

A PROPOSED SCHEME

How can this be accomplished?

Clearly, a successful scheme will satisfy several criteria: 1) it will provide incentives to energy consumers to seek alternatives to the continued use of oil; 2) it will provide the capital needed to make the investments; and 3) it will ensure that capital will not be wasted on projects that are not cost-effective.

In designing such a scheme, it is useful to note that the proper price incentive can be provided by the LDC government's offering to pay the difference between the subsidized price and the import price to investors in alternative energy equipment for each unit of oil they displace. For example, if the LDC pays $1.40 per gallon to import distillate fuel and the price to final consumers is subsidized at a level of $1.00/gal, then the government would pay $0.40 to the consumer/investor for each gallon displaced by alternative technologies; the $0.40/gal incentive payments plus the $1.00/gal directly saved by the investor provides the investor with $1.40 in net "savings," the proper price signal from the perspective of the LDC as a whole. Such payments would not require any additional governmental expenditures beyond those that would otherwise have been made to subsidize oil. Incentive payments higher than the difference between the import price and the subsidized price may be desirable and justified; to the extent that the shadow price of the foreign exchange needed to import oil is substantially higher than the nominal price, higher incentive payments for indigenously manufactured alternative technologies are appropriate.

Foreign exchange is already being expended to help LDC's meet their energy needs but it is being used to consume imported oil rather than being invested in economically productive alternative energy systems.

The elements of such a scheme are:

1. In countries where imported oil is used to generate electricity, the electric utility in the LDC offers to purchase power

*Even oil exporting countries are becoming increasingly concerned with the destabilizing aspects of the present situation and the long term consequences on their relationships with non-oil exporting LDC's. In recognition of this, some oil exporters are establishing funds to develop alternative energy projects in LDC's.

from private power producers generating power with approved technologies. The entire power output of the privately owned generating device (i.e., not just the excess over the facility's internal usage) is purchased by the utility at the utility's long run marginal cost of conventional power. Technologies qualify for approval if they use renewable resources or if they use fossil resources in a more efficient manner than does the electric utility. (If the private generation system does not reduce the net consumption of fossil fuels in the LDC, then it does not qualify for approval.)

2. Oil distributors, or the oil import agency where appropriate, are required to offer to pay energy developers who invest in renewable resource consuming or energy efficient thermal or mechanical energy producing equipment the difference between the subsidized price of oil and the country's marginal cost of imported oil for the quantity of oil that they displace through new investments in alternative energy equipment. The money for these payments is provided by the central government with funds that would have otherwise been spent subsidizing oil consumption.

3. For protected industries with little or no incentive to participate in the programs outlined in 1 and 2 above, a schedule of phased reductions in oil allocations is established for those industries where alternatives to the continued consumption of oil exist.

4. An International Energy Development Bank could be established to provide financing for alternative energy projects.* This Bank could potentially operate through the existing regional development banks and could be funded initially by the same international financial institutions that currently finance oil imports. The Bank would play an active role in seeking out and evaluating investment opportunities and in assisting in the execution of projects by identifying suitable technologies and vendors.

To provide the initial capitalization for the International Energy Development Bank, additional investment capital will be required from international financial institutions beyond that required to finance oil imports. Eventually, the need for loans to cover operating deficits will disappear as

*The proposed Energy Affiliate of the World Bank is an example of the type of institution which would be required.

the local economy is strengthened by the substitution of indigenous, cost-effective energy projects for imported oil.

The Energy Development Bank can serve as a source of technical expertise as well as a source of capital. The economics of alternative energy systems are technology and site-specific. Furthermore, a large number of vendors offer a confusing multiplicity of devices which, not infrequently, have accumulated only limited operating histories. The expertise required to evaluate a variety of alternative energy projects under differing climatological and operating conditions is likely to be beyond the capabilities of most LDC development banks. This technical and financial expertise could be channeled efficiently and effectively by the Energy Development Bank.

POTENTIAL BENEFITS

This scheme requires no modification to the country's existing subsidy structure for energy commodities.* Aside from making available investment funds through the Energy Bank, funds are only expended when alternative energy projects are complete and are contributing to the LDC's energy requirements. Since the payments are only equal to the difference between the subsidized price of energy and the marginal cost of energy, there is no incentive to invest in projects that would be providing energy at a cost higher than that which the LDC would otherwise by paying. At the same time incentives are created for investments in projects that produce energy at a cost higher than the subsidized cost of energy (but lower than the cost the LDC would have otherwise incurred for that same energy). Although the developers of alternative energy projects receive new government payments, no one in the LDC pays additional taxes or higher prices for energy than they would have otherwise paid if the project had not been developed (except that the developers will now be paying tax on the profits of their new enterprises).

The scheme is illustrated in the hypothetical example shown in Figure 1. Under the existing arrangements, the LDC imports 200 energy units (e.u.) of oil for which it pays 200 monetary units (m.u.) and subsidizes oil prices at a level of 50% of the cost of oil. The subsidies are financed by general

*However, it may, of course, be both appropriate and politically acceptable to modify the price structure to bring about more efficient use of the country's resources. For example, the serious burden imposed on LDC economies by the cost of oil imports may justify subsidies above the incentive payment scheme described here.

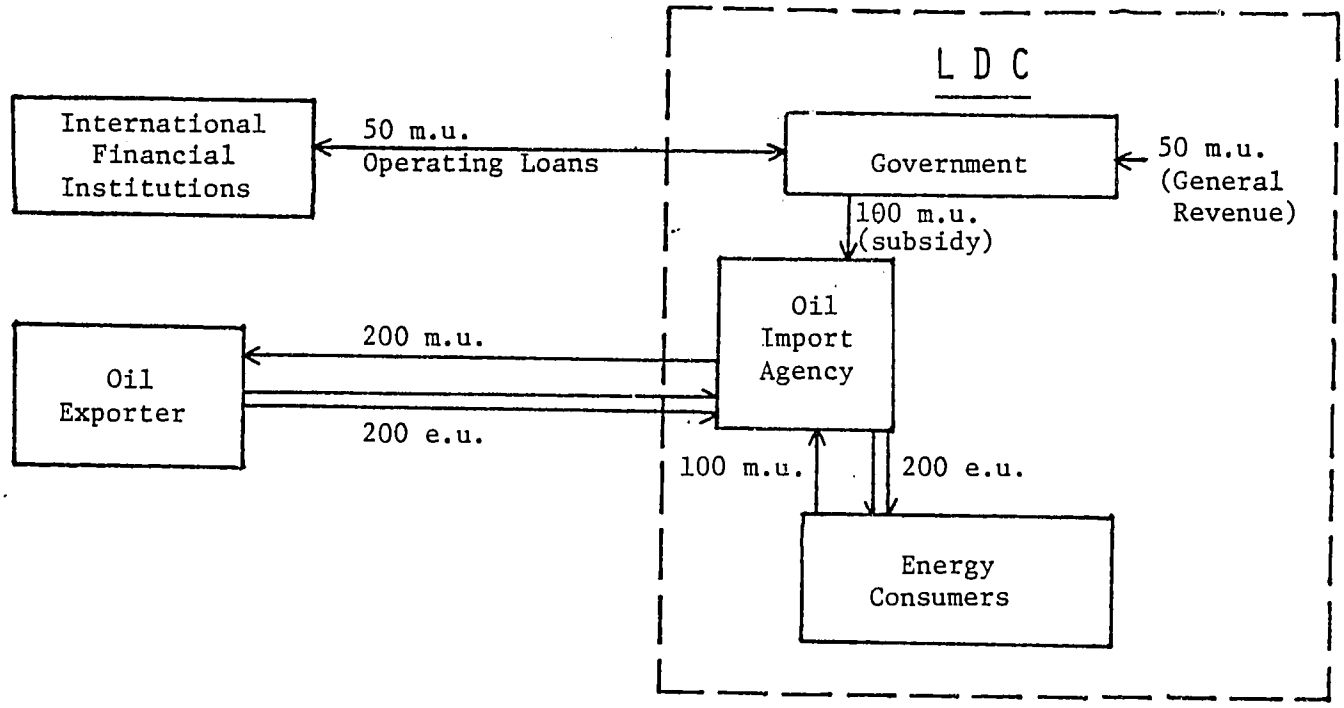


Figure 1 A. Existing Arrangement.

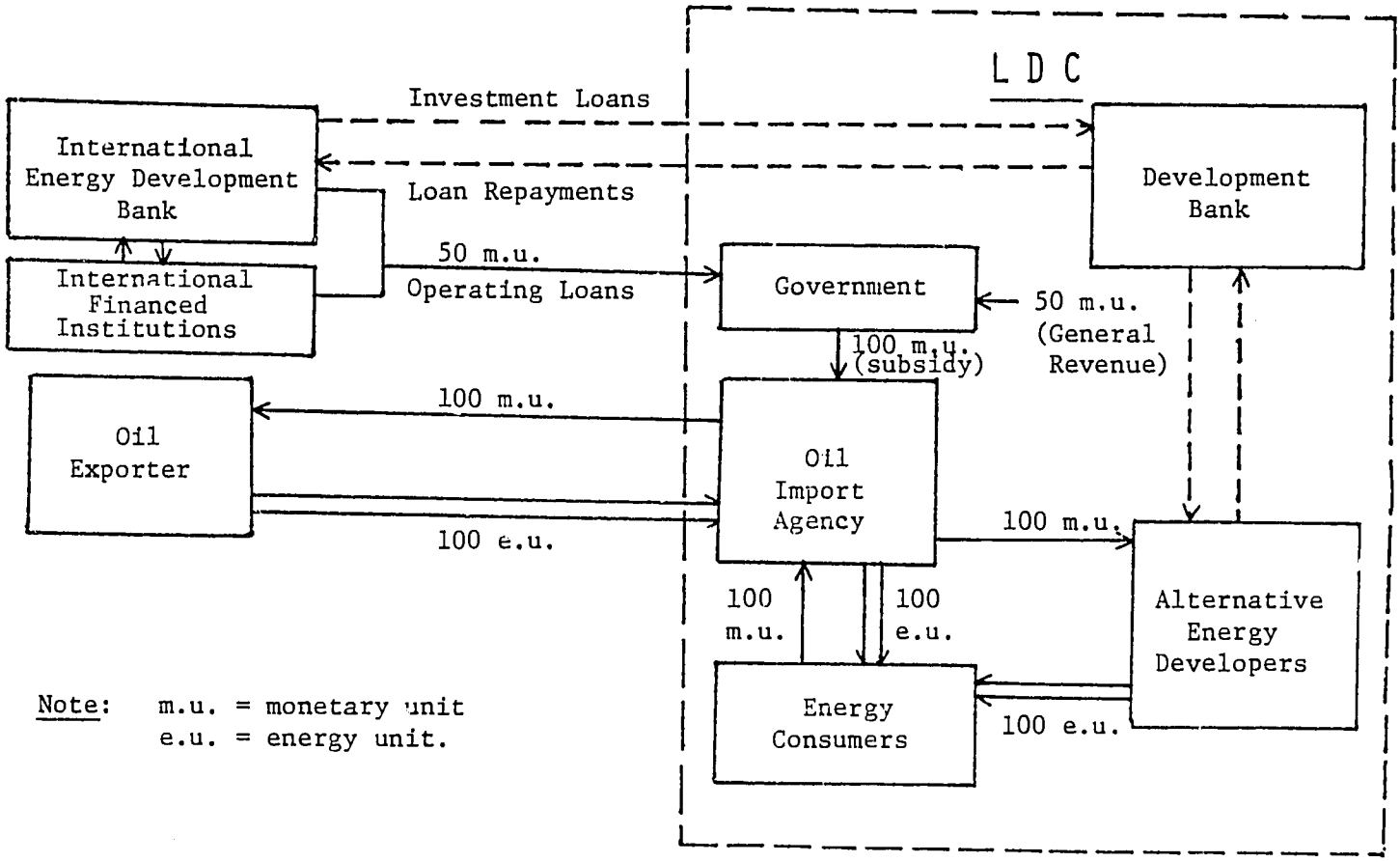


Figure 1 B. Hypothetical Arrangment.

tax revenues and by loans from international banks. With the scheme described above, the LDC receives additional investment loans from the international banks which are channeled through its Energy Development Bank into alternative energy projects. After a few years, a successful program of this type might result in the situation shown in Figure 1B. The LDC has succeeded in reducing its oil imports by 50% with the difference made up in contributions from the alternative energy systems. The oil import agency, instead of paying 200 m.u. for imported oil, now pays only 100 m.u. The other 100 m.u. is now paid to the in-country developers of the alternative energy projects. Energy consumers continue to pay 100 m.u. for the energy they receive even though it is now consisting of 100 e.u. of oil and 100 e.u. of energy from the alternative energy systems. The government continues to use 50 m.u. of general tax revenues and 50 m.u. of loans from international banks to supply the balance of the oil import agency's revenue requirements.

Several benefits have been achieved with this scheme. The country has reduced its need for foreign exchange to import oil from 200 m.u. to 100 m.u. The difference is being spent within the LDC as payments to the developers. The international banks are rewarded with the knowledge that their 50 m.u. of operating loans now remain within the country and help to build the local economy. As time goes on the need for the 50 m.u. from the international banks will disappear. The developers will pay new taxes to the government and have available new investment capital out of the profits of their projects. Finally, to the extent that programs of this type are established and prove successful in the LDC's, worldwide demand for oil is lessened, possibly alleviating the upward pressure on oil prices.

THE U.S. EXAMPLE

A scheme of this type covering privately generated electricity is currently being implemented in the United States. Until recently, private power production faced a variety of institutional barriers in the U.S. The most significant of these was the unwillingness of electric utilities to purchase privately produced power and to provide supplementary and backup power at reasonable rates. The Public Utility Regulatory Policies Act (PURPA) of 1978 changed this by requiring electric utilities to purchase power from qualifying cogenerators and small power producers at the utility's "avoided costs"

(marginal savings due to the reduction in the utility's own generation). Utilities are also required to sell supplementary, backup, and maintenance power to such producers at normal rates. A facility could qualify for benefits if it was less than 800 MW in capacity and if it used equipment relying on renewable resources or efficient cogenerating equipment burning conventional fuels. Qualifying facilities were exempt from federal and state regulation, further easing the institutional barriers to private generation.

PURPA proclaimed one of its main objectives to be the encouragement of cogeneration and small power production. Its economic provisions were designed to be as favorable to private power production as possible without increasing costs to other utility customers. To provide the maximum possible incentives consistent with this restriction, avoided costs were defined to be the full savings in energy and capacity expenditures experienced by the utility due to the private generation. Also, qualifying facilities could sell their entire output to the electric utility at avoided costs while continuing to purchase power at rates based on "embedded" (i.e., average) costs; alternatively, the facility could elect to sell only the excess power over its internal needs if that were more favorable.

Since the primary responsibility for regulating electric utilities in the United States rests in the state public utility commissions, the implementation of PURPA was left largely in their hands. The implementation process is still underway in the U.S. and its ultimate outcome is not yet clear since electric utilities are seeking to weaken the effect of the legislation through court challenges and through the adoption of watered-down provisions by the state commissions. Nevertheless in the more progressive states, especially those in which oil-fired generating equipment is widely used (at least at the margin), the effect on the economics of private power production has been dramatic.

To illustrate the changes in the economics of private power production brought about by PURPA, consider the following example: The marginal cost of generation for utilities using oil-fired units as the marginal supply is at least 5.5 c/kWh. In most cases the utility's use of less efficient units for marginal generation and adjustments for line losses and transmission credits raise this figure to 8 c/kWh or more. A facility owner with a required rate of return of 25% comtemplating the purchase of a small power producing system

using a renewable energy resource (which we assume for simplicity to be free) and operating at a capacity factor of 50% could thus afford to spend over $1400/kW on capital equipment. Before PURPA, the facility owner was likely to have been offered average generating costs at best, substantially below the marginal costs and would have faced arbitrarily high supplementary and backup power rates. Alternatively, the utility would not have permitted interconnection, requiring the producer to consider investing in a substantially larger generating system (to provide the redundancy needed to supply reliable power when operating independently from the utility) at a substantial increase in capital cost, or to abandon the project. Under these conditions, very few found it profitable to install private generating equipment.

APPLICATION TO LDC'S

PURPA provides an appropriate framework upon which to model LDC institutions for creating incentives for private investment in alternative electricity generating systems. Implementation in the LDC's, where electric utilities are frequently government owned and where dual federal and regional government regulation is uncommon, should, in most cases, be simpler than in the U.S. where state commissions and private utilities are proving reluctant to be fully faithful to the spirit of the PURPA legislation.

The institutional infrastructure for providing incentive payments for oil saving investments not associated with electricity generation will be somewhat harder to implement. The key problem will be safeguarding the procedures from fraud. Whereas private electrical generation in equipment that is interconnected with the utility grid is easily monitored through metering equipment and will not, in general, be wasted (power unused at the facility is automatically transferred to other users through the grid), facility owners could collect incentive payments for thermal process heat generated but never utilized.

An example would be a facility with solar industrial process heat collectors. Since the fuel is free, the facility operator would be tempted, during periods when the facility did not require process heat, to continue to "produce" process heat and to exhaust it unused to the atmosphere in order to collect incentive payments. Metering equipment must be able to distinguish whether or not the process heat is actually used. The use of two or more

time-correlated meters, one connected to the solar collector and one to the output of the industrial equipment, with payments tied to the coincident output of the two, may be necessary to reduce the possibilities for fraud.

The inclusion of purely energy conserving equipment (i.e., where there is no actual generation of energy by the equipment) in the incentive scheme creates a more difficult measurement problem. However, even in this case, solutions are possible. For example, in the U.S., newly formed energy conservation companies are signing contracts with commercial and industrial facilities whereby the facility pays the company a defined fraction (e.g., 90%) of an estimate of what its energy costs would have otherwise been. In return, the company is permitted to install energy conserving equipment at its own expense and to gain the difference between the total savings and the reduced payments by the facility. The estimation and measurement procedures called for in such contracts can form the basis for a fraud-resistant incentive payment structure for an LDC.

ACKNOWLEDGMENTS

The author wishes to acknowledge his debt to Drs. Robert Nathans of the State University of New York at Stony Brook, Philip Palmedo of Energy/Development International, and Vinod Mubayi and David Jhirad of the National Center for Analysis of Energy Systems, Brookhaven National Laboratory who participated in the development of the ideas underlying this paper.

REFERENCES

"Energy Aspects of the Economic Interdependence Between the United States and Developing Countries," (Philip F. Palmedo and Michael H. Adams), Energy/Development International, March 30, 1981.

APPENDIX B

REGULATORY DEVELOPMENTS TO ENCOURAGE RENEWABLE RESOURCE DEVELOPMENT AND EFFICIENCY: IMPLICATIONS OF RECENT EXPERIENCE IN THE UNITED STATES

Edward Kahn, Ph.D.

Policy Analyst
Energy and Environment Division
Lawrence Berkeley Laboratory
Berkeley, CA 94720

INTRODUCTION

Major regulatory innovations are accelerating the development of renewable resource technologies and creating new channels for capital flow into increased energy efficiency. Both of these trends are reflections of new roles for regulated electric and gas utilities. To understand these developments, the nature of the U.S. energy utility industry must be characterized so that the innovations can be generalized to other conditions.

The principal feature of energy pricing by utilities, the embedded or average cost basis, explains much of the impetus toward new and innovative arrangements. Prices for energy delivered by regulated private utilities are typically set below the marginal cost. This subsidy to consumption results from the traditional regulatory practice of averaging low-cost energy sources with the higher-cost supplies.[1] The administrative procedures for setting prices in this way are time consuming and tend to reduce industry earnings because of inflationary effects.[2] This unfavorable economic environment has created a problem of capital access for the electric utilities in particular.[3]

There are many potential mechanisms for restoring financial equilibrium to the U.S. electric utilities. Some of these include reforms in the pricing methods that will improve earnings by bringing rates in line with costs. Simply raising consumer prices, however, will not bring about any reorientation of traditional utility investment policy. These policies, which focus on large baseload conventional power stations, are thought to contribute to industry problems. Therefore, price methods alone have been rejected in some jurisdictions, or are being supplemented with new mandated activities. The discussion that follows will outline two of the most important areas of innovation: (1) private-party entry into electricity generation, and (2) residential energy efficiency financing by utilities.

PRIVATE-PARTY ENTRY INTO ELECTRICITY GENERATION

In 1978 the Public Utilities Regulatory Policy Act (PURPA) became law. PURPA, among other things, established a framework in which the regulated monopoly on the production of electric power was opened to private parties. The basic principles of this limited deregulation are "avoided cost pricing" for "qualifying facilities." The sponsor of a small power project (<80 MW), a qualifying facility, is allowed to sell his output to local utility

companies for a regulated price that is based on the cost avoided by the purchasing utility. PURPA creates a market for private producers by requiring that utilities purchase their output. Previously, no such obligation existed. Consumers are protected in this arrangement by regulating the price paid to "qualifying facilities." The purchase price is equal to the costs a utility can avoid by the PURPA-induced transaction. These costs can include avoided energy (or fuel costs) as well as avoided capacity costs. A detailed look at the legislative background of PURPA is available in a study of the rules implementing these principles.[4] Policy issues and regional variations in the impact of PURPA have been studied in some detail.[5]

The PURPA framework allows risk-taking entrepreneurs to develop resources that utilities have tended to ignore. This effect is greatest where the avoided cost price to private electricity producers is based on oil. A qualifying facility that receives an oil-equivalent price for electricity (say, 6¢/kWh = $36/bbl at 10,000 Btu/kWh) can earn a potentially large rate of return on invested capital. The same project sponsored by a utility would only earn the average return allowed in administrative proceedings. There are many projects for which these differences can be large.

Further, where any technical risk is involved, utilities can be expected to be risk averse, and so avoid the potential gain. This risk aversion stems from current market uncertainties, the upper limit on profit potentials, and the bad experience with nuclear power. This last factor, the risks of nuclear power, illustrates the limitations on government's ability to insure against the technical risk associated with innovation. The U.S. electric utility industry relied upon government assurances and incentives in the development of nuclear power.[6] These failed to underwrite the risks of nuclear generation with the result that utilities are reluctant to compromise their basic service function by undertaking new risky projects.

Given the necessity of maintaining a certain basic level of electric power service and utility aversion to the risks of renewable resource development, the PURPA framework allows innovation to be sponsored by private capital. The utility, by passing through the revenues to PURPA entrepreneurs, acts like a taxing agent. This feature of economic regulation -- that is, its resemblance from a social point of view to government tax programs -- has been recognized for some time.[7] Opinions differ about the normative

121

aspects of "taxation by regulation," but its pervasiveness suggests that some social function is being served. In the case of PURPA, what has been achieved is an inducement to private sector capital to invest where the utility, for legitimate reasons, has limited interest. Thus innovation is encouraged without unduly shifting risk to consumers or the basic utility business.

It is still too early to tell if PURPA will, in fact, achieve this balance, or what other factors will turn out to determine outcomes significantly. Nonetheless, experience to date does allow for a further understanding of the innovation process for small-scale electric power technology. To illustrate the pattern of project development in the PURPA framework, it is useful to focus in detail on two examples. Both examples represent a pattern that has been called "third-party development." In this model an entrepreneur brings together an equipment vendor, a resource owner or by-product consumer, and finance capital to create a project. Two projects that fit this general description are (1) the Windfarms, Ltd., Hawaii, project, and (2) the Trenton, New Jersey, district heating project. These will be described in turn.

Windfarms, Ltd., is proposing an 80-MW project at Kahuku Hills that will produce electric power with large-scale wind turbine generators. Since Hawaii's electricity system is fueled almost exclusively by oil-fired generators, the PURPA price would be based on avoided oil costs of at least 6¢/kWh. One important feature of the PURPA framework is that the utility that purchases power is not obliged to enter into long-term fixed-price contracts. A project sponsor, however, needs something like such a contract to secure financing. This creates room for bargaining. Windfarms reached a compromise agreement with Hawaiian Electric. The utility will pay Windfarms 10 percent less than avoided cost over a 25-year period with an automatic indexing mechanism. The long-term security of such an arrangement makes it possible for debt investors to help finance the project. Because of the technical risks, however, Windfarms is seeking equity investment by the vendors of the wind machines. It appears that this will be forthcoming.[8]

In Trenton, New Jersey, a small district heating system is being proposed by the Cogeneration Development Corporation in conjunction with the New Jersey state government. This project can also secure financing only

with long-term contracts for heat and power. A contract for heat has been concluded with the state government for its buildings in Trenton. An agreement has yet to be reached with the utility for power sales. Under the PURPA rules, qualifying facilities can receive payment either through a published tariff or through a contract.[9] The rules do not specify that utilities must provide long-term contracts that are adapted to the financing requirements of project sponsors. This ambiguity makes for bargaining possibilities between the parties. The Trenton project will only be viable with a suitable agreement. Presumably, as in the Hawaiian case, some discount from avoided cost will be required by the utility.

The Trenton project also illustrates the role of equipment vendors. The project sponsor, Cogeneration Development Corporation, is a subsidiary of Cummins Diesel. It is likely that diesel engines purchased from Cummins would be the equipment used to generate heat and power. Although Cummins is not a direct equity investor, as in the Hawaii case, they provide financial support through working capital for the subsidiary.

A further financial alternative for small power project is the debt guarantee mechanism from a utility to project sponsor. This situation is illustrated in a recent contract proposed between the Pacific Gas and Electric Company (PG&E), a utility serving northern California, and California Power and Light (CP&L), the sponsors of a wood-pellet-fired cogeneration project. CP&L does not have sufficient credit to secure fianncing for this 50-MW project, in part because of the risk associated with the unconventional boiler fuel. The project becomes financially viable if PG&E provides a debt service guarantee, agreeing to make substantial monthly payments regardless of performance to the holders of project bonds. If CP&L should default to PG&E due to project performance difficulties, the facility's ownership will be transferred to PG&E. In exchange for this underwriting of wisk, CP&L gives a 40 percent discount from avoided cost in determining the price PG&E will pay for the power. This contract has been analyzed as if it were an insurance policy, comparing the utility's maximum obligation with the avoided cost discount. In these terms the present-value cost of the guarantee is roughly 60 percent of the utility's maximum obligation.[10]

The debt guarantee mechanism is an intriguing alternative for utility contracts with private producers. This form of risk socialization is common

for governments. In the energy sector, risk pooling through the utility is considered more practical where amny small projects are involved, as opposed to the case of a few large-scale projects. Just as governments have found that loan guarantees are an inexpensive way to stimulate development, their use by utilities might be an extremely efficient way to stimulate private sector investment. Successful implementation of this approach will require prudence, however, because it will not be worthwhile to underwrite any and all proposed projects. Assessment of risk also requires a method to price risk. Where technical uncertainty is large, the price of risk will be correspondingly high. The PG&E/CP&L contract represents a large premium; in cases of conventional cogeneration, PG&E has requested smaller risk adjustments.[11] The institutional framework for making adjustments in cost and risk burdens from PURPA contracts will require some maturation.

The PURPA framework will allow private capital to flow into renewable resource power projects and cogeneration. This will accelerate their development. PURPA relieves the utility of financing burdens and makes it function more like a taxing agent. The benefit to society of this arrangement is increased innovation on the supply side. To complete the discussion, we will now turn to regulatory innovation on the demand side and explore the role utilities play in promoting end-use efficiency.

RESIDENTIAL ENERGY EFFICIENCY INCENTIVES FROM UTILITIES

Many studies comparing the costs of increased energy efficiency with the cost of incremental supply conclude that the former are considerably less expensive than the latter. It is inefficient to allocate capital to high-cost supply when lower-cost efficiency improvements are available. In perfectly functioning capital markets, this situation could not occur. But institutional and informational barriers of several kinds hinder the flow of investment into end-use energy efficiency. The problem is particularly severe in the residential sector. To capture these opportunities, utilities in several regions of the U.S. are offering incentives to residential customers to improve efficiency. The general rationale for this activity is discussed in Reference 2. A detailed study of California conditions is given in Reference 12.

The basic difficulties confronting the goal of improved energy use efficiency are access to capital and appropriate valuation of benefits. The

124

structure of public utility pricing in the U.S. tends to undervalue energy. Consumers do not get the appropriate price signals. Even if this were corrected, however, high inerest rates and unfavorable loan terms prevent investment in efficiency. Utility incentive programs are designed to surmount these problems. The principal tool is a financing subsidy. Design of programs to provide such subsidies confront several issues: (1) What form of loan subsidy? (2) What magnitude? and (3) How should the capital be raised? These will be discussed in turn.

The first large-scale program of residential efficiency incentives was offered by Pacific Power and Light (PP&L) and other utilities in the Pacific Northwest. This program offered zero-interest loans for weatherization of single-family homes with no repayment until resale of the building. Variations on this approach include zero interest with four- to eight-year amortizations. This was recently adopted in California (see Reference 13). The California Commission also adopted a 6 percent loan program for solar water heating with a 20-year amortization (see Reference 14). In that same decision the California Commission also offered the alternative of monthly cash rebates instead of loans.

Settling the size of the subsidy to be offered requires some careful analysis. The strategic aspect of this analysis focuses on the relative importance of efficiency incentives in the entire portfolio of utility activities. If opportunities warrant, this activity could play a major role in utility planning. For some utilities this appears to be the choice (see Reference 15). In other cases, efficiency incentives will play a very minor role. One example of this is Consolidated Edison in New York (see Reference 16). In the case where major emphasis is planned, subsidies offered are substantial. These are usually related in total cost to the difference between the marginal cost of energy and average utility rates. This is the amount of money tht nonparticipating rate payers can afford to spend without being worse off. Useful discussions are found in References 17 and 18. An example of such calculations and general discussion is found in Reference 19.

Raising capital for conservation programs is tied to estimates of market potential. In the New York case, where small programs are anticipated, utilities tie activities in with banks. The customer is referred to a lending institution that offers loans at 9 to 10 percent. The difference

between this rate and the higher market rates is subsidized. In California, project financing techniques will be used. In this case the utility will set up a financing subsidiary. It will be capitalized at 80 percent debt and a 20 percent equity investment by the utility. The California Commission has agreed in principle to provide a tariff mechanism that will guarantee revenues, including equity returns, to this subsidiary (see Reference 13). With such an unprecedented regulatory guarantee, there should be no difficulty raising funds. Combined with the short maturities of the proposed loans, conservation finance incentives are well adapted to the uncertain capital market conditions (see Reference 3).

SUMMARY

The innovative activities of selected U.S. energy utilities just described is not characteristic of the entire industry. Regional variations in economic climate and regulatory policy make for considerable differences among utilities. In the cases described, utilities are expanding their traditional roles to bring additional capital into the industry and/or to use it in a more socially efficient manner. These changes tend to give private utilities more of the quality of quasi-public agencies. While this is desirable from the viewpoint of achieving public goals, there are ambiguities about the proper delineation of roles that have yet to be settled. As further experimentation takes place, the best methods to encourage renewable resources and efficiency projects will emerge.

126

REFERENCES

1. J. Bonbright, Principles of Public Utility Rates (New York: Columbia University Press, 1961).

2. C. Pranl and W. Marcus, Energy Service Corporations: New Opportunities for California Utilities (Sacramento, Calif.: California Energy Commission, December 1980).

3. "Big Financial Problems Hit Electric Utilities; Bankruptcies Feared," Wall Street Journal, February 2, 1981, p.1.

4. R. Danzigev, P. Caples, and J. Hunning, The Rules Implementing Sections 201 and 210 of the Public Utilities Regulatory Policy Act of 1978: A Regulatory History, DOE/JPL-1012-48 (Pasadena, Calif.: Jet Propulsion Laboratory, September 15, 1980).

5. E. Kahn and M. Merritt, "Dispersed Electricity Generation: Planning and Regulation" (Washington, D.C.: U.S. Congress, Office of Technology Assessment, forthcoming).

6. A. Gandera, Electric Utility Decision Making and the Nuclear Option, R-2148-NSF (Santa Monica, Calif.: RAND Corporation, 1977).

7. R. Posner, "Regulation as Taxation," Bell Journal of Economics and Management Science.

8. "Vendors to Help Fiannce Kahuku Hills 80-MW Wind Farm Project," Wind Energy Report, December 1980, pp. 5-7.

9. 45 Federal Register 12224.

10. W. Marcus, California Energy Commission Staff, Testimony in CPUC Appl. No. 60077, December 12, 1980.

11. California Public Utility Commission, Staff Report in OIR-2, January 28, 1981.

12. E. Kahn, P. Benenson, and B. Brown, Commercialization of Solar Energy by Regulated Utilities: Economic and Financial Risk Analysis, LBL 11398 (Berkeley, Calif.: Lawrence Berkeley Laboratory, October 1980).

13. California Public Utilities Commission, Decision No. 92653, January 28, 1981.

14. California Public Utility Commission, Decision No. 92251, September 16, 1980.

15. Pacific Gas and Electric Co., Long-Range Planning 1981-2000 (San Francisco, Calif., December 1980).

16. Third Annual Report on Implementation of the New York State Home Insulation and Energy Conservation Act (New York: New York Public Service Commission, January 31, 1981).

17. L. G. Baldwin, Pacific Gas and Electric, Testimony in CPUC Appl. No. 60153, December 1980.

18. C. Cicchetti and R. Schaughnessy, "Is There a Free Lunch in the Northwest? (Utility Sponsored Energy Conservation Programs)," Public Utilities Fortnightly, December 18, 1980.

19. E. Kahn, "Using Utilities to Finance the Solar Transition," Solar Law Reporter, Vol. 2, No. 3, October 1980.

128

APPENDIX C

RENEWABLE ENERGY INSTITUTIONS FOR THE DEVELOPING WORLD: THE POTENTIAL RELEVANCE OF RECENT U.S. REGULATORY, LEGAL, AND INSTITUTIONAL EXPERIENCE

Elliot Taubman[1]

Jerome Weingart[2]

[1]Senior Research Fellow
The Institute for the Study of Human Issues
New York, NY and Philadelphia, PA, and
Associate, Teknekron Research, Inc.

[2]Participating Guest
Energy and Environment Division
Lawrence Berkeley Laboratory
and
Associate, Teknekron Research, Inc.

INTRODUCTION

Energy is a crucial ingredient of development and prosperity. However, high petroleum prices have placed less developed countries under severe financial pressures and have slowed international development. Increasingly, both the industrialized and the developing world will come to rely on non-traditional primary energy sources, including solar radiation, wind, thermal gradients in the ocean and new systems of biomass production to provide the fuels, electricity, and heat required for modern industrial societies. At the same time, increased use of coal, hydropower and, in some cases, uranium, will also be required for expansion of the industrial, commercial, and modern residential sectors. In the rural regions of LDC's, increased efficiency and new techniques for the use of traditional energy resources, especially biomass, can provide a greater array of energy-related services without the precedent of a modern industrial and commercial energy infrastructure.

While the availability of technically proven and economically interesting hardware to harness renewable energy sources or to increase the efficiency of energy use is a prerequisite for the use of these energy sources, it is not enough. In even the richest and most industrialized nations, institutional, political, regulatory, and legal factors inhibit the widespread introduction and diffusion of renewable energy technologies and techniques for increasing the efficiency with which energy is used. The use of technologies which harness intermittent sources of energy to produce electricity poses special problems and challenges to the design or modification of institutions and regulations to provide the best possible economic environment for their use on any significant scale.

This paper discusses some of the institutional, regulatory, legal, and financing aspects of the introduction and large-scale use of renewable energy technologies in the developing world. We use the experience of the United States to illuminate the non-technical issues which many countries may have to address in facilitating the use of renewable energy technologies.

In doing this, we are not attempting to tell decision makers in other countries what they should do. In fact, the enormous plurality of institutional experiments in the United States suggests that we also are not sure of the best ways in which to facilitate use of these technologies. Because of a considerable lack of precedent in these matters, we are forced to fumble freely into the future. However, over the past several years we have begun to see the results of various legal, regulatory, and institutional initiatives. The successes and limitations of these initiatives in stimulating the use of new technologies can provide useful information to those contemplating similar actions.

SOME BASIC ISSUES

There are many non-technical questions to ask regarding the use of renewable energy technologies. These include:

- Who evaluates the technologies?
- What are the available technologies?
- Who decides where and how the technologies are used?
- How are the choices financed and taxed?
- How is the use of these technologies regulated?
- How are basic conflicts resolved (energy allocation, siting, etc.)?

The primary energy sources considered by the United Nations conference on new and renewable sources of energy include solar radiation, geothermal energy, wind, tides, waves, ocean thermal gradients, biomass (including peat, charcoal, and fuelwood), draught animals, oil shale, tar sands, and hydropower. Harnessing the renewable energy flows will require energy systems which incorporate energy conversion, storage, and transport plus power conditioning. Moreover, the entire flow of energy, from the initial mobilization to final end use needs to be considered. This is especially important, since the scarce resource in the world is not energy. The resource in short supply, especially in developing regions, is financial capital and skilled labor. This means that the efficiency with which energy is used is extremely important.

Excluded from the list of energy supply options considered by the UN Conference is energy "conservation", or increased efficiency in the various stages of energy production, conversion, transport, storage and use. However, considerations of energy efficiency most ultimately be incorporated in the technical and economic analyses of the role of renewable energy sources. Regional energy planning aimed at maximizing the energy services provided to the region for a given level of capital investment requires an explicit integration or coupling of supply and demand projections. Detailed national and regional assessment of the role of renewable sources of fuels, heat and electricity require careful preparation of energy demand projections and the incorporation of increased energy efficiency in the projections.

Investments in increased energy efficiency in the industrial, commercial and residential sectors have substantially higher internal rates of return than investments in many renewable energy supply systems, even when the latter appear competitive on an annualized basis with indigenous or imported fuels. Just as in the United States and Europe, where investments in retrofit of existing commercial and residential buildings has proven both cheaper and easier than the use of solar water and space heating, so will investments in improvements in the efficiency of the various elements of the energy system be a cheaper and faster way to provide increased energy benefits and displacement of imported oil than renewable energy technologies.

It is over the longer run of the coming several decades that the renewables will be able to make their impact felt. Because of the potential promise of these supply options, new incentives for their expanded use have been put in place in the United States to stimulate full commercial development and use of such technologies.

AN INSTITUTIONAL VIEW

The organization of society includes its social, political, economic, and religious institutions. All of these institutions can affect the implementation of new energy technologies. Use of these technologies within an institutional perspective requires consideration of the legal and regulatory structures which can be used or are used.

Where and how the various technologies are used may be decided at the local or village level, the regional level or the national level. In some instances, decisions affecting the villages will be made at the international

level, through international development banks and UN agencies or through bilateral assistance programs involving industrialized nations. Multinational corporations are also involved in many national and regional development projects. How the choices are financed and taxed may determine whether or not the project can go forward. Basic conflicts within the affected society can also affect the nature of the project. This can be accomplished in a regulatory context or purely by rule of law; it can also be done on an ad hoc basis by governmental fiat. There appears to be little in the way of detailed published inquiries into the institutional, legal, and regulatory frameworks internationally within which new energy technologies would have to be implemented. This problem is discussed later in the section containing recommendations for action.

THE STRUCTURE OF ENERGY LAW AND REGULATION IN THE UNITED STATES

INTRODUCTION

Now that crude oil and gasoline prices have been decontrolled in the United States, the remaining regulation of energy is primarily that of utility prices and services at the state level, and by tax incentives, loans, and grants at both the state and Federal levels. With an overlay of substantial Federal economic incentives, the traditional state role of utility regulation has again become important. In the transportation sector, there has been a movement toward both government ownership and decontrol of prices. Barge and truck transportation and the individual automobile remain in the private section. Where once almost every aspect of bus, rail, truck, taxicab, and air fares and services were controlled, only local service will remain subject to any substantial control.

The one area where regulation has remained tight is state and local regulation of utility rates and services. In the United States, retail rates for electricity, natural gas, steam, telephone service, and water are regulated by state agencies. This is historical in nature, reflecting the federal nature of the United States Constitution. The exception is government-owned utility systems. Even in the case of government-owned systems, there is usually an independent Board of Directors or a city council with a regulatory oversight role. The kinds of regulation include:

- Allocation of rates among residential, commercial, industrial, agricultural, and government sectors;
- allocation (rate design) within each sector;
- establishment of overall levels of rates which the various utilities are authorized (but not guaranteed) to earn;
- authorization of the sale of stocks and bonds to finance operations;
- setting of conditions of service on such matters as security deposits, termination of service for non-payment of charges, metering and billing.

Also, the state regulators usually have control over the type, size and location of physical facilities. This control, if exercised, can determine whether the next 1000 MWe of generation capacity is to come from a nuclear power plant or a combination of hydro and geothermal plants, or even from increased energy conservation in buildings, financed in part by the utilities themselves.

Tax Law

Tax law[4] is of immense consequence in the U.S. economy. Traditionally the tax law has favored capital intensive alternatives for utilities and others. This has been changed in both the Energy Tax Law of 1978 and the Crude Oil Windfall Profit Tax Act of 1980, to favor energy systems which use renewable energy sources, and those that reduce reliance on imported petroleum. Tax credits between 20% and 25% and generous accelerated depreciation benefits are provided for solar (25%), wind (25%), hydroelectric (21%), and other renewable resources. The new investments can be both labor as well as capital intensive, since in most instances tax deductions and tax credits are allowed for value added by capital and labor.

Sometimes the tax consequences of particular actions become more important than the actions themselves. Consider the case of tax normalization -- the creation of an ostensible tax deferral which is actually a tax saving which is charged to utility rate payers. The amount of normalized taxes was estimated in 1977 to be many billions of dollars. The utilities industry has claimed that this was needed to finance nuclear power plants, and that if this revenue was not forthcoming, the plants would not be built. In other countries, the choice of technology would be made by either a planning decision or a subsidy rather than by a tax decision. The contrary is true in the United States. The Internal Revenue Code, and its extensive gloss of

[4]The tax law in the United States comes primarily from the Internal Revenue Code of 1954, part of the United States Code, but also includes tax regulations, ruling, and numerous court decisions. Recently state tax law has had an impact on energy decision making as well, e.g., California adopting a 55% solar tax credit.

regulations, rulings, and court decisions has an immense impact on both the United States and the world economy. A simple change in the accounting treatment of utility investment (tax normalization over the life of plant rather than the flow through of tax benefits in the year obtained) can have a multibillion dollar impact.[5]

[5]See the discussion of the tax impact of multinational corporation investments in renewables.

FEDERAL LAWS AND REGULATIONS

PUBLIC UTILITIES REGULATORY POLICY ACT OF 1978

The Public Utilities Regulatory Policies Act of 1979 is a major change in the laws applicable to energy and to utility rate design in particular. The major purpose of the act is to promote "increased conservation," "increased efficiency," and "equitable retail rates" for electricity, and to some extent natural gas. In this summary we discuss relevant sections including Section 111 (adoption of rate standards), Section 122 (consumer representation), Section 133 (information on costs of service), Section 203 (wheeling), Section 306 (gas utility rate design proposals), and Section 605 (conserved natural gas).

Much attention at state regulatory commissions is directed at the provisions of Title 1, subtitle B. These provisions deal with standards for cost of service, declining block rates, time-of-day rates, seasonal rates, interruptible rates, and load management techniques.[6] State utility commissions have held hearings on some of these matters, both before and after the passage of PURPA. All of these measures have been incorporated in some states to varying degrees. There has been a recent and substantial change in utility rate design in the United States away from bulk discounts for electricity and natural gas and toward flat or inverted rates, time of use and seasonal rates, and consideration of the increasing cost of new facilities.[7]

The consumer representation requirements of Section 122 have an interesting applicability to the problems facing retail utility customers who may wish to participate in or intervene in various standard-setting proceedings. This section states that if a "retail electric customer" is unable to effectively participate or intervene in such proceedings because it cannot afford to pay reasonable attorney's fees, expert witness fees, or other reasonable costs associated with preparation for and participation or intervention in

---

[6]Cost of service is a complex issue. The arguments generally center around the concept of average-historical costs versus current or future costs (marginal costs). PURPA has required consideration by regulatory bodies of some version of marginal costs and this in turn has caused the adoption of new systems of rate setting such as charging higher rates for higher usage where costs are increasing. See Appendix I for numerous examples.

[7]The actual trends are noted in one Table of Citations on Rate Design and Public Utility Regulatory Policy Act Developments. This table shows the range and variety of regulatory decision making.

such proceedings, then these costs can be recovered under either Section 122(a)(1) or Section 123(b). In these provisions, "electric customer" is defined in Section 3(5) to mean "any person, State agency, or Federal agency, to which electricity is sold other than for purposes of resale."

The provisions of Section 133 require detailed information by utilities relative to rate design. Other provisions of the law make this information available to interested persons, S133(c), c.f. S121(b). This information can be quite valuable; by 1981 the utilities are supposed to have detailed studies of the electrical load on their systems and to break down this information into subclasses of users (e.g., small commercial). This means that for the first time accessible information will exist on the distribution of electricity use by the various customer classes, and on the contribution serving each of these customers makes to the overall utility system costs. In addition, these costs must be shown based on both marginal costs (current and anticipated) and embedded or average costs. The regulations of the Federal Energy Regulatory Commission (FERC) exempt some smaller utilities from the S133 filing requirements. Unfortunately, the FERC regulations do not require an explanation of the data in a form understandable to lay persons, so the data must be reviewed and translated by persons knowledgeable in the field of utility regulation.

Section 203 (wheeling) comes under the jurisdiction of FERC, and requires that if a customer is one who sells power and is defined as an "electric utility," then power must be transferred (wheeled) to that electric utility on such terms as found appropriate by FERC. An "electric utility" is one who sells power and is defined as "any person, State agency, or Federal agency which sells electric energy" S3(4), 16 U.S.C. S 2602(4). To the extent that any entity which produces electric energy resells it, it could have both the benefits and the burdens of this law. For instance, if electricity from Utility A is cheaper in the winter than that from Utility B, and a city wants to trade gas-generated power in the middle of the summer, then under S203 and its companion provisions, Utility B would be forced to wheel the power in both directions. Some interesting international situations can arise with this law. For instance, if the Los Angeles Dept. of Water and Power wished to buy geothermal power from the proposed Mexican government utility unit in Baja California, San Diego Gas and Electric Company which

lies between the two entities could refuse to wheel the power. Similarly, the Power Authority of the State of New York could refuse to wheel hydroelectric power from Quebec, Canada to New York City. In each instance, there is an interrelation among international law, national law, and local law. While the utilities would generally cooperate in such wheeling, there could be a situation in which this cooperation broke down, and one matter could require multi-lateral treaties to resolve federal decision making or anti-trust review. Matters such as the application of the General Agreement on Tariff and Trade (GATT) and FERC review of imports may have an impact. There is presently a dispute among the Public Service Company of New Mexico, El Paso Electric Company, and the other Texas utilities over interstate connections for bulk power supply which may determine availability of power to Mexico.

Section 210 of PURPA is one of the most dramatic recent changes in the laws affecting utility operation in the United States. In several ways it represents a revolutionary change in the regulation of electricity production, distribution and use; one which is almost certainly without precedent world-wide. While most of the rest of PURPA is concerned with procedural matters, Section 210 requires certain innovative features of rate design and regulatory treatment for cogeneration and small (renewable) energy generation. One impact of this is that the rates paid by utilities to alternative sources of electricity are much higher than they were previously. In the past, utilities could charge very high backup rates and pay little or nothing for excess power from alternative power generators. Now, unless evidence is established to the contrary, the normal rate for electricity (e.g., industrial interruptible rates) must be charged, and at least the incremental cost of fuel (i.e., the fuel adjustment charge per kilowatt hour) must be paid for electricity generated from sources such as large office buildings with diesel cogeneration systems (total energy systems) or industrial sites with privately owned wind turbines.

In addition, to the extent that a utility can avoid capacity additions through the purchase of power from alternative generation sources, it must pay this source the avoided cost of the new capacity which would otherwise be required. In the case of new generation facilities requiring fossil fuels, the avoided fuel cost alone can be in the range of $0.03 to $0.06 per kW/hr.

If the capital costs of the new facility are in the range of $1000 to $3000 per kW, then the additional capital charges for the marginal power will be on the order of $0.02 to $0.14, depending on the locally applicable fixed charge rate and the operating capacity factor of the plant.

A potentially important case involves the Hawaiian Electric Company (HECO), which services the island of Oahu. HECO has agreed to pay a private San Francisco-based corporation, Windfarms, Inc. ninety percent of the avoided cost of oil-generated electricity from the proposed Windfarms 80 MWe wind generation facility slated for installation on the north shore of Oahu. Moreover, the contract provides for indexing the price of the wind-generated electricity to oil prices over the coming 25 years. It has been argued by some people in Hawaii that this is overly generous to Windfarms since the corporation already enjoys substantial tax advantages. However, Windfarms is proposing to use a new, essentially untried new technology, and could be incurring substantial risk. Without the coupling of tax incentives and an attractive contract with HECO, it would be difficult to attract the necessary risk capital to the venture. Similar arguments have been made about development of geothermal power and biomass resources on the island of Hawaii.

The FERC regulations have procedural requirements for utilities and small generators of power. The regulations, among other things, require that state regulatory commissions adopt regulations for categories of small power generators who produce less than 100 MWe. There are also FERC requirements regarding information gathering and preemption of state regulation on anything but the prices for purchase and payback. In effect, this means that the small power producers are not considered public utilities. A final requirement is that a utility or combination of utilities must own less than 50% of a "qualifying facility" in order to receive favorable treatment by both the FERC and the Internal Revenue Service.[8]

THE NATURAL GAS POLICY ACT OF 1978

Two of the most important consequences of the Natural Gas Policy Act of 1978 are that it raises natural gas prices, and that it passes on the price

[8]Further discussion of the implications of Section 210 is found in the paper by Edward Kahn.

increases first to industrial users. The price of natural gas will be fully decontrolled by 1985. Even at a higher commodity cost, however, off-peak industrial use of natural gas may still be a bargain since it is considerably less polluting than coal or oil and may be less expensive than imported oil. The whole issue of natural gas rate design has substantial impact on the future of renewables.

THE POWER PLANT AND INDUSTRIAL FUEL USE ACT OF 1978

The Power Plant and Industrial Fuel Use Act of 1978 was designed to encourage utilities and large industrial users of oil and natural gas to shift from these fuels towards coal and other "alternative fuels." The Act (FUA) has precipitated considerable debate but there has yet been little shift to coal except in some southern regions of the U.S. Conversion to coal has been slowed by environmental constraints imposed under the Clean Air Act, as well as by problems experienced in attempts to rapidly increase the rate of production, transport and use of coal. By contrast, if the alternative energy is derived from conservation, cogeneration, or renewable energy sources including solar industrial process heat and wind-generated electricity the environmental obstacles are not important.

The law contains special provisions for cogeneration and fluidized bed combustion techniques; the FUA encourages these technologies by exempting them from certain provisions of the Act. Further, all alternative fuels receive special treatment in the FUA regulations, since existing non-exempt fuel users must demonstrate that they have explored conservation and other alternatives before they can continue to use oil or natural gas. Thus, a plan to move to alternatives and conservation would have some force against utilities and industries who are opposed to switching away from gas and oil.

NATIONAL ENERGY CONSERVATION POLICY ACT

The National Energy Conservation Policy Act, (NEPCA, 1978) has important potential which is now just beginning to be realized. The law has five major parts. These include:

Title I -- Administrative provision

Title II -- Residential energy conservation program

Title III -- Local school and hospital energy efficiency program

Title IV -- Energy efficiency standards program for appliances and autos

Title V -- Energy conservation and solar energy on Federal buildings.

The Title I program involves the financing of energy conservation improvements in buildings by utilities and federal financing entities, development of energy performance standards for buildings, and weatherization of low income family dwellings. This reflects the fact that conservation is the fastest, cleanest, and cheapest way to achieve substantial decreases in our dependence on foreign oil.

ENERGY TAX ACT OF 1978: WINDFALL PROFITS TAX ACT OF 1980

The Energy Tax Act of 1978, (ETA, 1978), and the Crude Oil Windfall Profits Tax Act of 1980 are considered together here. This is because the ink was barely dry on the Energy Tax Act and regulations when it was amended to further promote conservation and alternative (mostly renewable) energy technologies. Depending on how narrowly the laws are interpreted by the Internal Revenue Service (IRS), there may be very strong incentives for the promotion of new energy options.

The most important provisions for business investment in energy may be the provisions for additional investment tax credits and double declining balance accelerated depreciation found in the Energy Tax Act and Windfall Profit Acts. The basic provisions in the Energy Tax Act were amended in the later act to given an additional 10 to 15% investment tax credit for qualified energy expenditures. Such investments include solar and wind energy property, alumina electrolytic cells, small hydroelectric generating property, some kinds of cogeneration property, qualified intercity buses, ocean thermal energy conversion property, and energy-related pollution control property. Qualified property is also eligible for the large deductions of accelerated depreciation which allow a quick return on investment and help to beat inflation for the tax payer. These legal provisions are at least as generous as any other legal provisions which have been used as tax shelters. While utilities receive generous treatment in other parts of the tax code, these new benefits cannot innur to them nor to an entity which is more than 49% owned by a utility. This is explicitly stated in the FERC regulations.

This has important consequences for financing choices. The exception to the non-availability to utilities is small hydroelectric retrofit.

The Windfall Act also has some new provisions regarding the use of non-taxable municipal development bonds for energy facilities. These provisions require that such facilities be owned by the governmental entity that finances them, although a contract for operation may be given to a private firm. To take advantage of this provision, a facility must not receive benefits under other government programs.

A final provision of the law is the low income energy assistance block grant program. To the extent that this $3.1 billion program receives appropriated funds, it could have a substantial impact. One interesting provision of the law is that if a state increases the grant for public assistance in order to pay for increased energy costs, this increase shall not be used to reduce food stamp (food subsidy) allowances. This provision would be helpful to urban centers if any increase in income maintenance grants were stated to be to pay for energy costs.

THE ENERGY SECURITY ACT

The Energy Security Act, adopted on June 19, 1980, is intended to promote the production of synthetic fuels in three different ways: through the creation of the United States Synthetic Fuels Corporation, through the creation of the Solar Energy and Energy Conservation Bank and through funding projects by the Department of Energy for biomass and alcohol projects. There are also important miscellaneous provisions regarding utility financing, geothermal energy, the Strategic Petroleum Reserve, and various studies and funding provisions. The funding for the U.S. Synthetic Fuels Corporation itself does not apply to renewable energy except for the provisions on loan guarantees and other provisions for magnetohydrodynamic topping cycle facilities and hydrogen production from electrolysis.

The provisions for biomass, including municipal solid waste, appear to be potentially helpful for cities and rural areas. Provisions for the Solar Bank provide planning and operational guarantees and funding which could be applied to energy production from MSW and sewage, and possibly the production of energy from aquatic plants.

Under the new Administration it is not clear how all of these laws will fare. We expect a decrease in authorized funds, and in some cases we expect

a push for removal of these laws. If this happens, there will have been little time to evaluate the impact of these new and often innovative, occasionally revolutionary departures from previous U.S. practices.

THE EXPERIENCE OF SEVERAL STATES

INTRODUCTION

The various states have different levels of energy demand and different patterns of demand, geographical and in time. The historical forms of energy used differ from state to state, and the resources available to a state, both from within its borders, and from other states also vary considerably. The variety and extent of renewable sources of energy also varies widely, but in many states there is sufficient sunlight, wind, biomass potential, geothermal energy and ocean thermal energy to be worth developing if it can be done in an economically, environmentally and socially acceptable manner. Hawaii and Puerto Rico have them all, California has everything except ocean thermal energy, and Washington state has extensive resources of biomass wind and hydro potential. All of these states and many of their public and private utilities now recognize the need for increased efficiency in energy use. Energy conservation can achieve the same energy-related goals at a fraction (often less than 1/4) of the cost of new supply systems, and can be brought on-line more quickly and with less difficulties than new supplies. Also, since it is very difficult in many states to build new power plants, investment in conservation buys time by slowing down or halting the rate of growth in demand for fuels and electricity.

Overlaid on the array of energy resources and technical systems is a lattice of institutions and laws. Some are of recent origin, while others are undergoing changes. The specific experiences of certain regions, as they grapple with their present and expected energy problems, provides insite into the effectiveness of various institutional mechanisms for increasing energy efficiency and promoting the use of renewables. Some examples are discussed here.

HAWAII

Hawaii is a subtropical island state in the Pacific, 200 miles from the U.S. mainland. The state depends on imported petroleum for 92 percent of its energy needs. Jet fuel, diesel fuel and gasoline are the basis of transportation. Electricity and synthetic gas is produced from oil. However, Hawaii has the potential of being totally self-sufficient using local renewable and geothermal resources.

The Hawaii Public Utilities Commission (P.U.C.) is beginning to consider issues associated with conversion to renewables. Historically, about 8% of electricity has come from bagasse, the fiberous residue of sugar cane refining. There is now a movement to increase the bagasse use at the same time as there is increased interest in biomass fuels. There is an application pending before the Hawaii P.U.C. and FERC for approval of an 80 megawatt windfarm which would produce power from wind turbines on the windy north shore of the island of Oahu. The PUC must decide whether the payment the ratepayers will make to Windfarms, Inc. through the rates paid to Hawaiian Electric Company justify the price equivalent of imported oil. Similarly, the PUC must decide whether the price for eucalyptus-derived energy and geothermal energy on the big island of Hawaii should be based on the equivalent price of oil. The Commission has recently approved a new gas turbine and a biomass burning facility for Molokai Electric Company which services the island of Molokai. The biomass boiler will run on pineapple waste, hay, and garbage and will be backed up with coal. The facility will be leased from an insurance company to provide the tax benefits to that entity, although it will be built and maintained by the utility.

Molokai is a particularly interesting case. Most development has by-passed Molokai, which has a higher proportion of native Hawaiians than one other large islands. Much of the Molokai population wants to stop any development except for agriculture and aquaculture. They were recently successful in preventing county approval of a condominium complex to be built on the least populated part of the island, by showing how it would disrupt the economy. Possibilities for the island include more use of existing biomass, and the growing of giant banana and soybeans. These products can be used either for combustion or production of methanol or ethanol for local vehicles. The proteinaceous parts of these plants can be used to feed humans or cattle. Since these plants are legumes, they fix nitrogen thus improving the land for other crops. For hundreds of years there has been fishing and fish farming in Molokai's coastal waters. The 60 ocean fishponds on the southern side of Molokai could be used for growing seaweed for energy, and production of shellfish and seafish as cash crops and for food. There is a substantial potential for wind energy conversion on the western end of Molokai. Studies show that the windpotential on the western end of Molokai

is three times the need of the island in 1990. This energy could be exported to the far wealthier island of Oahu (Honolulu), but the question is how this development could be used to provide jobs and housing for the people already living on Molokai. One possibility is to limit such development unless certain conditions in taxation (property taxes) and land use are satisfied. One hopeful sign for Molokai is the substantial production of solar hot water systems by Aloha Energy, a profit making subsidiary of the non-profit community organization Maui Economic Opportunity. This project imports components from the mainland, using federal seed money, makes up the solar systems and installs and services them. The systems work, produce jobs, and reduce oil use.

Another issue in Hawaii is the possible development of an undersea power cable from the island of Hawaii with its abundant geothermal potential to Honolulu. This raises similar issues to a cable from Molokai to Honolulu to transfer wind power, the energy could be used on the Big Island to produce manufacturing jobs and the development itself could change the character of the island. Also, the price for geothermal electricity charged on the Big Island, under current federal law will be the same as that produced from oil. The provisions of PURPA and the tax law and the manner in which the Hawaii P.U.C. interprets the law will be important here. Further, this will interrelate with the Hawaii state department of Planning and Economic Development and county planning boards. Hawaii is unique in the United States in having statewide land use planning, although it is more like other states in that decisions to apply the plan can be made on a county basis.

ALASKA

While Alaska has the largest supplies of oil and natural gas in the United States, people in northern Alaska pay the highest prices in the U.S. for electricity, bottled gas and diesel oil. The electricity for the long Arctic night comes from diesel fuel refined in California and airlifted back to Alaska. Until recently, military bases in Alaska paid the equivalent of $2 per barrel for natural gas, which was not even available to some residents. Also, the residents where it was available paid the commodity cost of the gas. Now the situation has changed somewhat, but there is still the heavy reliance on imported diesel oil.

With electricity prices at 40¢/kwh, many energy options appear competitive and northern Alaska could soon use wind machines. The royalty interests of the state of Alaska in the oil and natural gas are radically reducing taxes for Alaskans while a high inflation rate makes it difficult for simple necessities to be bought.

The influence of the federal government over energy decisions in Alaska is stronger than it is in other states. The federal government owns so much of Alaska that it is difficult for the state to plan around this. As elsewhere in the U.S., the Alaska Public Utilities Commission operates with a formal rate case structure. Major decisions about the use of energy are decided in the context of either an application for a rate increase by the utility (electric, gas, water, telephone) or a rule-making proceeding. Even though the U.S. government owns much of the land, with additional substantial state land ownership, neither provides much utility service. Anchorage, Alaska's largest city has a municipal utility department, as does Fairbanks, the second largest city. While these utilities pay less for fuel than others must in the northern part of the state, they rely almost entirely on oil for electrical generation. The fuel price differences could mean it will take longer to make renewables economic in the southern part of the state unless there is a conscious decision to move to renewables. Alaska has adopted the OPEC concept of using current petroleum funds to build for the future and has created a huge trust fund for this purpose. The funds are not yet being used to promote renewables although conservation has come into greater use purely as a function of cost.

BLOCK ISLAND, RHODE ISLAND

Block Island, located off of the Atlantic Coast, is part of the state of Rhode Island. Block Island has the lowest per capita income in the state, although the land is quite valuable. The island has a great deal of wind, a substantial amount of peat, and during the summer tourist season, there is a great deal of garbage. There is a 200 kw Mod-0-A wind mill on the Island which is the only other source of electricity other than very inefficient old diesel generators. Block Island has some of the most expensive electricity in the United States. The average cost per kilowatt hour is $0.29. In these circumstances, an integrated energy system may be very efficient, where it may not work otherwise even in the absence of federal loans or grants. For

instance, the peat, garbage, and the sewer sludge on the island could be gassified and used in the existing diesel generators. The waste heat from the gasification and combustion can be used for aquaculture or greenhouses since the island can get quite cold in the winter. Eventually, with additional windmills, there is the possible production and use of hydrogen as fuel for vehicles, as well as use of electric cars and trucks.

The energy regulatory structure in Rhode Island includes a Public Utilities Commission, a land use planning agency, taxing authorities, and coastal zone management. If Block Island is to develop its indigenous resources or return to the historical use of peat as a source of fuel there must be a permitting process. Among the considerations are whether the P.U.C. will keep a tight rein on the investor-owned utility so alternative systems will have an opportunity to develop. The state tax credits of 10% over and above the federal tax credits for passive and active solar, wind, geothermal and low head hydro, have stimulated some activity in these areas. Solar water heating systems have recently been installed.

While Rhode island has a long coastline and in many places has the same climate as Block Island, the much higher rate and the insularity of the system could promote a completely renewable system on Block Island. Some people hope that within 10 years much of the economy will be based on wind, peat, aquacultural and agriculture. One of the interesting legal sidelights is that one of the impediments to peat use will be ancient property rights in peat which have not been exercised because of formerly low cost pertroleum usage.

NEW MEXICO

New Mexico is blessed with as much sun as the Sahara Desert. But because of high altitude and the Rio Grande river it has a more hospitable climate. The capital of New Mexico, Santa Fe was founded by Conquistadores as the capital of Nuevo Mexico (Northern Mexico and Western United States) in 1610. The largest group of people in New Mexico are hispanic and the rest of the population is Native American (Navajo, Apache, Pueblo) and non-hispanic Caucasian. The architecture has historically used the sun. The resurgence of interest in climate-sensitive design has spawned many solar buildings, with considerable emphasis on passive solar design. The state had a 25% tax

credit for active solar installations before a federal credit was adopted and this has stimulated many solar hot water installations. In addition to the simpler thermal systems there is experimentation on more advanced systems at Los Alamos National Laboratory, Sandia Laboratories and New Mexico State University. In addition to research, there is commercial use of solar technologies for irrigation, crop drying and other agribusiness uses.

The New Mexico Public Service Commission has before it an application for substantial commercial geothermal facilities which would take advantage of the provisions of PURPA and federal tax law. The PSC has to consider the impact on the religious sites of Jemez Pueblo in deciding whether to grant approval since the Valle Grande Caldera area has always been sacred to the Jemez indians. The land is owned by the federal government and by the descendents of a Spanish land grant so there are competing interests of environmental law, freedom of religion, and the need for new sources of energy. The likely conclusion will be a limitation on the area of drilling and a monetary payment to the Pueblo.

One of the 200 KW DOE experimental windmachines (MOD-O-A) is in Clayton, New Mexico. The Northeast part of New Mexico is quite windy, as are other high mountain parts of the state. The rural areas are generally operated by cooperatively-owned or municipally-owned utilities which historically have had a lower cost of financing because they are tax exempt. However, a move by the United States administration to require market interest rates by the Rural Electrification Administration and to reduce Farmers Home Administration financing (using for municipal energy/waste systems) could reduce the ability of these isolated system to convert from natural gas and oil.

NEW YORK CITY

New York City is one of the largest urbanized areas in the world and may have the greatest diversity and concentration of electric groups that has ever existed. It uses more energy than any other city and has very high costs by United States standards.

Improved energy end-use efficiency and changes in commercial and industrial operating patterns can have a significant impact on energy use. A method of efficient use of energy that has been little used in New York City is load management. Load management is the use of price and direct

130

controls to control the electricity use profile for different end-users. The price aspects have to a certain extent been explored by the Public Service Commission (PSC) in its order requiring time-of-day rates based on marginal cost for the 170 largest customers of Consolidated Edison. Load management is being studied by the PSC staff but has not been implemented on a direct basis in applications such as cycling of air conditioning or hot water loads. The potential for the timing of loads to reduce use on summer and winter peaks is substantial. To the extent that very expensive, polluting, inefficient peaking plants using imported oil are a proportionately lesser amount of the total electric usage, then there will be lower fuel adjustment clause charges, less pollution and less waste heat. The load management option could be explored for city buildings, all government building in the City, or with private buildings. It is technically possible to cycle city buildings alone, but it would be more efficient to have it done on a city-wide basis by Consolidated Edison. Tax incentives or financing strategies such as have been used in Detroit and Georgia could be tried.

Cogeneration is a subject of great dispute in the City. Present federal law favors cogeneration, at least in the commercial and industrial sectors, by both tax and regulatory policies. City policies can remain neutral, inhibit cogeneration, or encourage those kinds of cogeneration which promote other City policies. For instance, while it has been argued that a large number of point sources can produce more air pollution than a single large utility plant, this has been in the context of small diesel oil fired plants. Consolidated Edison's own data presented before the Public Service Commission shows that the use of natural gas produces very little air pollution. Further, the city pollution peak occurs in the summer, which is the off-peak period for natural gas use. Thus, the city could chose to support cogeneration that used natural gas or biogas, while discouraging or staying neutral on systems that used diesel fuel in the middle of the summer.

Changes in the patterns of use can be quite varied. The Public Development Corporation has indicated that in the initial phase a of an industrial energy audit program, $2,000,000 in savings have been indicated out of a total energy bill of $4,200,000. These savings come from changes of use with no capital expenditure over $10,000. In the industrial sector, the capital should be readily available. Changes can be as simple as not running

machinery during times it is not being used or changing thermostat settings. In the commercial and large residential sectors, changes in thermostat setting are more difficult to achieve. There then may be the need for either regulations, economic incentives or mechanical devices (e.g. locked thermostats) to enforce appropriate behavior. Clearly economic incentives (e.g. utility rate design) are preferable to mandatory requirements or mechanical systems which may interfere with lifestyle choices. All the mechanisms may have to be used, but it is most consistent with freedom and diversity to create economic incentives permitting individual decisions.

While the demand side technologies appear to be more cost effective for now, there are known technologies which may be acceptable to the City and which are not being promoted by other suppliers at this time. Among the technologies are the use of garbage, sewage, wind and sunlight. The specific technologies vary, but the use of garbage and sewage can be combined with coal if new technologies such as fluidized bed can be used to eliminate harmful air pollution.

The use of garbage solves two problems for the City: waste disposal and energy. Among the processes are the production of synthetic biogas or an oil type product. These products can be further used and/or made into alcohol for fueling vehicles. In addition, oxygen or hydrogen stored from electrolysis could be used as fuel or to increase the Btu content of biogas. As with most other things it is a question of financing.

Wind energy is on the verge of becoming commercially feasible. Recent studies done for the U.S. Department of Energy find commercially available wind regimes in the environs of New York City on the shore. These could be used to supplement City power and happen to come at their maximum intensity at the time of PASNY's winter peak which in part determines the rates charged for City agencies. The question again becomes how these wind machines will be financed and what regulations and taxes will apply.

CALIFORNIA

A final example from the United States is California which has rapidly implemented several renewable energy technologies; particularly wind and solar heating. Both the economics and the solar energy are there, but the state has gone further by financing and tax incentives to promote such an option while forcing utilities to participate by giving them no other choice.

15

In recent years, California has had to respond to a broad range of social, economic and logistical pressures which include:

- A pervasive and powerful environmental ethic, which has resulted in stringent controls on emissions from stationary sources and prevented the burning of coal in the State,
- Rapid rises in the prices of imported oil and of natural gas from Texas and Canada,
- Growth in demand for electricity and fuels resulting from population growth, increased industrialization and decreased efficiencies in energy use in buildings (until recently),
- Major opposition to nuclear power,
- An innovative public with strong interest in solar energy, wind, biomass, etc.,
- Political leadership in both legislative and executive branches extremely concerned with issues of energy and the importance of conservation and renewables.

One of the most significant institutional innovations has been the recent creation of the Zero Interest Program (ZIP). This program requires that utilities assist home owners in retrofitting their homes to be more energy efficient. The utilities provide financing in the same way as they would obtain financing for new generation capacity. By putting conservation and capacity expansion on the same footing, there has been a considerable increase in the rate of retrofitting of buildings for increased energy efficiency. This reflects the fact that saving additional capacity through such retrofit activities costs about ten to twenty percent of the cost of new capacity.

ATTACHMENT I

TABLE OF DECISIONS ON RATE DESIGN AND
PUBLIC UTILITY REGULATORY POLICY ACT DEVELOPMENTS*

Elliot Taubman

ALABAMA

Re Alabama Power Co., Docket #17261 (Ala. P.S.C. April 26, 1977). See Docket #17752 (Ala. P.S.C., 1979) considering cost-of-service, declining block rate, adopted seasonal and interruptible rates. All of the following have been adopted: master metering, automatic adjustment clauses, information to consumers, procedures for terminations, and advertising paid by shareholders, owners. Considering further action in Re Alabama Power Co., Docket #17859 (Ala. P.S.C., 1980).

ALASKA

Re Alaska Gas & Service Co., Docket #U-75-94 Order #16 (Alaska P.U.C. 1977). Gas rates flattened, PURPA standards being considered. Alaska Village Rural Electric Cooperative has the dubious honor of most expensive electricity in U.S.

ARIZONA

Tuscon Gas & Electric Company has an experimental 700 kWh lifeline; Re Arizona Public Service Company, Cast #U-1345; Re Tucson Gas & Electric Case #U-1933 considering cost-of-service rates, prohibition of declining block, TOD rates, seasonal rates, and load management.

ARKANSAS

Re Arkansas Power & Light Co., Docket #U-2762, Ark. P.S.C. (1977); Re Arkansas Power and Light Co., Docket #4-2666 (1978) TOD rate and interruptible rate for residential and commercial use. No increase in customer charge and flat residential rate. Marginal and incremental cost data used to set rates. Re Oklahoma Gas & Electric Co. Docket #U-2832 (1978) seasonal rates. In rule making Docket #U-2666 load management considered and not adopted, Commission adopted: automatic adjustment clause, information to consumers, and advertising charged to stockholders, owners; other areas of Section 113 (PURPA) under consideration on Docket F-001.

*Information comes from sources in each state and various publications and is up to date to the end of 1980.

154

CALIFORNIA

Re Pacific Gas & Electric Company Decision #84902 Cal. P.U.C. (1975). Assembly Bill #167, Chapter 1010 Public Utilities Code §739 (Cal. General Assembly, 1975); Re Electric Utility Rate Structure, Case #9804 Cal. P.U.C. (1975) Adoption of Lifeline and then inverted rate using marginal cost principles Rate Design for PG&E A. 57666 Commercial and Industrial use. Re California Pacific Utilities Co. Docket #85559 (3/1/676) TOD rate for Commercial and Industrial Tariff No. 171, Effective (8/2/78). Re Pacific Power & Light Co. Docket #85559 (3/1/676) TOD rate for Industrial use, Tariff #AT-47&48 effective 12/27/78. Re Sierra Pacific Co. Docket #8559 (3/16/76) TOD rate for Industrial use Tariff #TOU-3 effective 9/16/78. Re California Pacific Utilities Co. Docket #8559 TOD rate for Industrial use Tariff #T-170 effective 1/1/78. Re Pacific Gas & Electric Co. Docket #86632 (12/6/76) TOD rates for Industrial use Tariff #A-23 effective 12/6/76. Re Southern California Edison Co. Docket #87744 (8/23/77) TOD rate for Commercial use Tariff #TOU-8 effective 10/14/77. Re San Diego Gas & Electric Co. Docket #87745 (8/23/77) TOD rate for Industrial use Tariff #A-6 effective 9/17/77. Numerous experiments on TOD pricing. Presently the commission is holding generic hearings on termination, marginal cost, and fuel adjustment. It has also adopted utility financing programs for solar hot water insulation and energy efficiency improvements.

COLORADO

Re Public Service Co. of Colorado, Decision #87524 Docket #868 (Colo. P.U.C. 1974) pending generic proceeding. Load management experiment in interruptable rate for irrigation. Re generic proceeding Docket #5693 presently deciding PURPA issues. Approved advertising charged to stockholders, owners. Commission approved gas lifeline for senior citizens which was reversed by the courts as it discriminated between residential customers. Senior citizens opposed special rate for themselves and therefore no evidence in the record to support commission decision.

CONNECTICUT

Re New Pricing Principles & Rate Structures for Electric and Gas Companies Docket #7602-04 (Conn. P.U.C.A. 1976); DOE demonstration program: Re Connecticut Light & Power Co. Docket #770319 (Conn. P.U.C.A. 1977) Staff report Connecticut Peakload Pricing Test (May 1977) on residential use. Re

United Illuminating Docket #771118 TOD rate for residential use. Re Hartford Electric Light Co. Docket #770319 (Conn. P.U.C.A. 1977) TOD rate for residential use. Re Connecticut Light & Power Docket #770320 (Conn. P.U.C.A.) TOD rate for residential use. Presently there are several experiments on TOD rates for commercial and residential use. Generic Case #790101 considering cost-of-service methodology and low income rate design issues including lifeline. They have adopted flattened rates, master metering, automatic adjustment caluses, procedures for termination of electric service, and advertising charged to stockholders, investors.

DELAWARE

Re Delmarva Power & Light Co. Docket #978 (1978) Load management through equipment control for residential, commercial, and industrial use. Flat residential rate with no increase in customer charge in most recent decision. Re Delmarva Power and Light Docket #923 (Phase II) TOD rates (in hearing) Re Delmarva Power and Light Docket #602 (1971) seasonal rates. They have adopted automatic adjustment clauses, master metering, consumer information, procedures for termination, advertising paid by shareholders, owners.

DISTRICT OF COLUMBIA

Flattened gas rates including adjustment for master metered apartments. Electric lifeline adopted by commission in 1973. Re Potomic Electric Power Co. F.C. 685 eliminated declining block rate, mandatory time-of-day for large users Re Potmic Electric Power Co. Docket #630 (D.C. P.S.C. 1975) Re Washington Gas Light Co. Docket #610 (D.C. P.S.C.) flattened natural gas rates. Consumer Bill of Rights adopted prior to ?

FLORIDA

Re Florida Power & Light Co. Order #7843, Docket No. 760727-VA (Fla. P.S.C. 1977) Florida Power Corporation Residential Time-of-Day Study Report 9/77. Numerous experiments with load management using equipment control. One experiment with time-of-day for all types of use. Re Gulf Power Co., Florida Power & Light, Florida Power Corporation, and Tampa Electric Co. Docket #73694 (Fla. P.S.C. 1973). Florida Power & Light has inverted residential rates at 700 kWh with no increase in the customer charge. TOD, seasonal and interruptable rates. Re Generic hearing Docket #73694-EW lifetine rates being considered for all utilities. They have adopted advertising paid by shareholders and owners.

GEORGIA

Re Georgia Power Co., Docket #3002-U (Ga P.S.C. Sept. 5, 1977) adopted inverted rate for residential class, recovery from all classes. Decision based on cost of new plant and impact on poor and elderly. They have done an experiment in load management TOD for public schools. They have adopted automatic adjustment clause and information to consumers sections of PURPA. Presently holding generic hearing of PURPA rate design and other issues. Some municipals and cooperations in state have adopted direct radio controlled cycling of air conditioning to substantially reduce wholesale peak load charges from Georgia Power Co. Georgia Power itself is doing 5,000 home experiments on air conditioning cycling. Georgia Power filed studies showing lower use customers good load factors, mainly because of less use of air conditioning.

HAWAII

Re Generic Docket #2793 (2/78) (Hw. P.U.C. 1978) PURPA issues pending; have ordered (Jan. 1980) utilities to file TOD rates and move toward flat rates. Re Generic hearing Docket #3874 (Hw P.U.C. Dec. 1979) considering lifeline rates. Have adopted load control of hot water heating and a state policy of promoting the substantial use of alternative energy. Have also adopted advertising paid by shareholders, owners. In Re Molokai Electric Co. Docket #3692 (Hw. P.U.C. 1980) both company and Maui Economic Opportunity, Inc. proposed inverted rate for first 600 kWh of residential use if direct load control of water heating accepted; rate also applies to solar water heating users. Commission adopted. Also gave zero percent (0%) rate of return to residential class in part because of risk assessment.

IDAHO

Re Utah Power & Light Co. (Idaho P.S.C. 1977). Adopted slight inversion of rates below 600 vwh but also slight increase in customer charge. Presently considering PURPA rate design issues utility by utility in rate cases. Re Generic hearing Docket #P300-16 considering lifeline. They have adopted termination of service PURPA standard; others in hearing.

ILLINOIS

Re Central Illinois Public Service Co., Docket #80-0124. Will consider PURPA rate design issues. Will do other utilities as rate cases come up. Re

Commonwealth Edison Co., Docket #76-698 (Ill., Com. Comm. 1977) Re Central Illinois Light Co., Docket #770631 (1978) TOD, interruptable, and equipment control rates, feasibility study for all uses and a mandatory TOD experiment for residential. Experiments and reviews ordered on Direct Load control on air conditioning & water heaters on a sample of residential users to register when demand is made. Marginal cost data used to set rates with short run energy costs. They have adopted master metering, automatic adjustment clauses, information to consumers, procedures for termination of electric service, and advertising cost charged to stockholders, owners. Re Iowa-Illinois Gas and Electric Co., adopted "small-user" inverted rate based on load factor and economic impact; proposed by utility.

INDIANA

PURPA rate design issues will be considered by utility starting with Re Northern Indiana Public Service Co. They have had load management experiments with TOD rates for industrial and residential use. Re Indianapolis Power & Light Co., Docket #34363 (Ind. P.S.C., 1979) seasonal rates. Re Indiana Public Service Co., Cause #34215 (Ind. P.S.C., 1978) interruptable rates for some industrial users. Re Indiana & Michigan Power, Cause #35251 (Ind. P.S.C., 1978) interruptable rates for some industrial users. Adopted Master metering, automatic adjustment clauses, information to consumers, procedures for termination of electric service and advertising charged to shareholders, owners.

IOWA

Commission presently investigating cost-of-service rates and have experiments in seasonal rates for load management. Re Iowa Electric Light & Power Co., Docket #RPU-76-27 decision on TOD rates. Re Iowa-Illinois Gas & Electric Co., Docket #RPU-76-27 decision on seasonal rates. Re Iowa Soutern Utilities Co., Docket #RPU-76-15 (1978) seasonal rates. Re Iowa Power & Light Co., Docket #U-526 (1977) interruptable rates and load management. Re Iowa-Illinois Gas & Electric Co., Docket #U-433 (1976) interruptable rates. They have adopted master metering, automatic adjustment clauses, procedures for termination of electric service, and advertising charged to shareholders, owners. Re Iowa-Illinois Gas & Electric Co., Docket #RPU-78-12 (1978) adopted "small-user" inverted rate justified on load factor and economic-impact; rate was proposed by utility.

KANSAS

Re Generic hearing, Docket #115379-U all types of rate design presently being considered. They have adopted procedure for termination of electric service, automatic adjustment clauses, and master metering. Commission had previously adopted no increase in fuel adjustment clause for first 300 kWh.

KENTUCKY

Administrative case #203 PURPA rate design issues under consideration, utilities to file information in fall, 1980. Administrative case #202 considered lifeline but no decision expected soon due to new hearing above. They have used interruptable rates for load management. They have adopted Automatic adjustment clauses, procedures for termination of electric service and advertising charged to shareholders, owners.

LOUISIANA

Re Central Louisiana Electric Co., generic hearing on rate restructuring began in Nov. 78 is still pending. Commission moving toward flat rates, seasonal variation. Hearings with no decision yet on PURPA customer issues expect for automatic adjustment clauses.

MAINE

They ordered flat energy rates in 1978. There is a "Report of the Public Utilities Commission to the 108th Legislature on the Lifeline Demonstration Program for Maine" (Maine P.U.C. July 1977). Re Central Maine Power Co., Docket #F.C. 2332 (1978) TOD rate for residential use. Marginal incremental cost data has been used considering long- and short-run energy costs and long- and short-run capacity costs. Re Bangor Hydro-Electric Co., Docket #F.C. 2036 (1973) interruptible rates. Re Central Maine Power Co. (P.L. 1975, Ch 585) (1977) lifeline rates. They claim to have adopted PURPA Standards Automatic adjustment clauses, information to consumers, procedures for termination, and advertising charged to shareholders, owners. Decided not to continue "lifeline" rates without legislative authority but considering inverted rates based on cost and conservation impact.

MARYLAND

Presently investigating rate design by utility. Re Delmarva Power & Light Co., Docket #7174, Re Baltimore Gas & Electric Docket #7159, PEPCO also pending. Re Electric Utility Rate Structures, Cast #6808 Order #62568

(Maryland P.S.C. 1977) Generic hearing still pending, but Commission has flattened rates and kept customer charge at original level. They have adopted master metering and advertising charged to shareholders, owners. Re Generic hearing, Docket #7413 considering termination standards.

MASSACHUSETTS

Re Massachusetts investor owned electric companies, Docket #18810 (1977) TOD rates and equipment control rates for all classes of customers, reviewed standard of cost-of-service and declining block rates on a utility by utility basis. Re Boston Edison Co., Docket #19300 (Mass. D.P.U., 1978), Re Western Massachusetts Electric Co., Docket #18731 (Mass. D.P.U., 1977), have historically not increased first 384 kWh (and later 350 kWh) for Boston Edison. Adopted low income lifeline for Massachusetts Electric Co. and company request. Allocated rate increase by growth of peak among classes for Western Massachusetts Electric Co. All changes in electric rate design have been upheld by the courts. See Boston Edison Co. vs. Department of Public Utilities, 375 N.E. 2d (Mass. April 1979).

MICHIGAN

The Michigan Commission has reiterated its movement to inverted rates. Re Detroit Edison Co. Case U-6006 (Mich. P.S.C. 1980) Re Consumers Power Co. Case #U-5331 (1978). There are now two kinds of residential inverted rates. There is a three-step rate that goes from under 500 kWh, 500-1,000 kWh and over 1,000 kWh. In addition, senior citizens are offered an even lower rate for the first 500 kWh if they agree to load management. The Commission found that senior citizens had an excellent load factor, but chose to include the load management feature to guarantee this. Customer charges have not been increased. There is also a load management rate for centrally air conditioned residences and time-of-day rates for large commercial and industrial users. Gas rates have been flattened while customer charges were not increased. Re Michigan Consolidated Gas Co. (Mich. P.S.C. 1980). Legislature has just adopted legislation eliminating customer charges and requiring further inverted rates.

MINNESOTA

Minnesota has adopted a lower rate for the first three hundred kWh of residential use. Re Minnesota Power & Light Co., Docket #E015-GR077-360

(Minn. P.S.C., 1978). It also has adopted volumetric rates for natural gas where there is no customer charge and a flat charge per mcf. for all users.

MISSISSIPPI

Mississippi has traditional declining block rates and has challenged the constitutionality of PURPA. However, suggested charge more in line with the other units of Middle South Utilities and the Southern Company have been proposed, decision is pending. Mississippi Power & Light Co. has load management rate for electric water heating.

MISSOURI

Missouri adopted a lower rate for the first 300 kWh in Re St. Joseph Light & Power Co. Case #EO-77-56 (Mo. P.S.C., 1976). The PSC has held further hearings on several issues and is expected to make further change A stipulated settlement was adopted in Re Union Electric Co. Case No. EO-78-163 (Mo. P.S.C., 1980); stipulation to change rate design.

MONTANA

Montana was one of the first states to adopt flat rates in Re Montana Power Co., Docket No. 6289, Order #4293 (Mont. P.S.C., 1976). It presently has pending Phase II of a Montana Power Co. rate case and is considering rate design issues. Previously adopted TOD rate in Re Montana-Dakota Utilities, Order #4369 (Mont. P.S.C., 1977), interruptible rates, Order #4476 (Mont. P.S.C., 1979).

NEW MEXICO

Have been flattening rates, no increases in customer charges. Moving to marginally cost based TOD rates in New Mexico Public Service Company cases. Studying marginal cost and social and economic costs on gas rates. Adopted comprehensive conservation regulation including rate design and alternative energy standards. General Order #33 (N.M. P.S.C., 1979).

NEW YORK

New York has adopted marginal cost pricing as the basic standard for both electric and gas rate making. A major proceeding was the generic case #26,806 (N.W. P.S.C., 1976, 1978, 1979) which adopted marginal cost, time-of-day, state-wide costing standards, and an experimental "alternative form lifeline" based on marginal cost. See for TOD: Re Long Island Light Co.,

Docket #26,887 (N.Y. P.S.C., 1977), Re Central Hudson Gas & Electric Co., Docket #27,032 (N.W. P.S.C., 1978); Re Consolidated Edison Co., Docket #26,105 (N.Y. P.S.C., 1973); Re Orange and Rockland Utilities, Docket #26,738 (N.W. P.S.C., 1975). The Commission is presently considering fuel adjustment clause provisions at PURPA and other standards. Dockets #27,137, 26,998. Commission had previously adopted prior notice and hearing, serious illness provisions for utility terminations before PURPA.

NEW JERSEY

State of New Jersey Bill No. 1830 (Jan. 10, 1978), previously adopted lifeline, but commission asked for further clarification from legislature. See Docket #784-311 (N.J. B.P.U., 1978). Presently pending PURPA proceeding. TOD in force. Eliminated declining block rates, adopted TOD rates, seasonal rates, and interruptable rates in Re Public Service Electric & Gas Co., Docket #7711-1107 (N.J. B.P.U., 1978). Jersey Central Power & Light Co. presently has inverted rate in summer and declining blocks in winter.

NEW HAMPSHIRE

No substantial change from declining block rates; PURPA pending.

NEBRASKA

All electric utilities are public power agencies in this state so no commission regulation. Gas utility seeking to avoid regulation. Larger cooperatives and municipals considering PURPA standards.

NEVADA

Commission hearings on PURPA issues. Previously decided to consider lifeline in further proceedings -- before PURPA. Not increasing lowest charges. See Docket #475 (Nev. P.S.C., 1976).

NORTH CAROLINA

Commission has been studying changes in rate design. Have ordered voluntary TOD rates, Order #E-100, Sub 21 (N.C.V.C., 1977), and direct load control for water heaters and industrial interruptable load, Order #E-100, Sub 32 (N.C.U.C., 1978). "Commission decisions in electric rate proceedings have resulted in substantial flattening of rate structures." Andrew W. Williams, Director Electric Division, Public Staff, North Carolina Utilities Division. Also mandatory TOD for 450 residential customers of Carolina Power

& Light Co., Docket #E-100, Bus. 21 the Commission approved a voluntary TOD plan for 1,250 Duke Power Co., customers. Seasonal rates implemented for all the major utilities with a higher summer rate. In Re Duke Power Co., Docket #E-7, Sub 237 (N.C.U.C., 1978) "the Commission placed no increase for the first 350 kWh used each month by residential customers receiving Supplemental Security Benefits. In the order in that docket, dated August 31, 1978, the Commission found that lower cost of service could be identified for that small sub-class of customers (customers receiving SSI) and that the rates should reflect these lower costs." No general determination of the lifeline concept has been made.

NORTH DAKOTA

Commission has held hearings on Section 113 issues of PURPA with no decision yet. Utilities conducting survey on income/consumption issues. Generic rate design hearings to be held.

OHIO

Commission has found TOD approval for residential, commercial, and industrial customers, also interruptable and seasonal rates. Re Dayton Power & Light Co., Docket No. 76-823/92/AIR (Ohio P.U.C., 1978). Presently considering application of marginal or incremental costs since Docket #76-892-EL-CO/ (Ohio P.U.C., 1979). Rejected "lifeline" referendum, but one house of legislature has passed bill limiting customer charge to meter reading and accounts.

OKLAHOMA

Oklahoma now has flat residential rates in part, because of the conservation effect. It has not substantially raised customer charges. Re Oklahoma Gas & Electric Co. Case #26,495, Order #159951 (Okla. P.S.C., 1979), Cause #25495, Order #161697 (Okla. P.S.C., 1979).

OREGON

Commission has adopted TOD and seasonal rates; TOD for all residential users over 1,000 kWh. Re Portland General Electric Co., Pacific Power & Light Co., Docket #UF3346 (Ore. P.U.C., 1978). Use of marginal or incremental cost in the setting of rates. See Re Portland General Electric Co., Docket #78-521 (Ore. P.U.C., 1978). Did not want to adopt "lifeline" rates based on below cost concept in 1976 Docket No. 76-039 (Ore. P.U.C., 1976).

However, have flat or inverted rates based on LRIC. Prior notice and hearing, serious illness provisions for utility terminations adopted prior to PURPA.

PENNSYLVANIA

Pennsylvania has twice adopted a lower rate for the first 500 kWh and this has been upheld by the courts. Re Philadelphia Electric Co., Docket #76-PRMD-7 (Pa. P.U.C., 1977) Case #R.I.D. 865 (Pa. P.U.C., 1980). Basis of decision is cost of new plant benefits larger users by reduced fuel cost. Commission has ordered load control for certain major appliances.

RHODE ISLAND

Commission has adopted inverted rate in Re Newport Electric Co., Docket #1311 (R.I. P.U.C., 1979). A flat rate in Re Blackstone Valley Electric Co., Docket #1262 (R.I. P.U.C., 1979). Commission has indicated that any increase in the customer charge carries a heavy burden of proof since rate analysts tend to "dump" other costs in the customer charge. See also Re Narragansett Electric Co., #9515 (R.I. P.U.C., 1978) for adoption of seasonal rates. Re Block Island Power Company, #1517 (R.I. P.U.C., 1981) holding further proceedings on correction for wind power in fuel adjustment clause, purchase rates for private small power producers, and rate design. Staff has proposed an avoided cost per §210 from fuel of 12.6¢ per kWh to be adjusted monthly. Future adjustments possible for capacity costs.

SOUTH DAKOTA

Commission adopted flat rates for all customers with no increase in customer charge as a moderate first step in rate reform. Commission also adopted a lower rate for the first 300 kWh for senior citizens on the basis that there was a good correlation between these customers and low use. Commission granted fees to intervenors. Case in on appeal as Chamber of Commerce v. Public Service Commission. See also Re Montana-Dakota Utilities, Docket #F3240 (S.D. P.S.C., 1978); Re Northern States Power Co., Docket #3188 (S.D. P.S.C., 1978).

TENNESSEE

No consideration and no charge by state regulatory commission. However, TVA, which provides a majority of the service at wholesale in Tennessee has considered PURPA issues. It has been considering rate design charges but has

164

been more active in promoting conservation, wood, and solar energy as options in the Tennessee Valley.

TEXAS

Time-of-day is being used on experimental basis in Texas. Re Texas Electric Service Co., Order #'s 1776, 1903 (Texas P.U.C., 1978). For interruptable and load management rates see Re Houston Lighting & Power Co., Order #'s 1776, 2001 (Texas P.U.C., 1978). HP&L case also ruled against "lifeline" in that case (case was heard before PURPA was adopted).

UTAH

Commission will consider PURPA standards in particular rate cases rather than termination proceeding, but did adopt senior citizen rate. The senior citizen rate has a lower charge for the initial usage block. See Generic Proceeding. See Re Utah Power & Light Co., Case #79-035-12 (Utah P.S.C., 1979).

VERMONT

"Ten out of 27 utilities had time-of-day rates before 1977. Several have seasonal rates" -- Nancy Mossbach, Asst. to Chairman. See Re Central Vermont Public Service Co., Order #3758 (Vt. P.S.B., 1975). Marginal or incremental costs used in setting rates. Load management techniques and interruptable rates encouraged. Commission has a lower rate for first 300 kWh based on cost of PASNY (hydro) power which is supposed to be passed on to residential and form users.

VIRGINIA

Time-of-day option for Re Virginia Electric and Power Co., Docket #19,827 (Va. Corp. Comm., 1978). Lifeline issue pending before Commission and legislature. See PURPA case #PUE-790012 (Va. St. Corp. Comm.).

WASHINGTON

Several utilities have inverted rates as does Seattle Municipal Utility. Pending PURPA proceeding Docket #U-78-05.

WEST VIRGINIA

Commission has decided to not increase customer charge in a number of proceedings and has been flattening rates. Considering conservation -- lifeline in a pending case (G.O. 196, 197). The state legislature has required

considering lifeline, and other options. See Re Appalachian Power Co., Docket #79-140-E-42T (W.A. P.S.C., 1980).

WISCONSIN

Commission has adopted marginal cost, TOD, and conservation-inverted rate, Re Madison Gas & Electric Co., Docket #3270-ER-4/5 (Wisc. P.S.C., 1979) TOD tariff mandatory over 300 kWh per month, optional for 300 below that level. Also load management rate for customers with "alternative energy systems." Re Wisconsin Public Service Corp. Ripple control favored. "WEPCO plans to connect 150,000 customers water heaters to this control system. WEPCO is also studying the benefits of installing air conditioners." See general proceedings #05-EP-1 (Wisc. P.S.C., 1978). Also have inverted natural gas rates.

WYOMING

Commission rejected Senior Citizens Rate before PURPA. Utah Power & Light Co., Docket #9441 (Wy. P.S.C., 1978). In some case adopted seasonal and flattened rates. Rejected termination, master metering and information standards of PURPA in G.O. 43, but gave no reasons for rejection. Case appealed.

APPENDIX D

SMALL-SCALE ENERGY TECHNOLOGY PROJECTS IN THE PACIFIC TERRITORIES: A CASE STUDY REVIEW

Charles W. Case, Ph.D.

Staff Scientist
Energy and Environment Division
Lawrence Berkeley Laboratory
Berkeley, CA 94720

INTRODUCTION

In the spring of 1977, the Building and Community Systems Division of the Energy Research and Development Administration (now the Department of Energy – DOE) instructed its San Francisco Operations Office (SAN) to establish a pilot program for encouraging appropriate energy technology projects within Federal Region IX. This region includes Arizona, California, Hawaii, Nevada, and the Pacific Territories – the Pacific Territories include American Samoa, the Commonwealth of the Mariana Islands, Guam, and the Independent and Federated States of Micronesia. SAN announced the Appropriate Energy Technology Program (AET Program) in the fall of 1977, asking small businesses, individuals, nonprofit agencies, and Indian tribes to apply for grants for designing, constructing, and/or demonstrating small-scale energy technologies. These technologies were to conserve fossil fuel or use renewable energy resources, and were also to have community- or village-level social benefits. The program was popular; SAN received 1,100 applications requesting $21.3 million, an overwhelming response considering only $1.25 million was available.

For awarding grants, SAN used a review process that transferred much of the decision-making responsibilities to the states. Social, economic, technical, and innovative merits were equally stressed as selection criteria. After three separate reviews involving state and university groups and committees, SAN awarded 108 grants. The average grant was for $12,500: the largest, for $43,000; and the smallest, for $500.

The grants covered a complete spectrum of small-scale energy technologies, including solar active and passive systems, wind machines, biomass conversion systems, energy conservation devices, recycling methods, aquaculture and agriculture systems, hydroelectric devices, geothermal systems, and hybrid systems.

In the spring of 1979, DOE transferred the program administration to the new office of Small Scale Technologies within the Building and Community Systems Division of the Conservation and Solar Applications Program. This Office expanded the AET Program into all ten federal regions and offered funding cycles during the spring of 1979 and 1980. Using essentially the same review procedures as the pilot program, DOE awarded about 600 grants in each of these two years. Additional annual cycles will be offered in the coming years depending on new DOE budgets.

The San Francisco regional office now administers the program for Federal Region IX. This office has organized a system for monitoring the 29 Pacific Territory projects. This task includes offering technical advice and assistance, assessing the direct and indirect energy impacts, looking for projects with commercial possibilities, and encouraging the applicants to complete the projects on time. During the last three years the author has made five trips to the Pacific Territories to monitor the projects. The following case studies are the results of observations made during these visits.

CASE I

FISHDRI (Romanum Island, Truk District, Eastern Caroline Islands)

A. Background

The Trust Territory of the Pacific Islands includes about 1,000 islands scattered across 8 million square kilometers of Pacific Ocean between the equator and 22° N latitude and from 130° to 172° E longitude (see Figure 1). After World War II these islands were placed under the protectorate of the U.S. by a United Nations mandate. For administrative purposes the Trust Territory was divided into six districts – Yap, Palau, Ponape, Kosrae, Truk, and the Marshall Islands – now under the jurisdiction of the U.S. Department of the Interior. According to the mandate, the U.S. was to encourage these districts to become independent, and each district was to decide its own political fate by the early 1980s. In 1980 Truk District in the Eastern Caroline Islands (between the equator and 11° N latitude and from 148° to 154° E longitude) decided to enter into the independent Federated States of Micronesia with Ponape, Kosrae, and Yap districts.

The Truk Island Group consists of about 90 islands. Fifty of these islands are on a great encircling reef that encloses a lagoon with a radius of 48 kilometers. Within this lagoon are a number of high islands, including the district center, Moen. Truk is the most populated of the districts with a population of about 35,000 (1978) (Ref. 1, p. 427). There is a steady population migration to Moen, but many of the people still live in small villages scattered throughout the lagoon and outer islands.

These people are isolated from Moen. There are no commercial air flights or telephone links, and travel by small boat is dangerous and expensive. Because of this isolation, the villagers have retained much of their original culture. However, they are slowly being exposed to new technical advances. Increasing populations place stresses on day-to-day subsistence living, and now there are critical energy demands, primarily for refrigeration and communication systems and for better health facilities. Villagers need communication systems for both storm warnings and emergency aid requests after storms strike. Medical facilities require water hotter than the 80°F ambient temperature. Small diesel generating units supply the power for those islands having these facilities, but the generators are expensive to operate and difficult to repair, and fuel supplies are uncertain. Much of the living is still on a day-to-day basis. The islands have no cash economies – fishing and a very little farming are the main occupations. The islands are turning from this way of life and a few are searching for ways to start economies through small local businesses.

B. Project Description

Romanum Island is typical of the outer islands. It is about 5 square kilometers in size and has a population of around 200. The island is approximately 30 kilometers across the Truk Lagoon from Moen. There are no local businesses or cash economy. The people mainly fish and then scrape together whatever cash they can or trade the fish during infrequent trips to Moen for boat fuel or supplies.

Because of their proximity to Moen and the contact with the people there, the people of Romanum are changing from their traditional ways of living.

In 1978 the Romanum chief, along with a Peace Corps volunteer, applied for a grant to build some solar dryers for drying fish by-products. These by-products would then be ground up as chicken feed for their chickens. There is no electricity or refrigeration system on the island. Therefore fish left over at the end of the day are usually thrown out. Chicken feed is becoming expensive and requires a trip to Moen to purchase it. This project would thus solve the problem of excess fish and expensive chicken feed. In addition, they planned to start an island cooperative business and sell the chicken feed to neighboring islands. They also planned to experiment with a number of different dryers, find the best type for the location, and then encourage others to build similar systems.

DOE awarded the cooperative a grant for $12,000 to build and experiment with a number of dryers and to purchase equipment for the grinder. Work was to start in summer 1978 and finish a year later. This appeared to have all the ingredients for a successful project: the start of a local business, training of local people to build solar devices, solving an energy problem using renewable resources, and so on.

C. Project Results

After two and one-half years DOE terminated the grant. No work had been done and the money had been spent on other things. (According to the grant provisions, the grantee receives 60 percent of the money before the work starts.) There was about a half-year delay between the time the application was submitted and the grant was awarded. During this time the Peace Corps volunteer left and was replaced by another volunteer who was not familiar with the project nor technically equipped to do this type of work. The original volunteer was the only one on the island who spoke English and the only one familiar with solar dryers. He wrote the application and, with the chief's approval, submitted the application under the chief's name. The check for the project came directly to the chief.

In the Truk District and other Trust Territory districts, U.S. agencies have a history of giving monetary aid of various types without too much discretion or sensitivity. Money is given out according to U.S. standards without much awareness of how this money might affect Micronesian cultural and social structures. Often agencies do not follow up on the results of their expenditures — to the Micronesians the money then appears as handouts.

This was the case with the grant for Romanum. The chief received a check for $7,200 and, based on past experiences, took a broad definition of the project and what the money could be used for. Again, based on experience, he was sure no one would come to Romanum to check the progress of a small grant (agencies do not monitor larger grants in more accessible Moen). However, DOE monitors all the AET grants in Federal Region IX, and so the author made a trip to Truk in late fall 1978. The chief received a letter saying that a visit would be made in a few weeks. He felt that he should have some piece of equipment to show, but he could not build solar dryers. Therefore, he used the money to buy materials and

engines for some new fishing boats. During our visit we explained to the chief through an interpreter that he must complete the project. The chief and the new Peace Corps volunteer assured us that the work would be done.

Romanum is a difficult and expensive place to visit not only from the Mainland but also from the Trust Territory headquarters in Saipan. No one in Moen had the authority or the knowledge to help. It was difficult to correspond with the chief when only the Peace Corps volunteer wrote English. This was the last visit to Romanum and correspondence during the next year was not effective.

No work was done on the project and it has been difficult to determine the reasons. The chief probably had good intentions, but he was technically not capable of building the dryers. It is difficult for islanders to work within the grant structure, which includes reporting requirements and time schedules. The Peace Corps volunteer had good intentions too, but there were severe disagreements between him and the chief. Caught in the middle of local island politics, his help was refused by the chief. Each of the principals has a different reason why the project failed. Nevertheless, the money has not been returned — it has been spent on fishing equipment. The cost for DOE to get the money back would be more than the grant award, so they have decided to terminate the grant without further action.

D. Analysis of Results

The chief and the original Peace Corps volunteer had a good idea and purpose. This is the type of project sorely needed on these small islands, and they intended to do the work properly. The project failed in a physical and technical sense, and Romanum does not have a small business. There is no device producing energy or improving island life. But DOE learned some lessons and gained some experiences that have proved quite valuable in awarding and monitoring other grants.

First, for a project to have any chance for success the person who thought of the idea and submitted the application must be responsible for the project through its entirety. When there is a change in people responsible for a project, the project has problems. The original impetus is lost, technical skills are different, the purpose of the project changes, and so on. These are small, simple projects designed to be completed in a short time. There must be continuity and this continuity is lost when leadership changes.

Second, Peace Corps volunteers usually have a term of two years. They are often well qualified to provide technical skills and leadership, particularly with the appropriate technology training they receive now. However, the two-year term does not seem long enough for them to conceive of and then complete a project. It takes a half-year or so before they learn the problems and think of solutions. By the time they have written the application and awards have been made, at least another half-year has passed. It takes a few more months to receive 60 percent of the money. This hardly leaves much time even to start the project. There are exceptions to this, but usually the leadership must come from a local person with the technical knowledge and managing skills necessary to complete the project.

171

Third, the community must play a strong role in the project. Villagers should be aware of what is being done and have the interest to help. Ideally, they should be required either to provide some material or volunteer labor. They must have an interest in the results.

Fourth, funding agencies must be sensitive to the cultural and social ramifications of the grants. The Romanum grant was probably too large for the project. Projected wages were much higher than wages in Truk. A grant such as this can do much to disrupt a culture not familiar with a cash economy and the ways of U.S. funding agencies.

Fifth, funding agencies must realize that the entire concept of awarding money and then requiring someone to follow a schedule and submit written reports is strange to a culture not based on writing and management. The U.S. funding structure is established for the Mainland and while requirements may be reasonable in that context, they are often difficult for Micronesians to meet. The whole concept of a project is a difficult one for a society not used to building mechanical or technical devices. Even the concept of each step building on the previous step and work progressing in an organized pattern must be learned on these outer islands.

Sixth, all projects must be monitored, preferably by a responsible and knowledgeable person in the area. This is not easy for Micronesia as there are only two or three Micronesian engineers, and travel is difficult and expensive. Still, some type of contact must be maintained and it must be more often than once a year. It seems that the more remote the project, the more important this contract. Sensitivity must be used in striking a balance between local ways of working and doing business and funding agency requirements for working on grants.

E Conclusions

By DOE standards losing $7,200 is a small loss, but this loss follows a history of money poorly spent in the Trust Territory. Money is hard to come by for these small grants and so DOE must make it clear, in a fashion sensitive to Micronesian culture, that results are expected. DOE must also use sensitivity in selecting which grants to award and in predicting both energy-producing consequences and cultural effects. The project itself is only the direct and often minor consequence of the grant. The indirect effects, positive and negative, are far reaching in these fragile social and economic environments.

In this case the money will not be returned, but the lessons may have been learned cheaply. Mistakes made on this early grant have not been made again. Luckily, the long-range effects of this grant on Romanum will be few. They have two new fishing boats, which are expensive to fuel but which have also helped establish a fishing industry. This industry may eventually be more worthwhile than the chicken feed business. They are now realizing how expensive these boats are to run and there is interest in returning to their old native sailing ships – another worthwhile indirect effect.

172

CASE II

YAP INSTITUTE OF NATURAL SCIENCE APPROPRIATE TECHNOLOGY PROJECT (Yap District, Western Caroline Islands)

A. Background

The Trust Territory of the Pacific Islands includes about 1,000 islands scattered across 8 million square kilometers of the Pacific Ocean between the equator and 22° N latitude and from 130° to 172° E longitude. After World War II these islands were placed under the protectorate of the U.S. by a United Nations mandate. For administrative purposes the U.S. Department of Interior divided the Trust Territory into six districts: Yap, Palau, Ponape, Kosrae, Truk, and the Marshall Islands. The districts, along with the Commonwealth of the Northern Mariana Islands, include the Western and Eastern Caroline Islands, the Northern Mariana Islands, and the Marshall Islands.

According to the mandate the U.S. was to encourage these districts to become independent. In 1980 Yap, Truk, Ponape, and Kosrae entered into a federation independent of the U.S. called the Federated States of Micronesia. Palau and the Marshall Islands have become independent states.

The Yap District consists of nine inhabited atolls, two single islands, and four normally uninhabited islands and atolls. These islands and atolls are in the Western Carolines between the equator and 11° N latitude and from 136° to 148° E longitude (Ref. 1, p. 442). Yap, along with Kosrae, probably has retained more of its natural culture and traditions than the other districts. Portions of Yap Island, nearby Map, and the outer islands are relatively untouched by modern technologies. People still live the daily subsistence life, with farming and fishing the major occupations. Most of the small villages have no electricity. An occasional diesel generator provides electricity for small refrigerators for health supplies and radios for communication.

Yap is one of the least populated of the districts with a population of about 8,500 (1978). Population trends fall into the familiar Trust Territory pattern. Populations are increasing, and as people become exposed to new technologies they migrate to Colonia, the district center, on the island of Yap. Colonia seems to be handling the growth better than some of the other district centers, but they still have severe problems of health and sanitation, unemployment (see Table 2 for Pacific Territory unemployment), housing, and reliable supplies of energy. (During most of 1979, electricity from the oil-fired plant — 3.1 MW peak capacity — on Yap was available from 9:00 p.m. to 5:00 a.m. for the hospital only. See Table 3 for peak electrical generating capacity for the Pacific territories.)

One feature that impressed the author during a visit in fall 1980 was that the Yapese seemed to be very aware of their culture and traditions and are trying harder to maintain them than most of the other districts. Perhaps this is because Yap is isolated and has not been as affected yet by affiliation with the U.S. Nevertheless, advances are slow, and the political leaders seem to be considering as much as possible the social ramifications of each advance. At

173

present, parts of Yap, Map, and the outer islands offer some of the most beautiful vistas and unspoiled villages found in the South Pacific: untouched beaches with outlying coral reefs and a crashing surf, villages of artfully made thatched huts, friendly people, and an easygoing day-to-day existence. Amid these traditional ways, the new television facilities on Yap, broadcasting Mainland programs, seem very much out of place. Slow, deliberate changes may be difficult to maintain.

B. Project Description

As people migrate to Colonia they adopt the modern trappings of automobiles, electrical or kerosene appliances, standard housing, and so on. Many of the traditional ways are put aside. On the other hand, traditional ways that are still used on lesser developed parts of the district may be inefficient, unhealthy, and burdensome. Many of the communities still lack refrigeration for health supplies and communication systems. Local economies depending on copra are finding the traditional way of drying copra with coconut husk fires unsatisfactory. (Copra is coconut meat. It is dried and pressed to yield coconut oil for cooking and other uses.) Despite considerable wind, solar, and biomass resources, there are virtually no alternative energy devices. The reasons are the usual ones: lack of trained personnel, harsh environment, unreliability of such devices, and difficulty in obtaining repair parts.

In such a setting, the Yap Institute of Natural Science has been trying to promote appropriate technology devices for the last few years. The Institute is a family affair, run by a couple (he is a native of Yap and she is from Guam) and housed in a conglomeration of buildings, buses, and shacks on their property. They are energetic, technically quite skillful, and concerned with traditional ways and seem to have a good sense of how to go about a project. For these reasons they are well thought of locally, and the Institute has been quite successful.

Along with some volunteers and some part-time paid help, they have been experimenting and promoting alternative energy devices. Operating on an extremely low budget, they have managed to send a young woman to the University of the South Pacific in Fiji. She has returned and is now working at the Institute. They publish a variety of pamphlets, including the Yap Almanac Calendar. In addition, they are constructing a well-built, energy-efficient house combining traditional and western architecture.

In 1979 they applied for a grant from DOE to build and demonstrate a variety of alternative energy devices. DOE awarded them a grant with a term of two years to build a solar oven that could be used to dry copra and food, a passive solar ventilator for cooling homes, and a variation of a Lorena cooking stove.

The solar oven is an ingenious device in which the heat is controlled by varying the amount of air flow. This oven at low temperatures dries copra or food. (Traditional methods take four days in a smoke house over an open fire, use large amounts of coconut husks, and contaminate the copra with smoke.) They are monitoring this oven now and are comparing the results with other ovens and dryers they have built.

174

The passive solar ventilator creates a natural circulation of air by warming air with a solar collector on the roof. Cool air is drawn into the building through low vents in the walls.

The final device probably has the greatest potential. Throughout the Trust Territory much domestic cooking is still done over open fires using wood and coconut husks. Some families are now using kerosene or electric stoves, and this is proving to be expensive. The Lorena stove would be a logical solution to the problem as it is proving to be elsewhere in developing countries. Such a stove is easily constructed from a mixture of clay, sand, and water and uses efficient channeling of the heat to reduce fuel consumption (Ref. 4). Unfortunately, on Yap and other Pacific islands the sand is usually coral, which does not withstand the heat very well. Salt-laden sand does not work well either, and water for washing the sand is often in short supply. The Institute is experimenting with materials and designs that still use the same heat channeling principles as the Lorena stove. Its most successful design uses a series of cast concrete slabs stacked on top of each other, forming a single cooking unit. The first stove cracked after a bit, but now they are trying different mixtures of concrete with more success.

C. Project Results

The workers at the Institute have finished the current projects and are testing them. Within the next few months they will have written a series of brochures describing how these devices can be built. A number of communities will be building variations of their copra dryer. There also seems to be a good deal of local interest in the wood stove. With this small grant the Institute has become more established on Yap and is beginning to acquire a reputation throughout the western Pacific.

D. Analysis of Results

The Institute seems to be successful with their work for a number of reasons. First, they have a strong role in the life of Colonia. The work they do goes beyond experimenting with energy devices. They are sensitive to the problems of Yap, including conflicts between traditional ways and technical advances. They are working with and educating the villagers and are performing various community services.

More elegant small-scale energy devices can be found, but the Institute demonstrates their systems in a fashion compatible with Micronesian temperament. Too often the U.S. has used a hard-sell campaign with new ideas for the Pacific. Since World War II, Micronesians have seen their way of life completely changed by U.S. institutions. These changes were rapid and were inflicted upon them in ways that did not consider the Micronesian interests. Changes in the Pacific should occur in a slow way that complements their traditions. The Institute demonstrates their project in a manner that appears to work, albeit slowly.

Their method is simple: If an idea works, improves the qualify of life, and is acceptable culturally, people will try it. Ideas do not need to be sold – people will try good ideas of their own accord. The device must work and must work reliably over a period of time. Too many alternative energy devices are unreliable in the Pacific Island environment. Once they break down they are difficult to repair and parts are hard to find. U.S. manufacturers have a spotty record for servicing their products in the Pacific. A broken energy system does great harm in areas where people are now attracted to energy-consuming appliances. The Institute's devices work, seem to be reliable, and can be repaired with local materials.

An important part of the Institute's work is educational. Volunteers of all ages work on the projects. The publications are a community effort, and the community takes pride in the Yap Almanac Calendar (which promotes appropriate technologies). The Institute pays a few employees wages – the young woman from the University of the South Pacific is a part-time employee.

Finally, the projects were well thought out and the grant was the right size to do the work properly. The wages paid were compatible with local wages. The projects were not complicated and could be completed in a reasonable time. They were realistic about the problems they might encounter and had prepared a realistic time schedule. In general, the Institute seems to be a good model of how other similar institutions should operate in the Pacific.

E. Conclusions

If Pacific Island societies are to use less energy and are to find substitutes for petroleum products, the effort must start with local institutions. Most of the islands do not have a Yap Institute of Natural Science, but when one appears, island governments and federal agencies should offer encouragement. This is perhaps the most important element of this grant. The Institute received acknowledgment and encouragement for their work. With the publicity that attended this grant and with the success of the projects, their work will become easier.

The Institute will also play a key role in establishing a network of people working on appropriate energy devices throughout the Pacific. Such a network, which plays an important role in other countries, is just starting in the Pacific. A network serves to transfer ideas, promote successes, prevent failures from reoccurring, apply peer pressure to other people receiving grants, and so on. Travel and communication problems in the Pacific hinder development of such networks, but already other institutions are appearing on the other islands.

176

CASE III

TYPHOON-PROOF GREENHOUSE (Merizo, Guam)

A. Background

Guam is the largest (541 square kilometers) and southernmost of the seventeen islands in the Mariana Island chain. Its location is 13°26' N latitude and 144°43' E longitude. Bordered by the Pacific Ocean on the east and the Philippine Sea on the west, Guam is 2,170 kilometers south of Tokyo and 5,300 kilometers west of Honolulu. The U.S. acquired Guam as a possession in 1899 during the Spanish-American War and in 1950 made Guam an unincorporated territory with local legislative authority. The climate is generally tropical – hot and humid. Rainfall is heavy (about 200 cm/year), and often there is a heavy cloud cover (Ref. 1, p. 197).

Guam is the most westernized of the U.S. Pacific territories or possessions. It has been an important U.S. military base since World War II, and the military is the largest employer and economic unit on the island. In addition, Guam is a transportation and merchandising center for goods being shipped elsewhere in the Pacific and has a rapidly expanding tourist business from Japan. Guam's population is about 102,000 (1975) of which approximately 92,000 live in urban areas. Because of the military, a sizable percentage of the population is from the U.S. Mainland. The original natives of Guam, the Chamorrows, currently constitute a decreasing portion of the population.

Agana, the capital and principal city, has a population of about 50,000 and is similar to fast-growing U.S. towns of the same size. Peculiar features of Guam and Agana include a McDonalds Restaurant with the largest sales in the world, treacherous roads made of coral that become very slippery when wet, no mass transit system (resulting in large traffic jams and a waste of fuel), typhoons that do devastating damage almost annually, and the remnants of heavy World War II action.

Energy production on Guam is entirely from imported petroleum products, mostly from the Philippines. Two oil-fired plants produce the island's electricity. Primary end users include the transportation and military sectors. Because of Guam's vulnerability to fuel shortages, the Guam Energy Office (GEO) has been trying during the last few years to develop other alternative sources. There has been strong local political support for developing Guam's ocean thermal energy resource, which may be the best in the world. This new energy source is also seen as a source for economic development. The GEO is spending a smaller portion of its time working on other alternatives. Some of GEO's efforts include making energy audits, encouraging industrial and domestic conservation, assessing the solar, wind, and biomass resources, and promoting small energy demonstration projects.

Until recently little effort has been given to small decentralized systems or to alternative energy production in the outlying rural areas. These areas include small fishing and farming villages similar to settlements in other developing countries with low incomes and standards of living, subsistence farms, low mechanization, and expensive (if any) energy. There are very few energy-

producing devices using renewable resources and simple technologies. Materials are hard to come by and there usually is no local expertise. The environment is harsh and includes typhoons and a highly corrosive atmosphere.

B. Project Description

Until recently, the person who worked on this project lived in the rural village of Merizo, an old fishing and farming community located on the southern end of the island and about an hour's drive from Agana. This is one of the most fertile areas of the island. Unfortunately, because of its exposure the area is highly vulnerable to typhoons and seems to be heavily damaged almost annually.

The project worker lived on one of these small farms. He has worked at a variety of jobs on Guam and elsewhere and was one of the original staff of the GEO a few years ago. His background has given him an interest in alternative energy production, particularly small systems for outlying Pacific islands. Three years ago he was interested in trying to solve the problems of heavy storm damage to farmers' crops and the low level of productivity.

In 1978 he applied for a grant from DOE, but was unsuccessful because of the large number of applications and the small amount of money available. He applied again in 1979 and this time he received a grant for $3,000 to build and demonstrate a typhoon-proof greenhouse that would use French intensive gardening methods. He hoped this greenhouse, which would be built entirely from local materials, would be easily replicated by other farmers in the area. Construction was to include a wooden and metal pipe frame built on an existing 15' x 30' concrete foundation, raised beds for French intensive gardening, screening to keep pests away, and storm shutters. He planned to start work in the fall 1979 and complete work in a few months. Other farmers in the area were to help him and supposedly were quite interested in the results.

C. Project Results

This author has visited the site twice, once during fall 1979 and again in fall 1980. At those times no work had been done even though the construction was simple and the project could be completed in a few weeks. The work was finally done in late fall 1980 after considerable pressure from the GEO and DOE. Information from GEO says that the construction is fair at best and does not seem to meet the storm-proof requirements. The applicant, who has now moved from the island, apparently lost interest in the project. A new tenant on the farm will try to improve the greenhouse. There is no local interest and the final result is probably one of discouraging others from trying similar projects.

D. Analysis of Results

A project such as this in a remote location depends entirely on the individual for success. The applicant is a sincere person who is concerned with the quality of life problems of rural Pacific settlements. He has traveled widely and seems to have experience working with energy systems in a number of places. He is

172

eloquent and presents his ideas well. The greenhouse idea was a good one, filling a local need, and his budget and work schedule were reasonable. There was every intention on his part to complete this project successfully and to work with others promoting it.

In the early stages of the AET Program, grants were usually awarded throughout the western Pacific without input from the local energy offices. Many of these energy offices were just becoming organized and the personnel were unknown to DOE. Also, because of the low administrative budget, it was difficult to maintain contact with these offices or provide them with funds to do their own grant monitoring. The GEO, with its capable staff, should have had a more active role in awarding this grant. Based on the applicant's past work, they probably would not have recommended him for an award.

Also, it is important that these rural projects be monitored continually or regularly. The federal government has a history of awarding grants to Pacific communities on U.S. terms and with U.S. standards and then not caring about the results. DOE planned to monitor this project, but distance from Guam was a problem and the annual visits probably were not effective. During these visits promises were made and then quickly forgotten. Correspondence from the Mainland was not effective either. When the GEO intervened, it had its own problems. The applicant has had a continual disagreement with the GEO since his employment ended a few years ago. During their frequent visits he became increasingly nasty and felt he was responsible only to DOE. The GEO should have been responsible for monitoring this grant from the beginning.

The work meets all the criteria for a bad project. Grant money was probably spent on other things besides new materials. There is no local interest in the work. When an ultimatum was given to the applicant last fall, he finished the project but the quality was not good. Oddly, throughout the project term the applicant insisted that the project met his standards for fine work and was a worthwhile endeavor.

E. Conclusions

There are a number of lessons to be learned from this project. First, good ideas are easier to come by than the individuals to carry them out. Local energy offices or institutions familiar with the local people proposing the work should be involved with the grant award process. Second, projects at these remote locations should be monitored continually, preferably by people in the area. Monitoring provides technical advice and shows the grantee that the sponsoring agency is interested in the outcome. Allowances should be made for work in tropical conditions and for cultural differences in approaching a job, but the agency should hold the grantees accountable for their work and for adhering to reasonable work schedules. Third, projects should have local support and interest. This is true both for replication of the project and also to encourage and help the applicant.

CASE IV

ARAMAS KAPW, ALTERNATIVE/APPROPRIATE ENERGY DEMONSTRATION SITE (Ponape, Eastern Caroline Islands)

A. Background

After World War II, a United Nations mandate placed the Western and Eastern Caroline Islands, the Northern Mariana Islands, and the Marshall Islands under U.S. jurisdiction. These islands, referred to as the Trust Territory of the Pacific Islands (Micronesia), include 1,000 islands spread across 8 million square kilometers of the Pacific Ocean between the equator and 22° N latitude and from 130° to 172° E longitude. For administrative purposes the Navy and then the Department of the Interior grouped these islands into six districts: Yap, Palau, the Northern Marianas, Truk, Ponape, and the Marshall Islands. According to the mandate the U.S. was to encourage the islands to become politically independent. To achieve this, the U.S. was to help the islands establish economies; build schools, health and sanitation facilities, roads and other transportation facilities, and other modern infrastructures; start the mechanisms for self government; and teach the inhabitants the skills necessary to survive on their own.

The process of building strong, independent island entities has not worked out very well (Ref. 2, 3, 5, and 6). Nevertheless, the Trust Territory of the Pacific Islands is now being disbanded and the islands are establishing their own political identities. The Northern Mariana Islands, desiring closer affiliation with the U.S., established a commonwealth with the U.S. and became the Commonwealth of the Marianas Islands in 1977. At that time the Department of the Interior established a new district, Kosrae. In 1980 and 1981 Yap, Kosrae, Truk, and Ponape voted to join together in an independent federation called the Federated States of Micronesia. The remaining districts of Palau and the Marshall Islands, with the hope of stronger economies, are becoming independent states.

The island of Ponape is the government seat for the Federated States of Micronesia. Government buildings will be either in the present district center of Kolonia or in a new town proposed for the center of the island. Ponape is a high island located in the Eastern Carolines between the equator and 11° N latitude and 154° and 162° E longitude. The island has been the district center location for the Ponape District, which includes this high island, the 25 surrounding islands (most of which are volcanic), and eight coral atolls. The district has a population of about 21,000 (1978), and Kolonia, the only town of any size at present, has a population of about 7,500 (Ref. 1, p. 443).

Ponape is one of the most beautiful of the Micronesian islands. Its rainfall, approaching 400 cm/year in the center of the island, is one of the highest in the world and gives the island lush vegetation and spectacular streams and rivers coming from the mountains. The population is concentrated in Kolonia, but there are small rural settlements where people farm and fish. Kolonia has the charm and flavor of an old U.S. western town. There is a scattering of small stores and government buildings, a small junior college, and a few businesses. These businesses include the Ponape pepper processing operation and a new establishment making water catchment tanks.

170

Ponape's problems are the same as those of the other districts although in some cases perhaps not as acute. There is a shortage of sanitation and housing facilities, and the roads are awful. There is a new power plant (about 100 MW), but it is proving difficult to maintain and expensive to operate. There is a complete reliance on imported petroleum and an increasing use of electricity. There is very little local economy and unemployment is high. U.S. policies have disrupted the social structure and traditional ways of the Ponapeans.

Ponape has some excellent leadership, though, and as the political headquarters is in a position to solve its problems more easily than the other districts. Ponape also has an excellent natural hydroelectric resource with the streams and rivers — some of them already have prewar Japanese dams.

B. Project Description

Opposite Kolonia on the lagoon is a small peninsula of land called Nett Point. At the end of Nett Point, commanding a beautiful view of Kolonia, the bay, and the surrounding islands, is a renovated warehouse that is the headquarters for Aramas Kapw, a delinquency prevention Outward Bound type of school. The school was established a few years ago to provide educational and confidence building programs for young adults from all of Micronesia. The warehouse contains sleeping, cooking, and educational facilities. A few teachers present programs lasting from a few days to a few weeks, patterned after the U.S. Outward Bound programs. They also offer programs for adults from Ponape and training for Peace Corps volunteers.

The staff is exceptionally capable, comprising a combination of people from the Mainland and from Micronesia. All of them have had extensive experience working with young adults. The Micronesian from Truk who is in charge of the educational programs has had a fine history of teaching in the Trust Territory and has a good way with the school's participants. Funding for the school is low but adequate, coming from a variety of Trust Territory sources. The young adults return to their islands and homes, thereby providing the school with an excellent opportunity to pass on ideas to large numbers of people.

In winter 1980, Aramas Kapw applied for a grant for $26,000 to build a variety of renewable energy devices. The school planned to instruct the young adults on how to build and maintain these devices; in turn they would pass these skills on to others upon return to their homes. The project was well thought out and they had done substantial research on the available energy resources and the types of systems they should build. In spring 1980, DOE awarded Aramas Kapw $20,000, which was later revised to $26,000, to build or install and demonstrate:

- A Savonious rotor wind machine for producing about 200 watts of electricity
- A 2-3 kW commercial wind machine to produce electricity for the school (there is no electricity now)
- A 115-watt solar photovoltaic array as a backup source for the wind machines

- A solar water heating system and water catchment system
- Various types of solar crop dryers and fish dryers
- Small solar water distilling units

They also planned to collect operational data and publish a report.

C. Project Results

After receiving the grant the Aramas Kapw staff said they would make this the best small-scale energy project in Micronesia. They may have done so, as the project is progressing as planned and seems to be very effective. The water catchment system and the Savonious rotor were built during the 1980 summer program. The catchment system collects water from the warehouse roof and stores the water in two 250-gallon tanks (manufactured by the new water catchment tank business). This is the source of fresh water for Aramas Kapw. They will build the solar system during another educational program. The Savonious rotor is operating but they have not hooked it up yet because the proper size electrical wiring is not available locally. The Savonious rotor was also built during the summer program.

They have not yet installed the commercial wind machine. Because of increasing equipment costs they have ordered a 1.5-kW Aeropower wind turbine instead of the original 2-3 kW machine. During spring 1981, a group of students will erect a commercial 60' Rohn free-standing tower for the machine during a three-week course on alternative energy. They have received all the equipment (which is no small accomplishment for this part of the Pacific) and they have installed the control panels for the machine and the battery array. Community leaders from two nearby atolls chose the participants for this program.

The school has also received and installed the ARCO solar photovoltaic array. The system has not been connected to the batteries yet – wiring is the problem. During the spring program the participants will build solar stills and dryers and stoves and ovens, some of which they will take back to their atolls. In addition, they are learning what types of data are necessary for siting these systems and how to collect or estimate these data. The staff has taught them the theory of these devices, how to build them, and how to maintain them.

D. Analysis of Results

This type of facility is a natural for demonstrating small-scale technologies. The Outward Bound principles of training for young adults have been well established on the Mainland for some time. Aramas Kapw runs on the same principles, with certain changes for Pacific life. The school is well organized and the staff has a history of successful work with youth. There is a good combination of Micronesian talent, expertise, and a commitment to make this school a success. To help with the technical aspects of the projects, they have hired a young wind

expert from the Mainland to work with them for a few months. This has worked out very well. His work has been excellent. They are installing all the systems properly and both students and staff are receiving an education.

Others in remote areas of the Pacific have had problems ordering and receiving energy equipment from Mainland manufacturers. Orders often go unanswered, prices increase, shipments are delayed, or the right equipment is not sent. In their grant, Aramas Kapw asked for enough money to send their technical expert to the Mainland to select and order the equipment. This is expensive, but on the other hand, this is one of the few projects the author has visited where the proper equipment was received on time.

The project seems to have the right combination of commercial and home-built systems. The more complicated wind machines must be purchased from the Mainland. Still, commercial wind machines have not had a good history in the Pacific. High winds, corrosive atmosphere, vandalism, and lack of repair parts are a problem. Many of the islands have good wind regimes and it is worthwhile trying various commercial machines to see if these machines do have a future in the Pacific. Working with commercial machines is also a good way to teach Micronesian youth the principles of small-scale energy devices in general. Micronesians do not have the technical heritage or background of U.S. youth. These things must be learned and, therefore, it is important for them to be exposed to machines that work and to learn how to keep them working. (Lack of proper maintenance is a problem throughout the Pacific.)

The home-built systems are simple enough so that they can be built with local supplies. Maintenance should not be a problem even on the outer islands.

Aramas Kapw has also selected the right type of technologies to demonstrate. There is a great interest, particularly on the outer islands, in photovoltaic systems. The simple crop and fish dryers are also needed, and the use of efficient wood-burning stoves is just starting to spread.

The most successful element of this grant is the demonstration and educational factor. A project with working systems is most useful if people are being trained in the technical ways of building and maintaining these systems. An interesting contrast is that in addition to learning about energy systems at the school, the students are also relearning traditional crafts and skills such as making sail-powered fishing boats. These are the true appropriate technologies Micronesians were practicing just a few years ago.

E. Conclusions

This is an excellent project. It approaches the crux of the problem with technical systems in the remote areas of the Pacific — that this is a culture not used to such devices and without the technical background or heritage to adopt them quickly. For the last forty years the U.S. has been giving the Micronesians systems they do not have the skill to maintain. Even the simple ideas of reading plans or instructions or of preventive maintenance are new concepts. Aramas Kapw is giving their participants a complete education, starting with the basics

of working with mechanical and electrical equipment. Every successful Pacific project must have this very basic educational element.

Once again, project leadership has proven crucial. Every part of the project was well thought out, including elements that have caused problems elsewhere, such as purchasing equipment. The school has a commitment to educating young adults and to preserving the cultural ways of the Micronesians. This commitment is evident by the school's success.

CASE V

SOLAR HOT WATER SYSTEM FOR THE TROPICS (Majuro, Marshall Islands)

A. Background

The Trust Territory of the Pacific Islands includes about 1,000 islands scattered across 8 million square kilometers of Pacific Ocean between the equator and 22° N latitude and from 130° to 172° E longitude. After World War II these islands were placed under the protectorate of the U.S. by a United Nations mandate. For administrative purposes the Trust Territory was divided into seven districts, first under the direction of the Navy and then the Department of the Interior. According to the mandate, the U.S. was to encourage these districts to become independent and each district was to decide its own political fate by the early 1980s. The Northern Mariana Islands decided for a closer affiliation with the U.S. and became a U.S. Commonwealth, the Commonwealth of the Mariana Islands, in 1976. The Ponape, Truk, Kosrae, and Yap districts have just formed the Federated States of Micronesia and are becoming an independent federation with close ties to the U.S. Palau and the Marshall Islands have decided to become fully independent states, separate from the other districts.

The Marshall Islands are a double chain of coral atolls east of the Eastern Caroline Islands and north of the Gilbert Islands. Their location is from 5° to 15° N latitude and from 162° to 173° E longitude. The Marshall Islands include 34 low coral islands and 870 reefs, with a total land area of about 117 square kilometers. Majuro, the district center, is a coral atoll some 50 kilometers in length and less than 1 kilometer in width. The population is about 27,000 (1978) (Ref. 1, p. 445).

Like so many of the other Pacific Islands, the Marshall Islands are very important to the U.S. for strategic military reasons. The new political agreement between the Marshalls and the U.S. gives the U.S. military use of the islands in turn for various types of monetary aid. Majuro has no military bases but does serve as the transportation and merchandising center for the Marshalls. The population consists of a combination of people from the U.S. Mainland, Marshallese native to the area, and natives from surrounding areas who have migrated to the center.

With a growing population Majuro has a number of problems. It is a low island — the highest point is only a few meters — and in fall 1979, an unusually high tide innundated most of the island, destroying much of the housing. Tents were shipped from the U.S. and about 5,000 people are still living in tent cities. Fresh water is also a critical problem. Water is collected in rain catchment systems. The new airfield is engineered and built with a slight cant so that water runs off to a central collecting area. There are also a few shallow lense wells but pumping from these wells is tricky due to potential saltwater intrusions. During the author's last visit to Majuro in fall 1980, city water was available only from 5:00 to 7:00 p.m.

In addition to water, housing, and sanitary conditions, energy production is a problem. People both on Majuro and the outer islands are changing from a

subsistence form of living and are becoming more energy dependent. A new, more efficient, oil-fired plant is being built and there is some interest now in developing systems to use the local renewable energy resources, which are considerable. Small systems using solar active components, photovoltaics, and wind machines are being built both on Majuro and on outlying islands.

B. Project Description

Problems usual to the Pacific in developing small energy systems are found on the Marshalls. There is a lack of local expertise to build systems; once systems are built they are not maintained properly; systems are not engineered for the tropical environment; there is a lack of repair parts; and there is inadequate information about available systems. The applicant for this project is an architect from the Mainland residing for a few years on Majuro. This person, who is familiar with solar systems, felt that a successful demonstration of a domestic solar water system would encourage others to try similar systems. DOE awarded the applicant a grant for $4,620 to design, build, demonstrate, and test a solar system from fall 1978 to fall 1979. The original collector was to use copper tubing imbedded in a heat-absorbing material such as asphalt. The collector was to be 4' x 8' and circulation was to be through thermosiphoning. The water storage system was to be part of an ingenious water catchment system that the applicant had installed on his own home. The applicant planned to test this system, demonstrate it to others, and write a detailed report with the results.

C. Project Results

The largest piece of glass available on Majuro was 3' x 3' so the collector was built to that size. The copper tubing was shaped in a coil configuration. Although this configuration was efficient for heating the water, it prevented natural water circulation. An engineer helped the applicant redesign the copper tubing into an inverted conical shape with a mirrored pyramid in the center. The collector now lies flat but water rises and circulates through the conical configuration. The applicant also found that the closely spaced tubing makes additional absorption material unnecessary.

The applicant's job took him away from Majuro on and off for a year or so, so final construction was delayed. In late fall 1979, the system was operating and the applicant was just collecting data when four days of unusually high tides innundated Majuro. The applicant's home was in the area of heavy destruction and the house, collector system, and workshop were heavily damaged.

DOE, quite reasonably, expected that this would be the end of the project, so they were pleased when they received a detailed report a few months later describing how the system had been rebuilt and was operating again. The system has been operating now for over a year as a preheater to an electrical hot water system, but the monitoring data show that it could function effectively as a primary heat source. The applicant has included these data and a detailed description in a final report that DOE will be publishing (Ref. 7).

D. Analysis of Results

The features leading to this project's success are the applicant's commitment to a successful project, his perseverance, and his knowledge and ability to solve engineering problems. We have found that many applicants seem to lose interest in their projects during the project term, particularly if they encounter unusual barriers. In this case the entire project was destroyed, but the applicant had the interest to rebuild the system and continue with the tests.

Finding local help for engineering problems is extremely difficult throughout the Pacific. Here the applicant, who already had a background in renewable energy systems, was fortunate to have an engineer available who could help him redesign the collector. Running into engineering barriers such as these has proved a difficult barrier to circumvent for many of the Pacific projects. Another weakness seems to be collecting the proper data once the system is operating. The applicant has been collecting useful data for a year or so. Finally, and most important, the system works and lasts. These are the absolutely essential ingredients for a renewable energy project in developing countries. Too often a renewable energy device works for a short period and then fails, with no one to repair it. There the system stays, not operating, discouraging others from trying similar ideas.

This project meets most requirements for a successful project. It works and has been working for a while. It demonstrates renewable resources, is environmentally sound, has no cultural drawbacks, etc. Hot water uses only a small amount of the energy on Majuro but a solar heating system such as this is an effective way to demonstrate to others the principles of alternative energy devices. There are a few weak points, however. First, there is no training component. The only help provided was from a professional engineer. It would have been useful and educational if other people, not highly trained technically, had been trained to develop such a system.

Second, the project is difficult for others to replicate. Chances for replication in remote areas such as this are slim – particularly on outlying islands where expertise is even more limited. Also, the system is quite complicated, perhaps giving others the idea that such a system needs to be highly engineered. Finally, the applicant was able to repair this system, but would others?

E. Conclusions

With this project a clever and persevering individual has overcome engineering and environmental barriers to build a working solar hot water system in an area that has few working systems. He was fortunate to have engineering help – such a barrier on another island might have been the end of the project. He also had the interest to rebuild the system after it had been destroyed.

The purpose of these grants is to encourage the development of small-scale energy systems. To be effective, these projects must offer benefits beyond a system that is of use to just one family or group. Here an elegant system has been designed, built, and tested. It is operating efficiently and will probably

continue to do so. The chances of replication are small, however, and there was no training of local people who could certainly benefit from this kind of knowledge. The system is situated in a private home, and although the home is centrally located, the system's demonstration value is probably limited. At this time in the Pacific, though, any operating small energy-producing system should be considered a success, and for this reason alone the project is worthwhile. Finally, this is an unusual system that perhaps should be investigated in more detail in Honolulu or the Mainland.

REFERENCES

1. Pacific Island Year Book (New York, N.Y.: Pacific Publications, 1978).

2. Case, C.W., and Schaller, D.S., "Appropriate Energy Technology in the U.S. Pacific Territories," Solar Law Reporter 2, 6 (1981): 1083-1102.

3. Case, C.W., "Regional and Community Impacts of the Department of Energy's Appropriate Energy Technology Pilot Program in the Western Pacific," Proceedings of the 1980 Annual Meeting, American Section of the International Solar Energy Society, Vol. 3.2 (Newark, Delaware, 1980: pp. 1308-1313.

4. Wood Conserving Stoves: Two Stove Designs and Construction Techniques (Publication #48E) (Mt. Rainier, Md.: Volunteers in Technical Assistance, Inc., 1979).

5. Nevin, D., The American Touch in Micronesia (New York, N.Y.: W.W. Norton & Co., 1977).

6. Heine, C., Micronesia at the Crossroads (Honolulu, Hawaii: The University Press of Hawaii, 1974).

7. Hawpe, W.C., Solar Hot Water System for the Equatorial Tropics (to be published), San Francisco, Calif., U.S. Department of Energy.

PROJECT TITLE: Satawan Hospital Solar Hot Water System

APPLICANT: Office of Planning and Statistics
Trust Territory of the Pacific Islands
Saipan, Mariana Islands 96950

PROJECT TYPE: Installing and demonstrating a solar hot water system on a small health dispensary on an outer island

GRANT AWARD: $7,000

PROJECT TERM: September 1978 – September 1981 (three years)

PROJECT DESCRIPTION:

The Trust Territory Office of Planning and Statistics planned to install a commercial hot water system with solar heating on a new health dispensary being built by the Federal Economic Development Administration. The hospital is on Satawan of the Lower Mortlock Island Group in the Truk District of the Eastern Caroline Islands. This is a remote island, typical of the Pacific Territory outer islands. This new dispensary will be the first of its kind in this area and will serve about 3,500 people from the surrounding islands. They have no health facility now. The dispensary is without electricity and the solar system is the only source of hot water. The Trust Territory Office feels this will be a good demonstration site.

PROJECT RESULTS:

There have been long delays during construction of the dispensary. Construction should have been finished in 1978 but as of winter 1981 construction was still going on. There have also been problems with the dispensary design. A roof catchment system is the water source and, therefore, the hot water tank must be below the roof line for a gravity feed. The solar collectors were to be on the roof and, because of the lack of electricity, the circulating system was to be thermosiphon. With the collectors above the water tank, the water would not circulate so a small wind machine will be installed for circulating the water. Both the solar and wind systems have been ordered and will be installed when the dispensary construction is completed.

PROJECT TITLE: Solar Hot Water Heater Construction Demonstration

APPLICANT: Mr. Frank M. Jacquette
University of Guam
Box EK
Agana, Guam 96910

PROJECT TYPE: Building and demonstrating through workshops a simple solar water heating system for domestic use

GRANT AWARD: $12,000

PROJECT TERM: September 1978 — September 1980 (two years)

PROJECT DESCRIPTION:

There are not many domestic solar systems on Guam despite a fairly good solar resource. Mr. Jacquette has been working with solar systems for a number of years and has designed a simple system that can be easily built with local supplies and seems to withstand the harsh environment. With this grant he planned to build and demonstrate these systems by installing them on a number of public buildings during weekend workshops.

PROJECT RESULTS:

This project has been completed now and appears to have been fairly successful. Systems have been installed on the Guam Penitentiary, a village firehouse, and a home for juvenile adults. Workshop attendance was fair. The penitentiary system is no longer working and has not been repaired. The firehouse system has not been hooked up to the water supply. The juvenile home system is working after two years despite very little maintenance. This system seems able to withstand the storms and corrosive atmosphere and seems simple enough to replicate with local materials. This system is one of the few operating domestic solar systems on Guam. Mr. Jacquette has written three booklets describing variations of his simple design and they are available through the Department of Energy.

191

PROJECT TITLE: Solar Water Heating System for the Equatorial Tropics

APPLICANT: W. Carlton Hawpe
Majuro, Marshall Islands 96960

PROJECT TYPE: Developing and demonstrating solar water heating system for the Pacific Territories

GRANT AWARD: $7,620

PROJECT TERM: August 1978 – December 1980 (two and one-half years)

PROJECT DESCRIPTION:

This project is for designing, building, demonstrating, and monitoring a low-cost, efficient, and low-technology domestic solar water heating system. Despite the solar resource of many remote Pacific islands, such as the Marshall Islands, there are very few solar systems. These systems are often difficult to build with local materials, are not engineered for tropical conditions, and are not easy to maintain and repair locally. This applicant proposed to study a number of simple systems and build the one that seemed the most promising. He planned to demonstrate and monitor this system at his own home over the project term.

PROJECT RESULTS:

The first collecter Mr. Hawpe designed and built consisted of a spiraling ½" copper tube in a 3" square insulated box with a glazed top. The water was to circulate by thermosiphoning. The design required the collector to lie flat, but air locks developed, impeding the flow of water. A local engineer helped Mr. Hawpe redesign the spiral tubing in a conical shape so that the hot water rose naturally. A well-engineered and well-constructed water catchment and water heating system was built using this new design. Just after completion four days of unusually high tides swept over Majuro, damaging Mr. Hawpe's home and destroying the collector. Mr. Hawpe rebuilt the system and has monitored it for the last year. The Department of Energy is publishing a description of the design along with the operational data.

PROJECT TITLE: Solar Cooling for a Small Public Market Building

APPLICANT: New Guam Research Institute
P.O. Box 1256
Agana, Guam 96910

PROJECT TYPE: Making a technical and economic study of the benefits of modifying a small public market with solar passive features

GRANT AWARD: $5,000

PROJECT TERM: September 1978 – September 1979 (one year)

PROJECT DESCRIPTION:

A small market in Agana, Guam, is typical of other public markets throughout the Pacific. It has no air conditioning and uses western construction features that have not been modified for the local tropical conditions. The Institute planned to study how solar passive modifications could be made and what economic and comfort advantages these changes would offer. Results would be published in a small booklet.

PROJECT RESULTS:

Work never started on this project and the grant award was returned to the Department of Energy. For reasons DOE never could determine, the Institute lost interest in the project once the grant was awarded. Another group was interested in doing the work but the grant term had expired.

PROJECT TITLE: Wind Powered Lighted Navigation Buoy

APPLICANT: Mr. Charles Ludwig
NASA Tracking Station
DanDan, Guam 96916

PROJECT TYPE: Building and testing a number of lighted navigation buoys powered by wind

GRANT AWARD: $3,000

PROJECT TERM: August 1978 – August 1979 (one year)

PROJECT DESCRIPTION:

On many remote fishing villages throughout the Pacific Territories navigation is hazardous because there are no lighted buoys. Often fishing boats can travel only during daylight hours. Mr. Ludwig proposed to build and test a few wind-powered buoys in a remote harbor on Guam.

PROJECT RESULTS:

Shortly after being awarded the grant Mr. Ludwig was killed in an automobile accident on one of Guam's treacherous roads. (Most of the roads on Guam are constructed of coral, which becomes very slippery when wet, resulting in a high incidence of automobile accidents. The roads are slowly being rebuilt with basalt imported from the Northern Mariana Islands.) Mr. Ludwig did not start the project.

PROJECT TITLE: Fishmeal from Solar Heated Dryers

APPLICANT: Mr. Buruta Jicko/Lehland
Romanum Island
Truk, Eastern Caroline Islands 96942

PROJECT TYPE: Constructing and testing solar fish dryers and a fishmeal grinding device

GRANT AWARD: $14,100

PROJECT TERM: August 1978 – December 1980 (two and one-half years)

PROJECT DESCRIPTION:

Mr. Jicko, with the help of the Peace Corps and local villagers, planned to design, construct, and test solar dryers for drying fish by-products. The dried by-products then were to be ground up in a grinding device and used for chicken feed. Eventually they hoped to expand this operation into a small business.

PROJECT RESULTS:

No work was ever done on this project. The original Peace Corps worker moved to another island and the villagers and Mr. Jicko could not build the dryers themselves. Key parts for the grinder could not be obtained locally. The grant money was used to build some small fishing boats.

PROJECT TITLE: Utilization of Farm Wastes to Generate Power and Produce Clean Compost

APPLICANT: Msgr. Vincente T. Martinez/Pedro's Farm
P.O. Box 12
Agana, Guam 96910

PROJECT TYPE: Building and demonstrating a biomass conversion unit for converting pig wastes anaerobically to methane gas and for creating compost

GRANT AWARD: $7,720

PROJECT TERM: August 1978 — August 1979 (one year)

PROJECT DESCRIPTION:

Pedro's Farm is the largest vegetable and meat producing farm (a few hundred acres) on Guam. The farm is located in the low central mountains of Guam and is difficult to reach. Petroleum products for energy production are brought in by truck. In view of the critical need for energy on the farm, a few years ago they constructed a methane generator for their dozen or so pigs. Typhoon Pamela destroyed the system in 1976. With this grant they planned to reconstruct the generator and add a forced air compost creating cycle. They used local help and demonstrated the system to other rural farmers.

PROJECT RESULTS:

After receiving the award the digester and compost system were constructed very quickly with some professional and volunteer help. The system is operating successfully, but because of the farm's remote location, there is no demonstration value. The grant has bought a single successful well-built system, but at best will result in only a few more in the area.

PROJECT TITLE: American Samoa Tuna Sludge Project

APPLICANT: Territorial Energy Office — American Samoa Government
Pago Pago
American Samoa 96799

PROJECT TYPE: Designing an anaerobic process for converting tuna sludge waste to methane gas and evaluating the economic potential of this process for commercial use by local canneries

GRANT AWARD: $20,100

PROJECT TERM: September 1979 — January 1981 (one and one-half years)

PROJECT DESCRIPTION:

The two canneries on American Samoa must dispose of 5 to 6 million gallons of waste tuna sludge a year. The Territorial Energy Office is working with a consulting firm from Hawaii and some local people to study the possibilities of converting this sludge to methane, thereby solving the disposal problem and creating an energy resource. Samples of sludge have been analyzed at the University of Hawaii for solid matter content, salt content, methane-producing constituents, etc. A small 55-gallon digester and holding tank have been built from local materials, and sludge from both canneries has been digested on a batch basis for over a year. The digester has been monitored over the last year for methane production, sludge input, reliability, etc. Methane samples have been sent to the University of Hawaii for analysis. Data from the digester operation and from the sludge and methane analyses are being used to prepare an economic assessment of the feasibility of expanding this process to a pilot plant operation.

PROJECT RESULTS:

Sludge analysis showed a proper range of pH values, organic constituents, and nitrogen content necessary to produce methane. Some control of pH and total volatile solids may be necessary. Also there are some inconsistencies in the data, suggesting that sampling techniques should be controlled. In addition, because of differences in tuna processing between the two canneries, the salt content in sludge from one of the canneries was too high.

The local Marine Railway Authority constructed the digester, and the consulting firm trained local people to operate, monitor, and maintain the digester. Operation of the digester has been reliable over the year and output data are now being used to prepare the economic assessment report. Methane samples have been sent to the University of Hawaii. Based on data to date, the Territorial Energy Office will be encouraging the canneries to try this digestion process on a larger scale.

PROJECT TITLE: Typhoon-Proof Solar Greenhouse for Tropical Agriculture

APPLICANT: Mr. Eugene LeRoy
P.O. Box 8029
Merizo, Guam

PROJECT TYPE: Constructing and demonstrating a typhoon-proof solar greenhouse for subsistence, rural agriculture

GRANT AWARD: $3,000

PROJECT TERM: August 1979 – December 1980 (one and one-half years)

PROJECT DESCRIPTION:

Salt spray, rain, and wind from typhoons do extensive damage to small rural farms on Guam. Mr. LeRoy planned to build a small greenhouse that would resist typhoons and protect crops. The greenhouse would use French intensive gardening methods. Construction would be from inexpensive local materials and should be easily replicated.

PROJECT RESULTS:

The greenhouse has finally been completed but required a good deal of overseeing from the Guam Energy Office and the Department of Energy. The idea was good but Mr. LeRoy seems to have lost some of the original incentive and enthusiasm. He has moved from Guam and someone else is trying to improve the construction. There is some doubt as to whether the greenhouse is typhoon proof.

PROJECT TITLE: Yap Institute of Natural Science Appropriate Technology Project

APPLICANT: Yap Institute of Natural Science
Ngolog Village
Yap, Western Caroline Islands 96943

PROJECT TYPE: Building and demonstrating a variety of solar devices for local villagers on Yap

GRANT AWARD: $4,628

PROJECT TERM: August 1979 – August 1981 (two years)

PROJECT DESCRIPTION:

The Yap Institute of Natural Science is a small nonprofit institution that is trying to encourage, in a sensitive fashion, local adoption of small-scale technologies. With this grant they proposed to build, refine, and demonstrate three small appropriate technology devices: a solar oven and dryer combination, a passive solar ventilator system, and an adaption of a Lorena wood-burning stove. They plan to encourage villagers to try similar systems.

PROJECT RESULTS:

The Institute has finished the projects and they are now testing and demonstrating them. The devices were built with local help and materials and seem to be operating well. By the end of the project term they will have written a detailed brochure explaining how to build the systems. The projects are being demonstrated and the villagers are being encouraged to try similar systems with a soft-sell approach that seems to be successful on Yap. A variation of the solar oven/dryer will be tried at about ten villages for drying copra.

PROJECT TITLE: Solar Water Heater

APPLICANT: Community Development Office/Peace Corps
Lelu, Kosrae
Eastern Caroline Islands

PROJECT TYPE: Installing and demonstrating a solar hot water system for a district center hospital

GRANT AWARD: $13,100

PROJECT TERM: September 1979 – September 1981 (two years)

PROJECT DESCRIPTION:

Kosrae is the most remote of the Trust Territory districts. The small district center (population 4,500) has just completed building a hospital. Because of the island's limited electrical generating capacity, the hospital must limit its hot water supply. The Community Development Office, with help from the Peace Corps, planned to install two commercial self-contained solar water heating units. These units are available in Guam and are designed for tropical environmental conditions.

PROJECT RESULTS:

Immediately after DOE awarded the grant there was a turnover of Peace Corps workers. There was also a delay sending the grant money to Kosrae, and then the check was misplaced. For the first year or so no one could be found on Kosrae with the technical skills to work on the project. A new Peace Corps worker is interested now but there are still problems transferring the money. They are ordering the equipment and hope to complete the project by the end of summer 1981. This is a difficult project to monitor and assist because of its remote location.

PROJECT TITLE: Feral Pig Control by Solar Powered Electric Fence

APPLICANT: Dr. David Sleep
Department of Agriculture
Pago Pago, American Samoa

PROJECT TYPE: Constructing and testing a solar photovoltaic powered electric fence to keep feral pigs out of rural agricultural areas

GRANT AWARD: $1,120

PROJECT TERM: August 1980 – August 1981 (one year)

PROJECT DESCRIPTION:

Controlling wild pigs is a problem in outlying rural areas in American Samoa. Farms in New Zealand and Western Samoa have been successfully using electric fences powered by solar photovoltaic units. Dr. Sleep proposed to build and test such fences on the outer American Samoa island of Ta'u, Manu'a.

PROJECT RESULTS:

Dr. Sleep is just now (March 1981) installing the fence at two different sites on the island. (Different types of wild pigs are at each site.) He does not anticipate any unusual problems and reports that local farmers are enthusiastic about the fences.

201

PROJECT TITLE: Aramas Kapw, Alternative/Appropriate Energy Demonstration Site

APPLICANT: Mr. Venancio Alphons/Micronesia Bound, Inc.
P.O. Box 326
Kolonia, Ponape E.C.I. 96941

PROJECT TYPE: Building and demonstrating various alternative energy devices at an Outward Bound school for young adults

GRANT AWARD: $26,441

PROJECT TERM: September 1980 – September 1981 (one year)

PROJECT DESCRIPTION:

Micronesia Bound, Inc., is an Outward Bound school where young adults from all six Trust Territory districts come to learn a variety of skills and crafts. With this grant the staff plans to build with the students a 1.5-kW horizontal axis wind machine, a Savonius rotor unit for electricity production, a solar photovoltaic system to supplement the wind machines, a solar crop dryer, and a solar water heating and catchment system. The demonstration potential should be large as these young adults come from all the districts and have the potential to be island leaders.

PROJECT RESULTS:

Half way through the grant term most of the devices are either completed or nearing completion. A consultant from the Mainland is working with the staff. The staff, mostly Micronesian, are experienced educators and have a long history of working with the young. The project seems to be working exactly as planned: a variety of alternative energy devices are being built and the students are learning skills that they are bringing back to their district centers.

PROJECT TITLE: Solar Powered Refrigerators for Outer Island Dispensaries

APPLICANT: Mr. Samuel Falanruw
Department of Resources and Development
Colonia, Yap
Western Caroline Islands 96943

PROJECT TYPE: Installing two commercial Zeopower solar refrigerators for two small outer island dispensaries

GRANT AWARD: $2,916

PROJECT TERM: September 1980 – September 1981 (one year)

PROJECT DESCRIPTION:

Refrigeration of medical supplies is a problem on the outer islands that have no electricity. The islands of Woleai and Ulithi either do not have refrigeration systems or they import kerosene for powering their refrigerators. The latter is becoming increasingly expensive. With this grant Mr. Falanruw, with help from the Peace Corps, plans to install and test two small commercial Zeopower refrigerators. (Cooling is achieved through a phase change of a material volatized at lower temperatures using solar power.) If these systems are successful, Mr. Falanruw hopes they will be replicated elsewhere using local funds. These are the types of small solar systems that are critical for the outer Pacific Islands.

PROJECT RESULTS:

Between the time the application was submitted and the grant was awarded the price of the Zeopower units almost doubled. They are now too expensive for the intended purpose. Mr. Falanruw has ordered a small ARCO photovoltaic system instead. This sytem will be installed on one of the islands and tested. The grant is large enough for only one system now. There is a good deal of interest throughout the Pacific Islands in these small photovoltaic systems and it will be interesting to see how the system operates in such a remote location.

PROJECT TITLE: Shallow Lense Well Pumping Using Wind Power

APPLICANT: Mr. James Abernathy
Department of Public Works
Majuro, Marshall Islands 96960

PROJECT TYPE: Using commercial wind pumps for pumping water for shallow lense wells on Majuro, the Marshall Islands district center

GRANT AWARD:

PROJECT TERM: November 1980 – November 1981 (one year)

PROJECT DESCRIPTION:

A critical problem on the Marshall Islands is the supply of fresh water. This is particularly true in population centers such as the district center of Majuro. Water catchment systems for rainwater collection are used along with water pumping from two shallow lense wells. Shallow lense wells are also found on some of the outer islands. With this grant Mr. Abernathy proposed to install some commercial wind pumps for pumping water from the Majuro wells. If these systems were successful here he then planned to try similar systems on some of the outer islands. An important problem with pumping water is to control the pumping rate. If the fresh water is pumped too quickly the salt water will intrude, ruining the well. Mr. Abernathy is requesting some instruments to determine how far the wells can be pumped before intrusion will occur.

PROJECT RESULTS:

This project is just starting. Because of the limited funds available for the grant program, the grant has been reduced from the amount originally requested. Because of this and increasing costs of equipment, fewer wind machines will be installed. A Dempster unit has been ordered and should be installed soon. Tide recorders and instruments for determining salinity have also been ordered. One interesting point will be to see how the wind machine behaves in this corrosive atmosphere.

204

PROJECT TITLE: Solar Dryer Construction and Development

APPLICANT: Mr. Godfrey Chochol
State Planning Office
Colonia, Yap
Western Caroline Islands 96943

PROJECT TYPE: Building and testing different types of solar dryers for copra

GRANT AWARD: $8,645

PROJECT TERM: September 1980 – September 1981 (two years)

PROJECT DESCRIPTION:

Mr. Chochol, with help from the Peace Corps, plans to build and test three different types of solar dryers at twelve different locations on Yap and the outer islands of the Yap District. Drying copra by the traditional methods using a wood and coconut husk drying hut is time- and energy-consuming and also contaminates the copra with smoke. One type of solar dryer has already been tried with encouraging results. Two other types will also be tried and the results compared. After these systems are demonstrated, villagers should be able to build similar systems without additional federal support.

PROJECT RESULTS:

Betweeen the time the application was submitted and the grant was awarded, the Yap Institute of Natural Science developed a dryer that works very well, is easy to build with local materials, and seems to withstand the harsh environment. Most of the systems will probably use this design. They still plan to build three types of dryers, however, and if another design proves more successful, it will be used instead and built at nine other locations. There seems to be a problem siting these dryers in the local villages, but Mr. Chochol feels this will only cause a slight delay. No systems have been installed to date (spring 1981).

205

PROJECT TITLE: Smokeless Stove Demonstration Project

APPLICANT: Ms. Nancy Rody
Food and Nutrition Service Office
Trust Territory of the Pacific
Saipan, Commonwealth of the Northern Mariana Islands 96950

PROJECT TYPE: Building and demonstrating a series of wood cooking stoves for domestic and public school use

GRANT AWARD: $12,000

PROJECT TERM: September 1980 – September 1981 (one year)

PROJECT DESCRIPTION:

Throughout most of the Pacific Territory Islands cooking is done in the homes and school over open fires. Wood or coconut husks are fuel. The Community Education Training Center of the South Pacific Commission at Suva, Fiji, has designed an efficient cooking stove that uses about half as much fuel. With this grant the Food and Nutrition Service Office will oversee building a number of these stoves in the public schools of the Trust Territory district centers. The stoves will be demonstrated at these sites and materials and molds will be available for domestic construction.

PROJECT RESULTS:

At the time of this writing five stoves have been built at public facilities on Palau and Ponape. A consultant from the South Pacific Commission has helped build the molds and has trained local people to build the stoves. Users of the stoves seem to be quite enthusiastic about the energy savings and ease of cooking. The stoves are being effectively demonstrated in central locations. The important question now is whether or not local villagers will build these stoves for their own use.

206

PROJECT TITLE: Alcohol Distillation Plant for Tropical Village Communities

APPLICANT: School of the Pacific Islands/Palau Modekngei Learning Center
Palau
Western Caroline Islands 96940

PROJECT TYPE: Building and demonstrating a small village-level alcohol distilling unit for producing ethanol for outboard motors, refrigerators, etc.

GRANT AWARD: $40,358

PROJECT TERM: January 1, 1981 – January 1, 1982 (one year)

PROJECT DESCRIPTION:

The School of the Pacific Islands/Modekngei Learning Center has a reputation as one of the finest vocational and preparatory schools in the Pacific Territories. At the school they have built a small prototype alcohol distillation system that produces about 3 gallons/hour of 80 percent ethanol using a feedstock of corn and potatoes. With this grant they plan to build a bigger village-level unit that will produce fuel for outboard motors, refrigerators, etc. For this new unit they plan to use a different starch feedstock, increase the output, and simplify the distilling process so that these units can be built and repaired with local labor. Experience from operating the prototype will help them design the new unit. They plan to use some consultants from the Mainland to instruct the school's staff. The still will be located at an outlying village without electricity so a 200-watt wind machine will be used for electricity production. The new feedstock will be surplus matter from native plants. They will also try palm fronds, coconut shells, etc.

PROJECT RESULTS:

The project is just starting so they are just in the preliminary design stage. They have found that they must do more redesigning than they originally anticipated, particularly with the boiler. They have also decided to do all of the construction work locally and not depend on any construction from the Mainland.

PROJECT TITLE: Recycled Used Fluorescent Light Tube Solar Water Heater

APPLICANT: Mr. Frank Jacquette
University of Guam
Box EK
Agana, Guam 96910

PROJECT TYPE: Designing and testing a solar hot water collector that uses recycled fluorescent light tubes

GRANT AWARD: $7,520

PROJECT TERM: September 1979 – September 1980 (one year)

PROJECT DESCRIPTION:

For the last few years Mr. Jacquette has been designing and experimenting with a number of small solar hot water systems. In 1978 he received a small DOE AET grant to build and demonstrate a small domestic water system. He completed the project successfully, and in 1979 applied for another grant to determine if recycled fluorescent light tubes could be used as part of the collector system for a solar hot water unit. Glass is difficult to obtain on Guam and he hoped that these tubes would be a replacement for the glass. He planned to build and test a number of small collectors and hoped to build one with a high enough efficiency to provide hot water for an absorption refrigerator. After his 1978 project Mr. Jacquette wrote a series of excellent booklets describing his work. He planned to write the same type of booklet for this project.

PROJECT RESULTS:

This project was finished in the fall of 1980. Mr. Jacquette's daughter is drawing the illustrations for the booklet, which DOE will be publishing in spring 1981. Mr. Jacquette is a very clever builder and he devised a number of expertly crafted solar collectors using the tubes. These collectors are smaller models using 4-foot tubes. With another grant he received in 1980 he plans to build and install on a house a larger collector using 8-foot tubes. The tubes are opened and cleaned. A copper pipe is put into each tube. These pipes come off the collector manifold. The tubes are then resealed around the pipes and are evacuated, thereby providing a shield from convective and conductive heat losses (the same function as regular glass glazing). He has experimented with various selective coatings inside the tubes and has also tried various methods to reseal the tubes. Test data have not been completed yet but it appears as though the collector will work well enough for domestic hot water use but will not heat water to the 170°F or so required for absorption refrigerators. Five square feet of collector will heat 12 gallons of hot water up to 120°F during the day. The collectors should be able to withstand the harsh Guam environment.

PROJECT TITLE: Recycled Fluorescent Tube Water Heater Research and Demonstration

APPLICANT: Mr Frank Jacquette
University of Guam
Box EK
Agana, Guam 96910

PROJECT TYPE: Continuing research and demonstrating a domestic solar hot water system that uses recycled fluorescent tubes for the collector

GRANT AWARD: $7,100

PROJECT TERM: September 1980 – September 1981 (one year)

PROJECT DESCRIPTION:

In 1979 Mr. Jacquette received a small grant from DOE to do initial research on a solar collector that uses recycled fluorescent light tubes instead of the traditional flat glass for glazing on the collector. He built a small prototype model using 4-foot tubes with water circulating tubes inside the evacuated light tubes. Initial tests showed the five square feet of collector were able to heat water to 120°F during the day. This is adequate for hot water heating for most purposes but not for solar adsorption air conditioning or industrial uses as he had hoped. With this grant Mr. Jacquette planned to do additional research and to build a demonstration model using 8-foot sections of light tubes.

PROJECT RESULTS:

At this time (spring 1981) he has built three 32-square-foot collectors. He is still working on problems of evacuating and sealing the tubes with a tight joint around the water circulating tubes. The usual Pacific problems of availability of equipment and shipping delays have made some of the equipment difficult to get. He anticipates assembling the rest of the system sometime this spring and having the demonstration complete by summer. This is the third AET grant Mr. Jacquette has received, and as with the other two grants, there is a good deal of local interest in his work.

PROJECT TITLE: Development of a Wind-Powered Electric Generating Device for Aquaculture

APPLICANT: Mr. Barry D. Smith and Mr. Bruce R. Best
University of Guam Marine Laboratory
P.O. Box EK
Agana, Guam 96910

PROJECT TYPE: Installing and demonstrating a wind machine for providing electricity for a water pump for an aquaculture system at a remote location

GRANT AWARD: $8,086

PROJECT TERM: September 1980 – September 1981 (one year)

PROJECT DESCRIPTION:

The University of Guam Marine Laboratory has been building an aquaculture system for growing Malaysian prawn. This system is located at a remote place in the interior of the island. Water needs to be pumped from a nearby river to a holding pond and from there to the aquaculture ponds, but there is no nearby source of electricity for a conventional pump. Small diesel units are becoming increasingly expensive to run and their use is being discouraged throughout the Pacific. The Marine Laboratory thought this would be an excellent opportunity to demonstrate and test a wind electric machine. They have collected wind data and appear to have a good site. With this grant they plan to purchase and install a Scencenabaugh 1,000-watt corrosion-proof wind-electric system on a guyed 50-foot (approximately) tower. This will be a good chance to test a wind machine that supposedly will be able to withstand the corrosive and windy Pacific environment. There has already been a good deal of local interest in the aquaculture system so this will be a chance to demonstrate another renewable energy technology.

PROJECT RESULTS:

The Guam Energy Office is monitoring this project and from their reports and from the applicant's quarterly reports, the project appears to be going smoothly. The aquaculture ponds have already been built and cover an area of 3 acres. An additional ½-acre holding reservoir has just been completed. This work was done during fall 1980 despite two typhoons and the usual rainy season. The Sencenbaugh wind machine has been ordered but has not been received yet (January 1981). They have acquired a used tower that exceeds their specifications for perimeter and height. They are altering the tower to fit their needs and are also building the tower base. They are ahead of schedule with the tower and expect delivery of the wind machine soon. Test data on the wind machine will be interesting and valuable for other Pacific islands as this machine is designed to withstand particularly harsh environments.

210

PROJECT TITLE: Methane Gas Plant and Greenhouse for Cocos Island

APPLICANT: Merizon Shores Limited Partnership
Cocos Island, Guam

PROJECT TYPE: Building and demonstrating a methane-generating biomass converter and a greenhouse on the tourist attraction facility on Cocos Island

GRANT AWARD:

PROJECT TERM: September 1980 – September 1981 (one year)

PROJECT DESCRIPTION:

(This project is being monitored by the Guam Energy Office and current information is not available at this time.)

PROJECT RESULTS:

PROJECT TITLE: Wind Pump and Solar Still Demonstration

APPLICANT: Community and Cultural Affairs Division
Commonwealth of the Mariana Islands
Saipan, Mariana Islands 96950

PROJECT TYPE: Building and demonstrating a wind machine for pumping water and a solar still on a public bathhouse

GRANT AWARD: $1,200

PROJECT TERM: September 1979 – September 1981 (two years)

PROJECT DESCRIPTION:

The purpose of this project is to demonstrate to farmers and isolated villagers that they can use intermittent wind power to pump water from a well and store it in an overhead tank for toilet flushing, showers, and laundry. In addition, a simple solar still can be used for distilling brackish or polluted water for drinking and cooking purposes. The applicants and Mr. George Chan, a long-time proponent of using appropriate technologies in developing Pacific Basin countries, planned to build and install these two devices on a public bathhouse in a local park. The wind machine is to be a commercial one imported from the Mainland. The solar still is to be made from local materials.

PROJECT RESULTS:

This grant is one of three given to the government offices of the Commonwealth of the Mariana Islands and Mr. George Chan during 1979 and one of five they received during 1979 and 1980. The first two 1979 projects have been completed. This one is moving slowly because of problems in receiving the commercial wind machine from the Mainland and because of construction problems on the bathhouse. Also, they have encountered some bureaucratic barriers to installing the devices on the bathhouse. The wind machine, which was ordered a year ago, has just been received, bathhouse construction is continuing, and they are battling against the bureaucratic barriers.

PROJECT TITLE: Small Solar Heater

APPLICANT: Department of Education
Commonwealth of the Mariana Islands
Saipan
Mariana Islands 96950

PROJECT TYPE: Building and demonstrating, with the help of the local high school, two simple solar hot water heaters

GRANT AWARD: $600

PROJECT TERM: September 1979 – March 1981 (18 months)

PROJECT DESCRIPTION:

This grant is for buying supplies for the local high school students to build two simple solar hot water systems. Guidance was to come from the Commonwealth of the Mariana Islands Energy Office and Mr. George Chan, a person who has been very active for a number of years building small-scale energy devices for Pacific developing countries. One of the systems was to be built from a commercial kit, and the other system was to be built entirely from local materials. High school students would do the construction and both units would be demonstrated in a prominent location.

PROJECT RESULTS:

Both units have now been built and are being demonstrated. One system is located on the roof of the Energy Office Building and the other system is on the ground adjacent to a public building. Both systems are connected to hot water tanks – water is circulated by natural convection. The applicants experienced the usual Pacific delays in finding and receiving supplies for the collector built from local materials. Even materials such as lumber, which is usually available on the island, were hard to find. For a very small amount of money students have received training in building simple solar systems and these systems are being demonstrated. (This is one of five simple, low-cost grants that have been awarded to various Commonwealth government offices. Mr. Chan is acting as an advisor for all of the projects.)

PROJECT TITLE: Demonstration of Farm Biogas Digester and Algae Basins

APPLICANT: Division of Agriculture
Commonwealth of the Mariana Islands
Saipan
Mariana Islands 96950

PROJECT TYPE: Building and demonstrating a simple biogas digester and algae basin for producing methane gas and algae for livestock feed

GRANT AWARD: $1,500

PROJECT TERM: September 1979 – September 1980 (one year)

PROJECT DESCRIPTION:

This is the second of five small grants given to the government offices of the Commonwealth of the Mariana Islands. With this grant the Division of Agriculture, with help from Mr. George Chan, planned to build and demonstrate a small biogas digester and algae basin. Mr. Chan has designed and built this digester throughout the developing Pacific countries during the last two decades. The digester is built from reinforced concrete. A water column gives pressure to the biogas generated by anaerobic digestion of pig wastes. (The water column is used instead of the usual expensive steel gas holders.) A layer of water on top of the digester is used for growing algae, which is used for livestock feed. These digesters are relatively simple and inexpensive to build and are designed primarily for small farms and family use.

PROJECT RESULTS:

The applicants have just completed building the digester. The digester is located at the Department of Agriculture piggery. Capacity is 200 cubic feet – output at this time is unknown. Wastes are washed down twice a day from the piggery (about 100 pigs, I believe). Thanks to Mr. Chan's efforts, this type of digester has proved successful as a family and small farm digester in other countries. It is too early to tell yet if this unit will be replicated elsewhere on Saipan.

211

Table 1

Summary of United States Pacific Territory Islands

Entity	Location	Political Status	Number of Islands	Land Area (Main Island in square km)	Administration Center	Population (1978)
American Samoa	In the Samoan group east of 171° W long.	Unincorporated U.S. territory	7 (Samoan group)	197	Pago Pago	30,600
Guam	13°26' N lat. 144°43' E long.	Unincorporated U.S. territory	1 (Mariana Islands)	549	Agana	102,000 (1975)
Commonwealth of the Mariana Islands	15°12' N lat. 145°43' E long.	U.S. Commonwealth (formerly Trust Territory)	16 (Mariana Islands)	471	Saipan	15,200 (1975)
Palau	2° to 11° N lat. 130° to 136° E long.	Independent state (formerly Trust Territory)	Approximately 200 for the main group (Western Caroline)	559	Koror	13,500
Yap	Equator to 11° N lat. 136° to 148° E long.	Federated state (formerly Trust Territory)	Approximately 20 for the main group (Western Caroline)	—	Colonia	8,500
Truk	Equator to 11° N lat. 148° to 154° E long.	Federated state (formerly Trust Territory)	Approximately 90 for the main group (Eastern Caroline)	—	Moen	35,200
Ponape	Equator to 11° N lat. 154° to 162° E long.	Federated state (formerly Trust Territory)	Approximately 25 for the main group (Eastern Caroline)	703	Kolonia	21,200
Kosrae	Equator to 8° N lat. 162° to 166° E long.	Federated state (formerly Trust Territory)	1 (Eastern Caroline)	110	Lele	4,500
Marshall Islands	5° to 15° N lat. 162° to 173° E long.	Independent state (formerly Trust Territory)	Approximately 34 for the main group (Marshall Islands)	171 (total for all islands)	Majuro	27,100

Principal Source: Pacific Islands Year Book, New York, N.Y., Pacific Publications, 1978.

Table 2

Unemployment in the Trust Territory District Centers in 1973*
(Ref. 2, p. 1089)

Palau (Koror)	13.6%
Marshall Islands (Majuro)	21.6%
Federated States of Micronesia	
Yap (Colonia)	12.3%
Kosrae	20.4%
Ponape (Kolonia)	22.4%
Truk (Moen)	20.8%

* Office of Planning and Statistics, Quarterly Bulletin of Statistics, Trust Territory of the Pacific Islands, Saipan: Office of the High Commissioner, March 1979, vol. II no. 1, at 7. 1973 is the most recent year for which figures are available.

Table 3

Electric Generation Capacity and Peak Demand for the Territories*
(Ref. 2, p. 1089)

Territory	Electric Generation Capacity (MW)	Peak Electric Demand (MW)
Guam	314	150
American Samoa	24	18
Northern Marianas (Saipan only)	21	13
Palau	3.7	**
Marshall Islands	6.1	**
Federated States of Micronesia		
Ponape	5.4	**
Kosrae	0.8	**
Yap	3.1	**
Truk	4.5	**

* Data from Dept. of State, 1978 Trust Territory of the Pacific Islands 31st Annual Report, Washington, D.C.: Dept. of State, 1979, Publication No. 8972, Part XIII, at 23, Table 20, and from testimony presented at hearings on H.R. 7330, collected in Pacific Basin Energy.

** Peak demand data not available.

Table 4

Elements Contributing to a Successful Project (1978 Projects)

	Satawan Solar	Univ. of Guam Solar	Marshall Is. Solar	New Guam Res. Inst.	Wind Buoys	Fishdri	Pedro's Farm
Support of the local energy office	X	X	X	–	–	X	–
Project is monitored by DOE	–	X	X	–	–	X	–
Established institution is doing the work	X	X	X	–	–	–	–
Workers are dedicated	X	X	X	–	–	–	–
Workers are experienced	X	X	X	–	–	–	X
Realistic plan/schedule	–	X	X	–	–	–	X
Project is sensitive to the culture	X	N/A	X	X	–	X	X
Project uses village/local help	–	X	–	–	–	X	X
There are contributing funds/help locally	X	–	X	–	–	–	–
Project is accessible	X	–	X	X	–	–	–
Project uses mostly local materials	–	X	X	X	–	–	X
Proven technology for area	X	X	X	X	–	X	X
Elegant engineering	X	X	X	?	–	–	X
Parts available	–	X	X	?	–	–	X
Engineered for elements	?	X	X	X	–	X	X
The original applicant is in charge of work	X	X	X	–	–	–	X
Project is properly sized (including grant amount)	X	X	X	X	–	–	X
Realistic anticipation of problems	–	X	X	X	–	–	X
Problems beyond control of project (i.e., sickness)	X	–	X	–	X	–	–
Training of local help	–	–	–	–	–	–	–
TOTAL	12	15	18	7	1	6	12

Table 5

Elements Contributing to a Successful Project (1979 Projects)

	Tuna Sludge	Univ. of Guam Solar	Guam Greenhouse	CMI Solar	CMI Biomass	CMI Solar/Wind	Yap Inst.	Kosrae Hospital
Support of the local energy office	X	X	–	X	X	X	X	X
Project is monitored by DOE	X	X	X	X	X	X	X	–
Established institution is doing the work	X	X	–	X	X	X	X	X
Workers are dedicated	X	X	–	X	X	X	X	X
Workers are experienced	X	X	X	X	X	X	X	X
Realistic plan/schedule	X	X	X	X	X	–	X	–
Project is sensitive to the culture	X	N/A	X	X	X	X	X	X
Project uses village/local help	X	–	–	X	X	X	X	–
There are contributing funds/help locally	X	–	–	X	X	X	X	–
Project is accessible	X	–	X	X	X	X	X	X
Project uses mostly local materials	X	X	X	X	X	–	X	–
Proven technology for area	X	X	X	X	X	X	X	X
Elegant engineering	X	X	–	X	X	X	X	X
Parts available	X	X	X	–	X	–	X	X
Engineered for elements	X	X	–	X	X	X	X	X
The original applicant is in charge of work	X	X	X	X	X	X	X	–
Project is properly sized (including grant amount)	X	X	X	X	X	X	X	X
Realistic anticipation of problems	X	X	–	X	X	–	X	X
Problems beyond control of project (i.e., sickness)	–	–	–	–	–	–	–	–
Training of local help	X	–	–	X	X	X	X	X
TOTAL	19	14	10	18	19	15	19	13

Table 6

Elements Contributing to a Successful Project (1980 Projects)

	A.S. Energy House	Photovoltaic Fence	Photovoltaic Refrigerator	CMI Solar	Guam Aqua.	Univ. of Guam Solar	Cocos Island	Palau Alcohol	Aramas Kapw	Majuro Water	Yap Refrigerator	Yap Dryer	Woodstoves
Support of the local energy office	X	X	X	X	X	X	X	X	X	X	X	X	X
Project is monitored by DOE	X	X	X	X	X	X	X	X	X	X	X	X	X
Established institution is doing the work	X	X	X	X	X	X	–	X	X	X	X	X	X
Workers are dedicated	X	X	X	X	X	X	X	X	X	X	X	X	X
Workers are experienced	X	X	X	X	X	X	X	X	X	X	X	X	X
Realistic plan/schedule	X	X	X	–	X	X	–	X	X	X	X	X	X
Project is sensitive to the culture	X	X	X	X	X	X	X	X	X	X	X	X	X
Project uses village/local help	–	X	X	X	X	–	X	X	X	–	X	X	X
There are contributing funds/help locally	X	X	X	X	X	X	X	X	X	X	X	X	X
Project is accessible	X	X	X	X	–	X	X	X	X	X	X	X	X
Project uses mostly local materials	X	–	–	–	–	X	X	X	X	–	–	X	X
Proven technology for area	X	X	X	X	X	X	X	X	X	X	X	X	X
Elegant engineering	X	X	X	X	X	X	X	X	X	X	X	X	X
Parts available	X	X	X	X	X	X	X	X	X	X	X	X	X
Engineered for elements	X	X	X	X	X	X	X	X	X	?	X	X	X
The original applicant is in charge of work	X	X	X	X	X	X	–	X	X	X	X	X	X
Project is properly sized (including grant amount)	X	X	X	X	X	X	X	X	X	X	–	X	X
Realistic anticipation of problems	X	X	X	–	X	X	–	X	X	X	X	X	X
Problems beyond control of project (i.e., sickness)	–	–	–	–	–	–	–	–	–	–	–	–	–
Training or local help	–	–	X	X	–	–	–	X	X	X	X	X	X
TOTAL	17	17	18	16	16	17	14	19	19	17	17	19	19

APPENDIX E

INDUSTRIAL PROCESS HEAT APPLICATIONS AND ANNUAL REQUIREMENTS IN THE UNITED STATES (1974)

From

"Analysis of the Economic Potential of Solar Thermal Energy to Provide Industrial Process Heat," Volume 1.

Intertechnology Corporation, 1977
NTIS #COO/2829-1

Industrial Process Heat Applications

and Annual Requirements in the United States (1974)

Industry - S.I.C. Group	Application Temperature Requirement (°C)	10^{12}KJ/Yr.
1. Copper Concentrate-1021		
Drying	121	1.80
2. Bituminous Coal-1211		
Drying (including lignite)	66-104	19.00
3. Potash-1474		
Drying Filter Cake	121	1.09
4. Sulfur-1477		
Frasch Mining	163-171	63.00
5. Meat Packing-2011		
Sausages & Prepared Meats-2013		
Scalding, Carcass Wash, and Cleanup	60	46.10
Singeing Flame	260	1.12
Edible Rendering	93	0.55
Smoking/Cooking	68	1.22
6. Poultry Dressing-2016		
Scalding	60	3.33
7. Natural Cheese-2022		
Pasteurization	77	1.35
Starter Vat	57	0.02
Make Vat	41	0.50
Finish Vat	38	0.02
Whey Condensing	71-93	10.80
Whey Drying	49	3.10
Process Cheese Blending	74	0.07
8. Condensed & Evaporated Milk-2023		
Stabilization	93-100	3.09
Evaporation	71	5.48
Spray Drying	177-204	3.78
Sterilization	121	0.57
9. Fluid Milk-2026		
Pasteurization	72-77	1.52

Industrial Process Heat Applications

and Annual Requirements in the United States (1974)

Industry - S.I.C. Group	Application Temperature Requirement (°C)	10^{12}KJ/Yr.
10. Canned Specialties-2032		
Beans		
Precook (Blanch	82-100	0.42
Simmer Blend	77-100	0.25
Sauce Heating	88	0.21
Processing	121	0.40
11. Canned Fruits and Vegetables-2033		
Blanching/Peeling	82-100	1.98
Pasteurization	93	0.15
Brine Syrup Heating	93	1.08
Commercial Sterilization	100-121	1.76
Sauce Concentration	100	0.46
12. Dehydrated Fruits and Vegetables-2034		
Fruit and Vegetable Drying	74-85	6.16
Potatoes		
Peeling	100	0.35
Precook	71	0.50
Cook	100	0.50
Flake Dryer	177	1.15
Granule Flash Dryer	288	1.15
13. Frozen Fruits and Vegetables-2037		
Citrus Juice Concentration	88	1.40
Juice Pasteurization	93	0.28
Blanching	82-100	2.38
Cooking	77-100	1.49
14. Wet Corn Milling-2046		
Steep Water Evaporator	177	3.86
Starch Dryer	49	3.20
Germ Dryer	177	2.03
Fiber Dryer	538	3.09
Gluten Dryer	177	1.39
Steepwater Heater	49	0.81
Sugar Hydrolysis	132	1.99
Sugar Evaporator	121	2.89
Sugar Dryer	49	0.17
15. Prepared Feeds-2048		
Pellet Conditioning	82-88	2.40
Alfalfa Drying	204	17.70

277

Industrial Process Heat Applications

and Annual Requirements in the United States (1974)

	Industry - S.I.C. Group	Application Temperature Requirement (°C)	10^{12}KJ/Yr.
16.	Bread & Baked Boods-2051		
	Proofing	38	0.89
	Baking	216-238	6.75
17.	Cane Sugar Refining-2062		
	Mingler	52-74	0.62
	Melter	85-91	3.48
	Defecation	71-85	0.46
	Revivification	399-599	4.18
	Granulator	43-54	0.46
	Evaporator	129	27.84
18.	Beet Sugar-2063		
	Extraction	60-85	4.88
	Thin Juice Heating	85	3.25
	Lime Calcining	538	3.14
	Thin Syrup Heating	100	7.05
	Evaporation	132-138	32.50
	Granulator	66-93	0.16
	Pulp Dryer	100-138	17.40
19.	Soybean Oil Mills-2075		
	Bean Drying	71	4.27
	Toaster Desolventizer	102	6.41
	Meal Dryer	177	4.60
	Evaporator	107	1.71
	Stripper	100	0.32
20.	Animal and Marine Fats-2077		
	Continuous Rendering of Inedible Fat	166-177	17.40
21.	Shortening and Cooking Oil-2079		
	Oil Heater	71-82	0.76
	Wash Water	71-82	0.13
	Dryer Preheat	93-132	0.63
	Cooking Oil Reheat	93	0.34
	Hydrogenation Preheat	149	0.39
	Vacuum Deodorizer	149-204	0.37
22.	Malt Beverages-2082		
	Cooker	100	0.61
	Water Heater	82	0.56
	Mash Tub	77	0.63
	Grain Dryer	204	9.68
	Brew Kettle	100	4.20

Industrial Process Heat Applications

and Annual Requirements in the United States (1974)

Industry - S.I.C. Group	Application Temperature Requirement (°C)	10^{12}KJ/Yr.
23. Distilled Liquor-2085		
Cooking (Whiskey)	100	3.33
Cooking (Spirits	160	6.61
Evaporation	121-143	2.45
Dryer (Grain	149-204	2.05
Distillation	110-121	8.11
24. Soft Drinks-2086		
Bulk Container Washing	77	0.22
Returnable Bottle Washing	77	1.34
Nonreturnable Bottle Warming	24-29	0.45
Can Warming	24-29	0.55
25. Cigarettes-2111		
Drying	104	0.45
Rehumidification	104	0.45
26. Tobacco Stemming & Re-drying-2141		
Drying	104	0.26
27. Finishing Plants, Cotton-2261		
Washing	100	16.20
Dyeing	100	4.70
Drying	135	23.40
28. Finishing Plants, Synthetic-2262		
Washing	93	37.90
Dyeing	100	16.00
Drying and Heating Setting	135	24.50
29. Logging Camps-2411		
30. Sawmills & Planing Mills-2421		
Kiln Drying of Lumber	149	66.90
31. Plywood-2435		
Plywood Drying	121	53.40
32. Veneer-2436		
Veneer Drying	100	61.00
33. Wooden Furniture-2511		
Makeup Air and Ventilation	21	6.00
Kiln Dryer and Drying Oven	66	4.00

225

Industrial Process Heat Applications

and Annual Requirements in the United States (1974)

Industry - S.I.C. Group	Application Temperature Requirement (°C)	10^{12}KJ/Yr.
34. Upholstered Furniture-2512		
Makeup Air and Ventilation	21	1.50
Kiln Dryer and Drying Oven	66	0.90
35. Pulp Mills-2611		
Paper Mills-2621		
Paperboard Mills-2631		
Building Paper-2661		
Pulp Digestion	188	267.00
Pulp Refining	66	185.00
Black Liquor Treatment	138	173.00
Chemicals Recovery-Calcining	1038	101.00
Pulp and Paper Drying	143	404.00
36. Solid and Corrugated Fiber Boxes-2653		
Corrugating and Glue Setting	149-177	22.80
37. Cyclic Intermediates-2865		
Ethylbenzene	177	3.00
Styrene	121-177	37.00
Phenol	121	0.47
38. Alumina-28195		
Digesting, Drying, Heating	138	119.40
Calcining	1204	37.20
39. Plastic Materials and Resins-2821		
Polystyrene, suspension process		
Polymerizer Preheat	92-103	0.107
Heating Wash Water	88-93	0.068
Drying	93	0.036
40. Synthetic Rubber-2822		
Cold SBR Latex Crum		
Bulk Storage	27-38	0.189
Emulsification	27-38	0.091
Blowdown Vessels	54-63	0.912
Monomer Recovery	by	Flashing
& Stripping	49-60	4.319
Dryer Air Temperature	66-93	3.864
Cold SBR, Oil-Carbon Black Masterbatch		
Dryer Air Temperature	66-93	0.534
Oil Emulsion Holding Tank	27-38	0.030

226

Industrial Process Heat Applications

and Annual Requirements in the United States (1974)

	Industry - S.I.C. Group	Application Temperature Requirement (°C)	10^{12}KJ/Yr.
	Cold SBR, Oil Masterbatch		
	Dryer Air Temperature	66-93	1.15
	Oil Emulsion Holding Tank	27-38	0.095
41.	Cellulosic Man-made Fibers-2823		
	Polyester	<288	51.60
	Nylon	<279	44.00
	Acrylic	<121	24.80
	Polypropylene	<282	4.10
42.	Noncellulosic Fibers-2824		
	Rayon	<100	39.90
	Acetate	<100	39.70
43.	Pharmaceutical Preparations-2834		
	Autoclaying & Cleanup	121	19.88
	Tablet & Dry-Capsule Drying	121	1.05
	Wet Capsule Formation	66	0.05
44.	Soaps and Detergents-2841		
	Soaps:		
	Various Process in Soap Manufacture	82	0.53
	High-temperature Process	254	0.002
	Spray Drying	260	0.001
	Detergents:		
	Various Low-temperature Processes	82	0.38
	High-temperature Processes	260	0.03
	Drum-Dried Detergents	177	0.33
	Spray-Dried Detergents	260	0.020
45.	Organic Chemicals, N.E.C.-2869		
	Ethanol	93-121	6.00
	Isopropanol	93-177	12.00
	Cumene	121	1.00
	Vinyl Chloride Monomer	121-177	9.00
46.	Urea-2873215		
	High-Pressure Steam-Heated Stripper	191	5.35
	Low-Pressure Steam-Heated Stripper	143	0.94

221

Industrial Process Heat Applications

and Annual Requirements in the United States (1974)

	Industry - S.I.C. Group	Application Temperature Requirement (°C)	10^{12}KJ/Yr.
47.	Explosives-2892		
	Dope (Inert Ingredients)		
	Drying	149	0.006
	Wax Melting	93	0.124
	Nitric Acid Concentrator	121	0.074
	Sulfuric Acid Concentrator	93	0.026
	Nitric Acid Plant	93	0.235
	Blasting Cap Manufacture	93	0.017
48.	Paving Mixtures-2951		
	Aggregate Drying	135-163	92.90
	Heating Asphalt	163	5.20
49.	Asphalt Felts & Coatings-2952		
	Saturator	204-260	1.60
	Asphalt Coating	149-204	1.30
	Drying (Steam)	177	3.50
	Sealant	149-204	0.60
50.	Tires and Inner Tubes-3011		
	Vulcanization	121-171	6.52
51.	Plastics Products-3079		
	Blow-molded Bottles		
	High-Density Polyethylene	218	3.71
52.	Leather Tanning and Finishing-3111		
	Bating	32	0.03
	Chrome Tanning	29-54	0.063
	Retan, Dyeing, Fat Liquor	49-60	0.16
	Wash	49	0.036
	Drying	43	2.16
	Finishing Drying	43	0.14
53.	Clay Refractories-3255		
54.	Concrete Block-3271		
	Low-Pressure Curing	74	12.96
	Autoclaving	182	5.72
55.	Ready-Mix Concrete-3273		
	Hot Water for Mixing Concrete	49-88	0.36
56.	Gypsum-3275		
	Kettle Calcining	166	10.50
	Wallboard Drying	149	11.79

Industrial Process Heat Applications

and Annual Requirements in the United States (1974)

Industry - S.I.C. Group	Application Temperature Requirement (°C)	10^{12}KJ/Yr.
57. Galvanizing-3479		
Cleaning, Pickling	54-88	0.012
Galvanizing (melting zinc)	454	0.015
58. Inorganic Pigments-2816		
Drying Chrome Yellow	93	0.079

229