Volume I: Technical Report

RENEWABLE ENERGY RESOURCES
FIELD TEST PROJECT

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TASK 2.2.1 FINAL REPORT

Renewable Energy Technology/ Application Options Identification

Prepared for
EGYPTIAN ELECTRICITY AUTHORITY
Cairo, Egypt

and

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
USAID Mission: Cairo, Egypt

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LOUIS BERGER INTERNATIONAL, INC.
Washington, D.C.

Prepared by
MERIDIAN CORPORATION
Falls Church, VA

In Association with

EGYPTIAN ELECTRICITY AUTHORITY
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ENERGY AND ENVIRONMENTAL ENGINEERING, INC.
East Cambridge, MA

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TABLE OF CONTENTS

VOLUME I

		PAGE
1.0	INTRODUCTION	1-1
	1.1 Purposes	1-1
	1.2 Background	1-1
	1.3 Approach	1-2
	1.4 Evaluation Procedures	1-6
	1.5 Next Steps	1-11
2.0	THE EGYPTIAN CONTEXT	2-1
	2.1 Basic Country Data	2-1
	2.1.1 Geography	
	2.1.2 Demographics	
	2.1.3 Economy	
	2.1.4 Local Renewable Energy Industry Infrastructure	
	2.2 Energy Overview	2-6
	2.2.1 Present Energy Demand	
	2.2.2 Projected Energy Demand	
	2.2.3 Energy Supply Resources	
	2.3 Five Year National Development Plan	2-15
	2.3.1 Agricultural Sector	
	2.3.2 Industrial Sector	
	2.3.3 Energy Sector	
	2.3.4 Transportation and Communication Sector	
	2.3.5 Housing and New Communities	
	2.3.6 Environment	
	2.3.7 Trade Balance	
	2.3.8 Employment	
	2.4 Role for Renewables in the Five Year Plan	2-17
3.0	APPLICATIONS CHARACTERIZATION	3-1
	3.1 Water Pumping Applications	3-1
	3.1.1 Demand Characterization	
	3.1.1.1 Irrigation	
	3.1.1.2 Livestock Watering	
	3.1.1.3 Human Consumption	
	3.1.1.4 Land Reclamation and Industrial Application	
	3.1.1.5 Energy Requirements for Pumping	
	3.1.2 Need in Egypt	
	3.2 Livestock Operations	3-13
	3.2.1 Demand Characterization	
	3.2.1.1 Sheltering	
	3.2.1.2 Feeding	
	3.2.1.3 Product Handling	
	3.2.2 Need in Egypt	
	3.3 Urban Energy Requirements	3-18
	3.3.1 Demand Characterization	
	3.3.2 Need in Egypt	
	3.4 Remote Communications	3-18
	3.4.1 Demand Characterization	
	3.4.2 The Need in Egypt	

TABLE OF CONTENTS (Cont'd)

PAGE

3.5 Cathodic Protection..... 3-22
3.5.1 Demand Characterization
3.5.2 Need in Egypt
3.6 Agricultural and Industrial Process Heat..... 3-24
3.6.1 Food Canning
3.6.1.1 Demand Characterization
3.6.1.2 Need in Egypt

3.6.2 Hydrogenated Oil
3.6.2.1 Demand Characterization
3.6.2.2 Need in Egypt
3.6.3 Soap Manufacture
3.6.3.1 Demand Characterization
3.6.3.2 Need in Egypt
3.6.4 Pharmaceuticals
3.6.5 Beverage Industry
3.6.5.1 Demand Characterization
3.6.5.2 Need in Egypt
3.7 Building Climatization..... 3-43
3.7.1 Demand Characterization
3.7.2 Need in Egypt

4.0 RENEWABLE ENERGY TECHNOLOGY CHARACTERIZATION..... 4-1
4.1 Wind..... 4-1
4.1.1 Technology Description
4.1.2 Resource Availability
4.1.3 Market Readiness
4.1.4 Cost
4.1.5 Industry Status
4.1.6 Current R&D Thrusts
4.2 Photovoltaics..... 4-4
4.2.1 Technology Description
4.2.2 Types of PV Collectors
4.2.3 Resource Availability
4.2.4 Market Readiness
4.2.5 Cost
4.2.6 Industry Status
4.2.7 R&D Thrusts
4.2.8 Relevant Egyptian/Worldwide Experience
4.3 High Temperature Solar Thermal..... 4-7
4.3.1 Technology Description
4.3.1.1 Flat Plate
4.3.1.2 Evacuated Tube Collector
4.3.1.3 Parabolic Trough
4.3.1.4 Parabolic Dish
4.3.1.5 Central Receiver
4.3.2 Resource Availability
4.3.3 Market Readiness
4.3.4 Cost
4.3.5 Industry Status
4.3.6 Current Solar Thermal R&D Thrusts
4.3.7 Relevant Experience in Egypt

TABLE OF CONTENTS (Cont'd)

PAGE

4.4 Geothermal 4-11
4.4.1 Technology Description
4.4.2 Resource Availability
4.4.3 Cost
4.4.4 Industry Status
4.4.5 Current R&D Thrusts
4.4.6 Relevant Experience in Egypt Using Geothermal Technology
4.5 Biomass 4-14
4.5.1 Technology Description
4.5.1.1 Direct Combustion
4.5.1.2 Anaerobic Digestion
4.5.1.3 Fermentation
4.5.2 Resource Availability
4.5.3 Market Readiness
4.5.4 Cost
4.5.5 Industry Status
4.5.6 Current R&D Thrust for Technology
4.5.7 Relevant Experience in Egypt Using Biomass Technologies
4.6 Solar Ponds 4-18
4.6.1 Technology Description
4.6.2 Resource Availability
4.6.3 Market Readiness
4.6.4 Cost
4.6.5 Industry Status
4.6.6 Current R&D Thrusts
4.6.7 Relevant Experience in Egypt and Other Countries
4.7 Municipal Solid Waste 4-21
4.7.1 Technology Description
4.7.2 Resource Availability
4.7.3 Market Readiness
4.7.4 Cost
4.7.5 Relevant Experience in Egypt and Other Countries Using MSW
4.8 Passive and Hybrid Solar Heating and Cooling and Daylighting... 4-24
4.8.1 Technology Description
4.8.1.1 Passive and Hybrid Solar Heating
4.8.1.2 Passive Solar Cooling Systems
4.8.2 Resource Availability
4.8.3 Market Readiness
4.8.4 Industry Status
4.8.5 Current Passive Solar R&D Thrusts
4.8.6 Relevant Experience in Egypt and Worldwide

5.0 ECONOMIC FEASIBILITY OF TECHNOLOGY/APPLICATION OPTIONS 5-1
5.1 Power for Remote Non-Grid-Connected Applications 5-3
5.1.1 Application Characteristics
5.1.2 Wind and Solar Resource Characteristics
5.1.3 Wind, PV and Diesel Systems
5.1.3.1 Energy Supply Technology Evaluations
5.1.3.2 Assumptions Used in Analysis
5.1.3.3 Economic Analysis
5.2 Power for Pumping Applications 5-12
5.2.1 Applications Characteristics
5.2.2 Economic Analysis

TABLE OF CONTENTS (Cont'd)

PAGE

5.3 Anaerobic Digestion of Sewage Waste Water for Electricity Generation..... 5-20
5.3.1 Application Characteristics
5.3.2 Economic Analysis
5.3.3 Potential Application Sites
5.4 Anaerobic Digestion of Municipal Solid Waste for Electricity Generation..... 5-25
5.4.1 Application Characterization
5.4.2 Economic Analysis
5.5 Use of Biogas in a Dairy Farm..... 5-30
5.5.1 Application Characterization
5.5.2 Economic Analysis
5.6 Biogas Utilization in Poultry Operations..... 5-32
5.6.1 Application Characterization
5.6.2 Economic Analysis
5.7 Remote Communications..... 5-35
5.7.1 Application Characterization
5.7.2 Economic Analysis
5.8 Cathodic Protection..... 5-36
5.9 Solar Thermal Technology Utilization in Agricultural/Industrial Processing..... 3-39
5.9.1 Technology/Application Options Selection
5.9.2 Economic Analysis
5.10 Solar Design Options for Building Climate Control..... 5-51
5.10.1 Technology/Application Option Selection
5.10.1.1 Space Heating
5.10.1.2 Space Cooling
5.10.2 Economic Analysis
5.10.2.1 Economic Analysis for Space Heating
5.10.2.2 Economic Analysis for Space Cooling
5.11 Incineration of Municipal Solid Waste for Electricity Generation..... 5-66
5.11.1 Application Characterization
5.11.2 Economic Analysis.....

6.0 EVALUATION CRITERIA..... 6-1
6.1 Replicability in Egypt..... 6-1
6.2 Renewable Technology Status..... 6-1
6.3 Renewable Resource Availability..... 6-1
6.4 Government Priorities..... 6-3
6.5 Renewable System Economic Feasibility..... 6-3
6.6 Current Project Status in Egypt..... 6-7
6.7 Institutional Requirements..... 6-7
6.8 Social and Environmental Impacts..... 6-7

7.0 TECHNOLOGY/APPLICATION OPTIONS SELECTION..... 7-1
7.1 Field Test Candidate Selection Process Description..... 7-1
7.2 Data Collection..... 7-1
7.2.1 Characterization of Applications
7.2.2 Characterization of Technologies
7.2.3 Technology/Application Options Identification
7.2.4 Evaluation Criteria Selection

TABLE OF CONTENTS (Cont'd)

PAGE

7.3 Data Analysis..... 7-6
7.3.1 Phase I Analysis
7.3.1.1 Characterization of Options and Scoring
7.3.1.2 Development of a Composite Score
7.3.1.3 Calculation of Evaluation Criteria Weights
7.3.1.4 Phase I Analysis Results
7.3.2 Phase II Analysis
7.3.2.1 Evaluation Procedure
7.3.2.2 Recommended Field Test Candidates
7.3.3 Calculation of Evaluation Criteria Weights
7.4 Next Steps..... 7-22

VOLUME II

APPENDIX A: RENEWABLE ENERGY TECHNOLOGY CHARACTERIZATION

APPENDIX B: DEGREE-DAYS CALCULATIONS FOR ALEXANDRIA, CAIRO, AND ASWAN

APPENDIX C: CALCULATION OF HEAT LOSS CO-EFFICIENT FOR TYPICAL EGYPTIAN HOME

APPENDIX D: PRELIMINARY DESIGN OF A FLASH STEAM SYSTEM

APPENDIX E: HYBRID ANALYSIS

APPENDIX F: ROOF PONDS

APPENDIX G: ANALYSIS OF OVERHANGS

APPENDIX H: REFLECTIVE COATING AND LOW EMISSIVITY GLASS

LIST OF EXHIBITS

		PAGE
Exhibit 1.1	Project Task Areas	1-3
Exhibit 1.2	Overview of Renewable Energy Field Test Candidate Selection Process	1-5
Exhibit 1.3	Technology/Application Options Selected for Evaluation	1-7
Exhibit 1.4	Ranking of Technology/Application Options by Composite Score	1-8
Exhibit 1.9	Highest Ranked Technology/Applications Options	1-9
Exhibit 2.1	GOE Renewable Energy Decision-Making Process	2-2
Exhibit 2.2	Primary Energy Consumption in 1980	2-7
Exhibit 2.3	Traded Energy Consumption In Final Uses 1980 (MTOE)	2-7
Exhibit 2.4	Development of Electricity Generated and Maximum Load over 1970 - 1980	2-9
Exhibit 2.5	Development of Oil Products Consumption 1974 - 1980/81	2-10
Exhibit 2.6	Primary Energy Consumption for the Year 2000	2-11
Exhibit 2.7	Evaluation of Government Priorities Based on Public Sector Investment Targets (1981-87)	2-18
Exhibit 3.1	Consumptive Use Water Requirements in Egypt	3-3
Exhibit 3.2	Unit Water Requirements in the Nile Valley and Delta	3-4
Exhibit 3.3	Estimated Irrigation Water and Pumping Energy Requirements for the New Lands Project	3-5
Exhibit 3.4	Typical Water Requirements	3-7
Exhibit 3.5	Annual Water Requirements Per Water Point	3-7
Exhibit 3.6	Relationship Between Water Requirements, Pumping Head, Energy Requirements, and PV, Wind and Biogas Generator Requirements	3-10
Exhibit 3.7	Electrical Energy Requirements for Livestock Operations	3-16
Exhibit 3.8	Annual Urban Energy Reqirements	3-19
Exhibit 3.9	Photovoltaic Powered Remote Communication Systems to be Installed in Egypt	3-21
Exhibit 3.10	Thermal Size Plant Canning Process and Thermal Energy Flow Chart	3-26
Exhibit 3.11	Thermal Energy Load for the Egyptian Food Canning Industry	3-27
Exhibit 3.12	Process Flow Diagram for Vegetable and Animal Oil Hydrogenation	3-29
Exhibit 3.13	Thermal Energy Inputs for Edible Oil Hydrogenation	3-30
Exhibit 3.14	Hydrogenated Oil Industry Thermal Energy Consumption in Egypt	3-32
Exhibit 3.15	Process Flow Diagram for Kettle Soap Manufacture with Thermal Energy Requirements	3-33
Exhibit 3.16	Egyptian Soap Production and Energy Consumption	3-35
Exhibit 3.17	Schematic diagram of the Penicillin Manufacture Process	3-36
Exhibit 3.18	Process Flow Diagram for Aspirin Manufacture with Thermal Energy Requirements	3-37
Exhibit 3.19	Thermal Energy Load of the Pharmaceutical Industry in Egypt	3-39
Exhibit 3.20	Process Flow Diagram fo Beer Production with Thermal Energy Requirements	3-41

LIST OF EXHIBITS (Cont'd)

		PAGE
Exhibit 3.21	Thermal Energy Load of the Beverage Industry in Egypt	3-43
Exhibit 3.22	Climate and Heating/Cooling Loads for 3 Cities	3-44
Exhibit 3.23	Heating Load Calculation for Cairo	3-47
Exhibit 3.24	Cooling Load Calculation for Cairo	3-48
Exhibit 3.25	Projected New Residential Construction	3-52
Exhibit 5.1	Technology Application Options Selected for Evaluation	5-2
Exhibit 5.2	Wind Turbine and PV Array Output	5-4
Exhibit 5.3	Block Diagrams of Wind, Photovoltaics, Diesels and Hybrid Systems	5-6
Exhibit 5.4	Cost Assumptions	5-8
Exhibit 5.5	Energy Cost Variation with Energy Demand for Wind, PV, Diesels and Hybrid Systems	5-9
Exhibit 5.6	Economic Analysis Results of Wind, PV, Diesel and Hybrid Power Systems Lowest Cost Alternative	5-11
Exhibit 5.7A	PV, Wind, Diesel and Hybrid Systems Evaluation Program for Stand-Alone Applications	5-13
Exhibit 5.7b	Evaluation Program Graphical Output	5-14
Exhibit 5.8	Comparative Costs of Water Pumping for Livestock Watering	5-16
Exhibit 5.9	Comparative Costs of Water Pumping for Irrigating One Hectare	5-17
Exhibit 5.10	Comparative Costs of Water Pumping Systems for Land Reclamation	5-18
Exhibit 5.11	Summary of Water Pumping Economic Analysis	5-19
Exhibit 5.12	Sewage Plant Biogas Cogeneration System	5-21
Exhibit 5.13	Energy Balance for Sewage Wastewater Anaerobic Digester and Cogenerator	5-22
Exhibit 5.14A	Specific Generation Rates of Household Wastes for Different Living Standards	5-26
Exhibit 5.14B	Sectoral MSW generation pattern	5-26
Exhibit 5.15	MSW Composition	5-27
Exhibit 5.16	Material Balance for Electricity Generation for 100 TPD MSW Anaerobic Digestion System	5-29
Exhibit 5.17	Dairy Biogas Cogeneration System	5-31
Exhibit 5.18	Poultry Farm Biogas Cogeneration System	5-33
Exhibit 5.19	Cost Energy vs. Energy Demand	5-37
Exhibit 5.20	Features of a PV-Powered Cathodic Protection System	5-38
Exhibit 5.21	Temperature Requirements and Production of Priority Agricultural and Industrial Process Industries for Application of Solar Thermal Technology	5-41
Exhibit 5.22A	Summary of Performance and Economic Data for Solar Thermal Technologies Applied to Industrial Processes	5-42
Exhibit 5.22B	Projections of Solar Thermal Energy Costs in 1990	5-43
Exhibit 5.22C	Cost Bases for Solar Technologies	5-44
Exhibit 5.23	Data from a Computer-Driven Calculation of Solar Energy Output from a Flat Plate System	5-46
Exhibit 5.24	Schematic Diagram of an Unfired-Boiler Solar Steam System	5-47
Exhibit 5.25	Schematic Diagram of a Flash Solar Steam System	5-48

LIST OF EXHIBITS (Cont'd)

		PAGE
Exhibit 5.26	Schematic Diagram of a Parabolic Trough/Flat Plate Hybrid Solar Steam System	5-52
Exhibit 5.27	Evaluation of the Gasoil and Electric Options for Space Heating	5-53
Exhibit 5.28	Evaluation of the Solar Option for Space Heating	5-55
Exhibit 5.29	Evaluation of the Air Conditioner for Space Heating	5-57
Exhibit 5.30	Performance of Overhang Type H	5-58
Exhibit 5.31	Effect of Roof Pond on Cooling Load	5-59
Exhibit 5.32	Effect of Reflective Film on Absorbed Solar Radiation	5-60
Exhibit 5.33	Economic Evaluation of Gasoil Options	5-62
Exhibit 5.34	Economic Evaluation of Solar Space Heating	5-63
Exhibit 5.35	Economic Evaluation of Air Conditioners	5-64
Exhibit 5.36	Comparison of Passive Options	5-65
Exhibit 5.37	Refuse-to-Energy System	5-67
Exhibit 5.38	Typical Controlled Air, Modular Combustor	5-69
Exhibit 5.39	Energy Balance for Baltimore RESCO Plant	5-70
Exhibit 5.40	Energy Balance for a Typical 50tpd Modular MSW Plant	5-72
Exhibit 6.1	Renewable Energy Technologies Stages of Development	6-2
Exhibit 6.2	Evaluation of Government Priorities Based on Public Sector Investment Targets (1981-87)	6-4
Exhibit 6.3	Comparison of Production in 1981/82 with Expected Production in 1986/87	6-6
Exhibit 7.1	Overview of Renewable Energy Field Test Candidate Selection Process	7-2
Exhibit 7.2	Selected Renewable Technology/Application Options Considered for Egypt	7-7
Exhibit 7.3	Weights Selection using the Metfessel General Allocation Test	7-10
Exhibit 7.4	Ranking of Technology/Application Options by Composite Score	7-11
Exhibit 7.5	Scoring of Technology/Application Opportunities for Replicability Criteria	7-14
Exhibit 7.6	Scoring of Technology/Application Options for Technology Status Criteria	7-15
Exhibit 7.7	Scoring of Technology/Application Options for Resource Availability Criteria	7-16
Exhibit 7.8	Scoring of Technology/Application Options for Government Priorities Criteria	7-17
Exhibit 7.9	Scoring of Technology/Application Options for Economic Feasibility Criteria	7-18
Exhibit 7.10	Scoring of Technology/Application Options for Current Status in Egypt Criteria	7-19
Exhibit 7.11	Scoring of Technology/Application Options for Institutional Requirements Criteria	7-20
Exhibit 7.12	Scoring of Technology/Application Options for Social and Environmental Impacts Criteria	7-21

1.0 INTRODUCTION

1.1 Purpose

The purpose of the Renewable Technology/Application Options Assessment Report is to identify promising renewable energy technology/application combinations with widespread use in Egypt. This report is prepared as part of the Renewable Energy Resources Field Testing Project which is sponsored in joint cooperation between the Government of Egypt's (GOE) Ministry of Electricity and the U.S. Agency for International Development (USAID).

1.2 Background

The objective of the Renewable Energy Field Testing Project is to strengthen the capabilities of the GOE in designing, managing, and evaluating renewable energy systems for Egypt. Four major task areas are being performed for this project.

Task 1: Project Management - Provides the organization, staff and equipment necessary to develop the capabilities for performing the supporting analysis, field tests, and training required by the contract.

Task 2: Supporting Analysis - Provides for a broad range of technical, socio-economic, financial and market analyses through four subtasks.

2.1 Conducting economic and market analysis for the 11 candidate renewable energy field tests that have been identified for the Project.

2.2 Identifying and evaluating promising renewable technology/application combinations other than the 11 candidate field tests. This subtask involves: (1) conducting a preliminary technology application assessment to determine renewable options which warrant further evaluation for Egypt; (2) conducting detailed technical, economic and market assessments of selected options; and (3) developing technology/application program plans for implementing selected options and conducting field tests.

2.3 Designing, developing, and implementing a Renewable Energy Information System (REIS) for storing, retrieving and evaluating project data.

Task 3: Candidate Field Test Implementation - Involves the design, installation and operation of renewable energy field tests at 11 sites in Egypt. Five industrial process heat, three photovoltaic, and three wind energy systems are scheduled for completion in this task. Specific activities to be performed include application review, technology review, conceptual design, RFP preparation, proposal review, selection of an installation contractor, system implementation and oversight, and system performance evaluation.

Task 4: Training and Information Dissemination - Provides training to the GOE in the areas of project management, field test replication, and economic and market analyses. This will be accomplished by on-the-job and specialized training, both in Egypt and in the U.S.

Exhibit 1.1 depicts the task and subtask activities for this project. The Options Identification Report presented here is the first activity being performed under Task 2.2 Renewable Energy Applications Assessment. The results of this study will provide the basis for more detailed technical, economic, and market analyses of promising renewable energy technology/application options to be performed in subsequent phases of Task 2.2.

1.3 Approach

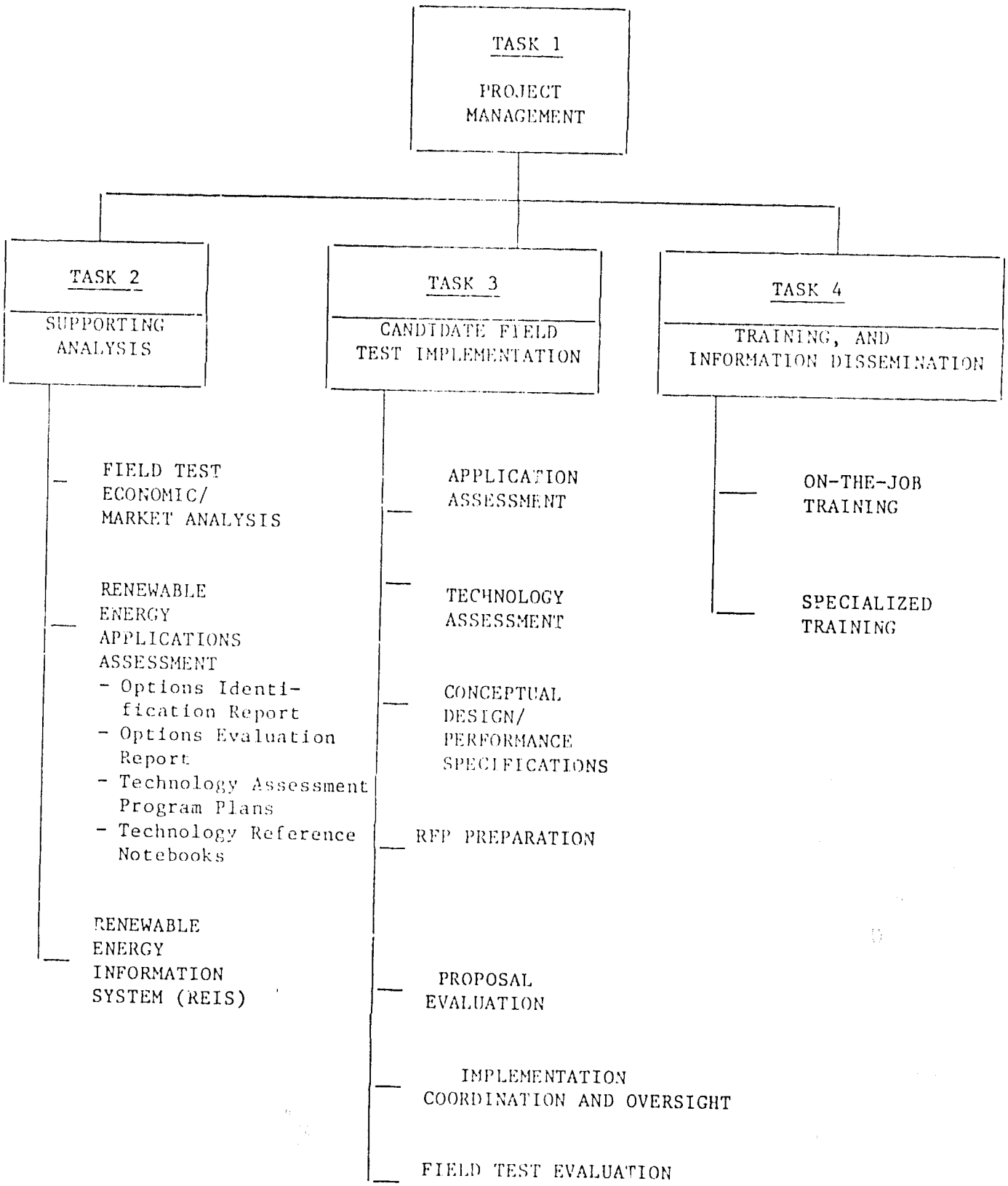
The technical approach to be used in identifying promising renewable energy technology/application options for Egypt, other than those selected for the 11 candidate field tests, is provided below.

Step 1: Delineate general economic and energy setting in Egypt as it pertains to the selection and evaluation of renewable energy technologies for the country. This includes a review of current and planned demographic, geographic, economic and energy balance characteristics, as well as a review of Egypt's development objectives.

Step 2: Identify potential energy application sector requirements in Egypt according to three categories: electric, heat and mechanical uses.

EXHIBIT 1.1

PROJECT TASK AREAS



Step 3: Identify renewable energy technologies which could satisfy the above sector applications. Critical issues to be considered include worldwide technology experience, resource availability, market readiness, economic viability, industry status, operating characteristics, R&D thrusts, and relevant experience in Egypt using the technology.

Step 4: Map the renewable energy technologies against the energy applications into a matrix which will identify suitable options for Egypt.

Step 5: Establish the methodology and criteria for prioritizing and selecting the most promising options. Parameters will include government priorities, resource availability, technology status, cost status, replicability in Egypt, current status in Egypt, institutional requirements, and social and environmental impacts.

Step 6: Select, in conjunction with the GOE, the most promising options in the Egyptian context. Evaluate as to whether they are near-, mid-, or long-term applications.

Exhibit 1.2 shows an overview of the technology/application field test selection process. It includes an identification of the role that each of the following chapters play in providing supporting data and analyses for the final options selection.

Since renewable energy technologies are dynamic in nature, with cost and technological breakthroughs occurring on an on-going basis, the Options Identification Report will be updated annually. This will ensure that Egypt has access to the most up-to-date information available for use in renewable energy system and project decision-making.

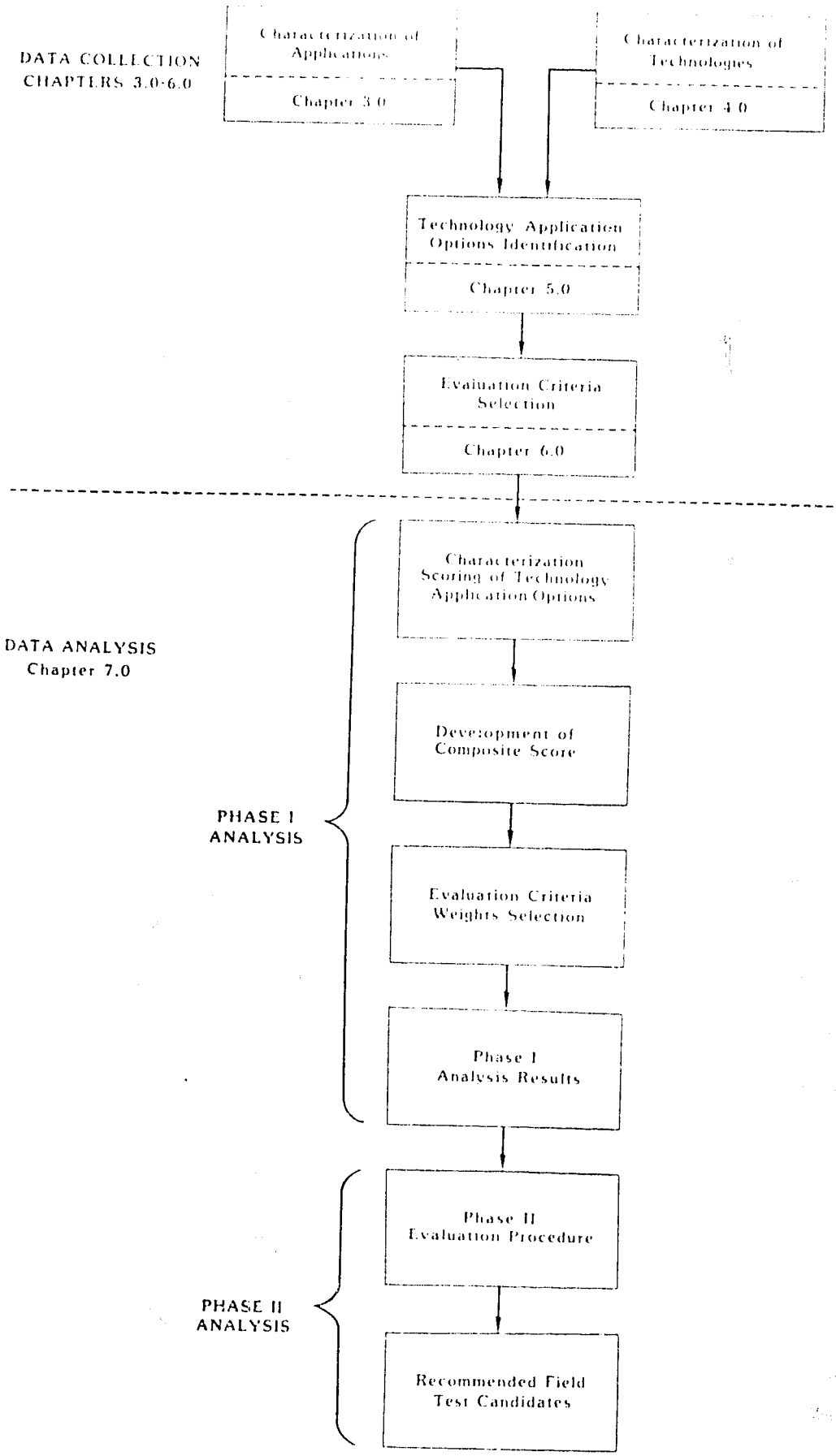
Data used in preparing the Options Identification Report has been obtained from the following sources:

(1) Discussions with key GOE, USAID and Egyptian private sector officials;

(2) Collection and review of technical reports, publications and journals on the current and projected status of renewable energy technologies and applications; and

(3) Collection and review of GOE planning and strategy documents.

EXHIBIT 1-2
OVERVIEW OF RENEWABLE ENERGY FIELD TEST CANDIDATE SELECTION PROCESS



1.4 Evaluation Procedure

Exhibit 1.3 shows, in a matrix format, the technology/application combinations that were evaluated. In total, 55 technology/application options were studied. A two-phased approach was used to reduce these 55 options to five field test candidates. This approach is described below.

1.4.1 Phase I Analyses

A multi-attribute, quantitative scoring scheme was employed in rank ordering the technology/application options. The evaluation criteria used were the following:

- o Replicability in Egypt
- o Renewable technology status
- o Resource availability
- o Government priorities
- o Renewable system ecomonic feasibility
- o Current project status in Egypt
- o Institutional requirements
- o Social and environmental impacts

Each of the 55 options were assigned numerical scores according to their ability to satisfy the evaluation criteria, with the highest scores reflecting the better candidate options for Egypt. Exhibit 1.4 presents the results of th analysis, with Column 10 presenting the rank ordered results. The leading options are listed in Exhibit 1.5. As evidenced, they represent a broad cross-section of renewable technologies, including biogas, solar thermal, active/passive solar, municipal solid waste, photovoltaics and wind.

1.4.2 Phase II Analysis

In the Phase II analysis, the leading options resulting from the Phase I analysis, were further screened in order to identify the best candidates for

APPLICATION	WIND	PHOTOVOLTAICS	WIND-PHOTOVOLTAIC HYBRID	WIND-DIESEL HYBRID	PHOTOVOLTAIC-DIESEL HYBRID	WIND-PHOTOVOLTAIC-DIESEL HYBRID	ANAEROBIC DIGESTION-URBAN MSW	ANAEROBIC DIGESTION-RURAL WASTE	LOW TEMPERATURE SOLAR THERMAL (< 100°C)	MOD. TEMPERATURE SOLAR THERMAL (100-250°C)	ACTIVE PASSIVE SOLAR HEATING AND COOLING	INCINERATION-URBAN MSW
EGG PRODUCTION	●	●	●	●	●	●		●				
BROILER PRODUCTION	●	●	●	●	●	●		●				
DAIRY FARM	●	●	●	●	●	●		●				
BEEF FEEDLOT	●	●	●	●	●	●		●				
IRRIGATION	●	●						●				
LIVESTOCK WATERING	●	●						●				
LAND RECLAMATION	●	●						●				
CITIES							●					●
BUILDING CLIMATIZATION											●	
REMOTE COMMUNICATIONS	●	●										
CATHODIC PROTECTION		●										
FOOD CANNING									●	●		
SOAP/DETERGENT PRODUCTION									●	●		
HYDROGENERATED OIL PRODUCTION									●	●		
BEVERAGES PRODUCTION									●	●		
PHARMACEUTICALS PRODUCTION									●	●		

Exhibit 1-3

TECHNOLOGY APPLICATION OPTIONS SELECTED FOR EVALUATION

Exhibit 1-4

RANKING OF TECHNOLOGY/APPLICATION OPTIONS BY COMPOSITE SCORE

SECTOR	APPLICATION	TECHNOLOGY	COL. 1 REPLIC. IN EGYPT	COL. 2 TECH. STATUS	COL. 3 RESOURCE AVAIL.	COL. 4 GOVT. PRIORIT.	COL. 5 ECON. FEAS.	COL. 6 CURRENT STATUS IN EGYPT	COL. 7 INSTIT. REQUIR.	COL. 8 SOCIAL/ ENVIR. IMPACTS	COL. 9 WEIGHTED COMPOSITE SCORE	COL. 10 RANK
WEIGHT -->			25	18	15	12	10	10	5	5	100	
POPULATION SUPPORT	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM SEWAGE	9	9	8	7	8	7	8	9	826	1
INDUSTRY	PHARMACEUTICALS	SOLAR THERMAL	8	7	8	8	5	8	7	8	747	2
POPULATION SUPPORT	RESIDENTIAL BLDGS.	ACTIVE/PASSIVE SOLAR	9	8	8	5	8	6	3	8	744	3
INDUSTRY	HYDROGENATED OIL	SOLAR THERMAL	8	7	8	7	5	8	7	8	735	4
POPULATION SUPPORT	COMMERCIAL/INSTIT. BLDGS.	ACTIVE/PASSIVE SOLAR	8	6	8	7	8	6	7	8	727	5
POPULATION SUPPORT	ELECTRICITY FOR CITIES	MSW INCINERATION/ELECTRIC	9	7	6	7	4	8	6	9	720	6
POPULATION SUPPORT	REMOTE COMMUNICATIONS	PV	8	8	8	6	8	4	3	8	711	7
INDUSTRY	SOAP & DETERGENTS	SOLAR THERMAL	7	7	8	7	5	8	7	8	710	8
AGRICULTURE	IRRIGATION	WIND MECHANICAL PUMPING	8	9	5	7	9	3	7	6	706	9
AGRICULTURE	IRRIGATION	BIOGAS MECHANICAL PUMPING	8	5	7	7	9	5	8	6	689	10
AGRICULTURE	IRRIGATION	WIND ELECTRIC PUMPING	8	6	5	7	8	8	5	6	682	11
AGRICULTURE	IRRIGATION	PV W/O BATTERY PUMPING	8	7	8	7	7	2	3	8	675	12
INDUSTRY	BEVERAGES	SOLAR THERMAL	6	7	8	6	5	8	7	8	673	13
INDUSTRY	FOOD CANNING	SOLAR THERMAL	5	7	8	8	5	8	7	8	672	14
AGRICULTURE	IRRIGATION	PV W/BATTERY PUMPING	8	6	8	7	5	4	3	8	657	15
AGRICULTURE	LIVESTOCK WATERING	WIND MECHANICAL PUMPING	7	9	5	5	9	3	7	6	657	15
AGRICULTURE	LIVESTOCK WATERING	BIOGAS MECHANICAL PUMPING	7	5	7	5	9	5	8	6	640	16
AGRICULTURE	LIVESTOCK WATERING	PV W/O BATTERY PUMPING	7	7	8	5	7	2	3	8	626	17
AGRICULTURE	DAIRY FARM	PV-DIESEL HYBRID	6	5	8	6	6	8	3	7	622	18
AGRICULTURE	LIVESTOCK WATERING	PV W/BATTERY PUMPING	7	6	8	5	6	4	3	8	618	19
AGRICULTURE	DAIRY FARM	BIOGAS ELECTRIC	6	6	7	6	7	5	6	6	615	20
AGRICULTURE	LIVESTOCK WATERING	WIND ELECTRIC PUMPING	7	6	5	5	6	8	5	6	613	21
POPULATION SUPPORT	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM MSW	8	2	6	7	5	9	3	8	605	22
AGRICULTURE	DAIRY FARM	WIND-DIESEL HYBRID	6	5	5	6	8	8	4	5	592	23
AGRICULTURE	DAIRY FARM	WIND-PV HYBRID	6	5	7	6	5	8	3	6	592	23
AGRICULTURE	DAIRY FARM	WIND	6	6	5	6	5	8	5	6	590	24
AGRICULTURE	DAIRY FARM	PV	6	5	8	6	1	8	3	8	577	25
AGRICULTURE	EGG PRODUCTION	BIOGAS ELECTRIC	5	6	7	2	9	5	6	6	562	26
AGRICULTURE	BROILER PRODUCTION	BIOGAS ELECTRIC	5	6	5	5	8	5	6	6	558	27
AGRICULTURE	EGG PRODUCTION	PV-DIESEL HYBRID	5	5	8	2	6	8	3	7	549	28
INDUSTRY	CATHODIC PROTECTION	PV	3	8	8	2	7	6	3	8	548	29
AGRICULTURE	DAIRY FARM	PV-WIND-DIESEL HYB.	6	4	7	6	1	9	3	6	544	30
AGRICULTURE	EGG PRODUCTION	PV-WIND-DIESEL HYB.	5	4	7	2	7	9	3	6	531	31
AGRICULTURE	EGG PRODUCTION	WIND-DIESEL HYBRID	5	5	5	2	8	8	4	5	519	32
AGRICULTURE	BROILER PRODUCTION	PV-DIESEL HYBRID	2	5	8	5	6	8	3	7	510	33
AGRICULTURE	CATTLE FEEDLOT	PV-DIESEL HYBRID	2	5	8	5	6	8	3	7	510	33
AGRICULTURE	CATTLE FEEDLOT	PV	2	5	8	5	5	8	3	8	505	34
AGRICULTURE	EGG PRODUCTION	PV	5	5	8	2	1	8	3	8	504	35
AGRICULTURE	CATTLE FEEDLOT	BIOGAS ELECTRIC	2	6	7	5	7	5	6	6	503	36
AGRICULTURE	EGG PRODUCTION	WIND-PV HYBRID	5	5	7	2	3	8	3	6	499	37
AGRICULTURE	BROILER PRODUCTION	WIND	2	6	5	5	7	8	5	6	498	38
AGRICULTURE	EGG PRODUCTION	WIND	5	6	5	2	3	8	5	6	497	39
AGRICULTURE	BROILER PRODUCTION	WIND-DIESEL HYBRID	2	5	5	5	9	8	4	5	490	40
AGRICULTURE	BROILER PRODUCTION	WIND-PV HYBRID	2	5	7	5	6	8	3	6	490	40
AGRICULTURE	CATTLE FEEDLOT	WIND-PV HYBRID	2	5	7	5	6	8	3	6	490	40
AGRICULTURE	BROILER PRODUCTION	PV-WIND-DIESEL HYB.	2	4	7	5	6	9	3	6	482	41
AGRICULTURE	CATTLE FEEDLOT	WIND	2	6	5	5	5	8	5	6	478	42
AGRICULTURE	LAND DRAINAGE	WIND MECHANICAL PUMPING	2	8	5	6	3	3	7	6	466	43
AGRICULTURE	BROILER PRODUCTION	PV	2	5	8	5	1	8	3	8	465	44
AGRICULTURE	LAND DRAINAGE	PV W/BATTERY PUMPING	2	4	8	6	1	8	3	8	459	45
AGRICULTURE	LAND DRAINAGE	PV W/O BATTERY PUMPING	2	4	8	6	1	8	3	8	459	45
AGRICULTURE	LAND DRAINAGE	WIND ELECTRIC PUMPING	2	4	5	6	3	8	5	6	434	46
AGRICULTURE	CATTLE FEEDLOT	PV-WIND-DIESEL HYB.	2	4	7	5	1	9	3	6	432	47
AGRICULTURE	CATTLE FEEDLOT	WIND-DIESEL HYBRID	2	5	5	5	3	8	4	5	430	48
AGRICULTURE	LAND DRAINAGE	BIOGAS MECHANICAL PUMPING	2	3	4	6	3	9	6	6	416	49

EXHIBIT 1.5

HIGHEST RANKED TECHNOLOGY/APPLICATIONS OPTIONS

APPLICATION	TECHNOLOGY
Electricity for Cities	Biogas Electricity from Sewage
Pharmaceuticals	Solar Thermal
Residential Buildings	Active/Passive Solar
Hydrogenated Oil	Solar Thermal
Commercial/Institutional Buildings	Active/Passive Solar
Electricity for Cities	MSW Incineration/Electric
Remote Communications	Photovoltaics
Soap and Detergents	Solar Thermal
Irrigation	Wind Electric
Irrigation	Wind Mechanical
Irrigation	Biogas Mechanical
Irrigation	Photovoltaics without Battery

field testing. Evaluation criteria used in this phase of the analysis included:

- o Scale of Potential Field Test and Required Budget
- o Current Project Status in Egypt
- o Commercial Status in Egypt
- o Replicability in Egypt
- o Resource Availability and Demand Match

As a result of this analysis, five technology/application options are recommended to the GOE as viable field test candidates.

o Active/Passive Solar - Residential Buildings

This option involves the field testing of active and passive solar systems for residential applications. These technologies are technically proven, cost competitive and have a large potential for replicability in the country, particularly to supply heating and cooling needs. For example, in the urban areas alone up to 800,000 new housing units are planned by the year 2000, with additional growth expected in the new communities being developed in the country. This option takes advantage of a readily available solar resource, meets the budget requirements of the project, and provides Egypt with experience in a new renewable technology/application.

o Biogas Electricity from Sewage - Electricity for Cities

This project involves development of a system which uses biogas electricity generated from sewage to produce power for urban areas. This option is particularly promising for Egypt in that is uses a technology which is commercially available and cost competitive, falls within the project budget, has a large potential for replicability in urban areas of the country, and presents a technology which has not been demonstrated previously in Egypt. Furthermore, this option is ensured of a stable resource supply from the good sewage collection systems in Egypt, produces a by-product with a high value as a fertilizer and soil conditioner, provides a viable alternative for supplying electricity for both sewage plant requirements and city grid power needs, and helps reduce health problems arising from untreated sewage entering the waterways.

o Solar Thermal - Pharmaceuticals and Hydrogenated Oil Industries

The two industrial field test candidate options involve the use of solar thermal technology for low-temperature steam applications. Specifically, for pharmaceuticals the temperature range is 120°-130°C, with hydrogenated oil production ranging from 130°-200°C.

Solar thermal systems have a high potential for replicability in these and other industrial sectors of Egypt, are economically feasible in

comparison to conventional systems, have no social or environmental impacts, make use of a readily available solar resource, contribute to GOE objectives to promote industrial growth and expansion, and meet the budget limitations of the project. Additionally, there are limited on-going solar thermal projects in Egypt, thus providing Egyptians with experience in a new technology area.

- Wind Mechanical - Small-Scale Irrigation

This field test candidate involves small-scale irrigation systems supplied by wind mechanical energy. These systems can be used for livestock watering, land reclamation (depths of up to 50m), and/or for potable water for human needs.

The advantages of performing a field test in this area are that the technology is simple, mature, proven and cost-competitive; it satisfies government priorities to both enhance productivity in the agricultural sector, and promote rural development; and has a large potential market in this country. Furthermore, these are small-scale systems which satisfy the project budget; utilize the strong wind resource that is available along coastal and outlying parts of the country; and provide Egyptians with exposure to a technology/application with which they have had only limited experience.

1.5 Next Steps

The above field test candidates, which have been selected on the basis of analyses conducted by representatives of the Egyptian Electricity Authority (EEA), Meridian Corporation and Energy and Environmental Engineering, Incorporated (E^3I), will be presented to senior-level EEA officials in a briefing planned for mid-September 1985. The purpose of this briefing will be to review the evaluation process, discuss the reasons for selection of the five candidates, and obtain concurrence to proceed with detailed analysis of these options. If the five candidates are acceptable, Subtask 2.2.2 will be initiated, which involves: 1) conducting a comprehensive engineering, economic, financial and market assessment of each of the options, and 2) identifying potential field test sites. If there is not agreement on the five options, comments will be obtained and further analysis conducted until there is senior-level EEA approval for a set of candidate field tests.

2.0 THE EGYPTIAN CONTEXT

Energy planning in Egypt, and ultimately the role that renewables will play in the country, is dependent upon a number of interrelated factors, including:

-- Basic data on the geography, demography, economy, and local renewable energy industry of the country;

-- Energy demand situation, current and projected;

-- Energy supply resources; and

-- Five Year National Development Plan objectives.

Combined, these elements provide the framework in which the GOE will conduct renewable energy decision-making for the country. Exhibit 2.1 graphically presents the renewable energy decision-making process for Egypt.

This chapter provides background information on each of the areas identified above. The information will be used in subsequent chapters to provide the basis for identifying, evaluating and selecting promising renewable technology/application options which should be implemented by the GOE given Egypt's particular needs and characteristics.

2.1 Basic Country Data

This section reports on basic country data which is required to assess the energy situation in Egypt.

2.1.1 Geography

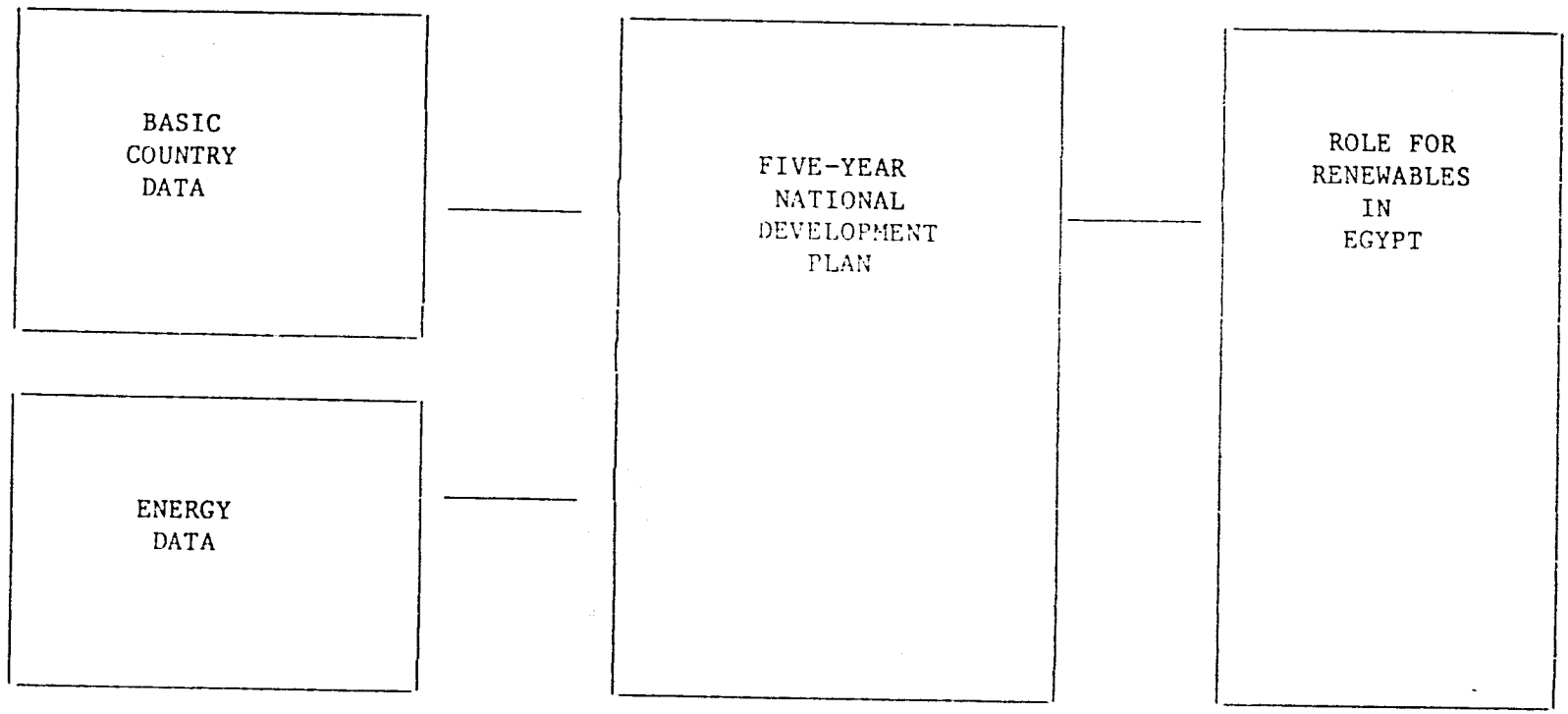
Egypt is located in the extreme northeast of Africa and consists of approximately 386,600 square miles of land. Egypt is generally organized into four major areas, as discussed below.

- Nile Valley and Delta - The Nile River is the longest river in Africa (1000 miles) and the lifeline of Egypt. The Nile enters Egypt at Wadi Halfa in the Sudan, and reaches the fertile delta in Cairo. It accounts for approximately 99 percent of the population, 4 percent of the land, and the country's only cultivable soil.

- Western Desert - The Western Desert, which accounts for 68 percent of the land area, is an arid region with vast sand plains, shifting dunes and large depressions. The Government considers this a frontier region,

EXHIBIT 2.1

GOE RENEWABLE ENERGY DECISION-MAKING PROCESS



- Demand
- Supply Resources

dividing it into two frontier governorates: Marsa Matruh to the North and New Valley to the south. There are seven important depressions in the Western Desert, and all are considered oases except the largest, Quattara. The Quattara Depression is uninhabited and contains badlands, salt marshes and lakes. The remaining depressions are characterized by limited agriculture, some natural resources, and permanent habitation. As oases, these depressions obtain fresh water in sufficient quantities from the Nile or other underground sources.

- Eastern Desert - The Eastern Desert, which accounts for approximately 22 percent of the land, is arid and defoliated. Its most prominent feature is the Red Sea Hills which extend from the Nile Valley eastward to the Gulf of Suez and the Red Sea. This region is considered isolated from the rest of the country, and is difficult to sustain agriculture. With only a few permanent settlements on the Red Sea, the importance of this region lies in its natural resources. The entire Eastern Desert is administered under a single governorate, Red Sea, with its capital at Hurghada on the Red Sea.

- Sinai Peninsula - The Sinai Peninsula is a triangular area of 23,600 square miles, situated east of the Gulf of Suez and northeast of the Eastern Desert. It is closely akin to the Desert, containing mountains in the southern sector that are a geological extension of the Red Sea Hills, the low range along the Red Sea Coast that includes the highest point in the country, Mount Catherine at 2,637 meters. Before the Sinai was seized by Israel in the June 1967 War, a single governorate embraced the whole peninsula. In 1982 the Egyptian Government divided the peninsula into the North Sinai, with its capital Al Arish, and the South Sinai, with its capital at Tur.

2.1.2 Demographics

In 1983, the population in Egypt was estimated at over 45.8 million with an annual growth rate of 2.9 percent per year. By the year 2000, the population is expected to increase to approximately 70 million.

As discussed above, 99 percent of the population live in the Nile Valley and Delta, which represents less than 4 percent of the total area of the country. Egypt is almost 57 percent rural, but the rapid population growth, in conjunction with massive rural migration, have resulted in tremendous urban growth at an average annual rate of 4.9 percent in the cities. This trend towards urbanization has remained unchecked and resulted in serious overcrowding in the cities.

2.1.3 Economy

Egypt faces a number of serious economic problems, although there is no pending crisis for the country. For 1983/84, imports are estimated at $8.9

14

billion, with export revenues expected to amount to $7.8 billion. This results in an estimated trade deficit of approximately $1.1 billion. Of the exports, petroleum and petroleum products provided approximately 32 percent ($2.5 billion) of the total revenues, and approximately 70 percent of all commodity exports. Service exports provide the remaining portion of the revenues, principally in the form of workers' remittances, Suez Canal tolls, and tourism receipts. Currently, only about 25 percent of oil production is used for exports, with the other 75 percent used for domestic consumption which is subsidized at approximately 20 percent of the world price. This situation deprives the country from earning valuable export revenues and offsetting the large trade deficit.

The major sectors of the economy are described briefly below:

- Agriculture. Of the total land area of 247,458,040 acres, only 3 percent or 8.3 million acres, are classified as agricultural land. This is almost exclusively along the narrow ribbon of soil deposited by and located close to the Nile. Urbanization and other construction has slowly diminished the available arable land in the country. This in combination with increasing population pressures has led to an intensive form of cultivation characterized by multiple cropping and widespread use of fertilizers and pesticides, as well as seeking the development of new agricultural areas.

  Agriculture employs 51 percent of the labor force, contributes 29 percent of the GDP, and 61 percent of the exports. Per capita availability of domestically produced food is about 10 percent lower than it was 10 to 20 years ago. Egyptian imports of food production represents one-third of total imports, one of the highest ratios in the world.

- Industry. Manufacturing industries are well established in Egypt, employing 26 percent of the work force, contributing 30 percent of the GDP, and providing 35 percent of the export value. The chief sectors are food processing (28%), textiles (26%), electrical and engineering (15%), chemicals and pharmaceuticals (13%) and construction materials (8%). Industry is concentrated in the areas of Cairo and Alexandria. Outside of this area, key industries include the iron and steel complex at Helwan, the steel mills of Upper Egypt, the textile mills of Mahalla el Kubra, and the chemical and fertilizer plants around Aswan.

- Mining. Egypt's known non-hydrocarbon mineral resources include phosphates (Isna, Safaga, Hamrawein, and Abu Tartar); iron ore (Aswan and Baharia); coal (Suez and Sinai); and manganese (Eastern Desert and Sinai). To a lesser extent there are also deposits of gold, nickel, cobalt, and copper; chrome, tantalum and molybdenum (all in the Eastern

15

Desert); uranium (Cairo); and gypsum (Alexandria).

- o Services. During the past decade, there has been deterioration in Egypt's physical infrastructure. Transportation, telecommunications and other facets of the infrastructure are inadequate for the desired growth of rural and urban economic activities. Although the government is taking steps to improve this situation, including increasing and enhancing roadways throughout the country; building a Cairo subway system; and updating the telephone systems, these services remain overburdened.

2.1.4 Local Renewable Energy Industry Infrastructure

In general, there exists no infrastructure that is specifically tailored to support renewable energy applications in Egypt. The existing administrative, manufacturing, financing, marketing and other infrastructural support facilities can, however, be diversified, modified or expanded to take care of the newly emerging renewable energy applications.

For the most part, renewable energy systems using low or intermediate technology could be manufactured in Egypt using indigenous labor and material resources. For example, solar-related energy systems are fabricated primarily from basic construction material such as steel, cement, glass and aluminum, which are produced locally in Egypt. Components such as towers of wind turbine units, collector array support structures, and flat plate thermal collectors are being manufactured domestically. More sophisticated subsystems, such as the blades of large wind turbines and photovoltaic solar cells, must be imported.

Many of the renewable energy subsystems, such as support structures, towers, and storage tanks, are similar in construction to conventional equipment. These subsystems require various skill levels in metal forming, welding, plumbing, mechanical assembly, site preparation, concrete pouring, and other labor skills common to a range of conventional power systems. There will be, however, special training required for many aspects of renewable energy related equipment design, manufacture, installation, operation and maintenance. This will range from training engineers to design and size solar water heaters, to training personnel to maintain wind turbine units. Training facilities in the Solar Energy Laboratory at the

16

National Research Center and in the Ministry of Industry Vocational Training Centers, as well as in higher education institutions (e.g., Cairo University and Helwan Institute of Technology), could all be extended to handle this manpower training load.

2.2 Energy Overview

This section describes the energy demand and supply situation in Egypt.

2.2.1 Present Energy Demand

In 1980, total primary energy consumption in Egypt amounted to approximately 24.2 million tons of oil equivalent (MTOE), of which 76 percent was supplied by commercial energy sources and 24 percent by non-commercial sources. A breakdown of primary energy consumption by fuel type is provided in Exhibit 2.2. As demonstrated in this exhibit, oil accounted for 73 percent of commercial energy consumption, natural gas for nearly 11 percent, coal for nearly 5 percent (virtually all coal used in Egypt is imported), and hydropower for 11 percent. Crop residues accounted for the bulk of the non-commercial consumption (77%), with animal waste, fuelwood and animal power supplying the remainder.

Overall domestic oil consumption accounts for approximately 75 percent of all oil produced in the country and this is sold at only about 20 percent of the world price. Only 25 percent of the Government's share of oil produced is exported at world prices.

Exhibit 2.3 depicts traded energy consumed by sector. As evidenced, oil makes up approximately 77 percent of energy consumption, electricity 11 percent, natural gas 7 percent, and coal 5 percent. Sectorally, the industry sector accounts for 40 percent of trade energy, the commercial sector 20 percent the residential sector 18 percent, the transportation sector 17 percent, and the agricultural sector 5 percent.

EXHIBIT 2.2

PRIMARY ENERGY CONSUMPTION IN 1980

Source Commercial		MTOE	% Commercial	% Total
Oil		13.5	73.4	56
Gas		2.0	10.8	8
Coal		0.9	4.8	4
Hydropower		2.1	11.0	8
	Subtotal	18.5	100.0%	76%

Non-Commercial		MTOE	% Non-Commercial	% Total
Crop Residues		4.4	77.2	18
Animal Waste		1.1	19.3	5
Fuel Wood, Animal Power, etc.		0.2	3.5	1
	Subtotal	5.7	100.0%	24%
		=====	======	====
	TOTAL	24.2	100%	100%

EXHIBIT 2.3

TRADED ENERGY CONSUMPTION IN FINAL USES 1980 (MTOE)

Fuel / Sector	Oil	Natural Gas	Coal	Electricity	Total
Industry	3.5	0.7	0.7	1.0	5.9 (40%)
Transportation	2.5	-	-	-	2.5 (17%)
Residential	2.0	0.3	-	0.3	2.6 (18%)
Agriculture	0.7	-	-	0.1	0.8 (5%)
Commercial	2.7	0.1	-	0.2	3.0 (20%)
TOTAL	11.4 (77%)	1.1 (7%)	0.7 (5%)	1.6 (11%)	14.8 (100%) (100%)

* Source: National Strategy for Development and Utilization of New and Renewable Sources of Energy (NRSE), July 1982.

One of the most disturbing aspects concerning energy use in Egypt is the rapid growth in consumption of petroleum products and electricity in the country. As shown in Exhibits 2.4 and 2.5, the annual average growth in consumption was 13 percent for petroleum and almost 14 percent for electricity during the period of 1974-1980/81. This is a fairly critical situation in that over two-thirds of the Nile's hydropower is already developed, and domestic petroleum resources are projected to last only another 10-15 years. A major contributor to this growing energy usage is the substantial subsidies provided for both fossil fuels and electricity, which result in consumers only paying about 20 percent of the true market value for these products.

2.2.2 Projected Energy Demand

By the year 2000, total projected energy demand is expected to increase to approximately 65 million tons of oil equivalent. This amounts to about 2.7 times the primary energy consumption in 1980 of 24.2 MTOE. Energy demand is anticipated to occur as follows:

- Demand for electricity is planned to increase from 18.4 billion kWh in 1980 to nearly 105 billion kWh in the year 2000. This reflects more than a fivefold increase over this time period, and amounts to approximately 29 MTOE or close to half of the total projected energy consumption. The increased electricity demand stems from the strong emphasis in Egypt on electrifying rural areas and upgrading the standard of living in the country.

  A breakdown of electricity demand is expected to include 4.5 MTOE (15 billion kWh) or 14 percent from hydropower; 11 MTOE (40 billion kWh) or 38 percent from the installation of 10 planned nuclear plants; and 14 MTOE (50 billion kWh) or 48 percent from thermal generation by oil, natural gas or imported coal. Thus, nearly 36 percent of Egypt's projected electricity requirements are expected to come from nuclear plants, none of which are even under construction; oil and gas which are expected to be depleted in the next 10-15 years; and imported coal, which will further hinder the trade deficit.

- Direct consumption of oil and natural gas is expected to be on the order of 34 MTOE, or 52% of total primary energy consumption. Adding thermal electricity generation, primary demand for which is estimated at nearly 13-15 MTOE, the total oil and natural gas requirements would amount to nearly 50 MTOE. Exhibit 2.6 shows primary energy consumption for the year 2000.

EXHIBIT 2.4

Development of Electricity Generated and Maximum Load over 1974-1980

Year	POWER GENERATED (mill. kwh)			annual rate of growth
	thermal	hydraulic	total	
1974	2395	6120	8515	-
1975	3010	6790	9800	15%
1976	3640	8005	11645	18.9%
1977	4535	9040	13575	16.5%
1978	5140	9935	15075	10.5%
1979	6755	9710	16465	9.2%
1980	8629	9801	18430	11.9%

Annual Average Rate of Growth = 13.7%

EXHIBIT 2.5

Development of Oil Products Consumption
1974-1980/81

(000' tons)

Product	1974	1975	1976	1977	1978	1979	1980/81
Butane gas	160	179	211	248	296	339	408
Natural Gas	-	33	110	362	587	852	1810
Gasoline	579	672	747	837	954	1041	1219
Kerosene	1110	1188	1225	1305	1380	1486	1555
Diesel	1196	1335	1477	1633	1848	2040	2714
Gas Oil	3291	3639	4012	4292	4382	4840	5495
Other Products	345	343	369	394	560	541	924
Total Consumption	6681	7389	8151	9071	10007	11139	14125
Annual Rate of Growth	-	10%	10%	11%	10%	11%	27%

Average Annual Rate of Growth = 13%

EXHIBIT 2.6

PRIMARY ENERGY CONSUMPTION FOR THE YEAR 2000

	(million tons of oil equivalent)		
ELECTRICITY		29.5	45%
Hydropower	4.5		
Nuclear	11.0		
Thermal (oil, natural gas, coal)	14.0		
DIRECT CONSUMPTION			
Oil and Natural Gas		34.0	52%
NEW AND RENEWABLE SOURCES (Excluding hydropower which is addressed under electricity)		1.5	3%
TOTAL		65.0	100%

Source: "The Energy Situation in Egypt," Dr. Hussein Abdallah, Senior Under Secretary, Ministry of Petroleum.

- New and renewable sources of energy (excluding hydropower) are expected to provide approximately 3 percent of total primary energy consumption by the year 2000 or 1.5 MTOE.

2.2.3 Energy Supply Resources

Egypt has a broad range of resources currently available, however, many of these exist in only limited quantities. A brief summary of the major energy resources in Egypt is provided below, with a more detailed description of the country's renewable energy resources presented in Chapter 4.0.

Petroleum. Crude oil production began in Egypt on a significant scale in 1969, with oil exploration activities intensifying in 1973. Although reserve estimates vary widely, from approximately 400-600 million tons, it is generally agreed that domestic petroleum demand will exceed available supplies within the next 15 years unless significant new discoveries are made. Production in 1981-82 was approximately 35.5 million tons, up from 8.5 million tons in 1973. However, as previously mentioned, domestic consumption during the same period has grown from 6.5 million tons to nearly 13 million tons, and may reach 50 million tons by 2000. Most of the existing reserves in the country are concentrated in the Gulf of Suez, the Sinai Peninsula, and most recently, the Western and Eastern desert regions.

Natural Gas. The amount of natural gas produced and consumed in Egypt has rapidly increased from 33 thousand TOE in 1975 to nearly 2 MTOE in 1980, primarily due to discoveries of natural gas associated with increased oil production. Proven reserves of non-associated gas are approximately 250 billion cubic meters, with three major fields providing the bulk of natural gas production. These include: (1) Abou Madi, which lies in the northern part of the Delta and has an average daily output of 80 million cubic feet and 1,750 barrels of oil derivatives per day; (2) Abu El-Gharadeek in the Western Desert which has an average daily output of 95 million cubic feet with 3,500 barrels of oil derivatives

per day; and (3) offshore Abu Air, which lies in the Mediterranean Sea, and has an average daily output of 70 million cubic feet with an additional 1,500 barrels of oil derivatives daily. Natural gas is a basic source of energy for industries such as iron, steel, chemicals and fertilizers. It is anticipated that natural gas will play an increasingly important role in Egypt's energy mix.

Coal. Few coal deposits have been discovered in Egypt, with estimated reserves in the range of 80 million tons. The bulk of these reserves are located at the Al-Maghara coal mine in the Sinai, which has been recognized as having 35 million tons of recoverable reserves with an economic recovery potential. Coal reserves and carbonic materials also exist in the areas around the Gulf of Suez, with limited quantities available in the Sinai and Western Desert. Other coal deposits in the country have either not been characterized, have poor geological characteristics, or are not otherwise considered economical for exploitation at the present time.

Uranium/Thorium. Currently, neither uranium nor thorium are being produced in Egypt. Geological surveys performed since 1961 show that there are very small quanittites of uranium in the Eastern Desert, which are uneconomical to explore. Other studies have predicted that sizable amounts of uranium and thorium oxides exist in the Red Sea and Mediterranean. However, uranium recovery is presently uneconomical unless it is combined with a larger project to recover other minerals in these regions. Therefore, Egypt's national program to build nuclear power stations will depend on the importation of nuclear fuels.

Solar Energy. Egypt has a very high incidence of solar radiation that could be used as an energy source, due primarily to its location and dry climate. In the winter the sun shines for approximately 7-10 hours daily, while in the summer sunshine is available for 12 hours daily. Overall, there are 3,400 hours per year of solar availability in the north and 3,900 hours in the south.

Wind Energy. At least two regions in Egypt have sufficient average daily and annual wind speeds considered high enough for the development of wind power generators. These include: (1) the Mediterranean Sea coast which has an average annual wind speed of about 20 km/hr, and (2) the Red Sea coast with approximately 22 km/hr. Useable electric energy output in these areas is estimated to be 650 kWh per square meter of windmill swept area.

Currently, Battelle Pacific Northwest Laboratories, under contract to AID/Cairo, is conducting a wind resource assessment in Egypt to update and verify wind resource data for Egypt. Six sites have been selected for study, El Kasr, Um El-Rakham Village and Ras El Hekmaan on the Mediterranean Coast; and Hurghada, Ras Abu Ghusan, and Zafarana on the Red Sea Coast.

Biomass Resources. The major sources of biomass in Egypt include animal waste and agricultural residues, both of which are used in rural areas to provide fuel and fertilizers. Substantial quantities of urban refuse and sewage are also available and could be used as an energy source.

Geothermal Energy. There is now only limited information available on the extent of geothermal energy resources in Egypt. Low geothermal temperature gradients (15-20°C/km) exist in Northern Egypt, the Nile Delta, and the Western Desert, with deep wells at the Bahariya, Dakhla and Kharga oases tapping aquifers with temperatures of 35-43°C. High thermal gradients exist along margins of the Red Sea and Gulf of Suez, with valves of 21-50° C/km.

The potential for geothermal energy has also been noted by the presence of hot springs on the east and west sides of the Gulf of Suez, as well as in several other isolated locations throughout the country. Overall, it is estimated that Egypt has a geothermal potential of about 20 MWe.

Water Supply. The Nile River is the only significant source of surface water in Egypt. Since construction of the High Dam at Aswan, approximately 56 billion cubic meters (m^3) of water per year have been available for downstream

uses. The maximum yield of the Nile is estimated to be 73 billion m^3 which is just enough to meet projected agricultural (44 percent increase) and industrial (87 percent increase) requirements if conservation and irrigation efficiency programs are implemented.

The Nubian aquifer in the Western Desert also has a very large amount of high quality, nonrenewable groundwater suitable for irrigation and/or industrial purposes. Adjacent to currently populated areas, a quantity of brackish and other waste water equal to at least one-fourth of the annual flow of the Nile is available from irrigation returns, drainage canals, dewatering wells and municipal/industrial waste systems.

2.3 Five Year National Development Plan

The Detailed Frame of the Five Year Plan for Economic and Social Development 1982/83-1987/88, incorporates country and energy data into a comprehensive plan for increasing the productive capacity of the economy and improving the standard of living in Egypt. Although directed primarily to the current five year period, the Plan reflects the country's medium- and long-term objectives through the year 2000. Thus, the Plan provides the base for specifying the role that renewable energy technologies can play in assisting the GOE to achieve its national development objectives.

The major objectives set forth in the Plan are to increase levels of growth in the industrial and agricultural sectors, as well as to develop the supporting service sectors including energy, transportation and communications. To achieve these objectives, a number of activities are being pursued, as discussed below.

2.3.1 Agricultural Sector

- Increase agricultural productivity through vertical expansion and higher vegetable and fruit crop intensity. This will require improved irrigation and drainage.

- Increase output of livestock, poultry, fish and beef feed lots.

- Reduce losses in agricultural output by improving facilities for food processing and refrigeration.

- Increase land reclamation and cultivation, particularly in the Sinai, Red Sea, Western Oasis (New Valley) and northwest coastal areas.

2.3.2 Industrial Sector

- Conduct balanced and integrated growth of the industrial sector and the other sectors of the economy, particularly the electricity sector. To date, power cuts have hindered the achievement of production targets in many industries.

- Increase production of construction materials, e.g., cement, brick, glass etc.

- Expand and diversify industries providing products for local consumption (e.g., food and clothing) and export (e.g., cement, gypsum and fertilizers).

- Increase production of biogas from farm waste.

- Increase production of solar equipment and appliances.

2.3.3 Energy Sector

- Reduce local use of petroleum and petroleum products in order to increase their export, as well as to generate revenues for offsetting the trade deficit.

- Maintain sufficient reserves of various energy sources to satisfy the expected increase in demand for energy.

- Increase the development of various energy sources, particularly petroleum, through intensifying exploration and survey efforts.

- Acquire modern and appropriate technology for the utilization of alternative energy sources, in order to reduce the burden on non-renewable sources.

2.3.4 Transportation and Communication Sector

- Expand transportation and communication networks to all regions of the country, particularly the new population communities.

- Rationalize the consumption of oil products in the transporation and communication sectors.

- Renovate railroad lines and maintain bridges.

2.3.5 Housing and New Communities

- Improve sanitation facilities in the country, particularly in urban areas.
- Reduce the population in urban areas through the establishment of new communities in the desert, rural and coastal areas. Also, establish residential areas around the major cities and non-cultivable land.
- Provide adequate energy to new communities. Currently, only 50 percent of rural households have access to the grid, leaving over 3 million households with no grid connected power.
- Increase supplies of potable water for rural areas and new developments.
- Expand health, educational, cultural and recreational facilities in rural areas; promote rural industries; and create employment opportunities in rural areas.

2.3.6 Environment

- Protect the environment from pollution emanating from industry, agriculture and consumption.

2.3.7 Trade Balance

- Offset the trade deficit by increasing exports of goods and services, substituting local products for imports, and rationalizing consumer imports, particularly luxury products.

2.3.8 Employment

- Increase employment in the country.
- Achieve a better distribution of population between rural and urban areas.
- Enhance Egypt's scientific and technological resource base.

Exhibit 2.7 depicts the level of investment associated with the major development areas identified in the Five Year Plan.

2.4 Role for Renewables in the Five Year Plan

Renewable energy technologies can contribute significantly to meeting the objectives established for the current five year planning period and beyond, in a number of ways.

EXHIBIT 2.7

EVALUATION OF GOVERNMENT PRIORITIES BASED ON PUBLIC SECTOR INVESTMENT TARGETS (1981-87)

SECTOR	RECIPIENT AGENCY	INVESTMENT (1000's of 1981/82 LE)	INVESTMENT % TOTAL
INDUSTRY	- FOOD INDUSTRY COMPANIES - SPINNING & WEAVING & CLOTHES CO. - WOOD INDUSTRY CO. - PAPER CO. - CHEMICAL INDUST. SECTOR CO. - CERAMIC, PORCELAIN & POTTERY CO. - MINERAL INDUST. SECTOR CO. - ELECTRONIC & ENGIN. INDUST. SECTOR - MINING SECTOR CO.	7,575,000	24%
SUPPORT SERVICES -ELECTRICITY	- ELEC. AUTHORITY & DISTRIB. CO. - ELEC. PROJECTS CO. - TRANSFORMERS & ELEC PROD. CO.	5,421,200	17
-PETROLEUM	- PETROLEUM PROD. CO. - REFINERY & PETROL. PROD. CO. - DISTRIBUTION CO. - TRANSPORT CO.	3,415,800	11
-COMMUNICATION	- NATIONAL AUTH. FOR COMM. - NATIONAL AUTH. FOR POST - TELEPHONE EQUIPMENT CO.	2,065,100	6

29

EXHIBIT 2.7 (Cont.)

EVALUATION OF GOVERNMENT PRIORITIES BASED ON
PUBLIC SECTOR INVESTMENT TARGETS (1981-87)

SECTOR	RECIPIENT AGENCY	INVESTMENT (1000's of 1981/82 LE)	INVESTMENT % TOTAL
HOUSING	- NAT. AUTH, FOR SEWAGE - HOUSING & CONSTRUC. CO. - CONSTRUC. CO. - CEMENT CO. - BUILDING MATERIALS CO.	4,410,700	14
RECONSTRUCTION	- CONSTRUCTION CO. - READY-MADE CLOTHES CO.	3,294,500	10
IRRIGATION	- IRRIGATION CO.	1,882,300	6
LAND RECLAMATION	- RECLAMATION COMPANIES - AGRICULTURE COMPANIES	1,552,500	5
HEALTH	- CHEMICAL & MEDICINE CO. - MEDICINE TRADE CO.	1,171,200	4
AGRICULTURE	- AGRICULTURAL COMPANIES - ANIMAL PRODUCTION COMPANIES - FISH PRODUCTION COMPANIES	885,200	3
		31,673,500	100%

First, renewable energy technologies can supply thermal energy (active/passive solar, biomass, geothermal, municipal solid waste, solar ponds and solar thermal), mechanical energy (wind), and electricity (biomass, geothermal, municipal solid waste, photovoltaics, solar ponds, solar thermal, and wind energy) for a broad range of applications. For example, in the agriculture sector, renewable technologies can provide energy for a number of priority areas identified in the Plan, including water pumping, irrigation, and desalination required for land reclamation and cultivation; food and crop drying; refrigeration; and general electrical power requirements for increasing productivity in target agricultural areas. In the industrial sector, renewables can be used for electricity generation, food processing, industrial processing, building heating and cooling, and sterilization, among others. Furthermore, renewables are particularly well suited to supplying energy needs of the new communities and satellite villages being developed in the desert, coastal and adjacent urban areas that are not included in the country's rural electrification plans. At these sites, renewables can provide non-grid connected power for lighting, cooking, cooling, desalination, refrigeration, sanitation, remote communications, cathodic protection, educational and health facilities, community centers, and general village power requirements. Additionally, in most cases, renewable technologies provide this power at lower costs than competing alternatives such as diesel, butagas and kerosene.

Second, renewable technologies make use of readily available and cost-free solar and wind resources base in Egypt, and thereby can replace petroleum and petroleum products in a number of agricultural, industrial and residential applications. Thus, extensive use of renewables frees up valuable petroleum commodities for export. This contributes to the Plan's objective to increase petroleum export revenues in order to offset the country's substantial trade deficit.

Third, renewable technologies provide significant opportunities for local employment through the manufacture, installation, operation and maintenance of these systems in the country. This accommodates the Plan's objectives to promote local industries, substitute local products for export, increase employment opportunities in the urban and rural sectors, and expand the country's scientific and technological base.

Lastly, renewable technologies are generally pollution free, thus providing a reliable and stable energy source that satisfies Egypt's environmental standards and requirements.

In summary, renewables can make a major contribution to the country's development objectives and should be strongly considered and promoted by GOE decision-makers. The following chapters discuss in detail the most appropriate renewable energy technology/application options based on the country's characteristics and development plan objectives.

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3.0 APPLICATIONS CHARACTERIZATION

This section discusses the equipment used, the energy use profiles and energy requirements for a number of applications that could effectively utilize renewable energy technologies. It also describes the extent to which these applications are, or could be in use in Egypt. The applications described are the following:

- o Water pumping
  - Irrigation
  - Human water consumption
  - Livestock water consumption
  - Land reclamation and industrial applications
- o Livestock operations
  - Poultry
  - Beef Feedlot
  - Dairy farm
- o Urban energy requirements
- o Remote communications
- o Cathodic protection
- o Industrial/agricultural process heat
- o Building climatization

The purpose of the application characterizations is to determine the suitability of renewable energy technologies as potential sources of energy for the above applications. These applications were selected after discussion with Egyptian Government officials and after determining the government priorities as described in the Five Year Development Plan. It excludes the applications included in the original eleven candidate field tests.

3.1 Water Pumping Applications

Water pumping applications include irrigation, livestock watering, human consumption, land reclamation, and industrial applications. Each of these applications are characterized by the quantity of water required, and sometimes by the seasonal variation in the water requirements.

3.1.1 Demand Characterization

3.1.1.1 Irrigation

Irrigation requirements for crops are governed by a number of factors including: the type of crop, crop growth cycle, climatic conditions (temperature, rainfall, humidity, wind and cloud cover), type and condition of the soil, land topography, field application and water conveyance efficiencies, and cropping practices. Exhibit 3.1 shows the consumptive use water requirements for a variety of crops grown in the Delta, Middle Egypt and Upper Egypt. The variation in water use between regions is due to the factors mentioned above. Water requirements for irrigation can, and often do vary substantially from month to month. Exhibit 3.2 shows the unit water requirements in the Nile valley and Delta. It varies from a high of about 80 m^3/day/hectare in the July to September period to a low of about 30m^3/day/hectare in January. The water demand may not necessarily match renewable energy resource availability. That is, months with higher insolation or wind speeds may not coincide with high water demand months.

Energy required for pumping is a function of pumping head, volume of water supplied and irrigation method. Irrigation method is a major determinant of energy needed for pumping due to the variations in the water application efficiency and water pumping pressure needed for the various irrigation techniques. Exhibit 3.3 shows water requirements, pumping head and energy requirements for irrigation in the New Lands Project. Water requirements are based on climatic conditions as well as selected crops and cropping patterns for each area under cultivation.[1] Unit energy requirements range from 40 kWh/fd/year (100 kWh/hectare) to 1,194 kWh/fd/year (3000 kWh/hectare) for off-farm pumping

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[1] For details see: Ministry of Irrigation and UNDP, (1984). Consumptive Use of Water by Major Field Crops in Egypt. Technical Report No. 17 and Technical Report No. 24, op. cit.

EXHIBIT 3.1

CONSUMPTIVE USE WATER REQUIREMENTS IN EGYPT

Crop	Cubic Meters/Fd. Net Cultivated Area		
	Delta	Middle Egypt	Upper Egypt
Winter Crops			
Wheat	1610	1990	2195
Bareley	1610	1990	2195
Lentils	1505	1505	1620
Lupines	1505	1505	1620
Fenugreek	1505	1505	1620
Horsebeans	1280	1570	1830
Sugarbeets	1620	1935	2720
Tomatoes	1620	1625	1860
Potatoes	1620	1625	1860
Green pees	1525	1545	1605
Strawberry	1525	1545	1605
Long berseem	2360	2845	3120
Flax 1410	1410	1410	1510
Summer Crops			
Sorghum	2430	2755	2755
Maize	2430	2610	2800
Rice(planting)	4545	4690	4895
Groundnuts	1870	1870	2350
Soybeans	2230	2585	3090
Sun flower	1810	1915	2000
Sesame	1810	1915	2000
Tomatoes	1825	1880	2055
Potatoes	1825	1880	2055
Melons	1825	1880	2055
Green corn	2430	2610	2800
Sweet corn	2430	2610	2800
Cow peas	2430	2610	2800
Fodder sorghum	2430	2755	2755
Fruit Trees			
Mangoes	3975	4145	4375
Guava	3975	4145	4375
Olives	3975	4145	4375
Grapes	3975	4145	4375
Citrus	5005	5185	5410
Date palm	5830	6870	8695
Wood trees	3975	4145	4375
Perennial Crops			
Mapler grass	6610	7795	9910
Alfalfa	6610	7795	9910
Sugarcane	7170	7170	9110

Assumptions: Net cultivated area is 85% of gross area. For rainfed areas 200 mm of water depth is subtracted. Field application efficiencies are as follows: 70% for surface irrigation; 85% for sprinkler irrigation; and 95% for drip irrigation. A 10% loss in the main conveyance system is assumed. For mixed water systems; 10% is added to the consumptive use values for leaching.

Source: Ministry of Irrigation and UNDP. (1984). An Economic Evaluation of New Lands Projects in the National Five Year Plan, 1982/83 - 1986/87. Technical Report No. 24 UNDP-EGY/81/031.

EXHIBIT 3.2.

UNIT WATER REQUIREMENTS IN THE NILE VALLEY AND DELTA

	Water Requirements per Month		
Month	m^3/Feddan	m^3/Hectare	m^3/Day/Hectare
January	350	897	29
February	503	1,290	46
March	507	1,300	42
April	508	1,302	43
May	673	1,725	56
June	797	2,043	68
July	958	2,456	79
August	946	2,425	78
September	923	2,366	79
October	883	2,264	73
November	634	1,625	54
December	521	1,336	43
Annual	8203	21,031	

Modified from: U.S.G.S. (1979) Joint Egypt/U.S. Report on Egypt/U.S. Cooperative Energy Assessment, Volume 2. DOE/IA-002/02

Exhibit 3.3

ESTIMATED IRRIGATION WATER AND PUMPING ENERGY REQUIREMENTS FOR THE NEW LANDS PROJECTS

PROJECT NAME	GROSS IRRIGATED AREA FEDDANS	WATER DUTY M3/FD/YR	PUMPING HEAD (M) OFF-FARM	PUMPING HEAD (M) ON-FARM	TOTAL WATER REQUIRE. MILL.M3/YR.	TOTAL ENERGY REQUIREMENTS THOUSANDS KWH/YR OFF-FARM	TOTAL ENERGY REQUIREMENTS THOUSANDS KWH/YR ON-FARM	UNIT ENERGY REQUIREMENTS KWH/FD/YR OFF-FARM	UNIT ENERGY REQUIREMENTS KWH/FD/YR ON-FARM
WEST NUBARIA	20,370	5,400	45	60	110	13,500	17,985	663	883
NEW AREAS	31,370	6,000	45	40	188	23,055	20,465	735	652
WOOD COMPANY	2,000	5,400	45	60	11	1,350	1,800	675	900
VEGETABLE FARM EXTENSION	1,630	7,300	45	2	12	1,470	65	902	40
SPECIALIZED FARM EXTENSION	1,600	5,400	45	60	9	1,105	1,472	691	920
WITHIN SUGAR BEETS	2,400	3,800	45	40	9	1,350	1,200	563	500
EAST BITTER LAKE	3,700	5,400	8	60	20	436	3,270	118	884
ADLIA	13,000	5,400	55	60	70	10,490	11,445	807	880
MARSHDA	16,000	6,480	28	60	104	7,935	17,004	496	1,063
ABO-MHADY & KALABSHO	20,000	8,030	6	2	161	2,616	872	131	44
SAFF, GHAMMAZA & ATFEEH	24,000	4,180	23	40	100	7,646	13,300	319	554
BALTEEM & KHASHAA	7,000	8,030	6	2	56	916	305	131	44
BOROLLOS DRYING	12,100	8,030	6	2	97	1,586	529	131	44
YOUTH PROVINCE	22,000	4,180	50	40	92	14,715	11,772	669	535
GHARRAET SHOEB	2,000	7,300	5	2	15	205	82	103	41
HAFEER EXTENSION	4,000	7,300	2	2	29	158	158	40	40
RAMSIS COMPANY	9,600	3,800	30	40	36	3,434	4,578	358	477
NEW MIT ABOUL-KOUM	5,000	5,400	8	60	27	590	4,415	118	883
EL KHATTARA	1,400	5,400	14	60	8	305	1,308	218	934
KHAREET VALLEY	3,600	8,760	20	2	32	1,855	185	515	51
ARAKI & EAST QUOSS	1,000	6,480	20	60	6	382	1,145	382	1,145
SANITARY DRAINAGE EAST	2,000	4,180	6	40	8	164	1,090	82	545
ISMALIA CANAL RIGHT BANK	1,400	3,800	5	40	5	82	654	59	467
HOSSEINEYA SOUTH	50,000	8,030	7	2	402	7,668	2,191	153	44
HOSSEINEYA NORTH	40,000	8,030	7	2	321	6,123	1,750	153	44
S. PORT SAID PLAIN	30,000	8,030	7	2	241	4,597	1,314	153	44
SOUTH OF PORT SAID	30,000	8,030	7	2	241	4,597	1,314	153	44
SALHIA DESERT	35,000	5,400	14	60	189	7,210	30,902	206	883
CAIRO-ISMALIA ROAD	17,000	4,180	6	40	71	1,373	9,156	81	539
EL MANAYEF	17,000	5,400	8	60	92	2,007	15,042	118	885
EZBET EL BORG	6,000	7,300	2	2	44	240	240	40	40
AL-BOSTAN	50,000	4,600	5	50	230	3,134	31,610	63	632
BARSEEQUE	5,000	8,030	6	2	40	654	218	131	44
WEST OF SUEZ	10,000	5,400	10	60	54	1,472	8,829	147	883
MATARIA	8,000	8,030	6	2	64	1,046	349	131	44
SANITARY DRAINAGE W.C.	6,000	4,180	6	40	25	507	3,379	85	563
EAST BAHR WAHBY	5,000	5,400	15	60	27	1,104	4,415	221	883
SOUTH QUARDUN	7,000	5,940	8	60	42	916	6,867	131	981
WEST BENI-SUEF	5,000	5,400	20	60	27	1,472	4,415	294	883
WEST GERGA	5,000	5,400	20	60	27	1,526	4,578	305	916
EAST ASSUIT	5,000	5,400	20	60	27	1,472	4,415	294	883
EAST AWALAD TOUQUE	10,000	6,480	20	60	65	5,543	10,628	554	1,063
EL-SAAYDA VALLEY	15,000	8,760	45	2	131	17,903	796	1,194	53
IF & REC. SUGAR BEETS	48,000	7,300	45	2	350	43,041	1,913	897	40
IF & REC. SPECIALIZED	8,000	7,300	45	2	58	7,112	316	889	40
REC. SCATTERED AREAS- N. COAST	10,400	3,000	55	40	31	5,096	3,706	490	356
EL-AREESH	1,000	3,800	50	40	4	545	436	545	436
BARIS, KHARGA & DEKHLA	1,500	8,760	50	2	13	1,771	71	1,181	47
EL ZAYYAT	600	8,760	50	2	5	681	27	1,135	45
FARFRA & ABO-MENKAR	1,200	4,560	50	40	5	1,090	872	908	727
EL LAQUITA VALLEY	500	4,560	50	40	2	409	327	818	654
SENNANEYA & OMDONGOL	2,000	7,300	2	2	15	93	93	47	47
TOTAL	636,370	6,119	23	33	4,049	225,745	265,268	355	417
RANGE									
-MAXIMUM	50,000	8,760	55	60	402	43,041	31,610	1,194	1,145
-MINIMUM	500	3,000	2	2	2	82	27	40	40

ASSUMPTIONS : For the three Delta regions (East, Middle & West) and the Middle Egypt region except Assuit governorate, water duties for fresh water irrigation are : surface irrigation, 7300; sprinkler, 5400; and drip, 3800 (cubic meters/feddan/year). For Assuit, Upper Egypt and New Valley the above figures are increased by 20% due to climatic conditions. When drainage water, mixed drainage or sanitary drainage are used with fresh water, water duty is increased by 10%. In rain-fed areas, 800 cubic meters/feddan/year is deducted from water duties. Dynamic heads required for irrigation are as follows : surface irrigation, 2m; drip, 40m; and sprinkler, 60m.

SOURCE : MINISTRY OF IRRIGATION & UNDP. (1994). AN ECONOMIC EVALUATION OF NEW LANDS PROJECTS IN THE

37

to 44 kWh/fd/year to 1,140 kWh/fd/year for on-farm pumping. On-farm pumping head is primarily determined by the type of irrigation method used. Off-farm pumping head is determined principally by the head difference between the water source and demand points. Total annual irrigation energy requirements for New Lands Projects is 491,000 MWh. The energy requirements are approximately equivalent to the energy output from a 100 MW baseload power plant.

The New Lands Project data has been reported only to indicate water and energy requirements; it is unlikely that these lands will be suitable for the renewable energy pumping systems since power for irrigating the New Lands Project areas will be supplied by the unified grid.

3.1.1.2 Livestock Watering

Livestock water requirements are easier to compute than irrigation water requirements. The volume of water required is simply the product of water consumed per head multiplied by the number of animals. Typical water requirements for livestock are shown in Exhibit 3.4. During the summer months, when temperature is highest and the fodder is driest, the water requirements could be greater. For example, water requirements for sheep and goats would increase to about 8 liter/day, and for cattle to about 40-60 liters/day.

Typically, to prevent overgrazing in the locality of the water hole, each water point should not serve more than 500 cattle or about 2000 sheep or goats. Average annual water requirements for cattle, dairy cattle, sheep and goats are shown in Exhibit 3.5.

The Water Master Plan assumes that a stereotypical herd consists of 600 cows (480 active, 120 culled), 424 heifers and steers and 632 calves. The water requirements for such a herd would be about 70 cubic meters/day or about 15,000 cubic meters/year. This herd would annually consume 19.28 MT of green fodder, 3.08 MT of straw, 2.79 MT of compound feed and 0.46 MT of hay. The annual

EXHIBIT 3.4

TYPICAL WATER REQUIREMENTS

Animal	Water Requirements Liters/Day
Horse	50
Dairy Cattle	40
Cattle	20
Pig	20
Sheep	5
Goat	5
Poultry	0.1

EXHIBIT 3.5

ANNUAL WATER REQUIREMENTS PER WATER POINT

Herd	Water Requirements (cubic meters)
500 Dairy Cattle	7300
500 Cattle	3650
2000 Sheep or Goats	3650

output of the herd would be 1,248 MT of milk, 185.58 MT of meat and 15,582 MT of manure.

3.1.1.3 Human Consumption

Domestic water requirements vary considerably as a function of water availability. A World Health Organization (WHO) survey in 1970 showed that water consumption in developing countries averaged about 35 to 90 liters/day/person. In contrast, urban areas in Egypt consume about 180-200 liters/person/day for domestic uses. Water consumption for all uses in desert industrial cities are expected to be about 1000 liters/person/day. The Five Year Development Plan expects to provide 150 liters/person/day of water in rural areas.

3.1.1.4 Land Reclamation and Industrial Application

These applications are both site and application specific. In general, land reclamation requires low head, high volume pumping. The World Bank project for drainage in the Nile Delta region plans to use pumps with capacities ranging from 1-5 m^3/second. The pumping power requirements are about 0.14 kW/fd (0.36 kW/hectare). The World Bank project uses 14 pumps to drain 600,000 feddans. These pumps are expected to operate 18 hours per day for 325 days/year. Total land area to be drained ultimately is estimated to be about 2.8 million feddans.

Water pumping for an industrial application would occur if the plant does not have access to pipe borne water or requires effluent water pumping. The water requirement for industry in Sadat City is expected to be about 100 liters/day/person, for a total daily consumption of 100,000 m^3/day.

3.1.1.5 Energy Requirements for Pumping

Energy requirements for water pumping is a function of quantity of water pumped, pumping head and pumping efficiency.

Energy supplied to the pump is given by:

$$E = \frac{V\ h}{366e} \quad kWh$$

Where e = Efficiency of the pumping system

E = Energy required in KWh

h = Hydraulic head in meters

V = Volume of water pumped in cubic meters

Exhibit 3.6 shows the relationship between quantity of water pumped, pumping head, and energy requirements.

For example, it shows that 500 cattle which need 3650 cubic meters of water per year (line A on graph), requires about 2000 kWh of pumping energy (line B on graph) annually when the pumping head is 100 meters. This energy can be supplied by a PV array of about 11.4 sq. meters, a 1.6 kW wind turbine, or a biogas generator which is supplied by 5 cows (line C on graph).

3.1.2 Need in Egypt[2]

Currently 6.3 million feddans are cultivated. Other areas which can be reclaimed and cultivated in the near-term, if the necessary water resources, material and labor can be found, is about 2.8 million feddans. In the long-term, an additional 5.5 million feddans can be cultivated, of which 3.5 million border the Delta, 50,000 are west of the Delta, and 1 million feddans are in the oases. Lands which can be irrigated through raising the Nile water (maximum 8 m) is about 4.9 million feddans. Specifically, the area targeted for agriculture development in the Five Year Development Plan are as follows:

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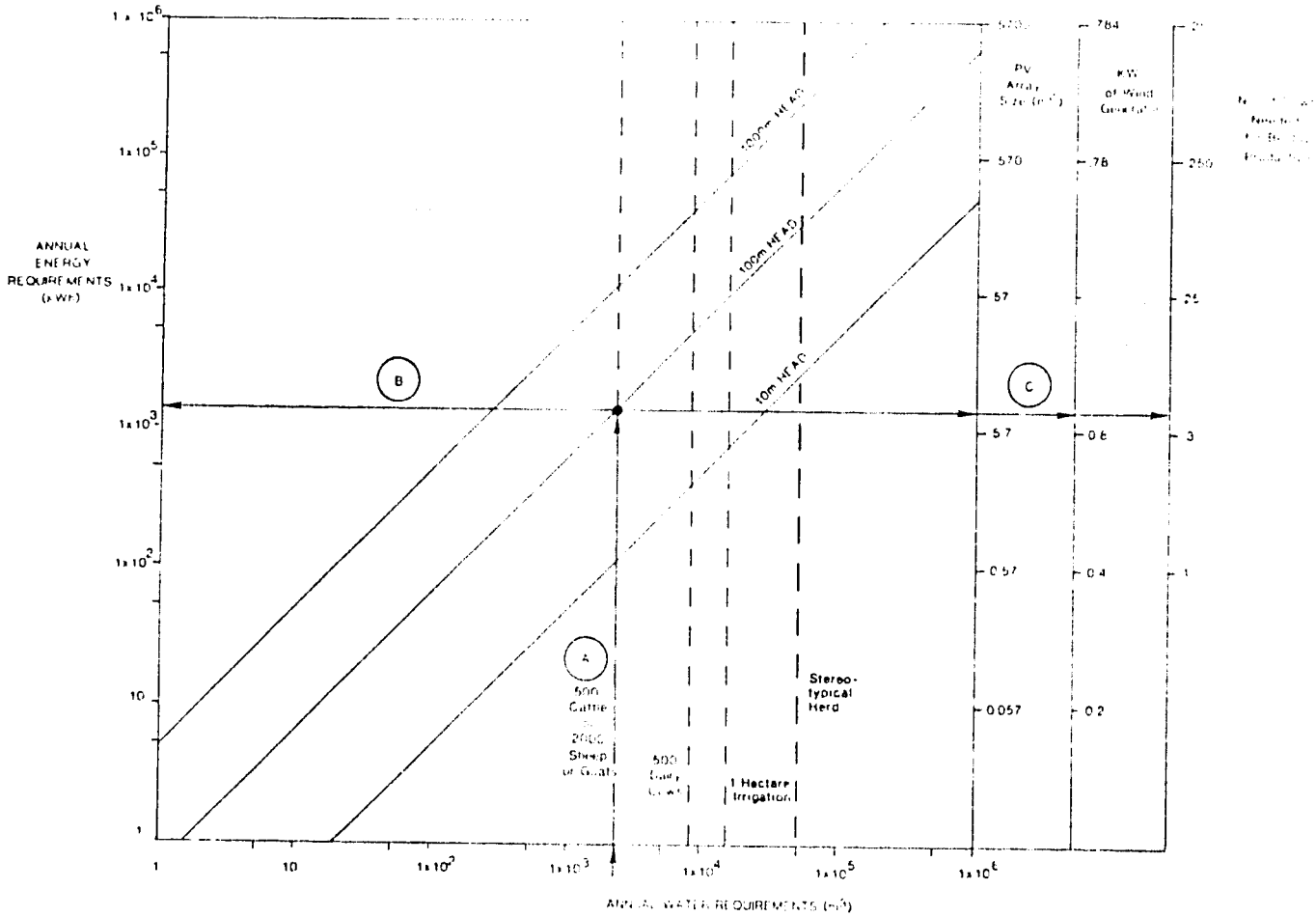
[2] Sources:. State Information Service, (1983) Agriculture in the Arab Republic of Egypt, Ministry of Information.

The American University, (1983) Egypt: A Country Study, U.S. Government Printing Office.

GOE/DOE, (1979) Joint Egypt/U.S. Report on Egypt/U.S. Cooperative Energy Assessment DOE/IA-0002/03.



Assumptions

1. PV array size is based on the output from a 72 wattp ARCO Solar PV module sited at Wadi El Ruwayan, in the worst energy output month (November)

2. Wind generators power output is based on the energy output characteristics of a Jay Carter Model 25 wind turbine (30 kW) located at Hurghada in the worst energy output month (November)

3. Number of cows needed for biogas production is based on 400 kWh equivalent of energy being produced annually by one cow (or equivalent)

4. Pump efficiency is 50 percent.

Important: These equivalencies should be used only to obtain order-of-magnitude values. Site technology, and application specific analyses should be conducted when preparing conceptual designs or conducting feasibility studies.

EXHIBIT 3-6
RELATIONSHIP BETWEEN WATER REQUIREMENTS, PUMPING HEAD, ENERGY REQUIREMENTS, AND PV, WIND AND BIOGAS GENERATOR REQUIREMENTS

- The North Western Coast:

  This coast extends 500 kms, from the city of Alexandria to the town of Sallum. 15,000 feddans have already been reclaimed (Maryut Extension Project). Potentially arable area is estimated at about one million feddans.

- Sinai:

  The most fertile portion of the Sinai are in the Al-Arish valley to the east. The Sinai has 15 million feddans of land which needs to be studied extensively to determine its suitability for agriculture production.

- The Red Sea:

  An area estimated at 284,000 feddans, on the shores of the High Dam lake may be cultivated through basin irrigation. Another area estimated at 264,000 feddans may be reclaimed through perennial irrigation.

- West Oases (The New Valley):

  The cultivable area is estimated at about 3 million feddans.

- Northern Lakes

  The cultivable area is estimated at about 350,000 feddans, if drainage systems are installed.

Currently, nearly all the available land is under perennial irrigation and double cropping. Therefore the need for mechanical pumping (both high and low head) is high.

The total energy consumed for all irrigation (including drainage) in Egypt in 1978 was approximately 1.9 billion kWh, with a modest growth to 2.3 billion kWh by 1985. Irrigation water sources can be subdivided into three categories: 1) pumping from primary and secondary canals, 2) pumping from tertiary canals and 3) pumping from isolated wells or regional reservoirs. The first two are, of course, confined to the Nile Valley and Delta.

Total off-farm and on-farm annual irrigation energy requirements in the New Lands Project is expected to be 226 and 265 x 10^6 kWh respectively (See Exhibit 3.3 for energy requirements details).

Off-farm pumping, such as pumping from primary and secondary canals, is a major responsibility of the Ministry of Irrigation. There are between 1,000 and 1,200 pumping stations with a total capacity of 700,000 horsepower. About 95 percent of the pumping stations were electrified with an annual consumption of 600 million kWh.

Pumping from tertiary and small channels (on-farm) is in private hands using animal drawn pumps and small diesel and electric pumps (approximately 10-20 hp). There were about 82,000 small pumps used for irrigation in the Nile Valley and Delta; most were diesel. About 100,000 tonnes of diesel fuel are estimated to be consumed annually. The Ministry of Irrigation is encouraging the private sector to shift from diesel to electric pumping. In work done by Louis Berger, International, Inc., the tertiary pumping electrification of middle and upper Egypt was seen to require 28,475 low lift pumps and 835 high lift pumps. This is part of the Egyptian Government's plans to eliminate gravity irrigation by lowering canal water levels and thus redressing the twin problems of rising ground water levels and increasing soil salinity.

Pumping from isolated wells and regional reservoirs is found throughout Egypt, generally outside the Nile Valley and Delta and particularly on the Mediterranean Coast west of Alexandria.

In the Western Desert, there is significant potential for increasing agricultural land. Currently 45,000 feddans are under cultivation. By the year 2025, 500,000 feddans could be cultivated. Water requirements would increase from 358 million cubic meters per year to 1280 million cubic meters. Water pumping energy requirements would increase from an average of 7 wh/m^3 to 300 wh/m^3 due to drawdown, since less accessible water would have to be used. Total annual energy requirements would increase from 2.5 million kWh to 384 million kWh.

The irrigation development projects in experimental farms in Giza, Kafr Al-Sheikh, Al-Minya, Wadi Al-Natrun and Inshas may be appropriate for conducting renewable energy field tests for irrigation applications.

The Five Year Development Plan aims at developing the water supply and sanitary sewage utilities throughout the country. The plan calls for expanding the capacity of existing water stations to meet increasing demand and also increase storage capacities to meet peak demands. The plan expects to increase per capita consumption of water in rural areas to 150 liters per day.

The Five Year Development Plan expects to develop the Western Desert and other areas outside the Delta and Nile Valley. Many of these outlying villages would require water for human and animal consumption and for irrigation. By the year 2000, 6.4 million households are expected to be in rural areas. At a per capita water consumption of 150 liters/day, annual water requirements in rural areas for human consumption alone will be about 17.5 billion cubic meters. Energy required to pump this quantity of water would be about nearly 250,000 MWh (assuming 25m head and 50% pump efficiency) which is equivalent to a 50 MW base load power plant.

The livestock industry, particularly, cattle, dairy and poultry, are important industries in Egypt. The livestock and poultry operations are potential markets for renewable energy pumping systems, particularly the biogas based systems due to this ready availability of manure.

3.2 Livestock Operations

3.2.1 Demand Characterization

Livestock operations characterized are poultry (broilers [chicken meat], and egg production), dairy farm and a beef feed-lot. These are three important livestock operations in Egypt. For the purpose of estimating electrical energy use in livestock operations, typical activities are grouped under several

general categories:

- o Sheltering
  - ventilation, heating or cooling
  - lighting
  - waste disposal
- o Feeding
  - solid food
  - water
- o Product Handling
  - These are product specific. For example, milking, milk cooling, egg handling.

The following sections will describe the factors influencing each of the activities mentioned above.

3.2.1.1 Sheltering

Ventilation requirements for livestock are governed by the type, age and size of animal; type of building; density of animals in enclosures; and outdoor temperatures and relative humidity. Thus, the energy requirements are animal and site specific. For the purpose of this study, applications such as air conditioning units, ventilation fans, or electric brooder lamps (if used) are considered.

Energy used for lighting depends on the types of animal and on the availability of natural light, the latter being a function of building design.

Waste disposal techniques, too, depend on the type of animal and the shelter design. Tractors or human labor could be used to dispose of waste, however, electrically driven pumps, cleaner arms, augers, conveyors, etc. can also be used.

3.2.1.2 Feeding

Feed requirements depends on the type of livestock, their age and size, type of feed used, and environmental conditions. Mechanization of feeding could be through the use of either tractors or automated conveying systems.

Water requirements for livestock also depend on the factors described above. Mechanization generally consists of a water pumping system.

3.2.1.3 Product Handling

This includes egg handling, grading, and cooling for a poultry operation, or milking parlor operation in the case of a dairy.

The BDM Corporation in a study[3] of photovoltaic use in U.S. agriculture identified the energy required for various livestock operations.

Energy estimates were obtained for each of the above operations. This data was used to calculate the electrical energy requirements per unit of product, and is shown in Exhibit 3.7. For the stereotypical dairy herd described previously, total electrical energy requirements are about 160 MWh/year (1248 MT of milk* 120 kWh/MT/year + 185.58 MT of meat* 40 kWh/year).

The poultry industry is a highly developed industry in Egypt. The General Poultry Company (GPC) is responsible for all government sector poultry operations. The private sector also plays a very active role in both egg and chicken meat production. The following poultry operation characterizations are based on discussions with Dr. Ezzat Abdel Hamid, General Manager, General Poultry Company.

- All GPC broiler and layer operations are fully automated. They use both open and closed ventilation systems. Automatic operations include feeding, watering, ventilation, manure collection (for layers), egg collection and egg grading.

- Each broiler house contains 12,000 to 15,000 birds and each farm contains about 8 to 12 houses. The GPC broiler operations produce 30 million broilers per year. The private sector broiler houses are smaller, they contain about 5,000 birds per house. However, the private sector produces about 120 million broilers per year. Based on data in Exhibit 3.7 annual electrical energy requirements for a GPC broiler farm is about 146 MWh, (assuming a 2 month growth cycle, and a 2 kg of chicken meat yield/bird).

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3 Mengel, R.W. et.al. Photovoltaic Applications Definition and Photovoltaic System Definition Study in the Agricultural Sector. Final Report, Volume III. SAND 79-7018, August 1978.

EXHIBIT 3.7

ELECTRICAL ENERGY REQUIREMENS FOR LIVESTOCK OPERATIONS

OPERATION	TOTAL ANNAUL ELECTRICAL ENERGY REQUIREMENTS IN ALBAMA, USA
	KWH
Beef feed-lot	40/MT of Meat
Dairy Operation	120/MT of Milk
Eggs Production	10.5/1000 eggs
	2.4/layer
Broilers	90/MT of Meat

Source: Mengel, R.W., O.H. Merrill, et al (1978) op. ct.

- A typical GPC layer operation has 10,000 birds per house. There are 100 GPC layer farms, each containing 3 to 4 houses. The private sector layer operations are smaller, and they are less automated. The typical private sector layer house has 2,000 to 3,000 birds. Based on data in Exhibit 3.7, annual electrical energy requirements for a GPC layer farm is about 96 MWh annually.

- GPC parent farms in Egypt produce 150 million pullets annually. They supply both the private sector (120 million) and the GPC broiler farms. The parent farms use No. 2 fuel oil for brooder heating.

- Broilers are kept on concrete floors lined with straw. Manure collection occurs at the end of the two month growth cycle when the manure and straw are removed and fresh straw is laid on the floor.

- Layers are kept on wire mesh. Manure is collected into pits by automatic sweeps. Manure from layer operations are presently sold as fertilizer. About 40 to 50 percent of the manure produced can be sold. The remainder is burnt.

- All farms are in electrified areas. However, since a reliable power supply is essential due to the ventilation, feeding and other critical requirements, all farms have backup diesel generators. Each layer farm has two 500kW generators and each broiler and parent farm has two 250kW generators. One is the primary generator and the other is the backup. These generators have to be used quite frequently.

For a 250 head beef feedlot, total electrical energy requirements would be about 30 MWh per year, assuming that three animals would be equivalent to one MT of meat.

3.2.2 The Need in Egypt

The livestock industry, particularly, cattle, dairy and poultry, are expected to play an important role during the Five Year Development Plan period. Between 1981/82 and 1986/87 animal meat production is expected to increase from 362,000 MT to 397,000 MT, chicken meat production from 150,000 MT to 251,000 MT and eggs from 90,000 MT to 131,000 MT. The total cattle herd strength in 1980 was 5.5 million. Private sector poultry farms totalled 4491 in 1981/82. Average number of poultry per farm was about 5,000 birds.

The Five Year Development Plan expects milk production to increase to 2.5 million MT by 1986/87. At 2.6 MT/year of milk per cow, the expected 1986/87 milk production would require about 1 million cows. For the stereotypical

49

dairy herd which has 480 milk cows, about 2,000 milk parlors would be required to supply the 2.5 million tons of milk. These milk parlors could be supplied with electricity generated using renewable energy technologies.

The planned development of the Western Desert and other outlying areas will undoubtedly result in livestock production operations being developed in these areas. Renewable energy power sources could prove to be feasible power sources for operations in these areas.

3.3 Urban Energy Requirements

3.3.1 Demand Characterization

Urban energy requirements are considerably higher than village energy requirements. Exhibit 3.8 shows the annual energy requirements for a 100,000 and 500,000 person city.

All urban areas are expected to be electrified. Therefore, it is unlikely that a renewable energy technology will provide electricity for a specific dwelling or commercial operation, rather, the technology will be integrated into unified the generating system.

3.3.2 Need in Egypt

By the year 2000, the urban population would have increased to about 33 million persons. The Five Year Development Plan envisages developing cities in the Wester Desert, Sinai and Red Sea area as a means of easing population pressures on existing cities. The increased urban population and the new cities will require substantial amounts of electricity and other forms of energy. This demand could be partly satisfied using renewable energy technology.

3.4 Remote Communications

3.4.1 Demand Characteristics

The applications include: microwave repeater stations, telephone and

EXHIBIT 3.8

ANNUAL URBAN ENERGY REQUIREMENTS

Demand Sector	100,000 Person City	500,000 Person City
Residential		
- Electricity (MWh)	45,800	228,900
- Butagas (MT)	3,600	18,000
- Kerosene (m^3)	800	4,000
Commercial (MWh)	30,500	152,600
Community Services (MWh)		
- Water Supply and Sewage	14,300	71,700
- Street Lighting	1,600	8,000
Total Electricity Demand (MWh) (Excludes industrial sector demand)	96,600	483,200

Derived from data in Egypt/DOE (1979), op. cit. Based on expected demand in the year 2000.

television repeater stations, television translators, satellite ground stations, radio-telephone interlink units, radio transreceivers and telemetering systems. Fiber optic-based repeater stations are well suited for renewable energy technology power sources. They offer increased voice and data transmission capability and lower power requirements. In many instances, communication systems are located in remote inaccessible sites (e.g., mountain tops) where the dependability and maintenance-free characteristics of renewable energy technologies make them ideal power sources.

Power requirements are, of course, application specific. Microwave repeaters require about 2.5 mW/channel per kilometer. Land mobile repeaters, unlike microwave systems, only transmit when remotely keyed. Since they are in a stand-by mode most of the time, they use just a fraction of the transmit power drain. A 120 wh/day system is sufficient for most 10W (RF power) repeaters and even some 25W repeaters, depending on the duty cycle. A 480 wh/day system can power a 90W repeater with a 10 percent duty cycle. A 1-2 kW system can power a continuous duty transmitter such as a VHF or UHF repeater with a current drain of about two amps at 24 V.

Egypt has recognized the appropriateness of using PV for powering remote communication system. In 1984 request for quotations for eight installations was made. PV power was required for five microwave repeater stations and three television (TV) transmission stations. Power requirements ranged from 150 W to 800 W. Details of these systems are shown in Exhibit 3.9.

3.4.2 The Need in Egypt

The Five Year Development Plan anticipates that the Ministry of Communications will spend L.E. 197 million[4] for replacement and renovation of existing systems;

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[4] US$ 1.00=L.E. 1.25

Exhibit 3.9

PHOTOVOLTAIC POWERED REMOTE COMMUNICATION SYSTEMS TO BE INSTALLED IN EGYPT

SYSTEM (Location)	DAILY DEMAND ENERGY(kWh)	DAILY DEMAND POWER(kW)	PV Array Peak Power* kWp	Battery Storage AH, V
5 Microwave Repeater Stations (25.75°N, 36.5°E; 25.38°N, 34.7°E; 25.00°N, 34.92°E; 24.58°N, 35.16°E)	3.6	0.150	1.22	525,48
TV Transmission Station at UM El Huwaitat (26.52°N, 33.66°E)	14.4	0.800	1.06	1800,48
TV Transmission Station at West 1 (27.85°N, 31.23°E)	14.4	0.600	5.53	1500,48
TV Transmission Station at West 2 (26.55°N, 31.5°E)	14.4	0.600	5.58	1500,48

* Includes 20% reserve power

L.E. 1,724 million for completion and expansion of communication networks; and L.E. 144 million for new installations. Total fixed investment in communications is expected to be L.E. 720 million. It is anticipated that part of these funds would be utilized in expanding the communication network to cover a larger area of the country, which would result in a significant demand for remote communication installation of the type discussed in Section 3.4.1.

3.5 Cathodic Protection

3.5.1 Demand Characterization

Renewable energy technologies can be a source of electric power for cathodic protection of pipelines, well-casings, storage, bridges, piers, docks and locks, ship hulls, and offshore metallic structures. The power source must supply a low voltage DC current between the metallic structure (cathode) and a passive electrode (anode). The electric current prevents oxidation reactions at the surface of the metal structure, thereby greatly prolonging its life. Power requirements are dependent on size and shape of the structure, the type of metal, the degree of protection (e.g. paint) soil characteristics and other factors. Typically, current required for protection can range from 1 mA/m^2 to over 100 mA/m^2 of surface.

The General Petroleum Corporation (GPC) is already using impressed current cathodic protection systems to protect submarine pipelines, oil storage tanks and petroleum well casings. They have observed that impressed current systems perform satisfactorily close to shore on submarine pipelines, but further out to sea, these protection systems are not very effective. Therefore, in the future, they plan to use sacrificial anodes instead of impressed current cathodic protection systems for their submarine pipelines. Onshore GPC storage tanks use epoxy coatings to provide 70 percent of this required protection. The remaining corrosion protection is provided by impressed current systems.

3.5.2 The Need in Egypt

The GPC currently has 14 submarine pipelines, each about 2 km long, protected using impressed current systems. Power for protecting the pipelines, storage tanks, and well casings are supplied by the grid or by diesel generators or gas turbines that also supply power to the petroleum pumps and other facilities at the well sites. Since most of their equipment that requires protection are within a short distance from the grid or the GPC power generators, they do not forsee a major need for alternative power sources for cathodic protection.

The Petroleum Transportation and Distribution Company may have a greater need for alternative energy power sources for cathodic protection if their pipelines are underground, since these pipelines cover longer distances in non-electrified areas. Petroleum transportation using pipelines is expected to play an increasingly dominant role in product distribution. In 1981/82, seven percent more crude oil and its products, six percent more natural gas, and ten percent more butagas was transported by pipeline compared to the previous year.

If some of the pipelines described below are underground, they could be protected by renewable energy technology-powered cathodic protection devices.

- Sumied pipeline which was built to serve the international market. It transports oil from the Red Sea to the Mediterranean.
- The pipeline network between Suez and Cairo and between those cities and Alexandria and the Delta region.
- The pipeline network that links the Abou Madi field with the fertilizer and power plant in Talkha, and the weaving and textile factories at El-Mahalla El-Kubra.
- The pipeline network connecting the Aboul Gharadeek field and the iron, steel and cement factories in Helwan, and its extension to Suez.
- The pipeline connecting the Abu Clir gas field with Uric fertilizer plants and the two electric power plants in Damanhour and Kaf El-Dawar.

The Five Year Development Plan expects the annual output of the public sector petroleum transportation and distribution companies to increase 17.5 percent and 11.5 percent, respectively. Any new pipeline networks that are required to support the production from those companies will also be candidates for cathodic protection systems.

3.6 Agricultural and Industrial Process Heat

In the following section, the five Egyptian agricultural and industrial processing industry candidates for application of renewable energy technology for low temperature steam applications are characterized. They are: food canning, hydrogenated oil, soap manufacture, pharmaceuticals, and beverages. Their suitability is based on two general criteria: a) they have a high requirement for moderate temperature thermal energy and, b) they are strategic and high growth industries.

The Egyptian Electrical Authority (EEA), has estimated medium temperature energy demand (<450°C) for the industrial sector - demand including existing facilities and those currently under construction - for 1981 to be 1.159×10^6 Tonnes of oil. This energy demand was projected to rise to 2.273×10^6 Tonnes by 1986 and 4.664×10^6 Tonnes by 2000.[5] Solar energy potential in meeting the 1981 energy demand was assessed to be 8.309×10^5 Tonnes, or approximately 72% of the load. Additionally, the food industry in 1980/81 consumed approximately 85% less energy than did the small chemical industry sector (85,000 tonnes of oil compared to 530,000 tonnes in the chemical industry).[5] Thus, due to its relatively high energy demand, the chemical production sector would seem to have higher priority in the application of renewable energy. Thus, there is an enormous potential for the application of renewable energy in the industrial

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5 Hegazi, A. (1984) Solar Energy Technologies and Their Practical Applications in the World and in Egypt. Egypt Electricity Authority Study.

sector.

3.6.1 Food Canning

3.6.1.1 Demand Characterization

Processing of food by canning is a thermal energy intensive operation with steam/water serving as the usual heat transfer medium. There are variations to the process, but there is a basic sequence which is common to the canning of all products (see Exhibit 3.10). The steps requiring thermal energy are blanching, cooking, brine or syrup addition (packing medium) and retorting or can sealing. Saturated, low pressure steam (15 psig) is used to provide the heat in all three steps. The temperature range is from 71°C (brining) to 127°C (sealing). [6]

An average tool process steam requirement for canned corn is 4.5 kg/hr per case (24 cans). However, the peak load is significantly higher at approximately 4,550 kg/hr (9.96 GJ/hr). This is because the sterilization, or retorting process, is a quick process requiring a large amount of heat. Thus, canning steam boilers have to be quite large relative to their base load demand.

3.6.1.2 Need in Egypt

The Egyptian food industry as a whole is expected to have increased its 1987 production 13% over its 1982 level (See Exhibit 3.11)[7]. The combined fruit and vegetable production level should show a 12% increase over this same period. The thermal energy energy consumption for the canning industry in Egypt is expected to increase to 1.68×10^{15} J per annum reflecting the above figures.[8] A typical Egyptian cannery producing 720 cases per hour (24 12-ounce cans per case) has a base load demand of 8 GJ/hr of thermal energy, or 3270 kg of steam per hour

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6 Desrosuv, N. (1977) Elements of Food Technology. Avi Publishing Company.

7 GOE (1982) The Five Year Development Plan 1982-1987.

8 GOE and U.S. DOE (1979) op. cit.

Exhibit 3.10

THERMAL SIZE PLANT CANNING PROCESS
AND THERMAL ENERGY FLOW CHART

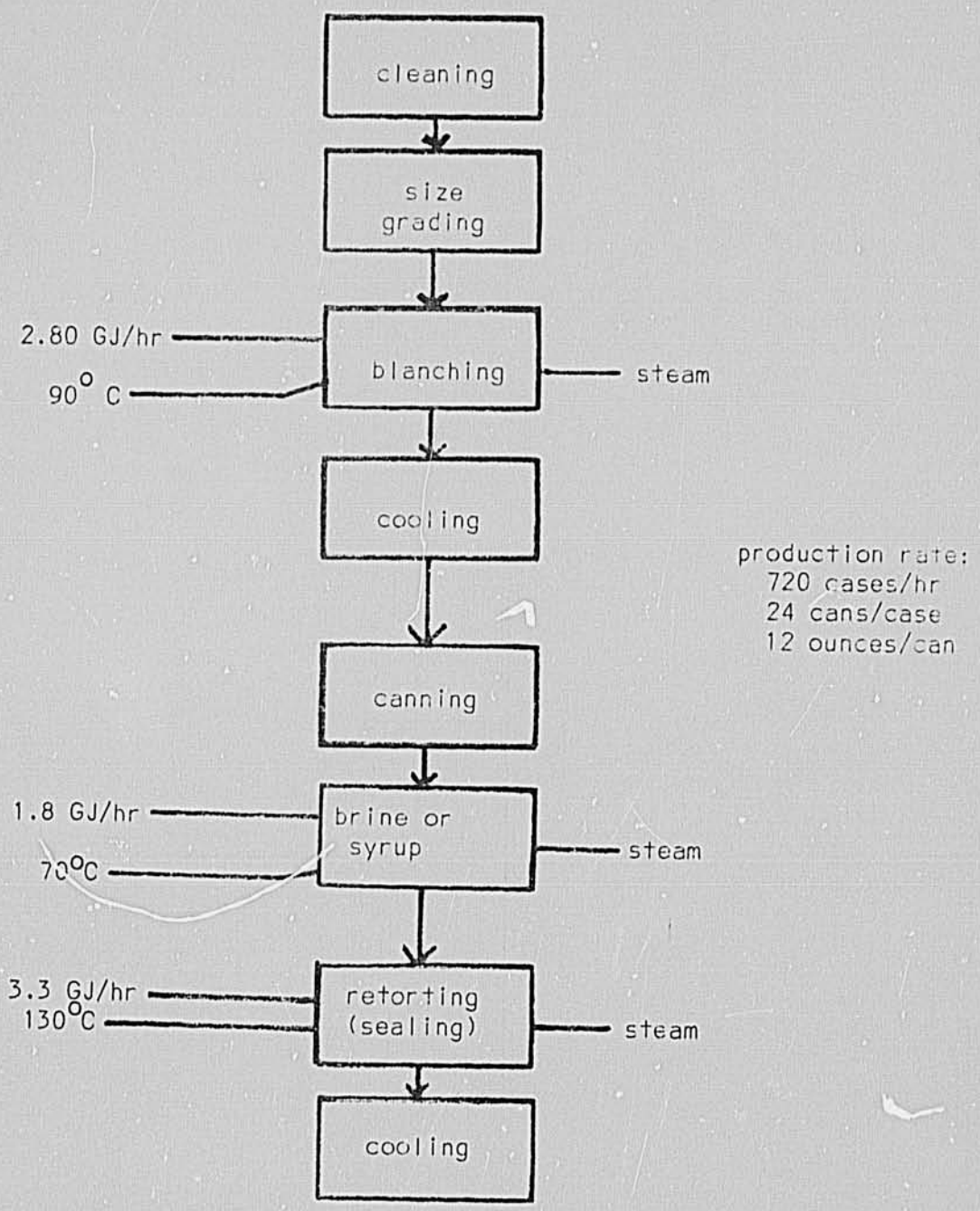

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Exhibit 3.11

THERMAL ENERGY LOAD
FOR THE EGYPTIAN FOOD CANNING INDUSTRY

	1981/82	1986/87
Production Level (10^6 tonnes)	12	13.4
Thermal Energy Load (10^{15} J)	0.147	0.168
Percent Increase	----	12

(.994 MJ/lb steam). Because canneries use low pressure (15 psig) steam, they are an appropriate application for solar energy technologies.

3.6.2 Hydrogenated Oil

3.6.2.1 Demand Characterization

Hydrogenated oils, used in many food processing industries, are one of the ten largest alimentary operations in Egypt, on a production level basis. Hydrogenating, or upgrading, of animal and vegetable oils, is a multi-step process (see Exhibits 3.12 and 3.13) which involves bleaching, vacuum drying, hydrogenating, deodorizing and packing. The entire process, however, is called hydrogenation. It is a continuous process with the operation being a function of the oil type feedstock intended for upgrading.

Approximately 50% of the thermal energy used in this process is used for vacuum drying the stock before it enters the hydrogenerator. The remainder is needed for saturated steam which is used in a water shift reaction to produce the needed hydrogenating agent H_2. The vacuum dryers are raised to temperatures between 200° and 250°C.[9] An Egyptian hydrogenation oil plant consumes 5×10^{10} J per annum of thermal energy (93% of total process energy requirement). For a 75 percent capacity factor and 24-hr day production, the average Egyptian hydro-oils plant (yielding 15 Tonnes/Hr or 98550 Tonnes/yr) has a 70 GJ/Hr heat flux load.

3.6.2.2 Need in Egypt

Hydrogenated oils are a major ingredient in many food processes and are also highly used in home food preparation. Since vegetable and animal oils are foodstuffs, their production and consumption are obviously a function of population. The 1982 production was 1.42×10^5 Tonnes.[10] The 1982-87 five-

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9 Heid, J.L. and M. Joslyn (1967) Fundamentals of Food Processing Operations, Air Publishing Company.

10 GOE (1979) op. cit.

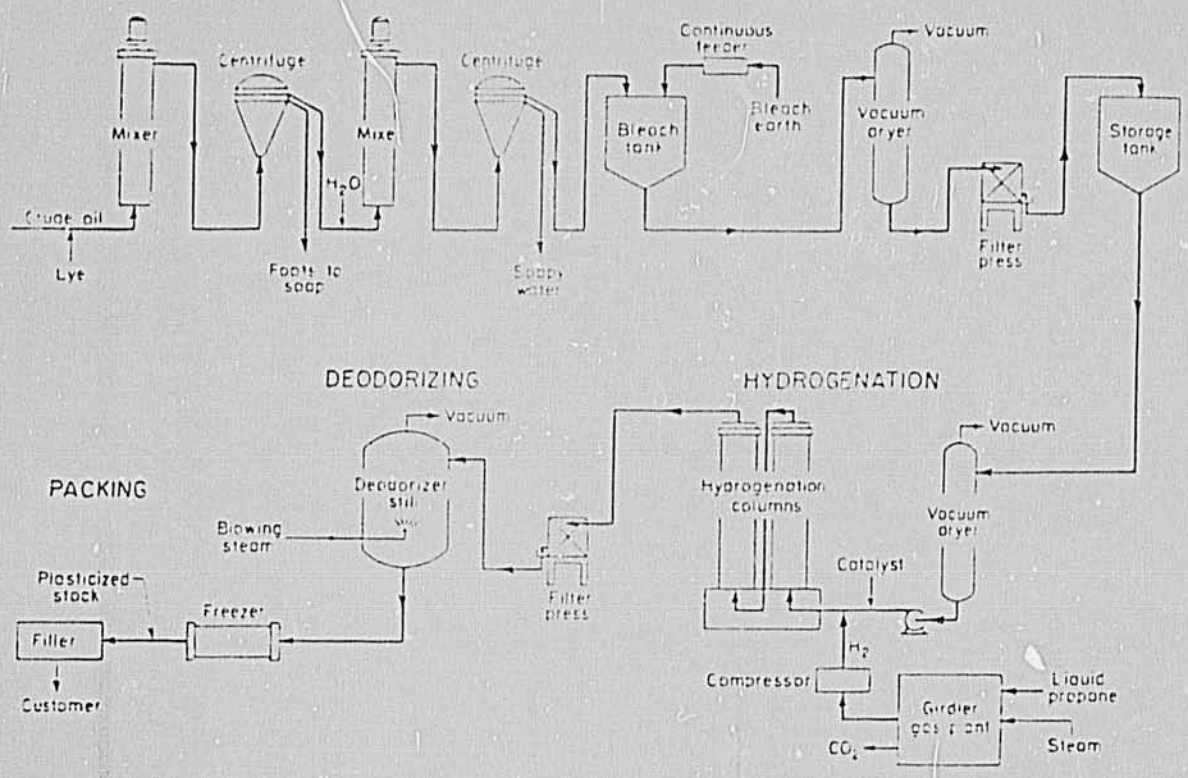
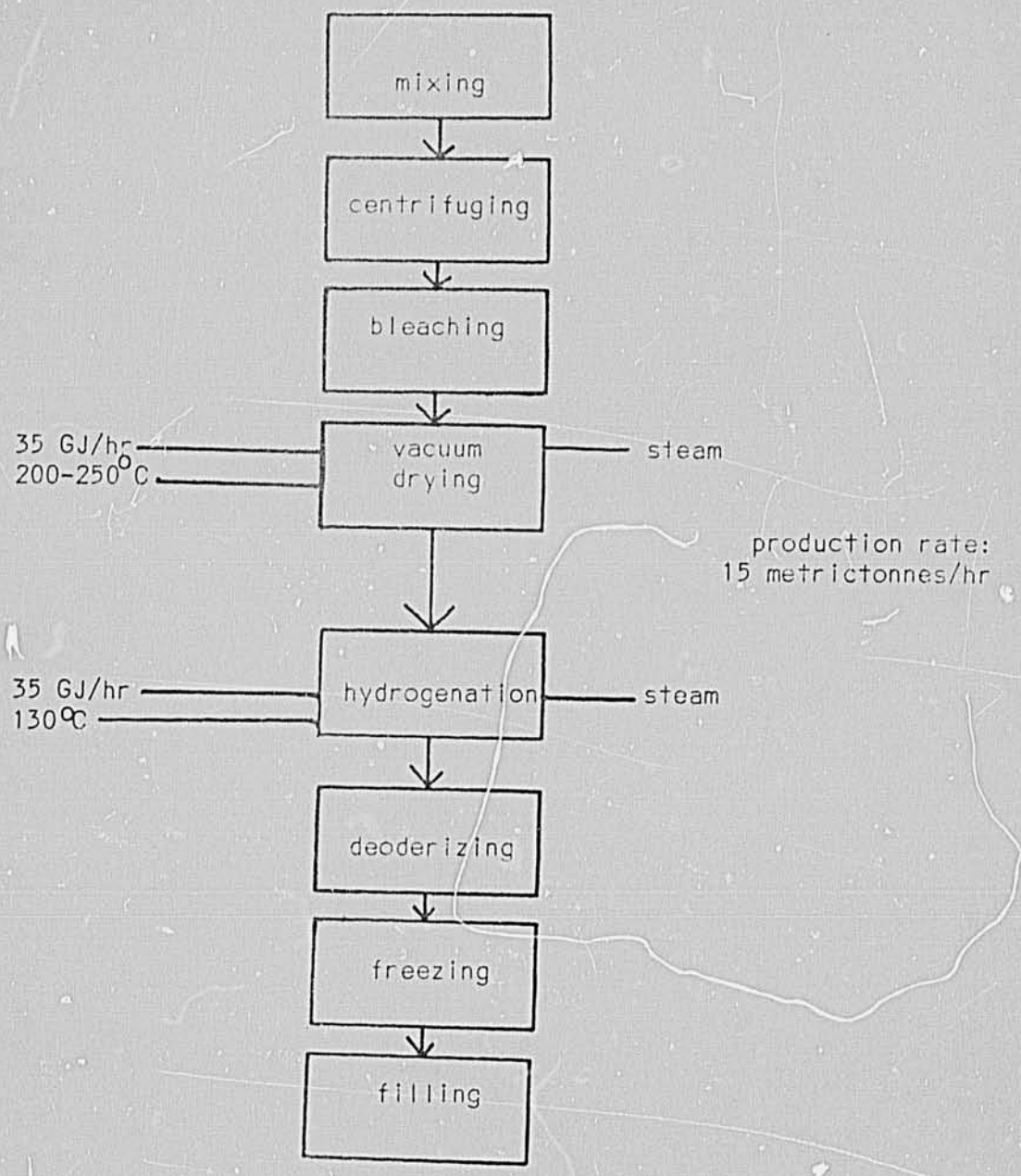


Exhibit 3.12

PROCESS FLOW DIAGRAM FOR VEGETABLE AND ANIMAL OIL HYDROGENATION

Exhibit 3.13

THERMAL ENERGY INPUTS
FOR EDIBLE OIL HYDROGENATION



62

year plan projects production to grow to 2.5 x 10 Tonnes/yr in 1987. Exhibit 3.14 gives the projected thermal energy consumption plans for the industry based on Egyptian government estimates and assuming a constant industry energy efficiency during the 1982-1987 period.

During this period the Egyptians not only hope to increase production to keep pace with predicted population growth, but also expect to decrease hydrogenated oil imports by 250%. The moderate temperature, high heat requirement for hydrogenation suggests a potentially successful application of solar thermal technology.

3.6.3 Soap Manufacture

3.6.3.1 Demand Characterization

Soap making is an age-old process whose basic manufacturing process has evolved over thousands of years. The overall commercial process is based on a seed chemical reaction: combining glyceryl stearate with caustic soda to form sodium stearate (soap) and glycerine.

The typical soap making process is comprised of two basic sub-processes: saponification and finishing. The saponification stage, the thermal energy intensive step, is where the soap making process variation is encountered. The batch or Twitchell process, such as is used in Egypt, consists of several steps (see Exhibit 3.15). The steam intensive step is the formation of the saponification charge. Live steam is introduced into the base of a boiling kettle to heat and agitate the oils. Once the mixture is boiling, the caustic soda is added, and the soap is formed.[11] The boiling of a one Tonne kettle requires 3.3 GJ/hr for a 12 hour period. For this process saturated, 100°C steam can be used. Steam is also used via heat exchange to dry the soap. For a 1000kg per day operation the drying requires 14.4 MJ/hr[12], less than 1% of

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[11] Encyclopedia of Chemical Technology (1983) Kirk and Other Academic Press.

[12] Proctor & Gamble Company, Quincy Mass. Personel communication, July 1985.

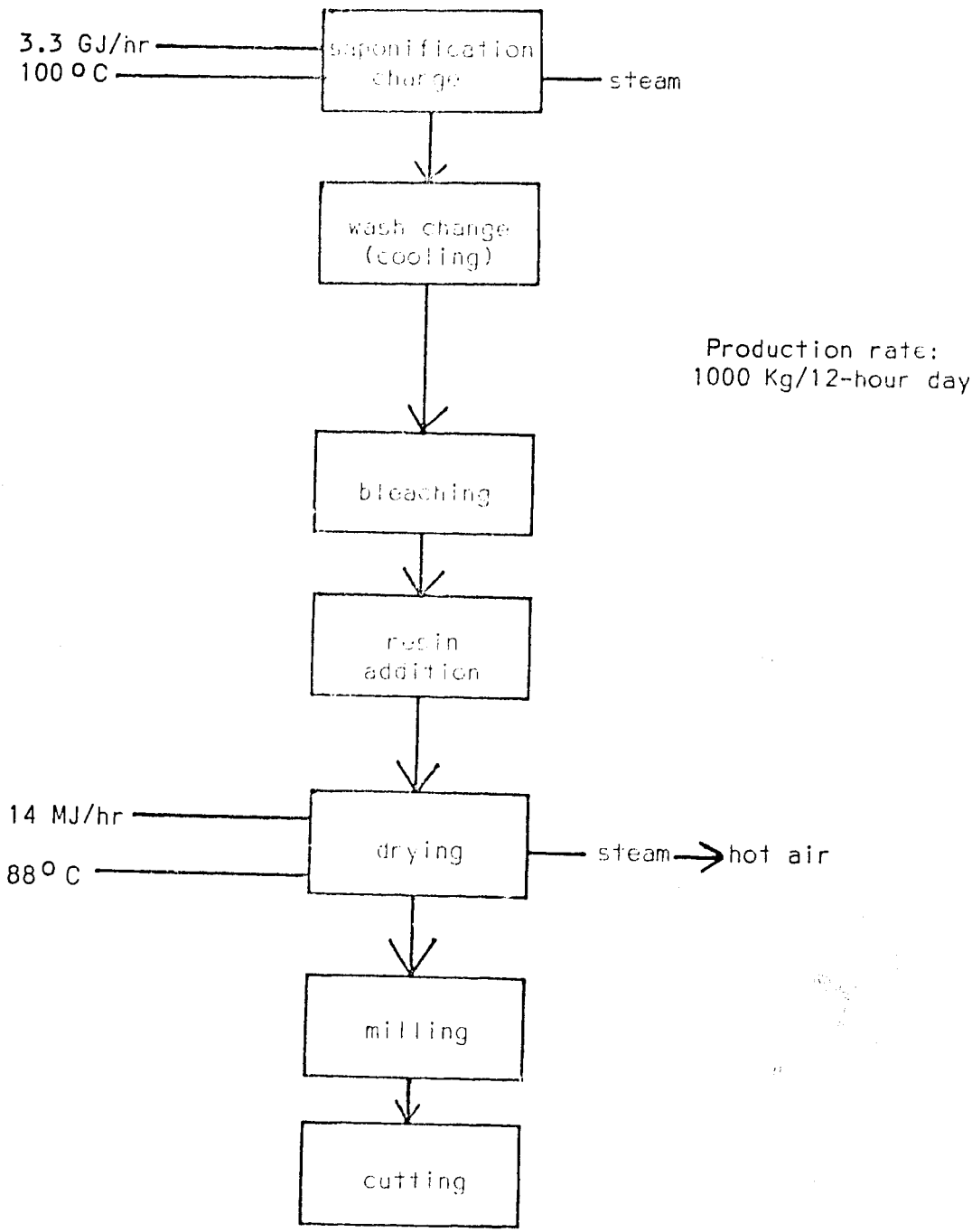
Exhibit 3.14

HYDROGENATED OIL INDUSTRY THERMAL ENERGY CONSUMPTION IN EGYPT

	1982	1986
Production Level (10^5 metrictonnes)	142	250
Thermal Energy Consumption (10^{15} J)	0.74	1.31
Percent Growth	----	76%

Exhibit 3.15

PROCESS FLOW DIAGRAM FOR
KETTLE SOAP MANUFACTURE WITH
THERMAL ENERGY REQUIREMENTS



the total requirement. A typical batch processing plant produces 200 Tonnes of soap per week. Thus, a plant would need to have a 661 GJ/hr steam supply.

3.6.3.2 Need in Egypt

Currently Egypt consumes 2.21 x 10^6 GJ/yr in the manufacture of hand and laundry soap with laundry soap using 90% of that total. According to the 1982-87 five year economic plan for Egypt, the domestic soap production is projected to increase 26% to 340,000 Tonnes per year by 1987 (see Exhibit 3.16). Since there is no expected change in the process engineering, i.e., upgrading of facilities to more energy efficient, expensive, continuous units; the energy consumption should increase by the same factor as production. Hence, it is expected the total annual steam energy requirement for the Egyptian soap processing industry will reach 2.79 x 10^6 GJ/yr in 1987.[13]

3.6.4 Pharmaceuticals

Pharmaceuticals is a general descriptor for a wide variety of products which, consequently, have a number of manufacturing processes associated with them. For example, the manufacturing of ascorbic acid, vitamin C, is a relatively simple four step process which is initiated with a glucose feedstock. Conversely, the penicillin process is quite complex involving precise control of culture propagation, fermentation, and precipitation, with each subprocess composed of many steps (See Exhibit 3.17).

We have chosen to characterize the salicylic acid, aspirin process. Aspirin manufacture is a multi-step process which requires substantial process steam (see Exhibit 3.18).[14] The production of salicylic acid requires four general reactions of the input chemical feedstocks: phenol, caustic soda,

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[13] GOE and U.S. DOE op. cit.

[14] Shreve, N. op. cit.

Exhibit 3.16

EGYPTIAN SOAP PRODUCTION AND ENERGY CONSUMPTION

	1982	1986
Production level (10^5 tonnes)	2.7	3.4
Thermal energy consumption (10^{15} J)	0.63	0.79
Percent growth	----	26%

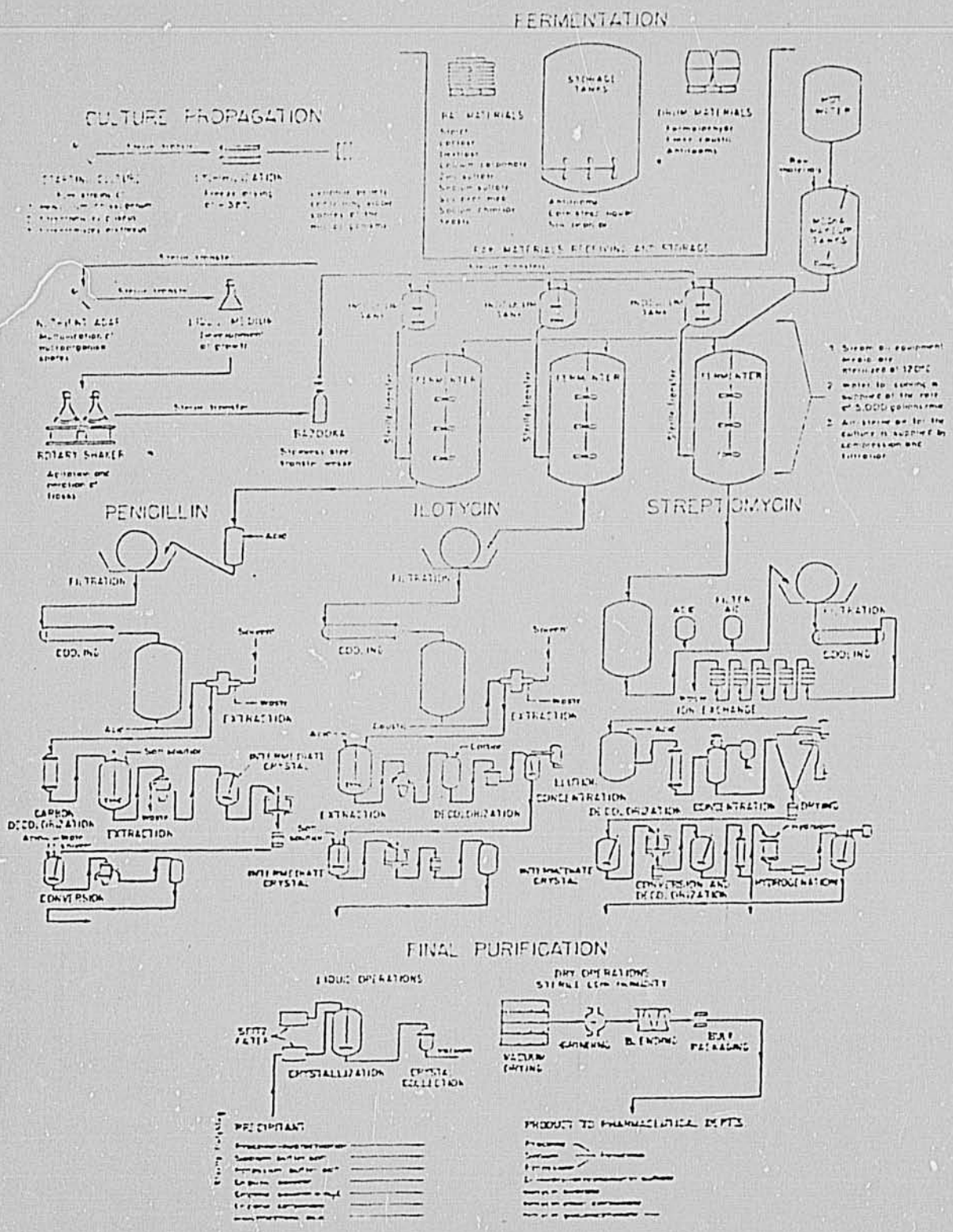
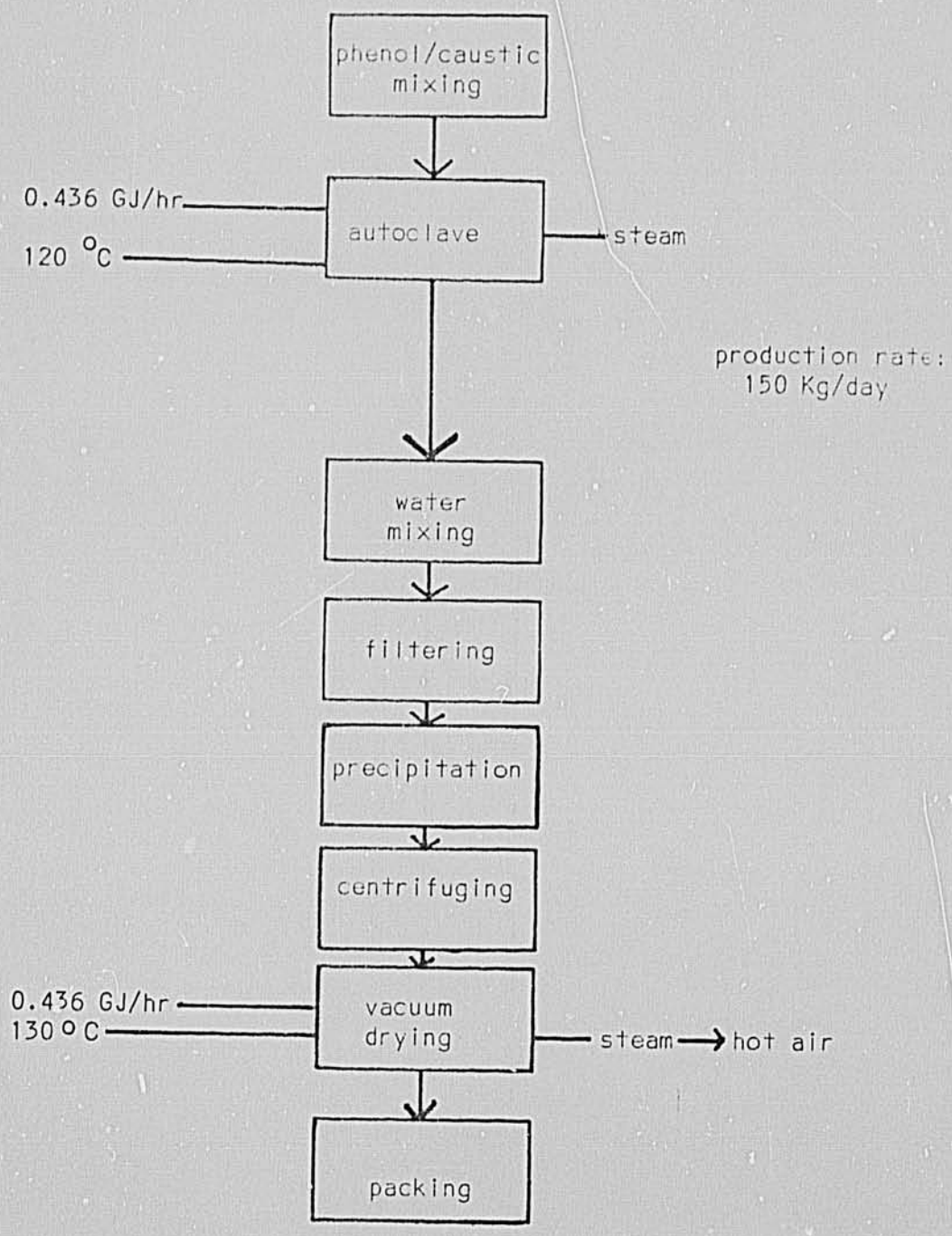


Exhibit 3.17

SCHEMATIC DIAGRAM OF
THE PENICILLIN MANUFACTURE PROCESS

Exhibit 3.18

PROCESS FLOW DIAGRAM FOR
ASPIRIN MANUFACTURE WITH
THERMAL ENERGY REQUIREMENTS



sulfuric acid, carbon dioxide, zinc and zinc sulfate.

A plant producing 1,820 kg of aspirin per day (152 kg/hr for a 12 hour day) requires 4,550 lbs of process steam. Thus the aspirin manufacture thermal energy requirement is 2.5 kg steam per kg of aspirin. The saturated steam temperature for the process is approximately 130° C thus, the thermal energy requirement is 2.62 MJ per kg of aspirin produced. Therefore, the aformentioned plant has a thermal energy load of 0.873 GJ/hr.

The GOE Five Year Economic Plan projects a 117% increase (1.56×10^5 Tonnes to 3.40×10^5 Tonnes) in domestic productions of medicines between 1982/83 and 1986/87.[15] This represents one of the largest production sector increases over the period. Assuming:

1) all pharmaceutical processes consume approximately the same thermal energy as aspirin manufacture

2) a 9 month, 12-hr/day annual production schedule

3) there will be no changes in process energy requirements (per unit basis) for the period.

The total Egypt thermal energy load used in the manufacture of pharmaceuticals for 1981/82 was 0.95×10^{15}J. This then should increase to 2.06×10^{15}J in 1986/87 (see Exhibit 3.19).

3.6.5 Beverage Industry

3.6.5.1 Demand Characterization

Beverage production is defined for this analysis to include the soft drink and malted beverage industries. The malted beverage, or beer, process is more energy intensive than soft drink making due to the added heat needed for fermentation. Secondly, the only process steam requirement for the soft drink process is for bottle sterilization which is essentially the same as the canning

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15 GOE op. cit.

Exhibit 3.19

THERMAL ENERGY LOAD OF THE
PHARMACEUTICAL INDUSTRY IN EGYPT

	1981/82	1986/87
Production Level (10^5 metric tonnes)	1.56	3.40
Thermal Energy Consumption (10^{15} J)	0.95	2.06
Percent Growth		117

retorting process (See 3.6.1). Thus, we have opted to characterize the beer making process.

Beer and malted beverages are non-distilled spirits made from a variety of grains and flavoring hops. The commercial process is quite sophisticated although the basic steps are quite simple. Coincidentally, the process was developed by the ancient Egyptians over 3,000 years ago. The four basic processes, malting (boiling), brewing (hops mixing), fermenting and storage, can be distinguished by their different process temperatures (See Exhibit 3.20). Malting requires boiling temperatures and, therefore, the most intense heat in the process. Hops mixing is done at 75°C, fermenting and storage at 7° and 0°C respectively. For quality brewing, consistent temperature maintenance is very important. Thus, temperature control is crucial in the energy flow for beer making.

The process requires 4.4 MJ per liter of beer produced.[16] Egypt's annual production is approximately 28,600,000 liters per annum.[17] Assuming a 9 month, 24 hour per day plant operating schedule, the Egyptian Pyramid Beer Company produces 20,000 liters per hour and therefore requires 90 GJ per hour in power and heat. Sixty percent of the energy used by commercial breweries is used for heat, thus the heat flux for the Pyramid plant is approximately 54 GJ/hr. The annual energy consumption is 1.25×10^{14} J/yr.

3.6.5.2 Need in Egypt

The brewing process is well-suited for the application of solar thermal technology. The temperatures are less than or equal to 100°C hence less expensive flat plate technology can be used.

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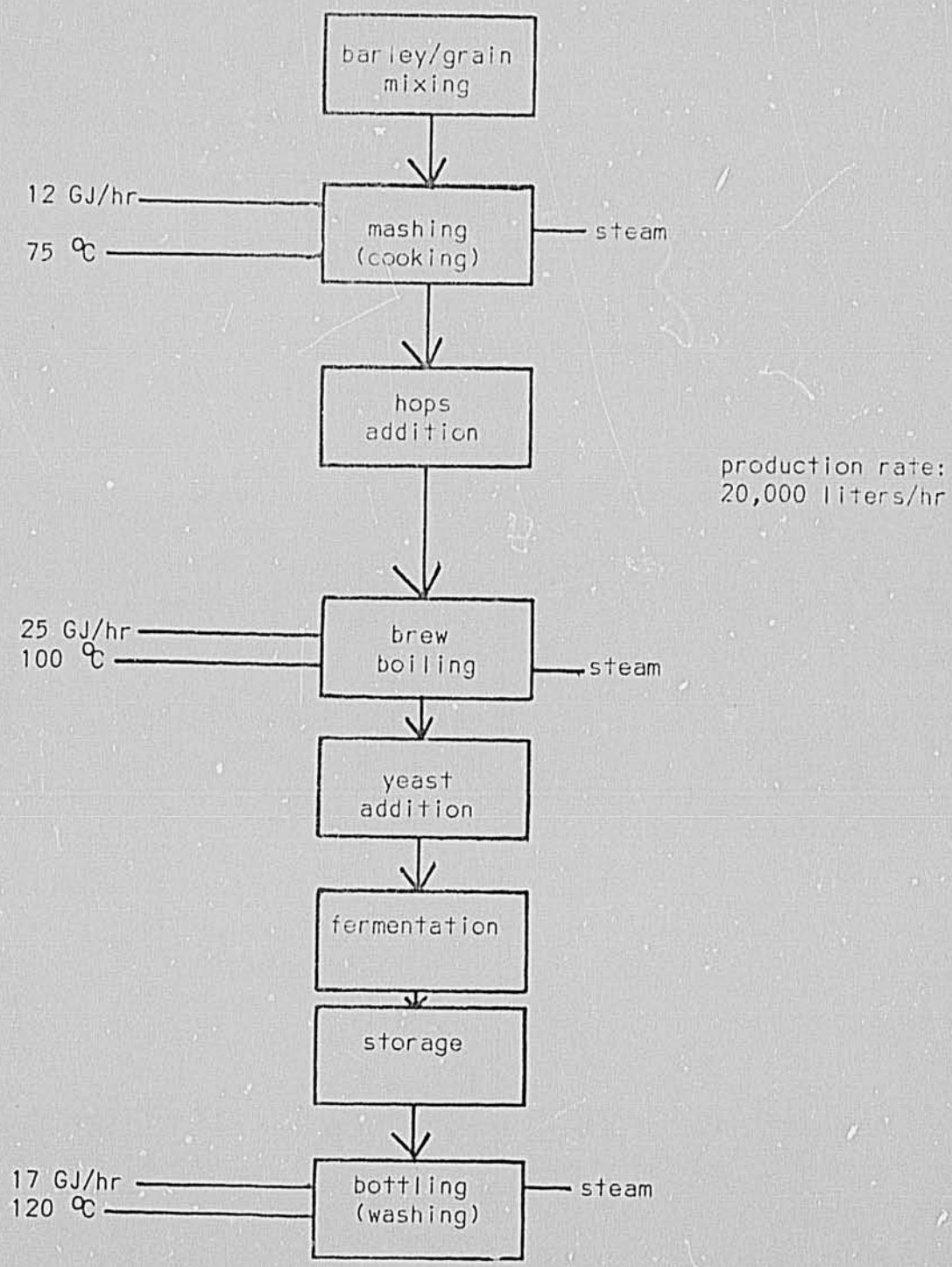
16 Shreve, N. op. cit.

17 GOE and U.S. DOE op cit.

Exhibit 3.20

PROCESS FLOW DIAGRAM OF BEER PRODUCTION WITH THERMAL ENERGY REQUIREMENTS



13

The malt beverage market in most societies is quite large and Egypt is no different. The Egyptian government predicts a 28% increase in production between 1982 and 1987 (See Exhibit 3.21), thus, the industry's annual energy consumption should rise commensurate to 1.6×10^{1}J.

3.7 Building Climatization

3.7.1 Demand Characterization

Building climatization encompasses a broad range of residential and commercial building energy requirements, including heating, cooling and lighting.

Egyptian commercial and residential buildings are generally similar in terms of construction techniques. Urban buildings often consist of low-rise, multi-story structures of thick masonry wall or, more recently, of cement, steel and cement block construction. Today, almost all new construction is made of cement and steel. In the rural areas, old style traditional masonry construction is more common, but here, too, cement and steel construction technology is gaining rapidly.

Heating needs in Egypt are small. Ambient temperatue in Cairo falls below 18°C [illegible] only 4 months in winter. The coldest month of the year is January [illegible] a monthly average temperature; of 13.2°C. Alexandria exhibits a similar winter with a January mean temperature of 13.5°C. The city of Aswan in upper Egypt has a much warmer winter with the heating season occurring in January when the average temperature stays around 16.8°C.

Cooling requirements vary substantially throughout Egypt. Using a temperature of 25°C as the reference cooling temperature, the cooling season is three months long in Cairo and Alexandira. In Aswan the cooling load is much higher due to its distance from the sea; the cooling season extends over 7 months per year. Exhibit 3.22 presents selected climatic data for all three cities and derives their heating and cooling loads. Appendix B contains the

Exhibit 3.21

THERMAL ENERGY LOAD OF THE BEVERAGE INDUSTRY IN EGYPT

	1981/82	1986/87
Production Level (10^6 liters)	2.86	3.66
Thermal Energy (10^{15} J)	0.125	0.160
Percent Increase	---	28

Exhibit 3.22

CLIMATE AND HEATING/COOLING LOADS FOR 3 CITIES

	Cairo	Alexandria	Aswan
Annual Mean Temperature (°C)	21.2	20.2	27.0
January Average Temperature (°C)	13.2	13.5	16.8
August Average Temperature (°C)	27.8	26.7	34.2
Average Annual Humidity (%)	56	70	27
Heating need (degree days)	400.4	521.6	122.4
Cooling need (degree days)	343.0	194.7	1504.0

detailed derivation for Aswan, Alexandria and Cairo.

The heating and cooling loads are derived using the degree days method. The degree-days method has traditionally been used for calculating the energy required to heat a building during a season. For any period, the energy required is estimated as the product of an overall building conductance, UA, and the number of heating degree-days evaluated at an appropriate base temperature.

The method is widely used and, in the United States the information is available in tabulated degree-days format for several hundred locations and a number of base temperatures. These degree-days statistics were calculated from daily temperature records for a thirty year period using a base temperature of 18.3°C.

In Egypt, such an analysis has not yet been undertaken or is not available. The evaluation of a heating and cooling load using the monthly average temperature can only be a rough approximation. The error in the analysis is most pronounced when the base temperature is approximately equal to the monthly average ambient temperature. Blindly applying the degree-days method leads to a zero heating or cooling load. In reality, daily and hourly temperatures are distributred around the mean and can show significant variations. Clearly, a need exists for better modelling of the random nature of temperature and its impact on degree-days estimation.

Erbs, Klein, and Beckman[18] have developed a method which only needs the monthly average ambient temperature to obtain estimates of daily bin data and the monthly heating or cooling degree-days for any base temperature. By defining a unit density distribution function for monthly ambient temperature it is possible to develop a more exact relationship between heating degree-days and

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18 Erbs, D.G., Klein, S.A., Beckman W.A., Estimation of degree-days and ambient temperature bin data from monthly-average temperatures, ASHRAE Journal, June, 1983.

the distribution of ambient temperature.

Using Cairo's average monthly temperature averaged over the 1931-1960 period, a more accurate estimation of heating and cooling degree-days was derived.

In order to calculate the heating and cooling load for typical Egyptian dwellings, a simplified evaluation of the heat loss coefficient was derived. The dwelling chosen as representative was a 120 m^2 apartment in a multi-story modern concrete building. Even though such a configuration is different than traditional building designs, it is representative of current and future building designs.

The heat loss coefficient for an Egyptian house is calculated to be 4.15 W/° C-M^2. Detailed evaluation of the heat loss of a typical Egyptian dwelling is contained in Appendix C. The value is high and reflects the lack of building insulation and the low air tightness of typical homes. U.S. houses are generally a factor of 2 to 3 lower in terms of heat loss coefficients.

Using a Lotus 123 model, the heating load for the representative apartment was calculated. The heating season is assumed to extend from the month of December to the month of March and heating is required for 33 percent of the space one third of the time. The annual heating load is calculated to be 483 kWh_{th} per year. This figure is higher than the guess in the U.S.-Egypt joint assessment figure of 250 kWh per year. A cause of the discrepancy could be that Egyptian households do not try to keep indoor temperatures as high as the 18°C used in the model. Exhibit 3.23 presents the results of the computer simulation used to derive the heating load.

The cooling load was derived in a similar fashion using cooling degree days as a basis for load calculations. Exhibit 3.24 describes the approach taken and the results of the analysis. Using a base temperature of 25°C as the required indoor space temperature, the cooling season is defined as the period

EXHIBIT 3.23

HEATING LOAD CALCULATION FOR CAIRO

DESCRIPTION	VARIAB.	UNITS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
BASE TEMP.	Tb	deg C	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
MONTHLY AVG. TEMP.	Ta	deg C	13.2	14.2	16.6	20.2	24.2	26.7	28.2	27.8	25.4	23.4	19.2	14.6
AVG. YEAR TEMP.	Ty	deg C	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2
DAYS PER MONTH	D	DAYS	31.0	28.0	31.0	30.0	31.0	30.0	31.0	31.0	30.0	31.0	30.0	31.0
HOURS PER MONTH	Hr	HOURS	744.0	672.0	744.0	720.0	744.0	720.0	744.0	744.0	720.0	744.0	720.0	744.0
CALC. FOR STD DEV.	SqT		64.0	49.0	21.2	1.0	9.0	30.3	49.0	43.6	17.6	4.8	4.0	41.0
STD DEV. Ta/Ty	SDy	deg C	5.5	5.0	4.5	4.3	4.3	4.2	3.8	3.2	2.5	2.1	2.0	1.9
STD DEV. Ta	SDa	deg C	1.4	1.4	1.3	1.1	1.0	1.0	0.9	0.9	0.9	0.9	1.0	1.1
H FACTOR	H		0.6	0.5	0.2	-0.4	-1.1	-1.7	-2.1	-2.1	-1.5	-1.1	-0.2	0.5
DIST. FUNC. OF Tb	Dh(Tb)		157.7	115.7	69.9	14.8	1.3	0.2	.0	.0	0.2	1.2	19.6	109.0
MONTHLY HEATING DDS	DDs	deg-days	157.7	115.7	69.9	14.8	1.3	0.2	.0	.0	0.2	1.2	19.6	109.0
YEARLY HEATING DDs	DDs	deg-days	489.7											
HEAT LOSS COEFF.	U	W/degC-M2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
DWELLING AREA	A	M2	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0
MAXIM. HEATING LOAD		KW-HRth	1884.6	1382.4	835.5	176.4	15.8	1.9	0.5	0.5	2.7	14.8	234.8	1302.9
AREA FRACTION			0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
TIME FRACTION			0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
TOTAL HEATING LOAD		KW-HRth	155.5	114.1	68.9	14.6	1.3	0.2	.0	.0	0.2	1.2	19.4	107.5
YEARLY HEATING LOAD		KW-HRth	482.9											

EXHIBIT 3.24

COOLING LOAD CALCULATION FOR CAIRO

DESCRIPTION	VARIAB.	UNITS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
BASE TEMP.	Tb	deg C	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
MONTHLY AVG. TEMP.	Ta	deg C	13.2	14.2	16.6	20.2	24.2	26.7	28.2	27.8	25.4	23.4	19.2	14.8
AVG. YEAR TEMP.	Ty	deg C	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2
DAYS PER MONTH	D	DAYS	31.0	28.0	31.0	30.0	31.0	30.0	31.0	31.0	30.0	31.0	30.0	31.0
HOURS PER MONTH	Hr	HOURS	744.0	672.0	744.0	720.0	744.0	720.0	744.0	744.0	720.0	744.0	720.0	744.0
CALC. FOR STD DEV.	SqT		64.0	49.0	21.2	1.0	9.0	30.3	49.0	43.6	17.6	4.8	4.0	41.0
STD DEV. Ta/Ty	SDy	deg C	5.5	5.0	4.5	4.3	4.3	4.2	3.8	3.2	2.5	2.1	2.0	1.9
STD DEV. Ta	SDm	deg C	1.4	1.4	1.3	1.1	1.0	1.0	0.9	0.9	0.9	0.9	1.0	1.1
H FACTOR	H		-1.5	-1.5	-1.2	-0.8	-0.1	0.3	0.6	0.6	0.1	-0.3	-1.0	-1.6
DIST. FUNC. OF Tb	Dh(Tb)		0.5	0.4	1.1	4.0	25.4	64.1	103.9	92.3	35.9	13.7	1.5	0.3
MONTHLY COOLING DDs	DDs	deg-days	0.5	0.4	1.1	4.0	25.4	64.1	103.9	92.3	35.9	13.7	1.5	0.3
YEARLY COOLING DDs	DDs	deg-days	343.0											
HEAT LOSS COEFF.	U	W/degC-M2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
DWELLING AREA	A	M2	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0
MAXIM. COOLING LOAD		KW-HRth	5.7	4.5	13.3	47.8	303.2	766.7	1241.9	1103.4	428.6	163.6	17.7	3.1
AREA FRACTION			0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
TIME FRACTION			0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
TOTAL COOLING LOAD		KW-HRth	0.7	0.6	1.7	6.0	37.9	95.8	155.2	137.9	53.6	20.4	2.2	0.4
YEARLY COOLING LOAD		KW-HRth	512.4											

when the average monthly temperature is higher. Assuming the cooling load is concentrated in one 40 m^2 area and for half of the time, the load is 512 kWh_{th}. Taking typical Egyptian air conditioner efficiency into account (COP = 1.8), the electric load is approximately 285 kWh electric per year. This figure is lower than the guess provided inthe U.S.-Egypt joint assessment which was 500 kWh per year. The difference is a function of the lower operation temperature of the air conditioner. If a base temperature of 22°C is used then the electricity consumption reaches 661 kWh.

The comparable heating and cooling loads for commercial buildings were not calculated due to the lack of data. They have been estimated to be 1250 kWh total: 833 kWh for cooling and 250 kWh per year for heating. Current application of space heating and cooling systems are limited. This is due in part to the good energy performance of traditional thick masonry walls, and in part to the high price and limited availability of central heating or cooling systems. However, the situation is rapidly changing in Egypt, especially in the urban areas. One factor is that traditional buildings are being rapidly replaced with the less efficient cement and steel modern buildings. Another factor is the rapid growth in urbanization coupled with a fast increase of income level for a large portion of the population. The government is responding to those trends by implementing a massive construction plan to alleviate urban congestion.

Total energy consumption for final use in the residential sector in 1980 was estimated in the joint assessment to be 2.6 MTOE, 2.0 of oil, .3 of natural gas and .3 of electricity; for the commercial sector the total was 3.0 MTOE, 2.7 of oil, .1 of natural gas, and .2 of electricty.

Residential and commercial space conditioning energy use together were projected to be 1102 MWh for fans and air conditioning in 1985, with an additional 8000 Tonnes of butagas to be used for heating in the residential sector.

Projections are that energy use will increase substantially between 1985 and 2000, to 5740 MWh and 30,000 Tonnes respectively.

Projections of lighting use show the same growth trend from 4580 MWh, with 662 thousand Tonnes of kerosene in 1985, to 13,069 MWh with 556 thousand Tonnes of kerosene in 2000.

The percentage saturation of residential air conditioning in urban areas is shown in these projections to be increasing from 5 to 20 percent between 1985 and 2000, the comparable figures for fans are 50 to 90 percent. The market saturation in rural sections will be much less - on the order of 2 percent for air conditioning and 25 percent for fans by the year 2000. Air conditioning and fans will account for 8 percent of domestic energy use in 2000, and for a more significant portion of commercial energy use - 36 percent. Lighting will represent 29 percent of domestic energy use and 64 percent of commercial energy use in 2000.

3.7.2 Need in Egypt

Egypt's building stock is growing at a very rapid rate, largely as a function of the investments undertaken as part of the Five Year Development Plan. Estimates are that approximately 500 housing units will be completed daily from 1980 until the end of the century. Other plans focusing on the upgrading or replacement of 2.1 million housing units are under implementation. The aggregate impact of these actions will be a major revamping and addition of the Egyptian housing stock providing a major opportunity to implement energy conservation features such as passive designs or active systems such as solar water heating.

In order to forecast heating and cooling demand for buildings, an assessment of the current output and the need for housing must be accomplished. Controversy surrounds the figures that exist regarding the housing situation in

Egypt. According to Selim[19] the 1976 census recorded the existence of 3,586 thousand urban dwellings. These units were occupied by an estimated 3,240 thousand households leaving a surplus of 339 thousand unoccupied units.

The National Housing Policy document, in contract, quotes a shortage of 555 thousand units in 1976. The 1978-1982 five year plan estimates the shortage at 850 thousand units in 1977. The difference in supply and demand could be caused by a stratified housing market where medium and high income dwellings are in excess supply and lower income dwellings in a shortage situation.

A large portion of the urban building stocks is old and of poor quality. 900 thousand dwellings were built before 1900 and are in need of replacement. Further, there is a growing need for replacing rooms and small units with flats. This means that an adequate representation of housing needs will need to take into account these replacement and quality improvement factors. An additional factor affecting urban housing demand is the increased urbanization affecting most cities.

Exhibit 3.25 provides a projection of the housing needs for urban and rural areas. Using the figure or 203,000 new households in 1980, urban housing demand is taken to grow at the average population growth rate of 7.5 percent. Increased urbanization is assumed to be equal to 10 percent of new urban household. The replacement and quality improvement in the old housing stock is estimated at 18 percent of all needs. The last column in the table estimates the rural housing need based on the population natural rate of growth minus the migration to the city.

The results of the residential construction projections presented in Exhibit 3.25 indicate that construction of new urban dwellings will reach 766

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[19] Selim, T.M. "Development of the Construction Industry in Egypt", MIT thesis C.E., Civil Engineering, 1983.

EXHIBIT 3.25

PROJECTED NEW RESIDENTIAL CONSTRUCTION

YEAR	URBAN NATURAL GROWTH (000 UNITS)	URBANI-SATION DEMAND (000 UNITS)	URBAN STOCK REPLACEMENT (000 UNITS)	TOTAL URBAN GROWTH (000 UNITS)	NEW CITIES (INCLUDED IN TOTAL URBAN) (000 UNITS)	PERCENTAGE OF NEW CONSTRUCTION (%)	TOTAL RURAL GROWTH (000 UNITS)	TOTAL RESIDENTIAL GROWTH (000 UNITS)
1980	107.0	10.7	21.2	138.9	0.0	0.0	85.3	224.2
1981	109.7	11.0	21.7	142.4	6.4	4.5	85.0	227.4
1982	112.4	11.2	22.3	145.9	10.0	6.9	84.8	230.7
1983	115.2	11.5	22.8	149.6	15.2	10.2	84.3	234.0
1984	118.1	11.8	23.4	153.3	21.2	13.8	84.2	237.5
1985	121.1	12.1	24.0	157.1	21.2	13.5	83.9	241.0
1986	124.1	12.4	24.6	161.1	26.6	16.5	83.6	244.7
1987	127.2	12.7	25.2	165.1	26.6	16.1	83.3	248.4
1988	130.4	13.0	25.8	169.2	26.6	15.7	83.0	252.2
1989	133.6	13.4	26.5	173.4	26.6	15.3	82.6	256.1
1990	137.0	13.7	27.1	177.8	26.6	15.0	82.3	260.1
1991	140.4	14.0	27.8	182.2	28.0	15.4	82.0	264.2
1992	143.9	14.4	28.5	186.8	28.0	15.0	81.6	268.4
1993	147.5	14.8	29.2	191.5	28.0	14.6	81.2	272.7
1994	151.2	15.1	29.9	196.2	28.0	14.3	80.9	277.1
1995	155.0	15.5	30.7	201.1	28.0	13.9	80.5	281.7
1996	158.8	15.9	31.5	206.2	23.8	11.5	80.1	286.3
1997	162.8	16.3	32.2	211.3	23.8	11.3	79.7	291.1
1998	166.9	16.7	33.0	216.6	23.8	11.0	79.3	295.9
1999	171.1	17.1	33.9	222.0	23.8	10.7	78.9	300.9
2000	175.3	17.5	34.7	227.6	23.8	10.5	78.5	306.0
TOTAL NEW CONSTRUCTION BY THE YEAR 2000				3775.4	466.0	255.6	1725.1	5500.5

SOURCE: DERIVED FROM GENERAL ORGANIZATION FOR HOUSING, BUILDING AND PLANNING RESEARCH, "CONSTRUCTION/CONTRACTING INDUSTRY STUDY," FINAL REPORT, CAIRO, JULY 1981. CITED IN SELIM T.M. OP. CIT. AND HEGAZY, ANWAR, "SOLAR ENERGY TECHNOLOGIES AND THE PRACTICAL SITUATION OF THEIR APPLICATION IN THE WORLD AND IN EGYPT," UNDATED TRANSLATION FROM ARABIC.

thousand units during the period of 1982 to 1986. This result compares favorably with the current five year plan projected output of 800 thousand units during the same period.

The current five year plan document indicates that a total of 449,500 new urban dwellings were built during the 1978-1982 period. Eight percent of those dwellings are considered luxurious or of above quality and 37 percent are considered average housing. If we assume that the proportion of dwelling type holds for the current five year plan, then an estimate of current air conditioning growth can be undertaken. Assuming that all luxury buildings are built with air conditioning and 52 percent of average quality housing equipment, then the demand for 1984 can be estimated to 26,400 new dwellings being equipped annually. This figure is within the range of production of MIRACO and KOLDAIR which produced approximately 37,000 units in 1984. In addition, a number of older residences are being retrofitted with air conditioners while upper class customers prefer to purchase imported models. The balance of the market and especially the larger units goes to the commercial sector. For the purpose of our analysis we will assume the residential air conditioning market to be 40,000 units in 1984.

Sales of air conditioners grew at 15 percent last year and show no sign of slowing down. Assuming a continuous growth at that rate and a per dwelling energy consumption at a conservative 500 kWh, yearly consumption just in post 1984 residential buildings will reach 187 million kWh/yr by the year 2000. The addition of a 35 MW electric power generating capacity every year will be required to meet that load.

4.0 RENEWABLE ENERGY TECHNOLOGY CHARACTERIZATION

The purpose of this section is to characterize promising renewable energy technologies that have potential for widespread use in Egypt. Renewable energy technology characterizations have been prepared for wind, photovoltaics, solar thermal, geothermal, biomass, solar ponds, municipal solid waste, and passive solar heating and cooling. Each characterization includes discusions of the technology, its operating characteristics, resource availability in Egypt, market readiness, cost, industry status, R&D thrusts and relevant Egypt/-worldwide experience in using the technology. Appendix A may be referred to for a detailed discussion of each technology.

4.1 Wind

4.1.1 Technology Description

Wind turbines are horizontal-axis or vertical-axis rotary devices in a wide variety of configurations. Both types contain five common basic subsystems: (1) a blade or rotor which is the energy conversion device; (2) a drive train, usually including a gearbox and generator; (3) a tower that supports the rotor; (4) various turbine supporting systems including controls, electrical cables, etc.; and (5) "balance-of-system" subsystems, which depending on the application, might include ground support equipment, interconnection equipment, etc.

The most appropriate type of wind driven electric generator for off-grid operation in remote desert or rural areas is the synchronous generator either with permanent magnets or with controllable direct current field excitation. They also have several features which make wind energy sytems attractive for use in providing grid-connected power.

The inconsistency of wind resource requires some means of energy storage. The conventional lead-acid battery is the most appropriate electrical energy storage device available especially for low demand communities. Other

types of batteries such as Nickel-Zinc, Metal-Gas and Zinc-Chlorine batteries can also be used for energy storage. Hybrid systems that utilize different renewable resources (solar, wind, biogas) could be used to supply the total energy requirements of a small community efficiently and economically with much smaller energy storage facilities.

The majority of commercially available mechanical systems are used for pumping water. The classic windmill is a well proven design available from manufacturers all over the world. Typical rotor sizes range from 2 to 3.5 m with about 18-20 fans per wheel. The rotor is coupled via a crank to a single-acting borehole pump. Most commercially available machines have similar performance characteristics. With a cut-in speed of around 3m/s, water output rises linearly with windspeed to around 8 m/s, the rated speed.

4.1.2 Resource Availability

At least two regions in Egypt have sufficient average daily and annual wind speeds considered high enough for the development of wind power generators. Available data demonstrates that the Mediterranean Sea coast has an average annual wind speed of about 20 km/hr, and the Red Sea coast approximately 22 km/hr. Useable electric energy output in these areas is estimated to be 650 kWh per square meter of windmill swept area.

4.1.3 Market Readiness

Progress in the development of wind energy technology has been substantial. Improvements in the technology and cost reductions has enabled substantial market for grid connected machines to develop. Water pumping continues to be an excellant application of windmill technology.

4.1.4 Cost

Cost of wind machines demonstrate considerable economics of scale.

Currently costs range from $5000/kW for small machines in the 1-5 kW range to about $1000/kW for larger machines in the 50-100 kW range. In the future, machine costs are expected to drop.

4.1.5 Industry Status

The wind technology industry in the United States has experienced a sustained growth. The technical feasibility of both large and small wind energy conversion systems for electricity is established. Considerable test and operational data on small machines now exists, and a data base is being established for large machines. There are currently approximately 60 U.S. manufacturers producing wind turbines. Most of the successful manufacturers sell small (less than 100 kW, rated capacity) horizontal-axis machines, although a trend appears to be developing and several companies are designing and beginning to market intermediate-sized (200-500 kW) machines. The growth of wind farms continues to be an encouraging indicator of progress.

4.1.6 Current R&D Thrusts

Although wind technology has advanced significantly since 1974, further improvements are required if wind energy is to be competitive with grid-supplied power from other sources. Developing these opportunities for improving wind technology requires research in two parallel areas: the basic science of wind turbine dynamics, and advanced components and systems research. Wind turbine dynamics research includes studies in atmospheric fluid dynamics, aerodyanmics, and structural dynamics. These activities are aimed at improved understanding of the basic physical phenomena created by the wind turbine's interaction with its environment. Advanced components and systems research includes research on advanced concepts, supporting research, applied technology testing, and multimegawatt systems. These activities are aimed at reducing technical barriers

and developing the technology base that will lead to major improvements in machine cost, performance, and lifetime. This area will involve not only R&D on individual components such as advanced airfoils and generators, but also systems analyses and testing to ensure that designs are optimized from an overall systems point of view.

4.1.7 Relevant Experience in Egypt Using Wind Technology

Wind energy-related activities in Egypt were initiated in 1972 with support from the U.S. Agency for International Development for resource assessment. Studies concerning design performance of different windmills and generators are underway at various academic institutions.

There are several ongoing joint projects between the National Research Center of Egypt and European development institutions.

4.2 Photovoltaics

4.2.1 Technology Description

Photovoltaics (PV) is the direct conversion of sunlight into electricity. In a PV system groups of cells are mounted and interconnected to form modules (or collectors), which in turn are connected into arrays. The cells are made from semiconductor materials that are processed such that when light strikes the cells, they generate a direct electric current.

Most applications require the use of a regulator to control voltage fluctuations in a system output. Regulators are essential because loads, such as batteries, converters and inverters can only tolerate certain variance in input voltage. Regulators, inverters and converters comprise what is referred to as the power conditioning system.

There are basically three generations of PV technology: ingot, ribbon and thin films. The current PV market is dominated by first generation technology - ingot cells. Second generation technology has just recently entered the

marketplace, while third generation technology for the power market is mostly in the laboratory stages.

4.2.2 Types of PV Collectors

There are two categories of collectors: flat plate and concentrator. The majority of currently installed systems use flat-plate modules. They collect both direct and diffuse radiation, so tracking devices are not necessary (ARCO Solar uses tracking flat-plate systems in their megawatt-scale projects, as they feel improved performance more than compensates for increased operation and maintenance expenses). Egyptian system experience has been solely with flat-plate modules.

Concentrator collectors offer an approach to PV power generation that reduces the need for lowering the price of high-performance cells. By using lenses to focus direct sunlight on to cells, the cell area required to generate a given output can be reduced by as much as a factor of 1000. Concentrator collectors only accept direct radiation and therefore require tracking devices.

4.2.3 Resource Availability

Solar insolation in Egypt is one of the highest in the world, making photovoltaics an attractive option: yearly average solar insolation is about 5.7 kWh/m^2-day with an average of 9-11 hours of sunlight per day. The direct component of radiation represents a large fraction of the total in many areas of Egypt (diffuse radiation is generally the result of sand and dust storms, which in some cases results in cloud cover of only 4-5 days out of the year).

4.2.4 Market Readiness

The major markets for photovoltaic systems are stand-alone; consumer products; grid-connected residential and commercial (intermediate) power; and central station utility power.

Remote stand-alone applications represent a market for which PV is ready. Types of applications include navigational aids, communications, rural electrification, and water pumping. PV for grid-connected residential and intermediate systems are essentially in the demonstration phase.

4.2.5 Cost

Presently, PV module prices range from 5 to 12 dollars per peak watt. The range reflects the quantity of modules purchased. In the small-to-medium size range, prices start at approximately $7/Wp. Installed system prices range from about $10 to $30/Wp, depending upon the location and the particular application. At these prices, PV is cost-competitive for many remote applications, but not for utility-interactive systems.

4.2.6 Industry Status

The world leader in photovoltaic systems technology and production has traditionally been the U.S. However, the U.S. leadership postion has decreased from an 85 percent market share in 1980 to 62 percent in 1983.

U.S. and Japanese involvement in PV can be characterized by technology and application markets. The U.S. is clearly the dominant figure in first and second generation technologies. Firms have used these technologies to penetrate the remote systems and central station utility markets. On the other hand, third generation technology (in particular, amorphous silicon) is dominated by Japan. The Japanese industry, shortly after entering the PV field, became extremely successful in the consumer products market. It has only been recently, that Japanese firms have expressed interest in the remote applications market.

4.2.7 R&D Thrusts

The key thrusts of PV R&D are to reduce the cost and improve the efficiency of systems. Balance of System technologies are well developed and

advancements in these areas will come from better designs. Current research is directed toward improvements in the modules.

4.2.8 Relevant Egyptian/Worldwide Experience

The Government of Egypt and academic institutions have had considerable experience in PV. Among the projects undertaken, include a 10 kWp refrigeration system at the High Dam, a 10 kWp electrification system, a 5 kWp pumping system at Sadat City, and eight television and microwave repeater stations.

4.3 High Temperature Solar Thermal

4.3.1 Technology Description

Solar thermal technologies fall into several categories: flat plate, evacuated tube, parabolic trough, parabolic dish and central receiver systems.

4.3.1.1 Flat Plate

The flat plate collector is normally oriented toward the south to intercept both direct and diffuse radiation from the sun. The radiation entering through the clear glazing is absorbed on a black metal plate called the absorber. Heat in the plate is then transferred to a liquid in tubes attached to the plate or to air that is circulated around the plate. This hot fluid is then transfered to the point of use. The collector is insulated to reduce thermal losses. The flat-plate liquid collector is generally limited to operating temperatures up to about 90°C while air collectors are capable of somewhat higher operating temperatures. While flat plate collectors cannot be used to produce high temperature working fluids, they can be used as a preheater.

4.3.1.2 Evacuated Tube Collector

The evacuated tube collector, because of its small absorber area and improved barrier to thermal loss, is capable of operating efficiently at temperatures of up to 150°C. Using a compound parabolic concentrator as a reflective

backing, solar concentration ratios of 1.5 to 5.0 can be obtained. Therefore, the evacuated tube collector is technically capable of providing industrial process steam.

4.3.1.3 Parabolic Trough

Parabolic troughs are one-axis tracking linear parabolic collectors that concentrate sunlight approximately 30 fold onto a receiver tube positioned along the focal line of the parabola. A working fluid in the receiver is heated by the concentrated sunlight and this energy is transported to the point of use by the fluid circulating in a piping system. Due to higher operating temperatures of 100°C to 315°C, troughs are usually considered suitable for many industrial process heat applications.

4.3.1.4 Parabolic Dish

A parabolic dish is a point focusing, two axis tracking collector that focuses sunlight at concentration ratios of several thousand times onto a receiver located at the focal point of a parabolic concentrator. Energy transferred as heat to a fluid circulating through the receiver can be used directly in thermal energy applications or used to produce electrical energy through a heat engine/electric generator coupled to the receiver. A complete dish module can be used individually or in multi-module systems. Parabolic dishes can produce temperatures up to 1700°C or more.

4.3.1.5 Central Receiver

In a central receiver system, a field of heliostats (tracking mirrors) focuses sunlight at concentration ratios of several thousand times onto a receiver mounted on a tower. The concentrated energy absorbed by the receiver can be transferred as heat to a circulated working fluid to power a heat engine or provide high grade heat for industrial uses. Central receiver systems can

produce working fluid temperatures up to 1700°C or more.

4.3.2 Resource Availability

Solar energy availability in Egypt was discussed in Section 4.2.3.

4.3.3 Market Readiness

Solar thermal systems have the potential to capture a share of the industrial market with applications such as mechanical parts and car washing, bleaching, air-conditioning, potato frying, beer brewing, latex production, sterilizing, enhanced oil-recovery and oil refining. Parabolic troughs, which are mainly medium-temperature systems, are ideal for this market. Flat plate and evacuated tube collectors are commercially available and are suitable for lower temperature applications.

The next area that solar thermal systems could be expected to penetrate is electrical generation, in hybrid systems that use solar energy to repower or retrofit a utility or industry currently using a fossil-fired system, or in stand-alone systems. Other solar thermal applications include cogeneration and total energy systems, each of which produces both heat and electricity. Central receivers, parabolic dishes, and to some extent, parabolic troughs are all potential candidates for electrical applications.

4.3.4 Cost

Currently solar thermal technologies are too costly to be competitive with conventional energy resources in the U.S. Of the higher temperature system, parabolic trough technology has the most potential for being economically competitive in the near term (1985-1990). Total installed system costs are about $750/kwt. Advanced trough concentrator systems are imported to cost about $400/kwt. Current costs for parabolic dish systems range from $1,500/kwt to $1800/kwt. Both capital and operating costs will have to be reduced consider-

ably to make this technology option economically viable in the future. Heliostats comprise approximately 50% of the central receiver system cost. Central receiver plant costs are currently about $4600/kwe and $1300/kwt. Cost is expected to come down to about $1600/kwt and $460/kwt by 1995.

4.3.5 Industry Status

In the past decade, nearly all private sales and most private initiatives have been for flat plate, evacuated tube and parabolic troughs. Only recently, major private initiatives have been undertaken by the solar thermal industry to promote and verify central receiver and parabolic dish systems in the user environment. Industrial process heat and electricity generation are industry's favored markets, and in the U.S., most purchases in the past were made by the government. Presently, industry is also concentrating their efforts toward stand-alone, remote solar thermal systems development.

4.3.6 Current Solar Thermal R&D Thrusts

A major R&D need generic to all concentrating solar thermal technologies is improvement in the cost/performance ratio of the concentrator. Low-cost, high-performance concentrators will require the development of stable, light-weight, long-life reflector materials as conventional materials are heavy and expensive. There is limited R&D activity in the U.S. in flat plate and evacuated tube technologies.

4.3.7 Relevant Experience in Egypt

The Solar Energy Laboratory National Research Center established in the early 1970's is the main center of solar research in Egypt. It has been involved in various experimental and moderate scale solar thermal projects.

In the Electrical Engineering Department of Al-Manjurah University, theoretical work on collectors for power generation has been undertaken. A

power generating project in cooperation with West Germany under a renewable agreement (December 1976-1979) operated a site with 8000 m^2 of cylindro-parabolic type collectors producing hot water at 110°C under six atmospheres pressure. A power generation project in cooperation with the U.S. under a renewable agreement (January 1975-June 1978) utilized a parabolic collector array made up of three heliostats having a total area of 108 m^2. In this project, steam was produced at 220°C at eight atmospheres pressure. The steam drove a 5 kWe turbo-generator (Terri turbine).

4.4 Geothermal

4.4.1 Technology Description

There are four primary technologies which produce electricity from geothermal resources: dry steam, flashed steam, binary cycle and total flow systems.

In dry steam, saturated steam in the reservoir is tapped by geothermal wells and becomes superheated as it flows up the well to the surface. The steam is piped to the power plant where it expands through the turbine to a condenser on the other side. The turbine shaft is hooked to a generator to produce electricity.

High temperature (>150°C), liquid dominated geothermal reservoirs can be used to generate electricity with flashed steam systems. The liquid brine is flashed at the surface by reducing its pressure in a "flash vessel," where part of the water then turns into steam. In some cases, the brine actually flashes in the wellbore, thereby requiring only a steam separator at the surface. The steam phase is fed to a turbine where electricity is generated, similar to dry steam energy conversion. The liquid portion of the fluid is usually disposed of by reinjection into the ground.

Binary cycle (or organic Rankine cycle) technology can use medium

temperature resources (90°-150°C) to generate electricity. The geothermal fluid flows, or is pumped, from the production wells into a heat exchanger where the heat is transferred to a secondary fluid, such as freon or isobutane. These fluids, with their low boiling points, will vaporize in the heat transfer process. The vaporized working fluid is then expanded through the turbine and is condensed upon exit. It is subsequently returned to the heat exchanger, completing a closed cycle. The spent geothermal fluid from the heat exchanger is reinjected into the ground.

Total flow geothermal systems expand the brine from the liquid phase directly without the intermediate process of flashing it into steam. By avoiding the losses in the flashing and separation processes, total flow expanders have a higher theoretical efficiency. There are a number of expander types which may be used in total flow systems, i.e. axial flow turbines, Francis turbines, Pelton wheels, helical screw expanders, etc. These systems are primarily being considered for high temperature (>150°C) applications.

The direct use of geothermal energy delivers heat from a geothermal fluid to any process requiring it. Generally, the temperature is limited to the wellhead temperature, although supplementary heating by fossil or other fuels has been used in certain cases. Most direct applications of geothermal energy use low temperature (<90°C) resources which cannot be used to generate electricity.

4.4.2 Resource Availability

Recent studies investigated the availability of geothermal energy in Egypt. These efforts found no indication of high temperature (>150°C) geothermal systems in the region. Evidence does support the possibility of medium enthalpy (>90°C) geothermal systems along the Red Sea coast.

The most favorable zones for geothermal exploration exist along the

border of the Gulf of Suez. Hot springs along the eastern shore and in the Sinai have surface temperatures as high as 70°C. This zone could extend as far west as Cairo and the Fayoum oasis and Wadi Natrum areas based on geochemical data, extinct geysers, and historic seismicity of these areas.

4.4.3 Cost

The economics of geothermal energy is strongly dependent on resource characteristics such as temperature, depth, possible flow rates, and brine chemistry. Other important cost factors include accessibility of the resource and rock hardness. Estimated installation costs for geothermal energy capacity range from $10-52/kWth for direct use to $946-1621/kWe for binary electric.

4.4.4 Industry Status

The structrure of the geothermal industry is set by the three major phases which make up geothermal exploration and development. These are resource exploration, field development, and end-use.

The exploration for geothermal energy is performed by a wide range of organizations including small and large exploration companies, government agencies, and universities. The tools and techniques of geothermal exploration are essentially those of petroleum and mineral exploration.

Geothermal field development includes well drilling and completion as well as the construction of surface fluid distribution systems. This technology is very similar to the development of an oil or gas field. The direct use of geothermal energy generally requires no more than a conventional water distribution system and suitable heat exchangers.

4.4.5 Current R&D Thrusts

A substantial amount of geothermal research is currently ongoing in the U.S., Europe, Japan, and New Zealand. Efforts include the improvement of

geothermal exploration techniques, extending existing drilling technology and instrumentation to higher temperatures, increasing the understanding of the behavior of geothermal reservoirs, and handling and treating highly corrosive geothermal brines. Research is also being performed to improve energy conversion techniques.

4.4.6 Relevant Experience in Egypt Using Geothermal Technology

There has been no effort to develop geothermal resources in Egypt to date. A number of investigations not specifically directed at geothermal exploration have provided some knowledge on development potential.

4.5 Biomass

4.5.1 Technology Description

Biomass is organic matter derived from plants and animals. There is no single biomass energy technology, but a number of biomass production techniques and conversion technologies that are interrelated in various combinations. Biomass resources include wastes and by-products from industrial and agricultural processes, plus biomass produced specifically for conversion to energy.

Biomass can be converted to solid, liquid and gaseous fuels through biochemical and thermochemical processes. The resulting energy products can be used by residential, commercial and industrial consumers for heat, power and fuel; by utilities for electricity production; and the chemical industry for petrochemical substitutes. The most practical utilization of biomass as an energy resource in Egypt are digestion systems. The major advantage of digestion is that biomass can be used both as an energy form and as a soil conditioner.

4.5.1.1 Direct Combustion

Combustion of biomass in open fire stoves is thermally inefficient ($\leq$10%), however, design improvements could double the efficiencies of cooking stoves.

Although agricultural residues or municipal wastes could be used as feedstocks in incinerator/steam turbine systems to produce electricity, the associated economies of scale make it uneconomical to operate small units.

4.5.1.2 Anaerobic Digestion

Anaerobic digestion provides an energy-efficient method for converting very wet or otherwise low-quality biomass resources, such as municipal sewage and animal manure. In an anaerobic digester (essentially an enclosed gas-tight tank containing an aqueous slurry of biomass material), the absence of oxygen and temperatures between 35°C and 60°C favor bacteria which decompose the feed into biogas, consisting of 50%-70% methane, with most of the remainder as carbon dioxide. The biogas formation rate depends on the feedstock retention time, pH (optimum between 6.8 - 7.4), temperature, and nature of the substrate.

4.5.1.3 Fermentation

Also in an anaerobic environment, biomass can be fermented by microorganisms (yeast or bacteria) to produce alcohol.

The production of ethanol involves: (1) treating the feedstock to produce a concentrated and sterilized sugar solution, (2) converting the sugar to ethanol and carbon dioxide through fermentation, and (3) distilling to remove ethanol from the fermented solution. Ethanol can be produced from sugar crops (sugar-cane, molasses, sweet sorghum, etc), starches (corn, potatoes, cassava, etc.), and from celluloses (wood, agricultural residues, etc).

4.5.2 Resource Availability

Bio-energy resources are not readily quantifiable because of their non-commercial nature. Exhibit A.33 of Appendix A presents estimates of the annual resource base available to Egypt. As this exhibit indicates, the largest single biomass energy resource is agricultural residues -- approximately 20

million tons annually. The principal residues are those from cotton, sorghum, maize, sugarcane, peanuts and seasame.

4.5.3 Market Readiness

Large-scale digesters for use in urban areas is well developed and present few technical or economic uncertainties.

The use of a variety of agricultural residues in digesters is still at the R&D stage at the village level and digester designs and operating procedures are being developed which will allow for a variety of biomass inputs (different combinations of grain straws, stalks, cattle droppings, etc.) while still maintaining effective operation.

4.5.4 Cost

Since transporting wastes long distances is very costly, the most economic use of digesters involves on-farm systems using animal manure and agricultural wastes available on-site and urban systems using sewage. The most economically attractive operations are relatively large poultry, dairy, beef or swine operations (enabling economy of scale) which are relatively energy intensive (enabling the displacement of large quantities of energy bought at retail prices).

Production of electricity from small, family-size units is not economically attractive, whereas larger systems in the 10 to 100 kW range may be able to produce electric power economically.

4.5.5 Industry Status

Besides the potential for economic production of fuel and possibly electricity, digestion produces an effluent which can be used as a soil conditioner or fertilizer and as an animal feed in some cases. The valuation of the effluent is very important in assessing economic feasibility.

The anaerobic digestion process is well known as it is often used in typical wastewater treatment plants to stabilize sludge. Because the process uses simple equipment, anaerobic digesters are very attractive economically. Private sectors prospects are improving because of new reactor designs.

4.5.6 Current R&D Thrust for Technology

The focus of biochemical conversion R&D activities in the U.S. are being directed toward the digestion of agricultural residues that are lignocellulosic and difficult to digest by other biochemical means. Pretreatment of these feedstocks, anaerobic bacteria strain selection, and nutritional factors that may improve the methane-producing capability of the cultures are being examined. The microbiology and biochemistry of digestion cultures and the genetic manipulation of bacteria in the methane production cycle are also being examined.

Feasibility of constructing biomass energy-producing facilities are also being studied. The issues being addressed include the feasibility of specific biomass energy technologies, biomass resource assessment and availability, financing alternatives, and the ability to construct and operate a facility producing biomass energy in an environmentally acceptable manner.

Other R&D areas include short-rotation woody crops and other silvicultural studies, herbaceous crops and aquatic species research, thermochemical and photobiological conversion research, and environmental studies.

4.5.7 Relevant Experience in Egypt Using Biomass Technologies

Most Egyptian R&D in the area of biomass energy emphasizes biogas production although research on improving design and efficiency of woodstoves and the development of small gasifiers is also underway. The most crucial biogas R&D involves the development of low-cost digester designs.

A national demonstration project for the development and application of village-scale digesters has been undertaken by the National Research Center

(NRC) since 1979. At present there are 45 field demonstrations, most of which are household units, along with 4 larger-scale units constructed in conjunction with livestock operations. Both laboratory and pilot scale testing involving modified Chinese and Indian digester designs are being conducted utilizing cattle manure, agricultural residues and water hyacinth. The goal of this research is to demonstrate that appropriate biogas technology is technically, socially, and economically feasible in rural areas of Egypt. A number of digesters based on the Indian and Chinese designs have been installed in Egypt. Exhibit A.36 of Appendix A presents the details of these digesters.

The Faculties of Agriculture in Fayoum, Minia and Assuit are currently conducting research, in conjuction with the Faculty of Engineering, Cairo University, involving an integrated renewable energy system which includes wind, solar and biogas energies.

4.6 Solar Ponds

4.6.1 Technology Description

In a salt-gradient pond, due to the presence of the constructed salinity gradient, natural convection is suppressed since warmer water in the lower layer has a higher salt content and, therefore, remains more dense than water at the upper layer. Consequently, the salt-gradient zone enables the pond to trap heat in the storage zone, where the temperature is allowed to increase steadily to a level substanially above ambient. Typically, temperature in a salt-gradient pond increases with depth, varying from slightly above ambient in the surface zone to 80-100°C in the storage zone.

The heat trapped in the storage zone can be extracted by means of in-pond or out-of-pond heat exchangers for both electric and thermal applications. Hot brine is withdrawn near the upper portion of the storage zone and circulated through an out-of-pond heat exchanger where a working fluid receives heat from

the brine to perform its designed duties. The cold brine is then returned to the pond near the bottom of the storage zone, usually on the opposite end from hot-brine withdrawal. Thermal energy extracted from the pond can be used to generate electricity or support a variety of thermal applications such as residential and commercial building space and water heating, industrial and agricultural process heating, and desalination.

4.6.2 Resource Availability

Solar energy availability in Egypt was described in section 4.2.3.

4.6.3 Market Readiness

The thermal energy of a solar pond can be used in various industrial, agricultural and residential applications. The need for thermal energy below 95°C is very high for industrial process heat applications. Food, furniture, paper, chemicals, leather and primary metal processing are among the major industries to which solar ponds can be a suitable energy source. Solar ponds can supply thermal energy to a number of agricultural processes: crop drying, livestock brooding, space and water heating for livestock, farmhouse space and water heating, and irrigation pumping.

Solar ponds can also provide energy for desalination of water as they are capable of providing thermal energy to the distillation/desalination process and electrical or mechanical power to reverse osmosis and electrodialysis process.

4.6.4 Cost

A number of factors must be considered when evaluating the technical and economic feasibilty of solar ponds. They include: insolation, land, water, salt, aquifer, geophysics and size.

The cost of installing a solar pond varies dramatically with the cost

of land, water and salt, and with the depth and size of the pond. Estimates vary from as low as $\$4/m^2$ to as high as $\$70/m^2$ for installations in the U.S.

Because of the great variance in cost, economically attractive sites must have natural soil liners, inexpensive salt, and enough land to construct a large pond. Larger ponds are more cost effective because of economies of scale in the construction and operation of a pond.

4.6.5 Industry Status

Solar pond research and development over the past two decades has established the viability of the solar pond technology concept. Several experimental and demonstration solar pond projects were undertaken throughout the world during this period. However, only recently have solar ponds become economically viable.

About two dozen solar ponds, all under two acres in surface area, have been constructed and operated around the world. Pond storage temperature varies from a low of about 30°C in winter to a high of 109°C in summer. Boiling can be achieved in high-insolation locations and can be avoided by scheduled heat extraction. A variety of thermal applications have been successfully demonstrated, including pool heating, grain drying, process water heating, space and greenhouse heating, etc. The Yavne and Ein Bokek ponds in Israel have established the feasibility of peaking and baseload electric power generation.

The solar pond industry in the U.S., during the past decade, has not been able to initiate any large solar pond projects.

4.6.6 Current R&D Thrusts

Salt-gradient solar pond research and development efforts have identified several major areas of technical uncertainties that can reduce the performance of a solar pond considerably. Current solar pond R&D efforts are addressing the following technical uncertainties:

- thickness of upper convecting zone;
- maintainable thickness of the nonconvecting zone;
- pond transmissivity;
- heat loss to the ground;
- maintenance requirements of the nonconvecting zone;
- heat extraction from the pond; and
- heat rejection options.

4.6.7 Relevant Experience in Egypt and Other Countries

Egyptian experience in this technology has been limited to several small scale experiments at various universities and research centers. There are other Arab and Asian countries with limited experience with the salt-gradient solar pond technology.

Most of the existing experience regarding the salt-gradient solar pond technology is limited to construction and operation of few laboratory scale experimental solar ponds during past decade. There are two large-scale power generating solar pond plants in Israel which are capable of producing 150 kWe and 5 MWe respectively. A large scale 48 MWe solar pond project is in its planning/design stage in the United States at present. Several other small scale experimental solar pond projects have been constructed and operated in the U.S. which have provided the industry and manufacturers with relevant experience.

4.7 Municipal Solid Waste

4.7.1 Technology Description

The conversion of municipal solid waste (MSW) to energy is a time-tested and well-developed concept. Several different types of technologies exist to recover energy and materials from MSW. The principal focus of this section is on MSW combustion technologies; Section 4.5 discusses anaerobic digestion techniques.

MSW technologies can provide a range of outputs, depending upon the system and operational requirments. Power output can be high pressure steam or low pressure steam, to provide heat, mechanical power electricity.

Most of the MSW technologies discussed here are used to provide steam which can provide heat or motive power. There are four major categories of MSW technologies available in the market and is discussed in detail in Section A.7.2 of Appendix A. These are (1) mass incineration; (2) refuse derived fuel; (3) cogeneration; and (4) co-disposal. In general terms, the major differences of these MSW conversion technologies concern:

1. the quantity and make-up of wastes handled;
2. capital and operating costs;
3. on-site energy requirements;
4. end products.

4.7.2 Resource Availability

Egypt has a population of 45 million people, with most of the population living along the Nile River. This high population density ensures that a sufficient quantity of MSW is available. The collection, transportation, and preparation of this waste will require an infrastructure that is either inadequate or not currently in place. The development of this infrastructure is a necessary prerequisite for MSW energy conversion in Egypt. In Egypt two cities are viable sources of MSW: Cairo and Alexandria. The Cairo area generates about 4200 tons of MSW per day. It is estimated that 1500 tons per day are currently collected and recycled for other uses. The remaining 2,700 tons per day represent a significant resource which can be converted to energy. The city of Alexandria generates approximately 1,700 tons of MSW per day, of which 700 tons per day are collected and recycled for other uses. Thus, there is a significant potential for energy from the remaining 1,000 tons per day.

4.7.3 Market Readiness

The availability of MSW technologies in the market is dependent upon the state of development and degree of successful commercialization for each of the technology types.

Mass incineration of MSW in refractory, modular, and waterwall systems is currently in commercial operation. These three technologies have been widely used in the United States, Europe and Japan.

Both co-fired systems and dedicated RDF boilers have been in commercial operation since 1972 in the United States. More widespread use of RDF systems has occurred in Europe.

MSW cogeneration technologies have been used in both Europe and the United States for over 30 years. Recent regulatory changes in the United States have encouraged cogeneration and contributed to accelerated development and increased use.

Co-disposal has been demonstrated and is commercially available in both the United States and Europe. The multiple hearth furnace has been used since the 1930's. The fluidized bed boiler has been in commercial operation in the United States since 1981. Mass burning co-disposal systems have been used in the United States since 1973.

4.7.4 Cost

The cost of an MSW technology is dependent upon several factors, including: the technology type; the system size; the output; and the quality of refuse burned. A review of installed system capital costs in the United, States clearly illustrates the range of costs for each of the technologies They range from $12,000/TPD capacity for a mass incineration modular unit to $168,000/TPD for a co-disposal modular unit, (see Exhibit A.41 in Appendix A for more details).

Whether MSW technologies can compete with existing direct fired systems remains to be determined. Installed capital costs for these systems is dependent upon the technology, pre-processing equipment, system size, site specific requirements, and many other factors. In favorable circumstances MSW conversion systems can be installed for $20,000/TPD. Systems can easily cost $150,000/TPD and more. The economics of MSW technologies in Egypt can only be determined after site specific analyses.

4.7.5 Relevant Experience in Egypt and Other Countries Using MSW

Internationally, there is a growing inventory of MSW conversion systems. The majority of these systems are in Europe, Japan, and the United States. As of 1983, there was 368 systems installed worldwide, of which 212 are European 85 are Japanese. Exhibit A.46 of Appendix A lists the systems by country.

The viability of MSW technologies in Egypt is dependent upon four factors: the public infrastructure; waste availability; industrial development; and experience.

4.8 Passive and Hybrid Solar Heating and Cooling and Daylighting

4.8.1 Technology Description

Passive solar heating and cooling technologies utilize thermal energy flows in the building system by natural means such as radiation, conduction and convection, using only energy available in the immediate system. Hybrid technologies integrate the use of other energy sources - such as electricity to power fans and pumps - to improve the heat transfer/heat flow mechanisms, but to a lesser degree than the heat transport function served in active solar systems. Daylighting involves integrating the use of natural lighting into building design by judicious placement of apertures and reflective surfaces. It should be noted at the outset that the first step towards improving the way a building uses energy is energy conservation, including initial design and

operations and maintenance over the period of the building's use.

4.8.1.1 Passive and Hybrid Solar Heating

The basic components of all passive solar heating systems are south-facing glass for collection, and thermal mass for heat absorption, storage and distribution. Systems have different methods of collecting, storing and distributing heat, and can be classified into three categories: direct gain, indirect gain and isolated gain. (See Exhibit A.47 of Appendix A).

These basic passive solar heating options can be assisted, by the addition of fans and heat pumps to the system, creating a hybrid system. The pumps and fans improve the distribution function by increasing the convective flow of air within or between rooms, especially when air between the rooms is stratified - on multiple levels or set apart by walls.

4.8.1.2 Passive Solar Cooling Systems

Passive solar cooling techniques, are not as much a function of equipment as of appropriate building design siting and construction techniques, and some ongoing maintenance or operation by building occupants. Techniques include load reduction, earth sheltering, roof ponds and stack effect, earth tube, natural ventilation, solar chimney designs, and dehumidification (see Exhibit A.49 in Appendix A).

4.8.2 Resource Availability

Egypt lies in the solar belt with an annual average insolation of 800 KJ/cm^2. The direct component of solar radiation is 88 to 95 percent of the total on a clear day. Sunshine hours vary from nine to eleven hours per day, with only thirty cloudy days per year in the North.

The largest need is for cooling - cooling degree days range from 2200 in Alexandria to 3000 in Cairo. There is a significant cooling resource in the

diurnal temperature swings and clear night skies which typify Egyptian climate. Lighting represents another target for passive application.

In additional to the solar radiation, there are requirements for basic construction materials. Materials such as steel, cement, glass, and aluminum are all manufactured in Egypt. The requirement for these materials is substantial since the utilization of solar energy resources requires considerable area with collection surfaces capable of withstanding severe environmental conditions. Support structures, towers, and storage tanks are needed in the passive solar design.

4.8.3 Market Readiness

Traditional Islamic architecture is well recognized as the origin of numerous passive solar cooling techniques. The courtyard, the high ceiling, and malkaff (wind catcher) are among the design features that have dominated Islamic buildings over the past few centuries. With the current substitution of modern design concepts, indoor comfort levels have, in many cases, deteriorated. The restoration of traditional Islamic design concepts along with the application of other passive cooling features has significant potential for improving comfort levels and reducing air conditioning demand.

4.8.4 Industry Status

Passive solar designs and technologies do not require the development of new industries or production facilities so much as the education of the construction industry and, for some applications, the building occupants.

4.8.5 Current Passive Solar R&D Thrusts

There is substantial research going on in all areas of passive solar technologies. Most of the research is directly or indirectly related to increasing the cost effectiveness of passive solar building design for heating,

cooling and daylighting, and on advancing and refining current technologies.

4.8.6 Relevant Experience in Egypt and Worldwide

Some limited passive solar activity is taking place in Egypt. Most notable, CARE has constructed some experimental structures in Aswan. The American University in Cairo has been at the forefront of developing passive solar technologies for desert development. A large building housing the Desert Development Demonstration and Training Center was built using locally available adobe bricks. The design is based on traditional Coptic and Moslem architectural principles with prominent use of traditional domes and vaults.

5.0 ECONOMIC FEASIBILITY OF TECHNOLOGY/APPLICATION OPTIONS

The technologies discussed in Section 4.0 can be used to supply the energy needs of many of the applications described in Section 3.0. In this section, a subset of technology/application options are selected and financial analyses are conducted to determine their near (1985-1990) and medium (1990-1995) term cost competitiveness. Technology/application options selection is based on the appropriateness of the technology for supplying the type and quantity of energy required by the application. Extent of use of these technologies for similar applications worldwide was also considered in selecting the technology/application combinations. Exhibit 5.1 shows in a matrix format, the technology/application combinations selected for evaluation.

Financial analyses of the selected options was conducted to determine their cost competitiveness with conventional power sources (e.g., diesel generator sets) as well as with each other. The analyses were conducted in constant 1985 dollars, using a 10 percent real discount rate and an analysis lifetime of 20 years. A diesel fuel price of $35/barrel and a real cost escalation of 2.5 percent per year was also assumed. The diesel fuel price of $35/barrel was the international F.O.B. cost of diesel fuel during the time of analysis.

It should be noted that the following analyses are based on average values for insolation, wind speed and other data. Also, cost of transportation for equipment, fuel, and personnel were not considered. Depending on the location and application, actual data will vary. Once a subset of technology/application options suitable for field testing has been identified, a more detailed, site-specific economic analyses will be conducted as a separate task under the Renewable Energy Field Test Project (Subtasks 2.2.2 and 2.2.3).

APPLICATION	TYPE OF ENERGY REQUIRED					TYPE OF ENERGY SUPPLIED	RENEWABLE ENERGY TECHNOLOGY											
	MOTIVE POWER	LIGHTING ELECTRONICS	THERMAL (HEATING AND COOLING)	ELECTRICAL	MECHANICAL	THERMAL	WIND	PHOTOVOLTAICS	WIND-PHOTOVOLTAIC HYBRID	WIND-DIESEL HYBRID	PHOTOVOLTAIC-DIESEL HYBRID	WIND-PHOTOVOLTAIC-DIESEL HYBRID	ANAEROBIC DIGESTION-MSW	ANAEROBIC DIGESTION-URBAN	ANAEROBIC DIGESTION RURAL WASTE	LOW TEMPERATURE SOLAR THERMAL (< 100°C)	MOD. TEMPERATURE SOLAR THERMAL (100-250°C)	ACTIVE/PASSIVE SOLAR HEATING AND COOLING	INCINERATION-URBAN MSW
EGG PRODUCTION	●	●	●	●			●	●	●	●	●	●		●				
BROILER PRODUCTION	●	●	●	●			●	●	●	●	●	●		●				
DAIRY FARM	●	●	●	●			●	●	●	●	●	●		●				
BEEF FEEDLOT	●	●		●			●	●	●	●	●	●		●				
IRRIGATION	●			●	●		●	●						●				
LIVESTOCK WATERING	●			●	●		●	●						●				
LAND RECLAMATION	●			●	●		●	●						●				
CITIES	●	●	●	●									●					●
BUILDING CLIMATIZATION			●			●											●	
REMOTE COMMUNICATIONS		●		●			●	●										
CATHODIC PROTECTION		●		●				●										
FOOD CANNING			●			●									●	●		
SOAP/DETERGENT PRODUCTION			●			●									●	●		
HYDROGENERATED OIL PRODUCTION			●			●									●	●		
BEVERAGES PRODUCTION			●			●									●	●		
PHARMACEUTICALS PRODUCTION			●			●									●	●		

Exhibit 5-1

TECHNOLOGY APPLICATION OPTIONS SELECTED FOR EVALUATION

114

5.1 Power for Remote Non-Grid-Connected Applications

The following discussion evaluates the economic feasibility of a number of renewable energy technologies in supplying electricity to several non-grid-connected applications. The technologies evaluated are the following:

- o Wind
- o Photovoltaics
- o Diesels
- o Wind-Diesel Hybrid
- o PV-Diesel Hybrid
- o PV-Wind-Diesel Hybrid

5.1.1 Application Characteristics

The applications selected for evaluation are the following:

- o A 30-40,000 bird egg production operation which corresponds to a GPC layer farm. Annual energy demand is 96 MWh/year.
- o A 600 cow sterotypical dairy farm. Annual energy demand is 160 MWh/year.
- o A 135,000 bird broiler operation which corresponds to a GPC broiler farm. Annual energy demand is 146 MWh/year.
- o A 250 head beef feedlot. Annual energy demand is 10 MWh/year.

Detailed characteristics of energy demand was presented in Section 3.0. The analysis assumes that energy demand is uniform across all months.

5.1.2 Wind and Solar Resource Characteristics

The following resource characteristics are assumed for the analysis. The wind generator output is assumed to be the output of a 50 kW Enertech 44/55 wind turbine located at a site with a wind regime similar to that at Ras Ghareb. The PV array output is assumed to be the output from a ARCO Solar module located at a site with insolation levels similar to that at Wadi El Ruwayan. The wind turbine and PV array output is shown in Exhibit 5.2.

EXHIBIT 5.2

WIND TURBINE AND PV ARRAY OUTPUT

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL
Wind Turbine Output (kWh/kW(rated)/month)	176	110	122	146	207	218	250	256	170	127	123	256	2,160
PV Array Output (kWh/m^2/month)	17.03	16.48	18.57	18.80	18.68	17.61	18.21	18.34	17.51	16.43	14.67	15.11	207.4

Note: The low wind turbine and PV array output in February and November does not make this site and ideal candidate for PV/wind hybrid.

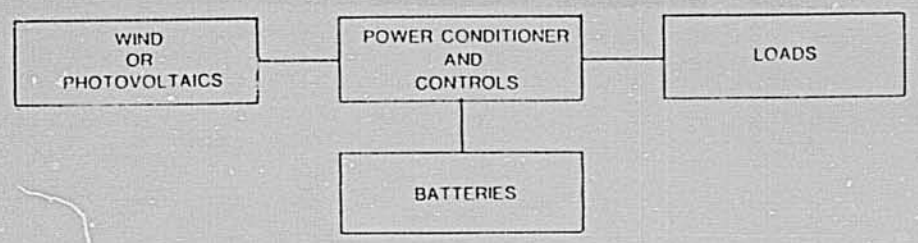
5.1.3 Wind, PV and Diesel Systems

5.1.3.1 Energy Supply Technology Evaluations

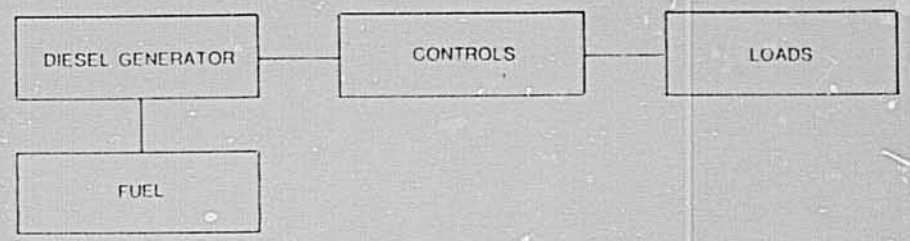
The technical feasibility of the renewable energy technologies being evaluated has been demonstrated in applications worldwide. Therefore the principal purpose of this analysis is to determine the economic feasibility of the power sources. Economic feasibility is determined by a number of factors: the cost of the components, component life, their operation and maintenance cost, resource availability at the site, demand profile, the feasibility of load management, system reliability and the cost of competing energy sources.

Exhibit 5.3 shows the block diagrams for wind, photovoltaics, diesels and hybrid power systems. If only a wind generator or a photovoltaic system is used, batteries are required. Since only one power source is used, if load management is infeasible, the PV array or wind turbine size is determined by the worst month resource availability. The amount of battery storage needed is a function of energy supply complementing demand, desired reliability, and the variability of the resource at the site. Typically, storage equivalent to 3-5 days of energy demand is used. An inverter for converting DC power to AC is needed if the load to be served requires AC power. For small systems the wind or photovoltaic system could provide DC power and the load that specifically requires AC power could have individual inverters attached to the load. Overall system efficiency is improved since the inverter draws power only when the specific AC load is needed, and since the inverter operates at peak efficiency. For large systems a central inverter is preferred.

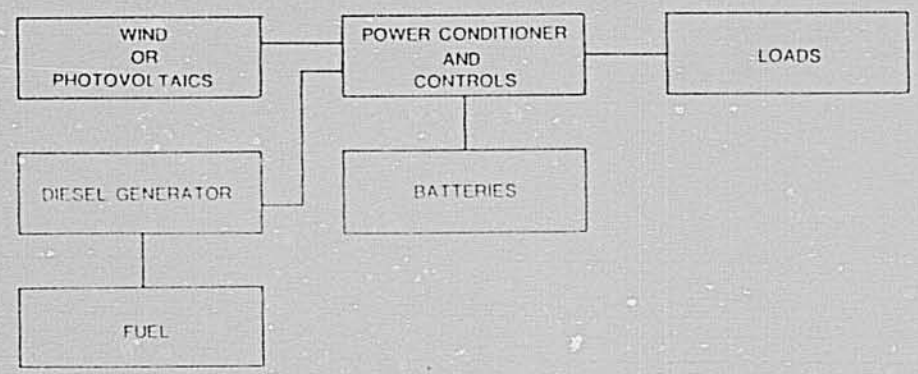
Since the PV array or wind generators are sized according to worst month conditions, during the other months excess energy will be available. If load management techniques are not used, this excess energy will be wasted, and the cost of energy used will be higher.



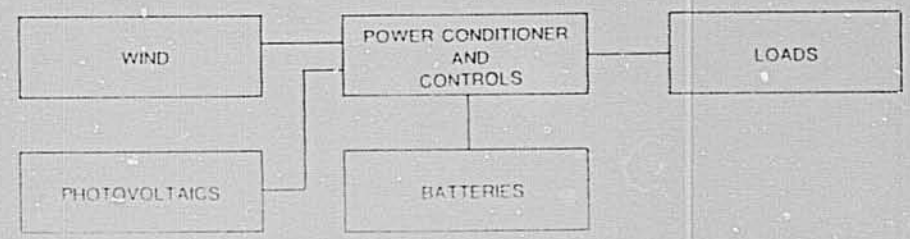
1. PHOTOVOLTAICS OR WIND GENERATOR



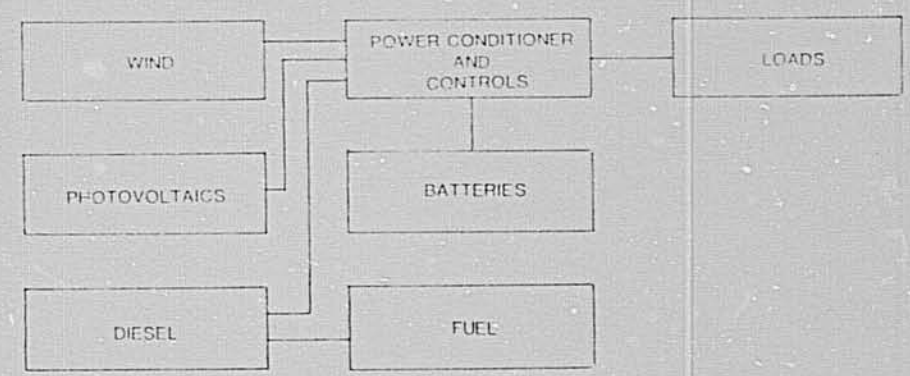
2. DIESEL GENERATOR



3. DIESEL AND WIND OR PV HYBRID



4. PHOTOVOLTAICS AND WIND HYBRID



5. WIND, PHOTOVOLTAICS AND DIESEL HYBRID

EXHIBIT 5-3

BLOCK DIAGRAMS OF WIND, PHOTOVOLTAICS, DIESELS AND HYBRID SYSTEMS

The diesel generator system (Exhibit 5.3.2) is of conventional design. The generator must be sized to meet the peak power demands. If the demand profile exhibits large variations in power demand, it may be more economical to operate two or more diesels in tandem.

Hybrid power systems (Exhibits 5.3.3 to 5.3.5) have a number of distinct advantages:[1]

- Since more than one power source is used, system reliability is higher.

- Battery storage requirements can be substantially reduced. For example, in hybrids involving diesels, if PV or wind supply only a small percentage of the energy, then batteries may not be needed. If the PV and/or wind generator supplies a substantial amount of the energy, then storage equivalent to about half to one day's demand is needed. In contrast, standalone systems utilizing either a PV or a wind generator requires about 3-5 days of storage. Since batteries are an expensive component (about $150-200/kWh of storage for long-life, deep discharge lead-acid batteries), reducing storage needs will substantially reduce costs.

- In regions having complementary wind and insolation resources (e.g., winter peaking winds or night peaking winds), hybrids with PV and wind generators require smaller PV arrays, wind generators and batteries. For a given wind generator, array size could be reduced 10-20 percent and battery size could be reduced 25-35 percent when compared to systems in a region with no resource complementarity.

- The diesel generator operating protocol can have a significant affect on cost of energy from hybrid systems. For example, in a PV-diesel hybrid, if the diesel generator is used to supply baseload power at night and be a peak load supplier during the day, energy costs can be reduced substantially when compared to a case where the diesel is used only for backup. There are two principal reasons for the cost reduction: (1) battery storage and PV array requirements are reduced and (2) the diesel can be sized to operate efficiently, thus increasing fuel efficiency and reducing O&M requirements.

These advantages translate into power systems capable of delivering lower cost, more reliable electricity to remote areas.

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[1] The following discussion is based on insights gained, and rules-of-thumb developed during a recent hybrid systems study (reported in: Cabraal, R.A., and J. Pena, (1983) Assessment and Conceptual Design of Photovoltaic Hybrid Systems, U.S. Department of Energy, NASA CR-168264).

119

5.1.3.2 Assumptions Used in Analysis

Exhibit 5.4 shows the cost assumptions used in the analysis of wind, PV, diesel and hybrid systems. The costs are based on current prices, except as noted.

EXHIBIT 5.4 COST ASSUMPTIONS

Diesel Generator Cost Function ($/kW)	= $(5819/kW + 238) for kW>3
Wind Generator Cost Function ($/kW rated)	= $1200/kW + 985) for kW>4
PV Array Cost	= $250/m^2 (expected 1990 prices)
Battery Cost	= $150/kWh
Inverter and Controls Cost	= $1,000/kW
Fuel Cost	= $35/barrel
Fuel escalation rate	= 2.5%/year
O&M Cost for PV, Inverter and Controls	= 1% of Capital Cost
O&M Cost for Wind Generator and Battery	= 2% of Capital Cost
O&M Cost Functions for Diesels ($/hour of operation)	= 0.059 + 0.0077*kW - 3.34 E-05*kW^2 + (labor rate)*(0.0099 + 0.00036*kW - 1.295E-06*kW^2) for kW<100
System Life	= 20 years
PV, Inverter, Wind Generator, Controls Life	= 20 years
Battery Life	= 10 years
Discount Rate	= 10%
Labor Rate	= $5/hour

5.1.3.3 Economic Analysis

Exhibit 5.5 shows in graphical form, the results of the economic analysis. The exhibit shows the relationship between levelized electricity costs ($/kWh) and annual energy output for each of the power systems. The hybrid power system using diesel generators employ PV and/or wind generators in a fuel saver mode.

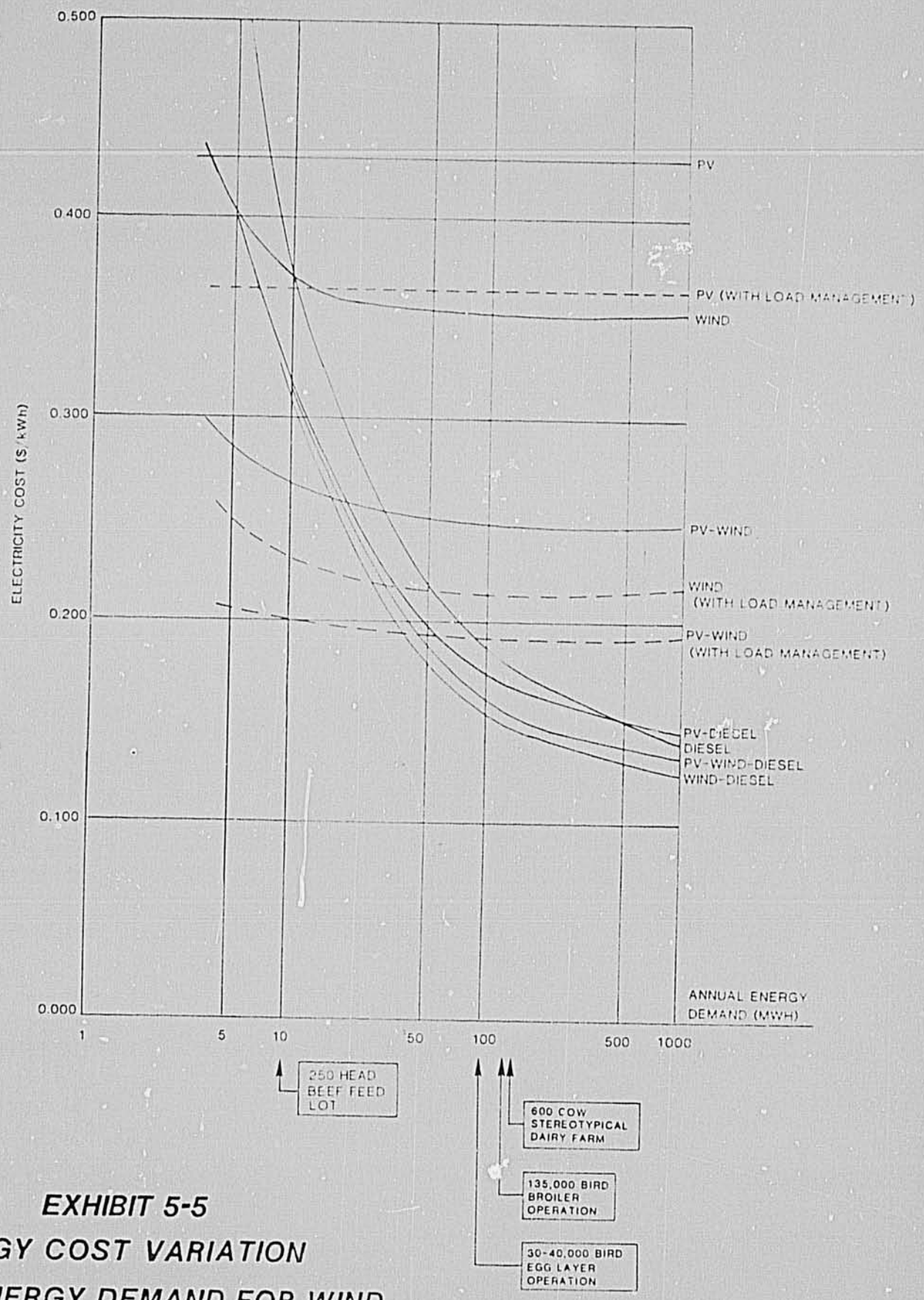


EXHIBIT 5-5
ENERGY COST VARIATION WITH ENERGY DEMAND FOR WIND, PV, DIESELS AND HYBRID SYSTEMS

Batteries were not used in the diesel hybrid systems.

The principal conclusions from the analysis are as follows:

- In the near-term (1985-1990), the lowest cost electricity for all applications requiring more than 30 MWh/year of electricity can be obtained from a wind-diesel hybrid.

- Stand-alone wind generators with load management are the near-term lowest cost alternative for applications requiring less than about 30 MWh/year and more than about 5 MWh/year.

- If the PV costs are reduced as expected, then by about 1990, a PV-wind hybrid system with load management would be the lowest cost alternative for applications requiring less than 40 MWh/year.

- In the mid-term (1990-1995), PV-wind-diesel hybrids have energy costs similar to that of wind-diesels. However, the PV-wind-diesel system is expected to have a higher reliability since there are three power sources.

- The hybrid systems, in general, can supply power at a lower cost compared to the individual power sources.

- PV stand-alone systems are the preferred option when energy demand is less than about 4-5 MWh/year.

Exhibit 5.6 summarizes the results of the economic analysis. It should be noted that these analyses were conducted for a specific wind and insolation profile. Other locations with different resource profiles would result in a different set of cost curves. A site-specific analysis should be conducted prior to selecting a power system.

An important point to note is that in the wind and PV non-hybrid cases a major cost component is the batteries. In both cases, the cost contribution of these batteries is about $0.20/kWh, which is 57 percent of the electricity cost for wind generators and 46 percent of the cost of electricity from the PV system. It clearly demonstrates the advantage of hybrid systems as a means of reducing battery storage requirements and thereby reducing energy costs.

The analysis discussed above uses a system sizing and costing procedure developed by Meridian Corporation. The system sizing procedure is based on conducting monthly energy supply-demand balances and selecting systems to

EXHIBIT 5.6

ECONOMIC ANALYSIS RESULTS OF
WIND, PV, DIESEL AND HYBRID POWER SYSTEMS
LOWEST COST ALTERNATIVE

Application	1985-1990 Period	1990-1995 Period
1. 30-40,000 Bird Egg Layer Operation	Wind-diesel	Wind-diesel*
2. 600 Cow Stereotypical Dairy Farm	Wind-diesel	Wind-diesel*
3. 135,000 Bird Broiler operation	Wind-diesel	Wind-diesel*
4. Beef Feedlot	Wind with load management	PV-wind with load management

*PV-wind-diesel hybrid systems have comparable energy costs.

satisfy the energy requirements throughout the year. Exhibit 5.7 shows a sample output from the system sizing and costing procedure.

This procedure is adequate for conducting a preliminary feasibility study. Once a system has been selected for detailed evaluation and conceptual design, a system simulation based on hourly supply-demand analyses should be conducted. This analysis will be able to determine system sizes more precisely and also determine optimal power system control and energy dispatch protocols.

5.2 Power for Water Pumping Applications

The alternative power sources considered are the following:

1. PV with battery storage
2. PV without battery storage
3. Wind turbine directly coupled to the pump
4. Wind electric generator
5. Biogas generator driving a gas engine which is directly coupled to the pump.

The PV system with battery storage has the advantage that the pump can operate at its optimal design point. However, the added complexity of the system, the energy losses in the battery (they are 50-80% efficient), and the cost of the battery may negate the advantage of the increased pumping efficiency.

The battery system also provides a means for better load matching. For example, if water supply is limited by, for example, a low well drawdown rate, then the pump has to operate longer hours at a lower pumping rate to provide adequate water. A battery is needed in such instances. Also, if water is being drawn from a distribution channel and the distribution times do not coincide with sunlight hours, a battery will be required. A battery system would be necessary if the array is to power other equipment besides the water pump.

Exhibit 5.7A

PV, WIND, DIESEL AND HYBRID SYSTEMS EVALUATION PROGRAM FOR STAND-ALONE APPLICATIONS

APPLICATION:EXAMPLE
SYSTEM : WIND-PV-DIESEL

DESCRIPTION	UNITS	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
MONTHLY ENERGY DEMAND	MWH	90.00	95.00	97.00	91.00	95.00	98.00	98.00	92.00	93.00	96.00	93.00	91.00	1,129.00
WIND TURBINE GENERATOR														
ENERGY OUTPUT	KWH/KW(RATED)	176	110	122	146	207	218	250	256	170	127	123	256	2,161
EQUIVALENT MACHINE SIZE	KW	511.36	863.64	795.08	623.29	458.94	449.54	392.00	359.38	547.06	755.91	756.10	355.47	
NO. OF WIND TURBINES	1													
SELECTED WIND M/C SIZE (KW)	104.49													
MONTHLY ENERGY OUTPUT FROM WIND	MWH	18.39	11.49	12.75	15.26	21.63	22.78	26.12	26.75	17.76	13.27	12.85	26.75	225.80
ELECTRICITY NEEDED FROM PV	MWH	71.61	83.51	84.25	75.74	73.37	75.22	71.88	65.25	75.24	82.73	80.15	64.25	903.20
ARRAY ENERGY OUTPUT	KWH/SQ. M	15.28	15.17	18.22	17.49	16.52	16.18	16.50	17.14	15.87	15.87	14.75	14.42	193.81
EQUIVALENT PV ARRAY SIZE	M**2	4,686.52	5,504.70	4,624.17	4,330.74	4,440.53	4,648.47	4,278.95	3,807.16	4,712.32	5,213.98	5,433.02	4,456.61	
SELECTED ARRAY SIZE (SQ. M.)	2,350.15													
MONTHLY ENERGY OUTPUT FROM PV	MWH	35.60	35.35	42.46	40.75	38.50	37.71	39.14	39.94	37.20	36.98	34.37	33.59	451.60
DAYS OF STORAGE	.60													
BATTERY SIZE (KWH)	1856													
ENERGY GENERAT. FROM PV & WIND	MWH	53.99	46.84	55.20	56.01	60.13	60.49	65.26	66.69	54.97	50.25	47.23	60.34	677.40
ENERGY NEEDED FROM DIESEL	MWH	36.01	48.16	41.80	34.99	34.87	37.51	32.74	25.31	38.03	45.75	45.77	30.66	451.60
NO. OF DIESELS	2													
DIESEL GENERATOR SIZE (KW)	52													
DIESEL FUEL REQUIRED	LITERS	16,760	22,417	19,456	16,288	16,231	17,463	15,238	11,784	17,704	21,296	21,307	14,270	210,214
EXCESS ELECTRICITY GENERATED	MWH	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	0	0	.00

COST ANALYSIS

CAPITAL COSTS	
WIND MACHINE(S)	$238,527
INVERTERS, CONTROLS ETC.	$77,329
PV ARRAY COST	$1,298,092
BATTERY COST	$509,457
DIESEL GENERATOR	$55,477
TOTAL CAPITAL COST	$2,338,881
ANNUALIZED COSTS	
CAPITAL COST	$248,107
PV, INVERT. & BOS O&M	$7,377
WIND GEN. & BATTERY O&M	$8,080
FUEL COST	$55,496
DIESEL GENERATOR O&M	$8,621
TOTAL ANNUALIZED COST	$327,681
ELECTRICITY COST	$.2902 PER KWH

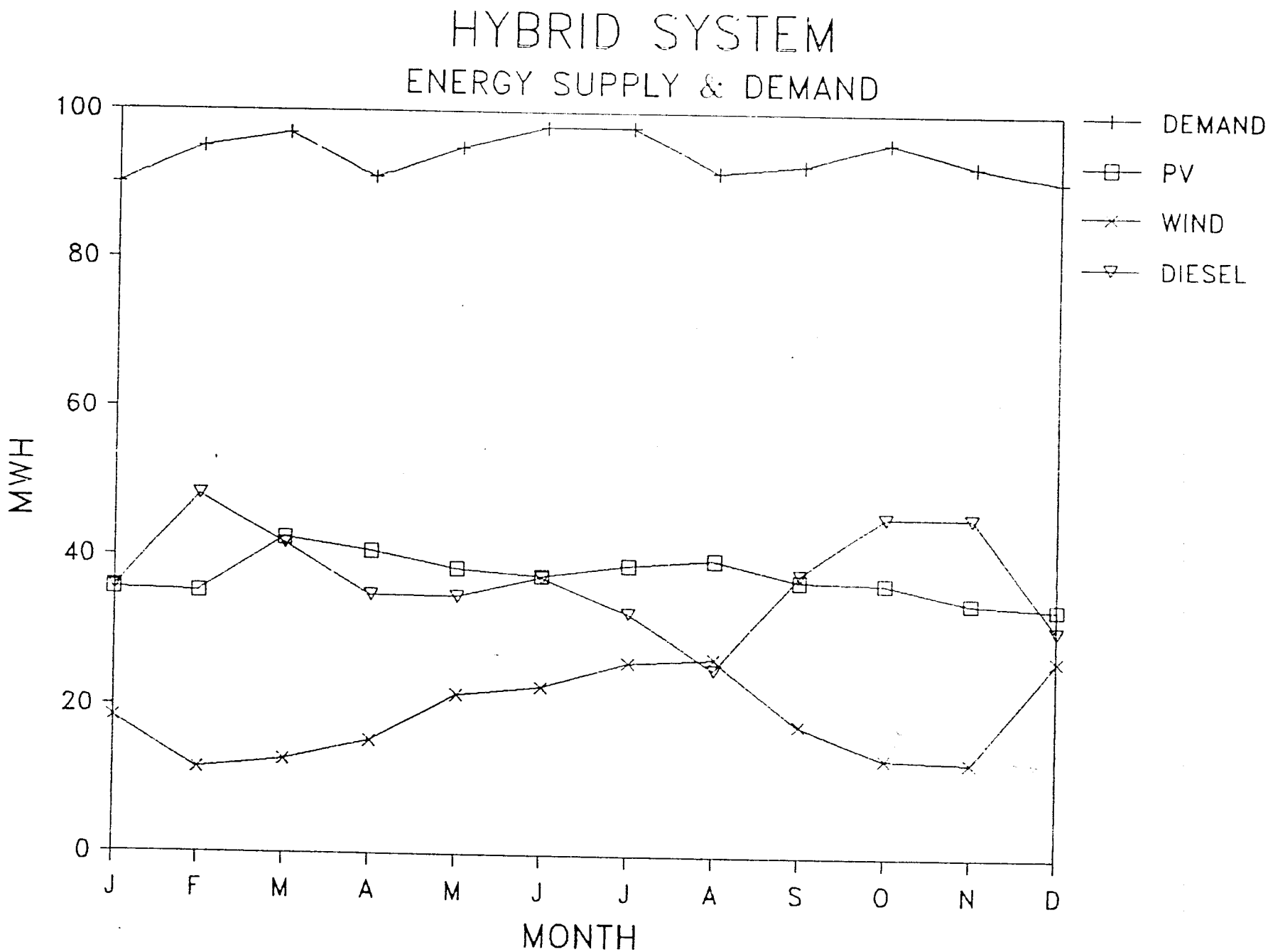
ASSUMPTIONS	8/20/1985	
DIESEL GENERATOR COST	$350	PER KW
WIND GENERATOR COST	$2,283	PER KW
PV ARRAY COST	$600	PER SQ. M.
BATTERY COST	$200	PER KWH
INVERTER & BOS	$77,329	TOTAL COST
O & M PV, INVERTER & BOS	.005	FRAC. OF CAPITAL COST
O & M WIND & BATTERY	.01	FRAC. OF CAPITAL COST
O & M OF DIESEL	$.9850	PER OPERATING HOUR
FUEL COST	$.2640	PER LITER
DISCOUNT RATE	.1	FRAC/YEAR
SYSTEM LIFE	30	YEARS
DIESEL ENGINE LIFE	120,000	HOURS
BATTERY LIFE	10	YEARS
WIND GENERATOR LIFE	30	YEARS
PV, INVERTER & BOS LIFE	30	YEARS
ASSUMED. GENER. CAPACITY	0	KW
O & M LABOR RATE	$5	PER HOUR
NO. OF DIESELS (IF USED)	2	
NO. OF WIND TURBINES	1	
MIN STOR.DAYS/ DIES. HYB	0	
FUEL COST ESCAL. RATE	0	
DEPTH OF DISCH. OF BATT.	.8	FRACTION

POWER GENERATION SOURCE(S) SELECTION

GENERATOR(S)	SELECTION YES=1, NO=0	FROM %	% ENGY ITEM	SYSTEM SIZES SELECTED WIND(KW)	PV(SQ.M.)
WIND	0		100%	.00	.00
PV	0		100%	.00	.00
DIESEL	0		100%	.00	.00
WIND+ -PV	0		0%	.00	.00
WIND+ -DIESL	0		0%	.00	.00
PV+ -DIESEL	0		0%	.00	.00
WIND+ - PV+-DIESEL	1		20% 40%	104.49	2,350.15

Exhibit 5.7B

EVALUATION PROGRAM GRAPHICAL OUTPUT



The use of a wind turbine mechanically coupled to the pump has the advantage of lower cost and complexity. However, ease of location may require the use of a wind turbine generator coupled to an electric motor driven pump. This electrical system could use batteries. The advantages and disadvantages attributed to the PV system with batteries is also applicable to the wind generator with batteries. PV array and wind turbine output data used in the analysis was shown in Exhibit 5.2.

5.2.1 Application Characteristics

The applications selected for evaluation are the following:

- Supplying water to 500 head of cattle from a well requiring a 50 meter pumping head. Annual demand is 3650 m^3 of water.
- Irrigating one hectare of land where the monthly water demand profile is as follows: January: 897 m^3, February: 1290 m^3, March: 1299 m^3, April: 1302 m^3, May: 1725 m^3, June: 2043 m^3, July: 2457 m^3, August: 2425 m^3, September: 2325 m^3, October: 2265 m^3, November: 1124 m^3, December: 1336 m^3. Assumed pumping head is 8 m.
- Reclamation of land where an electric motor driven pump with a 1 m^3/second capacity operates 18 hours a day for 325 days a year. Assumed pumping head is 10 m.

5.2.2 Economic Analysis

Exhibit 5.8 shows the comparative costs of water pumping for livestock watering. The lowest water costs are obtained from the biogas digester system. However, PV without batteries and wind powered mechanical pumping costs are comparable. The biogas system assumes that a digester can be built and operated adjacent to the water source. If the water source is some distance away from the source of raw material for the digester, practical considerations and raw material transport costs could preclude the use of the biogas option. Also, if the well is some distance away from the village, travel costs could make the biogas digester option infeasible. In the mid-term (1990-1995) if PV costs decline to $2.50/Wp and BOS costs to $0.5-1/Wp, then the PV-powered systems can

127

EXHIBIT 5.8

COMPARATIVE COSTS OF WATER PUMPING FOR LIVESTOCK WATERING

SYSTEM	GENERATOR AND BALANCE OF SYSTEMS			MOTOR			BATTERY			O&M AND FUEL	LEVELIZED WATER COSTS	ASSUMPTIONS
Water Ouput = 3650 cu. m/yr. Pumping Head = 50 m	SIZE	COST	LIFE	SIZE	COST	LIFE	SIZE	COST	LIFE	$ (% of Capital Cost)	$/Cubic[1] Meter	Analysis based on current system costs
1. PV with battery storage[2]	5.9 m^2	$5,900	20	1/2 kW	$ 150	10	3 kWh	$450	10	60 (1%)	0.24	$10/Wp for array and BOS 10 hours of pumping. Battery is 80% efficient and pumping is 60% efficient.
2. PV without battery storage[2]	5.7 m^2	$5,130	20	1 kW	$ 200	10	-	-	-	50 (1%)	0.19	$9/Wp for array and BOS. Pump is 50% efficient. 6 hours pumping/day.
3. Wind turbine - mechanical pumping[3]	3 m diameter	$5,000	20	-	-	-	-	-	-	100 (2%)	0.19	Source: Griffith et al. Foreign Applications for Wind Energy Systems. SERI/STR-21-1827.
4. Wind turbine - electric pump[3]	800 W (Rated)	$6,000	20	1/2 kW	$ 150	10	-	-	-	120 (2%)	0.23	Source: Griffith et al.
5. Biogas digester with 1 kW gas engine	2 m^3/day gas output	$ 500	10	-	-	-	-	-	-	550	0.18	$200/biogas digester and $300 engine. O&M from Griffith et al. for engine and an additional $100 for digestor maintenance
6. Gasoline engine	1.2 kW	$ 300	10	-	-	-	-	-	-	925	0.27	Fuel consumption is 1300 liters per year at $0.26/liter. O&M as above.

1 Unit water pumping costs will decrease in direct proportion to the reduction in pumping head.
2 Based on November insolation.
3 Based on February wind power.

EXHIBIT 5.9

COMPARATIVE COSTS OF WATER PUMPING FOR IRRIGATING ONE HECTARE

SYSTEM Water Output as in 2100 m^3/hectre/year Pumping Head: 8 m	GENERATOR AND BALANCE OF SYSTEM		MOTOR		BATTERY		O&M AND FUEL ($)	LEVELIZED WATER PUMPING COST ($/$m^3$)	ASSUMPTIONS
	SIZE	COST	SIZE	COST	SIZE	COST			
1. PV with battery storage[1]	6.3 m^2	$6,300	1/2 kW	150	3	450	71	0.043	$10/Wp for array and BOS 10 hours of pumping. Battery is 80% efficient and pumping is 60% efficient.
2. PV without battery storage[1]	6.0 m^2	$5,400	1 kW	200	-	-	56	0.034	$9/Wp for array and BOS. Pump is 50% efficient. 6 hours pumping/day.
3. Wind turbine-mechanical pumping diameter[1]	3 m	$5,000	-	-	-	-	100	0.032	Source: Griffith et al. Foreign Applications for Wind Energy Systems. SERI/STR-21-1827.
4. Wind turbine-electric pumping[1]	800 W	$6,000	1/2 kW	150	-	-	123	0.040	Source: Griffith et al.
5. Biogas digester with 1 kW gas engine	2 m^3/day gas output	$ 500	-	-	-	-	550	0.030	$200/biogas digester and $300 engine. O&M from Griffith et al and $100 for digestor maintenance
6. Gasoline engine	1 kW	$ 300	-	-	-	-	925	0.046	Fuel consumption is 1300 liters per year at $0.26/liter. O&M as above.

[1] Based on insolation and windpower in November.

EXHIBIT 5.10

COMPARATIVE COSTS OF WATER PUMPING SYSTEMS FOR LAND RECLAMATION

SYSTEM Water Output 21 x 10^6 m^3/year 10 m Pumping Head	GENERATOR AND BALANCE OF SYSTEM		BATTERY		O&M AND FUEL COST ($)	LEVELIZED[1] WATER COST ($/$m^3$)
	SIZE	COST ($)	SIZE (kWh)	COST ($)		
1. PV with battery storage	7,256 m^2	1,945,446	3150	472,500	30,735	0.015
2. PV without battery storage[2]	7,256 m^2	1,698,264	-	-	17,639	0.010
3. Wind turbine-mechanical pumping[3]	870 kW (equip.)	924,900	-	-	18,699	0.006
4. Wind turbine with battery storage	870 kW	990,562	3150	472,500	27,949	0.009
5. Diesel Engine	262 kW	74,000	-	-	147,339	0.007
6. Grid Electricity[4]	-	-	-	-	-	0.003

[1] Computed using procedure described in Section 5.1.

[2] If water flow rate requires 18 hours/day pumping, this system is infeasible unless water storage is possible so that pumping can occur during daylight hours. However, storage will add to costs.

[3] Siting problems may make this option infeasible.

[4] At $0.05/kWh.

deliver water at about $0.10/m^3 (with batteries) and $0.07/m^3 (without batteries).

Exhibit 5.9 shows the comparative costs of water pumping for irrigating one hectare of land. Again, the biogas digester system has the lowest water pumping cost, followed by the PV without batteries and wind powered mechanical pumping systems. In the mid-term the PV powered systems will have the lowest water pumping costs. Based on mid-term costs, the PV system with and without batteries could pump water at $0.02/m^3 and $0.01/m^3 respectively.

Land reclamation requires high volume, low head pumping. Currently, grid electricity provides power for drainage systems. Therefore the analysis should include a cost comparison with grid-powered pumping. Exhibit 5.10 shows the comparative cost analysis results. Grid-powered pumping is, by far, the cheapest. The next lowest cost is exhibited by wind powered mechanical pumping system. If a transmission line has to be built to the pump site, the breakeven distance where wind powered mechanical pumping becomes more economical is 60 km (assuming the tranmission line costs $10,000/km and has a 30 year life).

Exhibit 5.11 summarizes the results of the water pumping cost analyses.

EXHIBIT 5.11

SUMMARY OF WATER PUMPING ECONOMIC ANALYSIS

Application	Lowest Cost System 1985-1990	Lowest Cost System 1990-1995
Livestock Watering	Biogas*	PV
Irrigation	Biogas*	PV
Land Reclamation	Grid Electricity	Grid Electricity

* PV and Wind pumping costs are only negligibly higher.

5.3 Anaerobic Digestion of Sewage Waste Water for Electricity Generation

5.3.1 Application Characteristics

One application that appears to have considerable promise for generating electricity using urban sewage waste water is a biogas cogenerator. It can provide electricity needed for plant operation and excess electricity can be fed to the grid. Exhibit 5.12 shows a schematic for a typical plant. The following analysis is based on a system planned for the Sanitation District of the Los Angeles County, California.[2]

It consists of 32 digestion tanks that operate continuously. The gas generated is used to operate influent and effluent pumping, sludge drying, a dual-fuel diesel engine (12.6MW), and topping cycle waste heat boiler. The plant generates about 3.6×10^{12} J/day of gas. It also requires about 8000 litres of diesel pilot oil per day. An energy balance for this plant is shown in Exhibit 5.13. The excess electricity generated can be used internally or sold. The plant would generate 216 MWh/day of electricity which is equivalent to about 325 barrels of oil/day (net).

Plant sewage waste water input is about 1.6 million cubic meters per day, which is higher than the Cairo area waste water production. However, the unit could be scaled down.

5.3.2 Economic Analysis

The plant, as configured in Exhibit 5.12 has an estimated capital cost of about $12 million. It requires about 125,000 hours of labor to construct. Operation requires 6000 hours of labor annually, 8000 liters per day of #2 diesel oil and

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2 Lawrence Berkeley Laboratory, (1980) Characteristics of Solid Waste Conversion and Cogeneration Systems, U.S. Department of Energy DOE/EV-0105, September 1980.

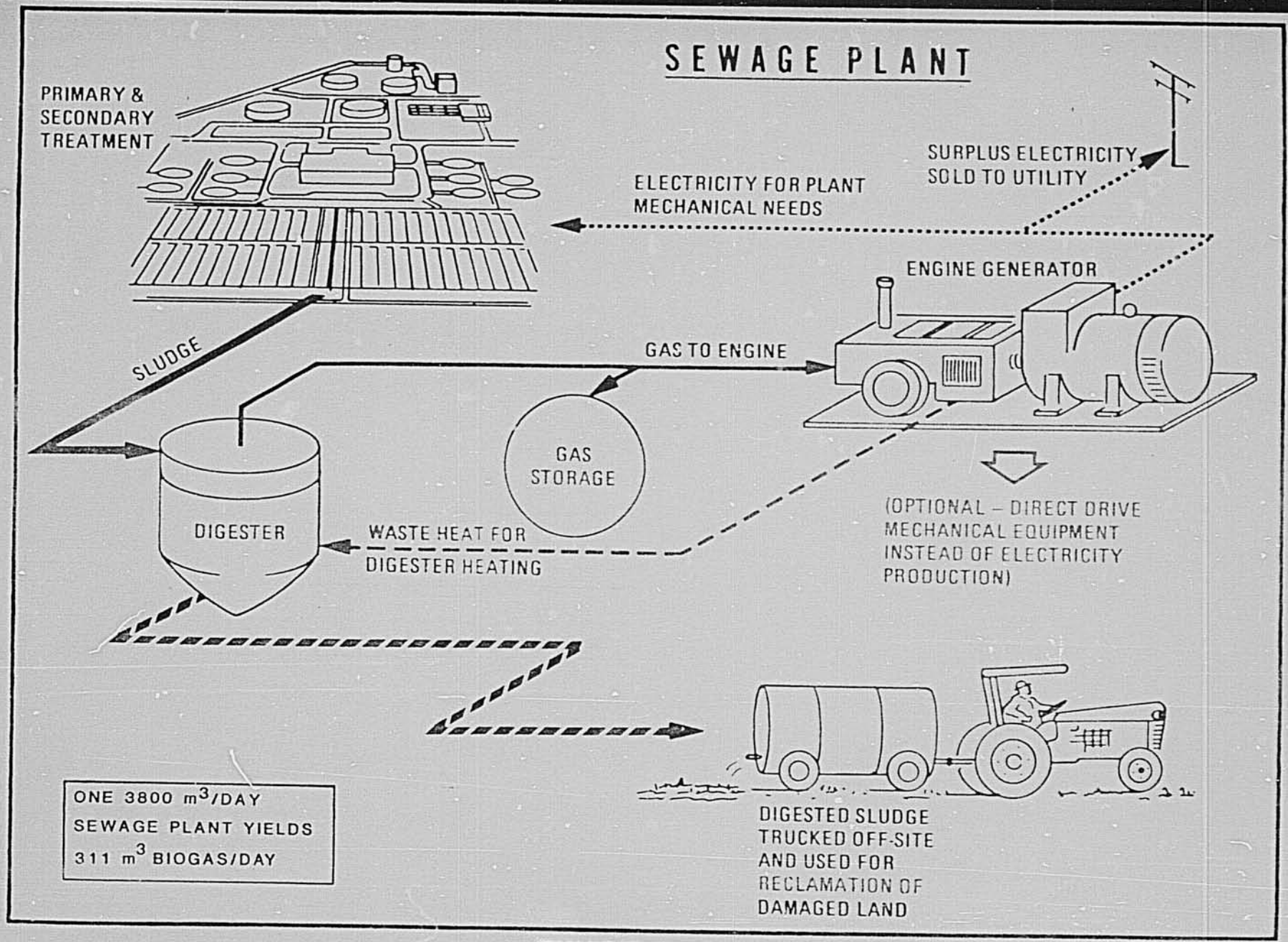

EXHIBIT 5-12
SEWAGE PLANT BIOGAS COGENERATION SYSTEM

Source: Energy Research & Application Inc. (1981) Biogas Electric Power Cogeneration, 25kW or Greater. Tennessee Valley Authority.

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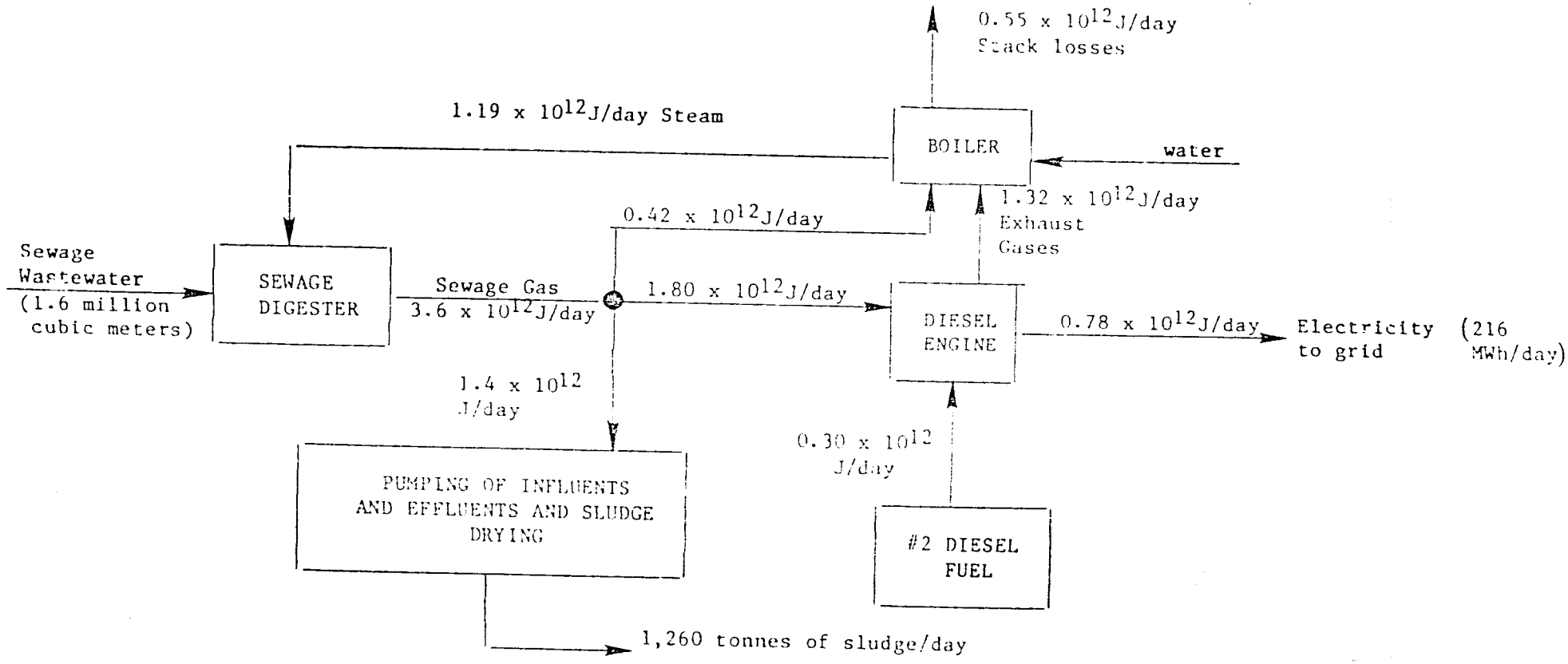

EXHIBIT 5-13

ENERGY BALANCE FOR SEWAGE WASTEWATER ANAEROBIC DIGESTER AND COGENERATOR

other miscellaneous materials. Assuming a 20 year plant life, cost of generating electricity is about $0.03/kWh. This cost is equivalent to petroleum at about $17/barrel, which is significantly less than the world oil price of $29/barrel. This type plant would only marginally increase the electricity generating capacity in Egypt, however, as a fuel saver, the plant has considerable merit.

In addition to the electricity generated, the plant also produces about 1260 MT/day (tpd) of dried sludge which can be used as a soil conditioner and fertilizer.

The City of San Diego, California has a similar plant currently undergoing testing.[3] Sewage inflow to the plant is about 570,000 m^3/day. A two-unit spark ignition engine generator system rated at 1350 kW each, consumes 34,000 m^3/day of sewage gas. The engines use 90 percent sewage gas and 10 percent natural gas. At present, half the sewage gas is flared since no demand has been identified. The installed cost of the plant was about $11-12 million. This included about $2 million for several site-specific contingencies.

The San Diego plant sewage inflow is comparable to the sewage inflow at the sewage treatment plant at Zenin, Cairo (400,000 m^3/day).[4] If the San Diego plant costs are scaled down to the size of the plant at Zenin, total capital costs would be about $7 million. Daily sewage gas output would be about 48,000 m^3/day. Daily electricity output would be about 54 MWh. Cost of electricity from the Zenin plant would be about $0.05/kWh.

5.3.3 Potential Application Sites

The sewage treatment facility at Zenin would be an appropriate site for an

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3 Maitski, Frank, Personal Communication, City of San Diego, Utilities Department. February 19, 1985, Telephone 619-236-7821.

4 Mohamed Alaa El-Din, Abu Talid and Jack Fritz. Biomass Energy Potential in Egypt - A Realistic Appraisal.

anaerobic digester cogeneration system. Additionally, appropriately scaled cogeneration systems of the type described above could be integrated into the many sanitary disposal projects being undertaken or being planned under the Five-Year Development Plan. The projects include the following:

- Ongoing sanitary disposal projects in the cities of Damietta, Ras El-Barr, El-Mansourah, Kafr El-Sheikh, Zagazig, Tanta, El-Mahalla El-Kubra, Kafr El-Zayat, Shebin El-Koum, Banha, Fayoum, Beni Souef, El-Minia, Assyout, Suez, El-Ismailia and Port Said.

- Completion of nine projects which for the first time provide sanitary disposal facilities for the town of Kafr El-Dawar, Shebra Khiet, Sammannoud, Munouf, Kalyoub, Sounag, Kina, Luxor and Aswan.

- Completion of studies for new sewage disposal projects in cities where first stages have started. Namely eleven towns Kafr Saad, Ezbet El-Borg, Farshour, Aboul Matameer, El-Kanater El-Khairia, El-Khanka, Shebin El-Kanater, Toukh, Kafr Shukr, El-Fikria and El-Mahmoudia.

- Carrying out projects east of the Nile: central tunnels, pumping stations and purification centers in El-Kalag and El-Gebel El-Asfar.

- Completion of the following projects: Moustafa Kamel collection center; dilution center, El-Mina El-Gharbi, El-Ras and El-Souda; collection centers and networks in El-Seyouf, and the main pumping station, and Hagr El-Nawatia.

- Completion of the pumping center at Sporting, collection centers in Sidi Bishr and the Western province, and the Western purification station in the Sumouha collection center.

- Beginning of sewage disposal networks in new and some of the older cities --- to meet the needs rising from urban expansion in those cities with already existing networks, also improving and increasing output of sewage networks relative to the use of water in homes.

These systems could also be installed in the new industrial cities being planned as a part of the plan for developing areas outside the Nile Valley and Delta.

5.4 Anaerobic Digestion of Municipal Solid Waste for Electricity Generation

The Cairo area generates about 4200 tpd of refuse. About 1500 tpd is recycled by 15,000 "Zebaleen," who make their living from this activity. Of the remaining 2700 tons/day, about, 1900 tpd is collected and 800 tpd is left to "rot."[5] Characteristics of MSW generation rates for several cities in Egypt are shown in Exhibit 5.14.

Organic material account for a substantial percentage of the MSW in Egypt. On the average, moisture content ranges from 40 to 60 percent and the energy content from 6300 to 7100 kJ/kg[6]. Exhibit 5.15 shows the MSW composition in several cities in Egypt.

5.4.1 Application Characterization

Anaerobic digestion of municipal solid waste for the production of methane involves four major elements: pretreatment, digestion, product recovery, and residue treatment. Pretreatment of the solid waste is desirable to separate inorganic matter and materials which disrupt mechanical operation of the digester and to increase the biodegradability of the substrate. The digestion process results in the decomposition of organic matter and production of gas. The gas produced may be used to generate electricity or undergo treatment for removal of carbon dioxide, leaving pipeline quality methane gas for the commercial market. A residue of undigested materials is dewatered and disposed in a landfill, incinerator, or used as a soil conditioner.

A plant for anaerobic digestion of MSW was built in the U.S. under the sponsorship of the U.S. Department of Energy. The facility known as the Refuse

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5 World Bank, (1978) Arab Republic of Egypt Urban Development Project Manual, Solid Waste Management in Cairo and Alexandria.

6 El Halwagi, M.M., S.R. Tewfik, M.H. Sorour and A.G. Abulnour. (1985). Solid Waste Management: A Comprehensive Assessment of Problem, Planning Approach and General National Trends, In: Proceedings of the Conference on Solid Waste Management, Volume 2. July 9-11, 1985, Cairo Egypt.

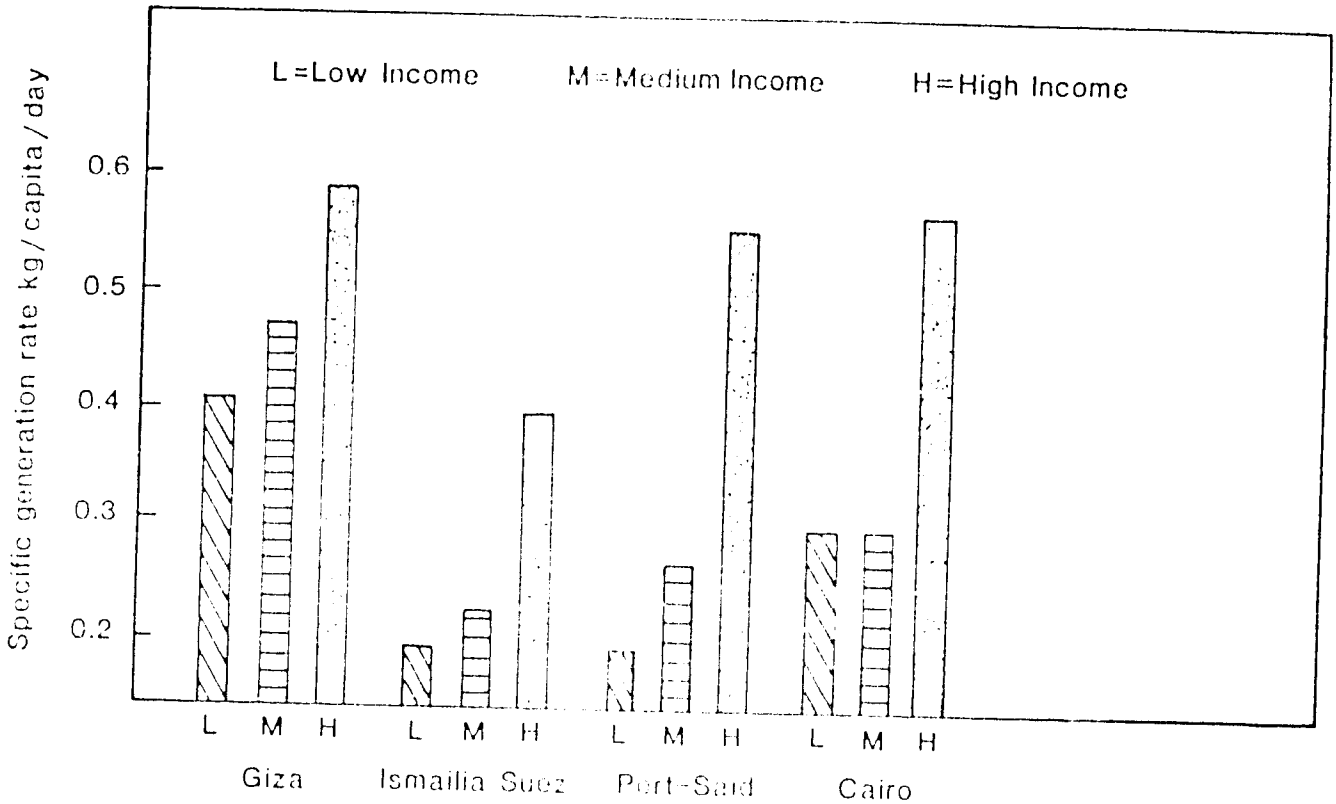


Exhibit 5.14 A
Specific generation rates of household wastes for different living standards.

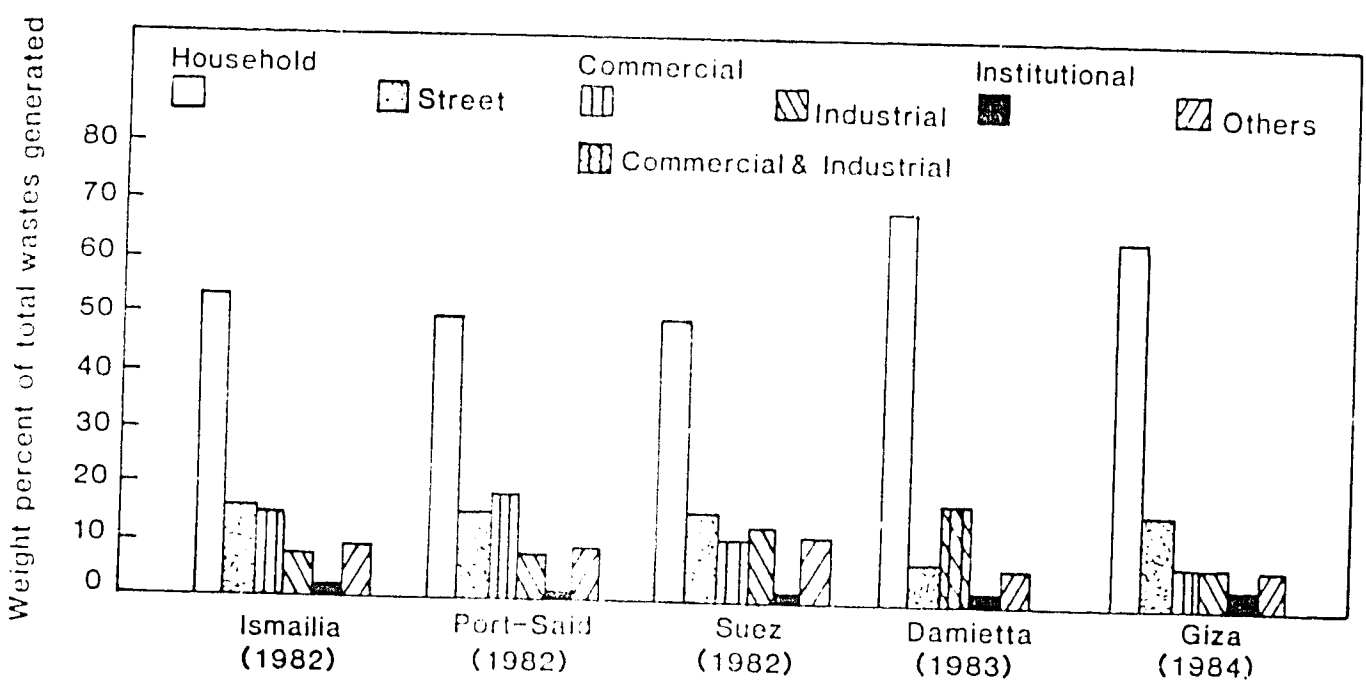
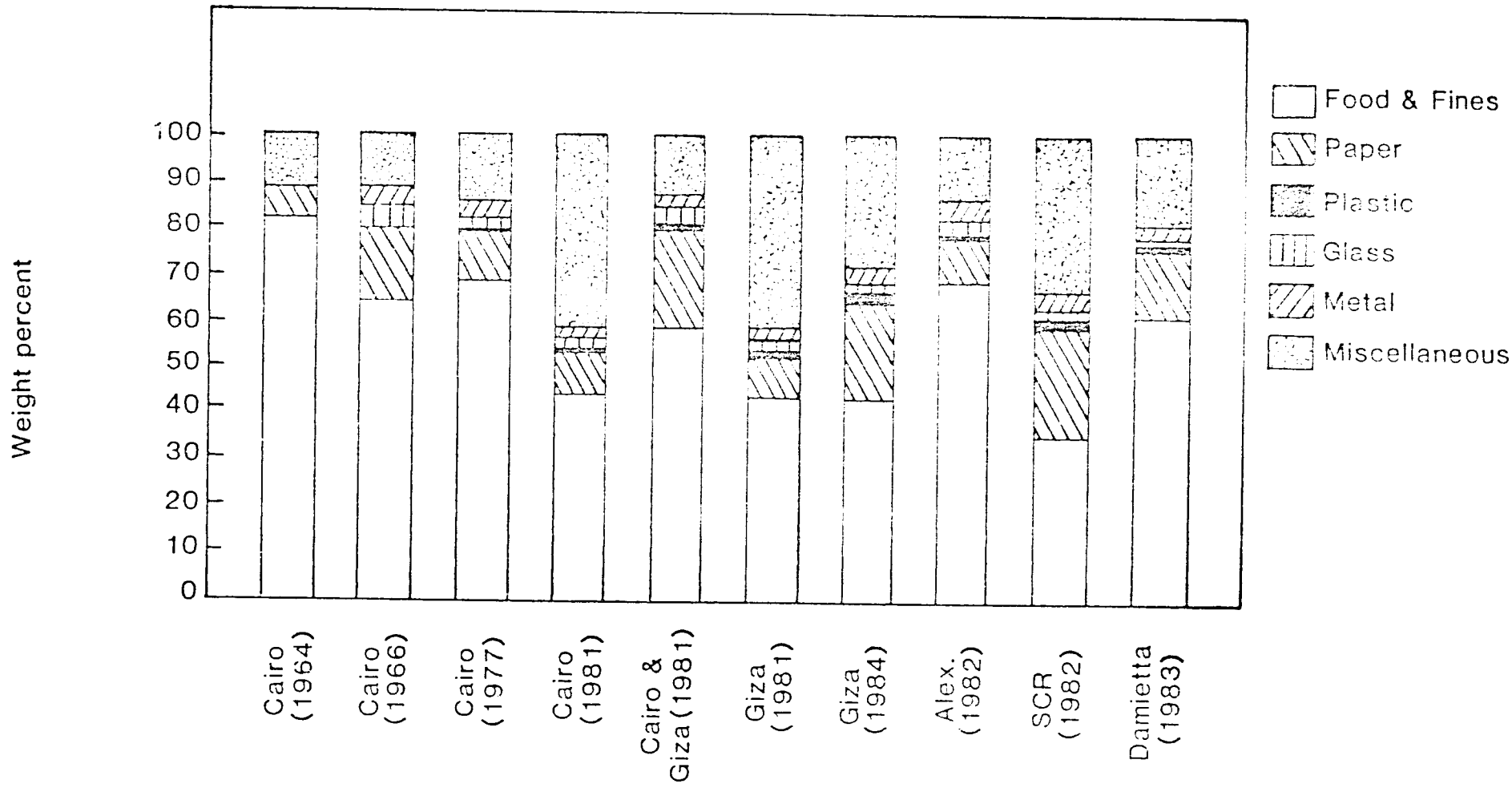


Exhibit 5.14 B
Sectoral MSW generation pattern.

Source: Halwagi, et al. op. cit.

EXHIBIT 5-15

MSW COMPOSITION



Conversion to Methane (RefCOM) is located in Pompano Beach, Florida. The RefCOM facility is the only large MSW anaerobic digester in the U.S. The primary technical objective of the facility is to demonstrate the ability of the process to produce gas economically over the long-term.

Material balance for the 1000 ton/day (tpd) RefCOM facility is shown in Exhibit 5.16. Assuming 14 MJ/kg as the energy content of the input solid waste, the gross energy yield in the form of methane is 34 percent. The net energy yield (as methane) allowing for electric power and heat required, is 22 percent. The net energy yield in the form of electricity is about 8 percent. Electricity generated by the plant is about 400 MWh/day. Electrical energy requirements of the plant is 53 MWh/day. Thus, about 350 MWh of electricity is available for sale.

Since the average energy content of MSW in Egypt is only about half that at the RefCOM plant, electrical energy output would be corresponding lower (assuming conversion efficiencies do not change). Therefore a 1000 tpd plant in Egypt would generate 200 MWh/day of electricity. Plant energy requirements could be slightly less if some of the pretreatment processes are conducted by the Zeballeen. For example, the magnetic separator, trommel screen and air classifier together use only 3 MWh/day of the energy requirements. Net electricity output from the Egypt plant would be 150 MWh/day. This is equivalent to about 260 barrels of oil per day. In addition, the plant produces about 700 tpd of soil conditioner and miscellaneous recyclable materials such as glass and metals.

5.4.2 Economic Analysis

The RefCOM plant cost about $32 million.[7] For the Egypt plant diesel fuel cost is about $0.75 million annually. Assuming an O&M cost of 5 percent

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[7] Kispert et al. op. cit.

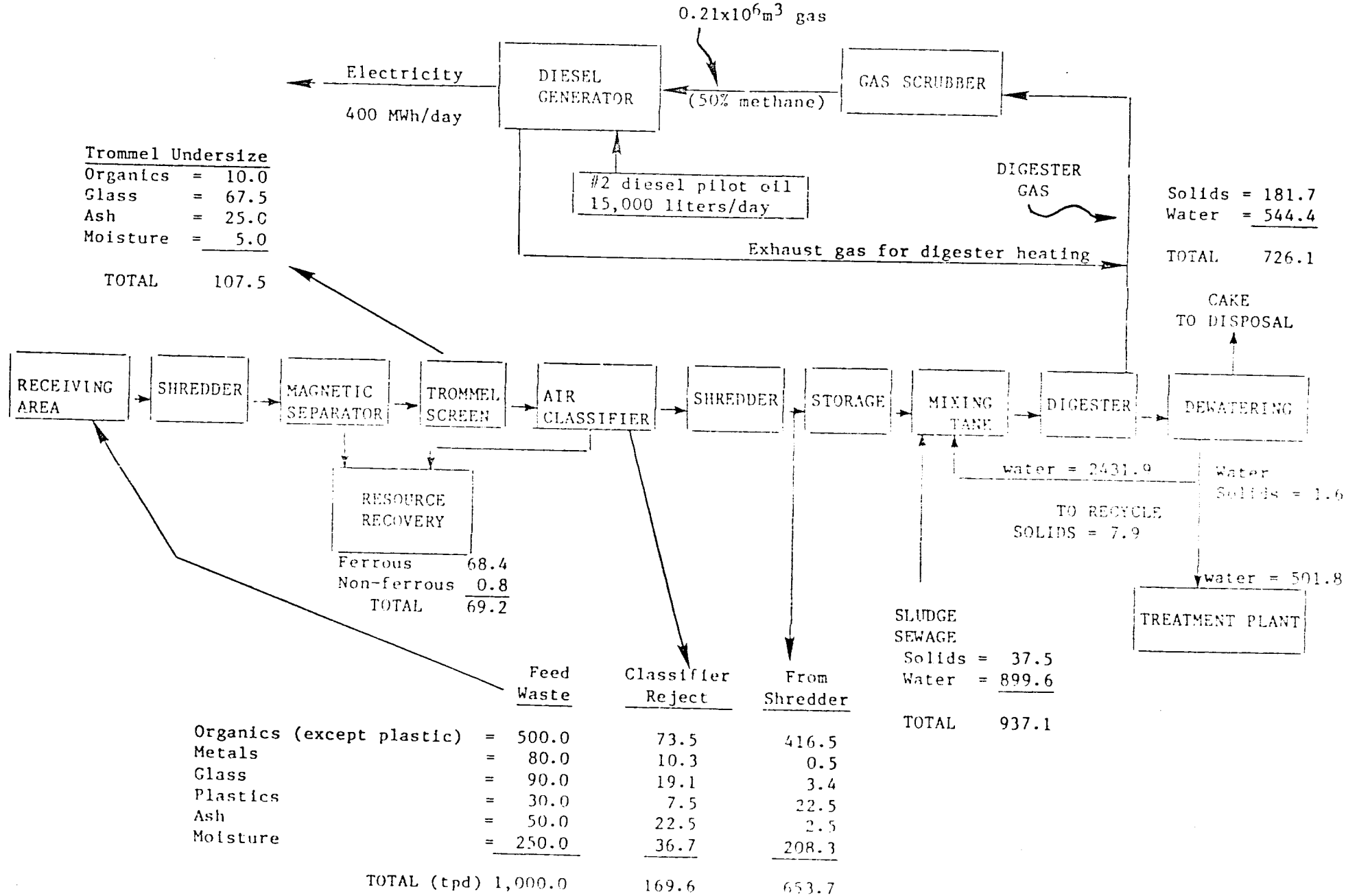

EXHIBIT 5-16

MATERIAL BALANCE FOR ELECTRICITY GENERATION FOR 100 TPD MSW ANAEROBIC DIGESTION SYSTEM

of capital cost and a 20 year plant life, the levelized cost of electricity will be about $0.10/kWh. This is higher than to current world oil prices. If credit can be taken for the soil conditioner and recyclable materials produced, the cost of electricity generated can be reduced.

An alternate configuration is to use a combustion turbine in place of the diesel generator. The turbine has better energy recovery potential than a diesel, also it does not require diesel fuel for operation. The combustion turbine does have a number of disadvantages. They require sophisticated compression equipment to raise the pressure and flow rate of the biogas into the turbine. Also, engine failure has been known to occur due to the fouling of the compression and peripheral equipment by H_2S in the biogas.

It should be noted that anaerobic digestion of MSW is at the R&D stage, unlike anaerobic digestion of sewage which is a commercially proven technology.

5.5 Use of Biogas in a Dairy Farm

5.5.1 Application Characterization

A dairy farm could effectively utilize biogas to provide source of electricity for its electricity and heating requirements. A schematic diagram of a dairy cogeneration system is shown in Exhibit 5.17.

The 600 cow sterotypical dairy produces about 15,600 MT of manure annually. This is equivalent to a daily production rate of 43 MT. The potential gas production rate is equivalent to about 2350 kWh/day (assuming a gas production rate of 0.44 cubic meters of biogas/kg of volatile solids, 0.08 kg of volatile solids/kg of manure, biogas energy content of 6.2 kWh/cubic meters of biogas and an engine-generatoy efficiency of 25 percent).[8] The size of the generator required to produce 2350 kWh/day is about 200 kW.

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[8] Computed from data in: Energy Research & Application Inc. (1981). Biogas Electric Power Cogeneration: 25 kW or greater. Prepared for Tennessee Valley Authority, Solar Application Branch, June 1, 1981.

142

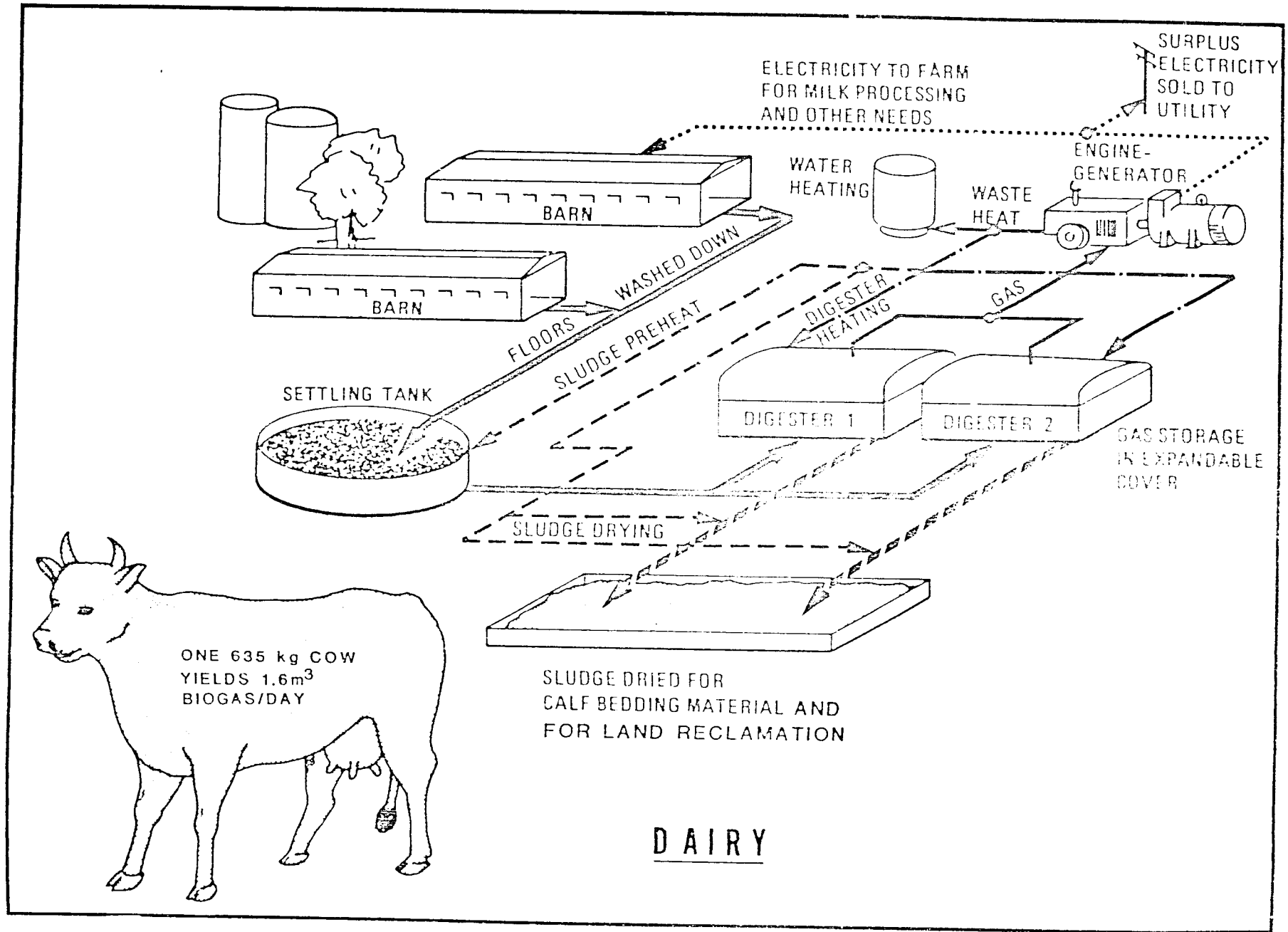

EXHIBIT 5-17
DAIRY BIOGAS COGENERATION SYSTEM

Source: Energy Research & Applications Inc. op. cit.

5.5.2 Economic Analysis

For the 600 cow stereotypical dairy, assuming a biogas electricity generation plant cost of $1500/kW and an O&M cost of 10% of capital cost, the cost of electricity is about $0.075/kWh. This is equivalent to about $44/barrel of oil. The cost is higher than the cost of grid power (international price - $0.05/kWh) but it is less than the cost of electricity generated using a 250 kW diesel generator.

The quantity of electricity demanded by the dairy is only 19 percent of the amount of biogas electricity generated, allowing a major portion of the electricity for other uses on-farm or for feeding the grid. The excess electricity generated annually is equivalent to about 1200 barrels of oil.

5.6 Biogas Utilization in Poultry Operations

5.6.1 Application Characterization

Due to the high biogas generation capability of poultry manure and the importance of the poultry industry in Egypt, this application is considered appropriate. Exhibit 5.18 shows a schematic of a poultry farm biogas cogenerator. The application considered is a typical GPC layer farm with 30,000 birds. Biogas can be produced and used to generate electricity to provide power for ventilation fans, feeding, lighting and egg conveying and cooling. The total electrical energy requirment is about 100 MWh/year.

The manure from 30,000 birds will generate about 420 m^3/day of biogas. If the biogas is used to generate electricity, the generated power could be utilized to supply the needs of the poultry operation. The quantity of electricity generated would be about 650 kWh/day.[9] The daily demand is 42 percent of this potential electricity generation capability, thus excess electricity is

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[9] Assuming that volatile solids production is 32 kg/day/1000 birds, 0.44 m^3 biogas/kg of volatile solids, biogas energy content of 6.2 kWh/m^3 of gas and an engine/generator efficiency of 25 percent.

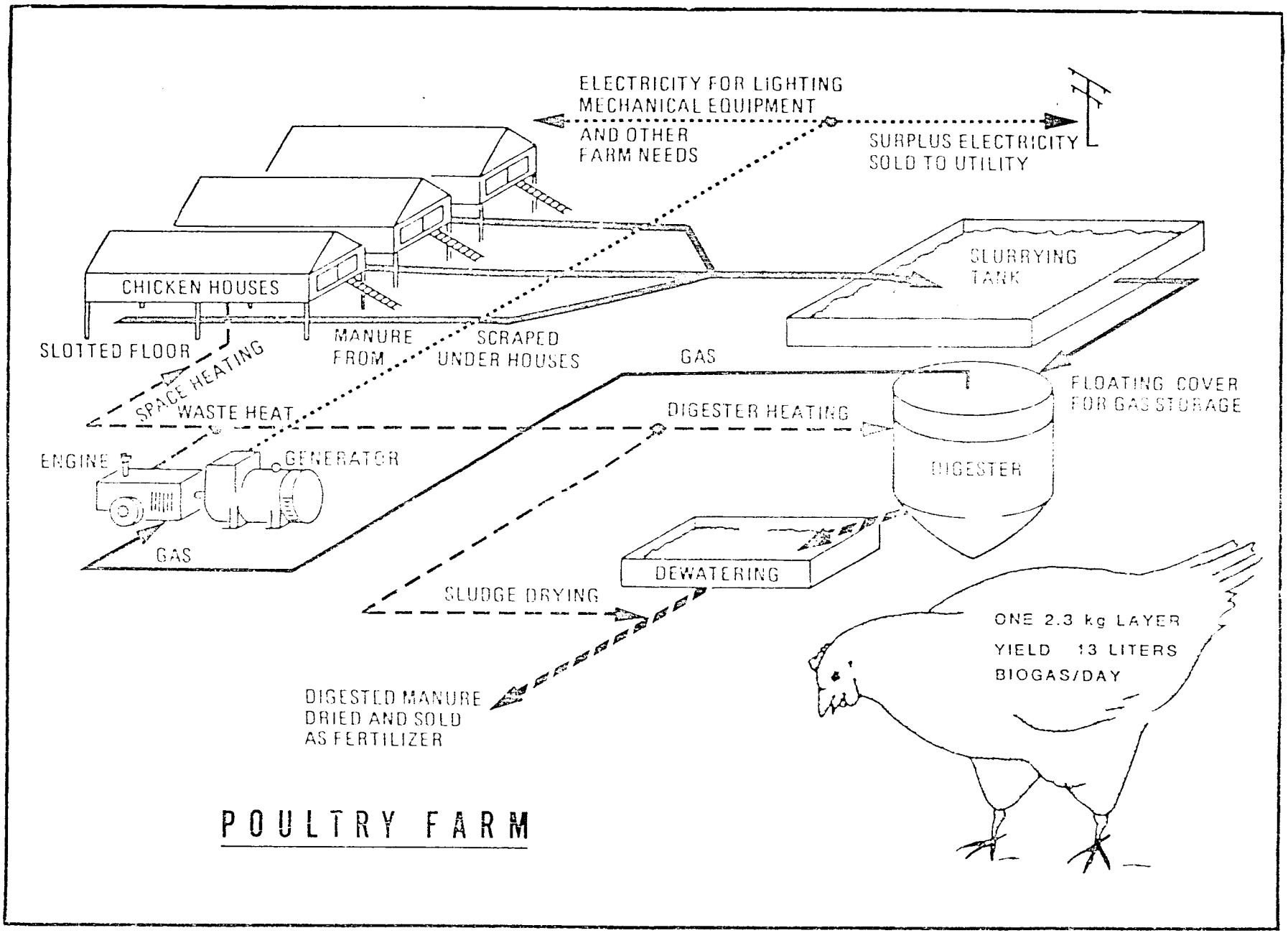

EXHIBIT 5-18
POULTRY FARM BIOGAS COGENERATION SYSTEM

Source: Energy Research & Applications Inc. op. cit.

available for other applications. A generator with a peak capacity of 90 kW could be used for electricity generation.

A similar plant could supply the electrical energy needs of a broiler operation. The 135,000 bird broiler GPC operation would require about 146 MWh/year of electricity for ventilation, feeding and lighting.

Since the GPC broiler farms collect manure on straw, these operation are not an attractive candidate for anaerobic digestion systems.[10] Also, since the manure is collected only every two months from each house, continuous digester operation is not possible. However, if manure can be collected as in the layer operations, the 135,000 birds could generate 1890 m^3/day of biogas. The quantity of electricity generated would be about 3000 kWh/day. The daily demand is only 13 percent of the potential generation capacity. A 250 kW generator could be used to generation electricity from the biogas.

5.6.2 Economic Analysis

At $1500/kW, the total plant cost would be about $135,000 for the 30,000 bird layer operation. Assuming that O&M cost is about five percent of capital cost annually, and system life in 20 years, the levelized electricity cost is $0.094/kWh.

For the 135,000 bird broiler operation, the plant would cost $375,000 at $1500/kW. Assuming that annual O&M cost is five percent of plant cost, and a plant life of 20 years, the corresponding cost of electricity is about $0.057/kWh.

If electricity had to be generated using diesel engines, the costs would

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[10] Generally materials that are higher in lignin (e.g. wood and crop residues) are poor feedstocks because the lignin protects the cellulose from bacterial attack. See: Pfeffer, J.T. (1978) Biological Conversion of Crop Residues to Methane. In: Proceedings of the Second Annual Symposium on Fuels from Biomass, Troy, N.Y. June 20-22, 1978.

be substantially higher. Additionally, the plant would generate valuable residue which can be used as a soil conditioner and fertilizer, or as a poultry feed supplement.

5.7 Remote Communications

5.7.1 Application Characterization

Photovoltaics, wind and photovoltaic/wind hybrids are often ideal sources of power for remote communication systems. The communications applications discussed in Section 3.0 are frequently sited in remote inaccessible location (e.g., mountain tops) where the maintenance-free characteristics and dependability of the renewable energy technologies make them ideally suited to power these applications.

Egypt has clearly recognized the advantage of PV stand-alone systems for powering remote communication systems and several are to be installed in Egypt. As discussed in Section 3.4, the PV-powered communication systems in Eygpt range in size from 150 W to 800 W power demand. Energy demand ranges from 3.6 to 19.2 kWh/day.

Hybrid systems are also appropriate for remote communications applications. They are particularly advantageous when the wind and solar resources are complementary. For example, in regions where wind energy is high at night, a PV/wind hybrid can result in a system with lower battery storage needs when compared to a PV or wind-only system. Furthermore, since there are two power sources, system reliability and energy availability becomes much higher. Studies conducted in the U.S. [11] have shown that PV/wind hybrids with one day of storage could provide power as reliably as a PV or wind only system with 3-5 days of storage.

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[11] See: Cabraal and Pena (1984) op. cit. Also see discussion in: Powell, W.R., et. al. (1981) Alternate Hybrid Power Sources for Remote Site Applications. U.S. Department of Transportation, CG-D-06-81.

5.7.2 Economic Analysis

Variation in electricity cost with daily electricity demand for low energy demand applications are shown in Exhibit 5.19. The energy supply technologies considered are PV, wind and diesel generators. The cost assumptions used in this analysis are the same as in Exhibit 5.4, except for the following: Near-term (1985-1990) PV module cost - $10/Wp; mid-term (1990-1995) PV module cost - $2.50/Wp; labor cost for maintaining the diesel generators - $10/hour. A higher labor cost is assumed since these applications are likely to be found in remote less accessible areas. The wind and solar resource availability assumption are the same as in Exhibit 5.2

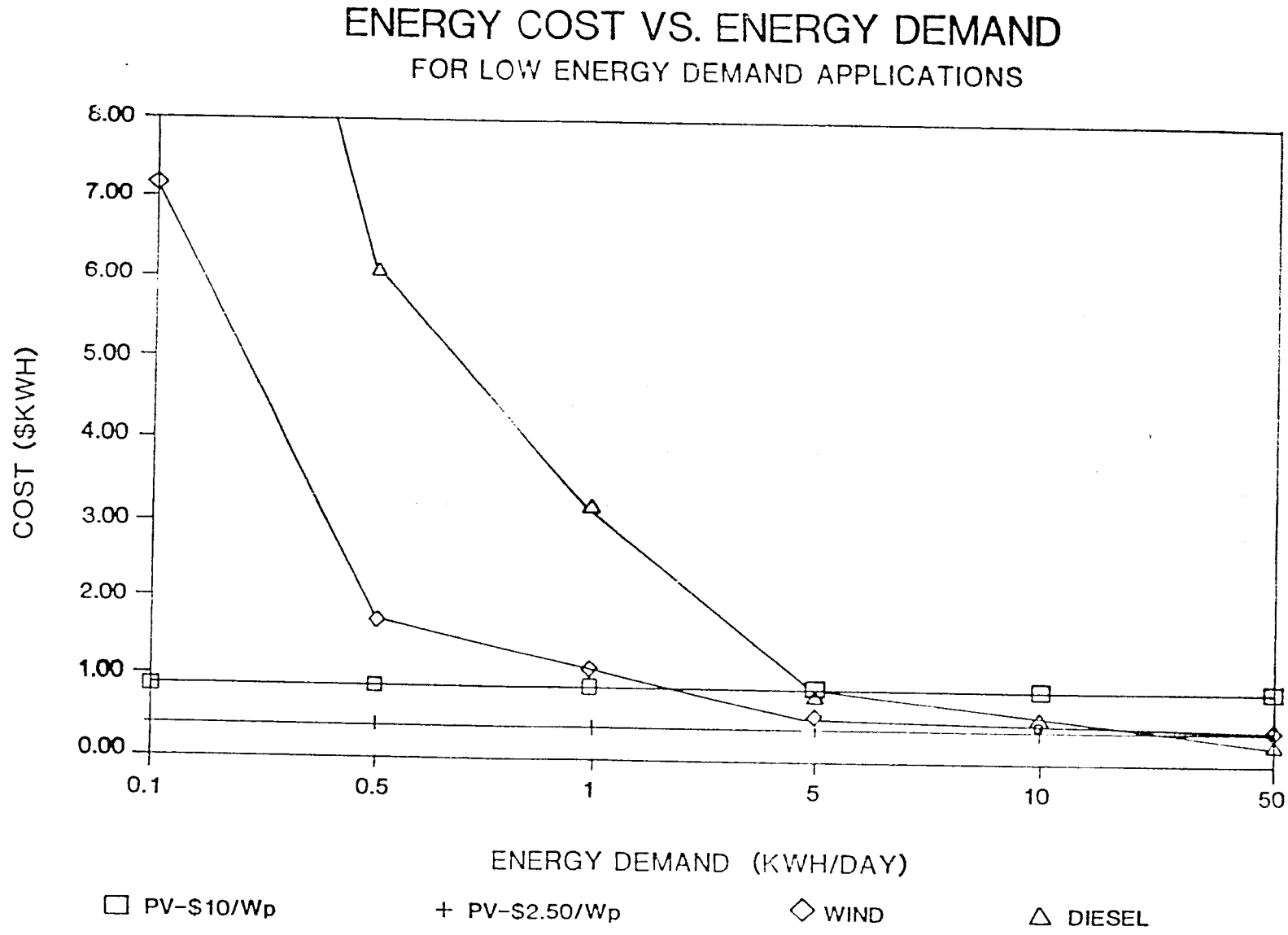
The analysis shows that in the near-term PV systems provides the lowest cost energy up to about 2kWh/day demand. For daily demand greater than 2 kWh and less than 30 kWh, wind systems are cheapest. In the mid-term, PV systems provide the lowest energy costs for demand up to 30kWh/day; diesels provide lower energy costs for application requiring higher energy demand.

It should be noted that the above analysis does not take into account the cost of fuel delivery which could be very high if the location is difficult to reach. Also, in many instances, the unreliability of diesels may preclude its use for many remote communication applications.

5.8 Cathodic Protection

Cathodic protection of pipelines, well-casings, storage tanks, bridges, piers, docks and locks, ship hulls, offshore platforms, bouys and other underground or underwater metallic structures is an ideal application of photovoltaics. The photovoltaic-powered low-voltage DC power supply prevents the corrosion of metallic structures which are in contact with the ground, groundwater, sea water or fresh water by passing a low-voltage DC current between the metal structure and a passive electrode. Exhibit 5.20 shows the features of a typical photovoltaic

EXHIBIT 5-19


ENERGY COST VS. ENERGY DEMAND
FOR LOW ENERGY DEMAND APPLICATIONS
COST ($KWH)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.1
0.5
1
5
10
50
ENERGY DEMAND (KWH/DAY)
PV-$10/Wp
PV-$2.50/Wp
WIND
DIESEL

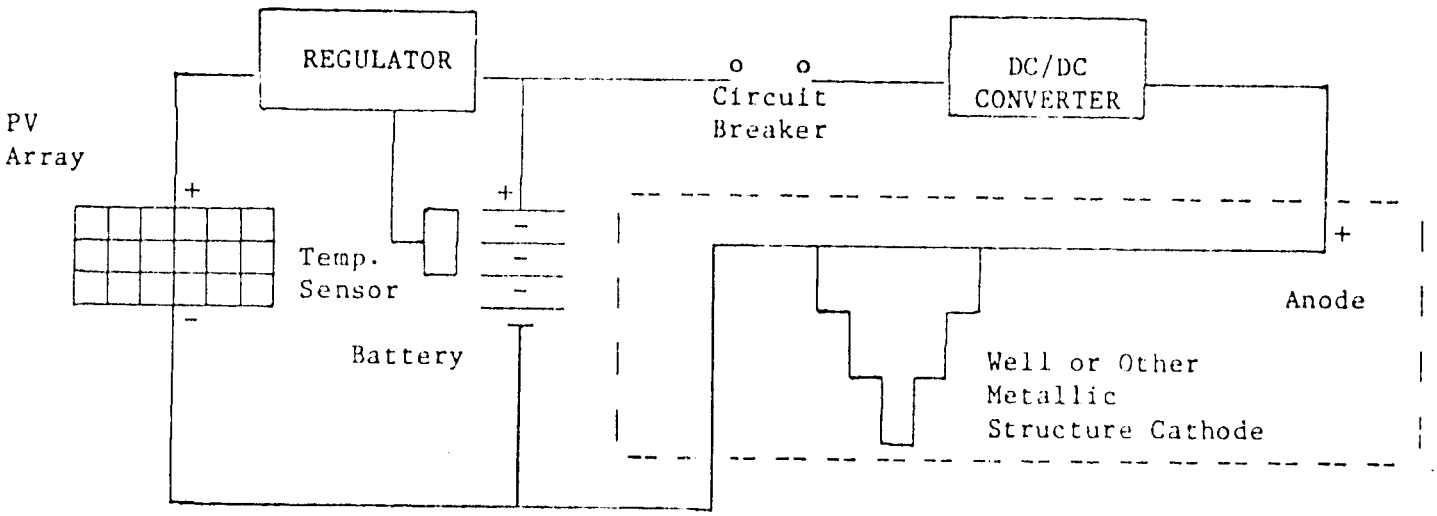


EXHIBIT 5-20
FEATURES OF A PV-POWERED
CATHODIC PROTECTION SYSTEM

powered cathodic protection system.

The size of the array and battery depend on the size and shape of the structure to be protected, resistivity of the transmission media and insolation. Protection currents can range from 100 mA/m^2 or greater for bare steel to 1 mA/m^2 for a heavily coated structure where the exposed metal surface is small. For example, a PV system generating 400 kWh annually could provide protection for a 40 km of a well insulated 30 cm diameter pipe. Under average insolation levels in Egypt, the PV array size would be about 200 Wp. The system would also require a battery which provides power at night and during the low insolation periods. A battery with about 5 kWh of storage would be required. Annual protection cost is about $0.006/$m^2$ of pipe surface.

Alternative power sources for cathodic protections are DC power supplies connected to the electric grid and thermal electric power supplies operating on bottled gas. In the case of using power from the grid the controlling factor is the cost of running subtransmission lines. If the location of the structure is close to an existing power line and the terrain is relatively flat, the utility grid power could be feasible. However, the structures are often in remote areas, far from the grid. Thermal electric power supplies have the disadvantage that they require a regular fuel supply. Also, they have to be highly reliable. Again the remoteness of the site may make resupplying cost prohibitively high.

5.9 Solar Thermal Technology Utilization in Agriculture/Industrial Processing

5.9.1 Technology/Application Options Selection

For the following analysis we have selected evacuated tube, flat plate, parabolic trough solar collector, and flat plate/parabolic trough hybrid technology. These systems were selected for the following reasons: 1) they are

161

considered relatively mature and proven solar thermal equipment and 2) they are expected to perform well in the Egyptian environment. Conversely, the parabolic dish technology was not chosen for analysis because it is not as mature a technology.

Exhibit 5.21 lists the applications characterized in Section 3.6. Their production and process temperature requirements are tabulated in Exhibit 5.21 and it is clear that both their current production levels and their expected rates of growth earmark them as high priority industries in the Egyptian production sector. Also the temperature requirements fell within the range of potential economic viability for solar thermal technology applications.

We have deleted form the analysis the cigarette industry. This is potentially a promising application which meets the requirement criteria mentioned above as those required of a candidate for the utilization of solar thermal energy. Upon assessment of the U.S.-style processing, we learned that they use very little, if any, steam as their process uses electricity entirely.[12]

5.9.2 Economic Analysis

For the economic analysis herein described we have chosen for our test case the application of evacuated tube, flat plate, parabolic trough solar collector and flat plate/parabolic trough hybrid technology to moderate temperature industrial thermal processes. Since this is only a preliminary screening of technology/applications it is sufficient to analyze selected loads and temperatures so as to preview what parameters are germane to the analysis and to demonstrate how economical solar technology can be in the "best case" treatment.

Exhibit 5.22 summarizes the performance and economics of the aforementioned

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12 Allen, P. R.J. Reynolds Tobacco Comapny, Personnel Communication, August 1985.

152

Exhibit 5.21

TEMPERATURE REQUIREMENTS AND PRODUCTION OF PRIORITY AGRICULTURAL AND INDUSTRIAL PROCESS INDUSTRIES FOR APPLICATION OF SOLAR THERMAL TECHNOLOGY

Agriculture/Industrial Product	Process Heat Requirement	Temperature C	Thermal Energy Consumption 81/82	86/87	Units	% increase
soap manufacture	saponification	100				
			6.3	7.9	10^{15}J	26
	finishing	65				
hydrogenated oil production	vacuum drying	200				
			7.40	13.1	10^{15}J	76
	hydrogenation	130				
Pharmaceuticals	autoclave reacting	120				
			9.5	20.6	10^{15}J	117
	vacuum drying	130				
food canning	blanching	90				
	brining	70	1.47	1.68	10^{15}J	12.5
	retorting	130				
malt beverages	cooking	100				
	bottle washing	120	1.25	1.60	10^{15}J	28
	brew kettle	100				

EXHIBIT 5.22 A

Summary of Performance and Economic Data for
Solar Thermal Technologies Applied to Industrial Processes

	UNITS	(b)		(c)		(d)		(e)	(f)
COLLECTOR TYPE		FLAT	FLAT	EVAC	EVAC	PARA	PARA	PARAST	HYSTEAM
TEMPERATURE OF PROCESS	DEG C	70	90	70	90	70	90	130	130
PROCESS LOAD (a)	GJ/YR	14454	14454	14454	14454	14454	14454	14454	14454
ENERGY PRODUCED	GJ/YR	6793	6504	6865	6685	7805	7732	8250	7615
COLLECTOR EFFICIENCY	W/M2/C	0.76	0.76	0.8	0.8	0.72	0.72	0.72	----
F FACTOR	UNITLESS	0.47	0.45	0.47	0.455	0.54	0.535	0.52	----
AREA OF COLLECTORS	M2	2500	2500	2500	2500	2500	2500	3300	3294
INSTALLED PRICE OF COLLECTOR	$/M2	371	371	418	418	500	500	500	489.5
DISCOUNT RATE (%)	%	10	10	10	10	10	10	10	10
LIFE (YEARS)	YEARS	10	10	10	10	10	10	10	10
CAPITAL COST	US $	927500	927500	1045000	1045000	1250000	1250000	1650000	1612413
OPERATION & MAINTENANCE %	%	1.5	1.5	1.5	1.5	3	3	3	3
OPERATION & MAINTENANCE	US $	13912.5	13912.5	15675	15675	37500	37500	49500	48372.3
ANNUALIZED CAPITAL COST	US $	150946.	150946.	170068.	170068.	203431.	203431.	268529.	262412.
TOTAL ANNUAL COST	US $	164858.	164858.	185743.	185743.	240931.	240931.	318029.	310785.
COST OF ENERGY	$/GJ	24.27	25.35	27.06	27.79	30.87	31.16	38.55	40.81
COST OF ENERGY	$/KW-HR	0.087	0.091	0.097	0.100	0.111	0.112	0.139	0.147
COST OF ENERGY IN TERMS OF #6 FUEL OIL	$/BBL	160.96	168.12	179.45	184.29	204.74	206.67	255.68	270.69

(a) for all the analyses we used a 3.3 GJ/hr load over a 4380 hour year.

(b) FLAT—Flat plate collector, all information obtained from Mathew Curgin, Novan Energy Inc., Boulder CO, personal communication, August, 1985.

(c) EVAC—Evacuated tube collector, all information obtained from Bill Idon, Joule Solartron Inc., Orange NJ, personal communication, August, 1985.

(d) PARA—Parabolic Trough collector, all information obtained from Ed Schmidt, Alpha Solarco Inc., Spartanburg, SC, personal communication, August, 1985.

(e) PARAST—Parabolic system for generating steam is detailed and referenced in 5.10.2 and Appendix D.

(f) HYSTEAM—The Flat Plate/Parabolic Trough hybrid for generating steam combined references B and D and those used in E.

154

EXHIBIT 5.22B

PROJECTIONS OF SOLAR THERMAL ENERGY
COSTS IN 1990

	UNITS	1990	1990	1990	1990
COLLECTOR TYPE		FLAT	EVAC	PARA	PARAST
TEMPERATURE OF PROCESS	DEG C	70	70	90	130
PROCESS LOAD (a)	GJ/YR	14454	14454	14454	14454
ENERGY PRODUCED	GJ/YR	6793	6865	9077	8662
FR*UL (TEST SLOPE)	W/M2/C	4.323	1.4	0.595	0.595
FR*TAU*ALPHA (TEST INTERCEPT)	UNITLESS	0.789	0.6	0.76	0.76
F FACTOR	UNITLESS	0.47	0.475	----	----
AREA OF COLLECTORS	M2	2500	2500	2501	3300
INSTALLED PRICE OF COLLECTOR	$/M2	320	353	392	521
DISCOUNT RATE (%)	%	10	10	10	10
LIFE (YEARS)	YEARS	15	15	10	10
CAPITAL COST	US $	800000	882500	980392	1719300
OPERATION & MAINTENANCE %	%	1.5	1.5	3	3
OPERATION & MAINTENANCE	US $	12000	13237.5	29411.7	51579
ANNUALIZED CAPITAL COST	US $	105179.	116025.	159554.	279808.
TOTAL ANNUAL COST	US $	117179.	129263.	188966.	331387.
COST OF ENERGY	$/GJ	17.25	18.83	20.82	38.26
COST OF ENERGY	$/KW-HR	0.062	0.068	0.075	0.138

EXHIBIT 5.22C

COST BASES FOR SOLAR TECHNOLOGIES

	UNITS	(a) FLAT	1990-(d) FLAT	(b) EVAC	1990-(e) EVAC	(c) PARA	1990-(f) PARA	(c) PARAST	1990-(f) PARAST
TEMP. OF PROCESS	deg C	70	70	70	70	90	90	130	130
PROCESS LOAD	GJ/HR	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
COLLECTOR SIZE	M2	2500	2500	2500	2500	2500	2500	3300	3300
COST OF CONTROLS	US $	5000	5000	5000	5000	16665	16665	30000	30000
COST OF COLLECTORS	US $	422000	295400	540000	378000	675000	405000	890000	534000
BALANCE OF EQUIP.	US $	8000	8000	8000	8000	16665	16665	25000	25000
ENGINEERING	US $	20000	20000	20000	20000	66660	66660	66660	66660
INSTALLATION	US $	472000	472000	472000	472000	475000	475000	649000	649000
TOTAL CAPITAL	US $	927000	800400	1045000	883000	1250000	979990	1650000	1304660
INSTALLED COST	$/M2	371	320	418	353	500	392	560	521
OPER. & MAINTENANCE	US $	13900	13900	15700	15700	37500	37500	44000	44000

(a) Mathew Curgin, Novan Energy Company, Boulder, Colorado August 9, 1985, quote by telephone, uninstalled price of collector—$169/m2

(b) Bill Idon, Joule Solartron, Orange, New Jersey, August 12,1985, quote by telephone, uninstalled price of collector--$215/m2

(c) Don Duffy, Acurex Solar Company, Mountain View, California, August 21, 1985, quote by telephone, uninstalled price of collector--$270/m2, steam application

(d) DOE projection, 30% capital cost reduction of collectors personal communication, A. Cabraal, Meridian Corporation, August 23,1985.

(e) DOE projection, 30% capital cost reduction of collectors personal communication, A. Cabraal, Meridian Corporation, August 23, 1985.

(f) DOE projection, 40% capital cost reduction, 5% efficiency increase, personal communication, A. Cabraal, Meridian Corporation, August 23, 1985.

technologies in various industrial applications. Each column of data is derived from an independent analysis performed for a given set of input data. For example, an analysis was performed for flat plate collectors applied to a process requiring 70°C and 3.3 GJ/hr in thermal energy.

Since the process loads are quite large for some of the technologies, i.e, flat plat and evacuated tube, and because we tried to maximize the fraction which solar energy could contribute to the total load, we opted for a rather large system for each analysis. Because the objective of this analysis is comparing economics, we standardized the configuration size at 2500 m^2. For all of the analyses input solar energy was given to be that characterized as Cairo West.[13] An example of the data from which Exhibit 5.22 was derived is shown in Exhibit 5.23.

The first six analyses of Exhibit 5.22 were done for flat plate, evacuated tube and parabolic troughs applied to 70° and 90° processing requiring 3.3 GJ/hr. The difference in collector efficiency accounts for the variation in energy production (also the parabolic system tracks the sun thus receiving more solar energy per unit area per day). From the table it is clear that the least expensive energy is that produced by a flat plate system for a 70°C process.

The steam calculation required a multi-level analysis which included not only computing the energy and mass flows of a solar steam system but also selecting the appropriate configuration. Exhibits 5.24 and 5.25 illustrate the two basic solar steam system designs.

In an unfired-boiler steam system Exhibit 5.24, an organic heat transfer fluid is pumped through the collector field and then to an unfired-boiler. The hot fluid within the tubes of the boiler vaporizes the water next to the tubes; this saturated steam is fed to the existing steam heater, which delivers energy

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13 Egypt Electricity Authority, Climatic Data, Unpublished Typescript, July 1985.

*** GENERAL SOLAR HEATING SYSTEM ***
** FLAT PLATE COLLECTOR **

	SOLAR GJ	LOAD GJ	STACK GJ	AUX GJ	F
JAN	162.7	58.9	1.23	28.2	0.52
FEB	162.7	53.2	1.15	23.0	0.57
MAR	187.5	58.9	1.26	24.7	0.58
APR	182.8	57.0	1.17	23.7	0.58
MAY	176.5	58.9	1.08	27.2	0.54
JUN	168.5	57.0	0.93	27.1	0.52
JUL	170.2	58.9	1.04	26.2	0.56
AUG	183.1	58.9	1.12	23.5	0.60
SEP	184.5	57.0	1.17	21.4	0.62
OCT	182.4	58.9	1.20	23.0	0.61
NOV	158.1	57.0	1.13	25.8	0.55
DEC	151.7	58.9	1.17	29.7	0.50
YR	2078.8	693.5	13.70	303.6	0.56

1	NUMBER OF COLLECTOR PANELS....	676	
2	COLLECTOR PANEL AREA.....	3.7	
3	FR*UL (TEST SLOPE).....	3.73	W/M2-C
4	FR*TAU*ALPHA (TEST INTERCEPT).	.79	
5	COLLECTOR SLOPE.....	45	DEG
6	COLLECTOR AZIMUTH (SOUTH=0)...	0	DEG
7	INCIDENCE ANGLE MOD TYPE(6-10)	8	
8	NUMBER OF GLAZINGS.....	1	
9	INC ANGLE MODIFIER CONSTANT.	0	
10	INC ANGLE MODIFIER VALUE(S).		
	1 .999 .998 .995 .991 .953 .882		
	.7 .35 0		
11	COLLECTOR FLOWRATE/AREA.....	.015	KG/S-M
12	COLLECTOR FLUID SPECIFIC HEAT.	4.19	MJ/KG-C
13	MODIFY TEST VALUES (1=Y,2=N)..	2	
14	TEST COLLECTOR FLOWRATE/AREA	.015	KG/S-M
15	TEST FLUID SPECIFIC HEAT....	4.19	MJ/KG-C

Exhibit 5.23

Data from a Computer-derived Calculation of Solar Energy Output from a Flat Plate System

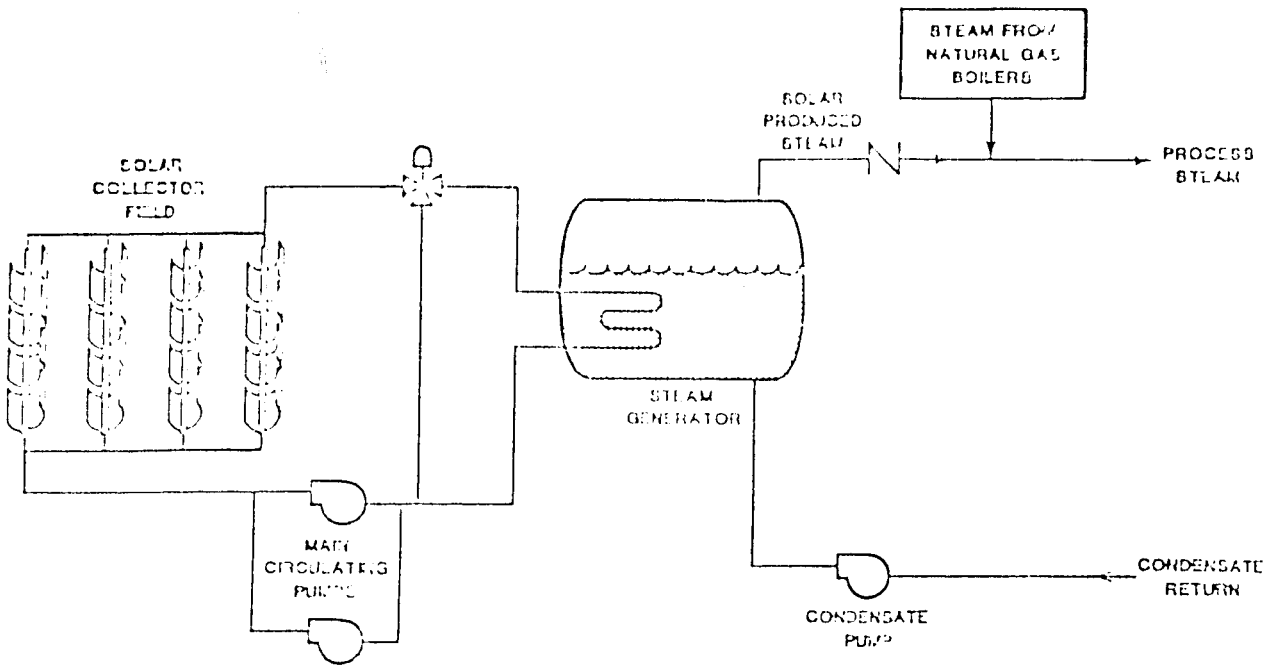

Exhibit 5.24

Schematic Diagram of an
Unfired-Boiler Solar Steam System

to the industrial process. As the steam is generated, additional condensate is supplied to the boiler. The hot condensate is assumed to be saturated. Steam generation is a latent-heat process; therefore, no temperature change occurs on the water side of the boiler. Because heat is being transferred from the collector loop fluid to the water, the fluid in the collector loop must always exceed the steam saturation temperature[14].

The unfired-boiler unit is a system which is advantageous in that it is generally the most reliable technology i.e., it requires less maintenance. Its disadvantages are that 1) it uses additional equipment (e.g. heat exchanger) and thereby is more costly and 2) the working fluids are normally toxic thus preventing their use in areas which process food.[15]

The design which competes with the unfired-boiler is the Flash Steam System (shown in Exhibit 5.25). In a flash steam solar system, pressurized water is circulated through the collector field and flashed to a low-quality steam across a throttling valve into a flash, or separator, tank. Flashing is a constant enthalpy process that converts the sensible heat of the water into a two-phase mixture of saturated water and saturated steam at conditions prevailing in the flash tank. The steam quality (fraction of total mass flow that is flashed to vapor) usually is less than 10%. Steam separated in the flash tank is fed into the plant steam distribution system to be used by the industrial process. The saturated liquid is recirculated through the collector field. To maintain the necessary liquid level in the flash tank, boiler feedwater is injected into the pump suction.

For analysis we chose to work with the Flash Steam model. It is a design which is less costly and has greater range in its application. This is

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[14] Kutscher, C. et al. (1982) Design Approaches for Solar Industrial Process Heat System, SERI.

[15] Corbin, P. Lockwood Greene, Inc. Personal Communication, August, 1985

particularly important in Egypt since replicability of technology factors highly in the renewable energy technology selection process. The results of our analysis are summarized in Exhibit 5.22A. The details of the calculation are shown in Appendix D. As expected, the higher temperature process of steam generation is significantly more costly than the other hot water process (130°C steam costs 25% and 52% more than 90°C hot water produced by parabolic and flat plate collectors respectively). It is noteworthy that there have been relatively few analyses performed on solar steam production and as we have discovered, the literature is both limited and occasionally error-prone.

Exhibit 5.22B is a summary of data similar to that presented in Exhibit 5.22A, which differs as a result of capital cost reductions in solar thermal collectors projected by the U.S. Department of Energy (DOE) for the year 1990. The flat plate and evacuated tube collectors are expected to decrease 30% in price, whereas the parabolic trough system should experience a 40% price reduction and a 5% efficiency increase by 1990.[16] Input data used in the economic analyses are shown in Exhibit 5.22C.

The preceeding analysis should be regarded as only preliminary and approximate and should only be used in a comparative sense. Major cost changes will result from such factors as Egyptian labor costs, shipping expenses, location changes (i.e., place other than Cairo West), etc. The process temperatures chosen reflect typical industrial temperatures in Egypt (e.g. food canning) and were used to present a realistic perspective.

We performed a preliminary analysis on a hybrid parabolic trough/flat plate steam generating system; the details of which are presented in Appendix E. For simplicity we used an approach which is based upon an assessment of the

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16 DOE projection, National Solar Thermal Research Program, 5-year Plan, December, 1984, via personal communication, A. Cabraal, Meridian Corporation, August 23, 1985.

maximum amount of energy which a flat plate array can contribute to a steam production cycle. A schematic diagram of the hybrid is shown in Exhibit 5.26. It is essentially a flash system with a flat plate field inserted upstream of the parabolic array. The resulting energy produced and collector areas were then combined to produce the cost shown in Exhibit 5.22.

This analysis shows that the hybrid system produces slightly more expensive energy than the parabolic-only unit. Since our analysis was not an analytical optimization it is possible that these economies may change using such an approach. A more detailed analysis of parabolic flash, parabolic unfired-boiler, flat plate/parabolic flash hybrid and flat plate/parabolic unfired-boiler systems will be performed in the analyses of Task 2.2.2. One can surmise that the optical efficiencies of the two collectors are not significantly different at the lower temperatures, and this coupled with only a moderate collector price differential would suggest that little, if any, savings can be realized by the hybrid system.

5.10 Solar Design Options for Building Climate Control

5.10.1 Technology/Application Option Selection

5.10.1.1 Space Heating

A primary use of domestic energy in the residential sector in Egypt consists of space heating. Currently, the energy used comes from the combustion of liquid fuels. Habitants of the rural areas often use biomass for space heating. However, due to the low cost of fossil and electric fuels the trend is toward increased consumption of commercial fuels. Urban households in their large majority use commercial fuels.

Exhibit 5.27 presents an evaluation of the use of both gasoil and electricity options for space heating for Cairo. The dwelling analyzed is the same 120 m^2 apartment used for the calculation of the heat loss coefficient.

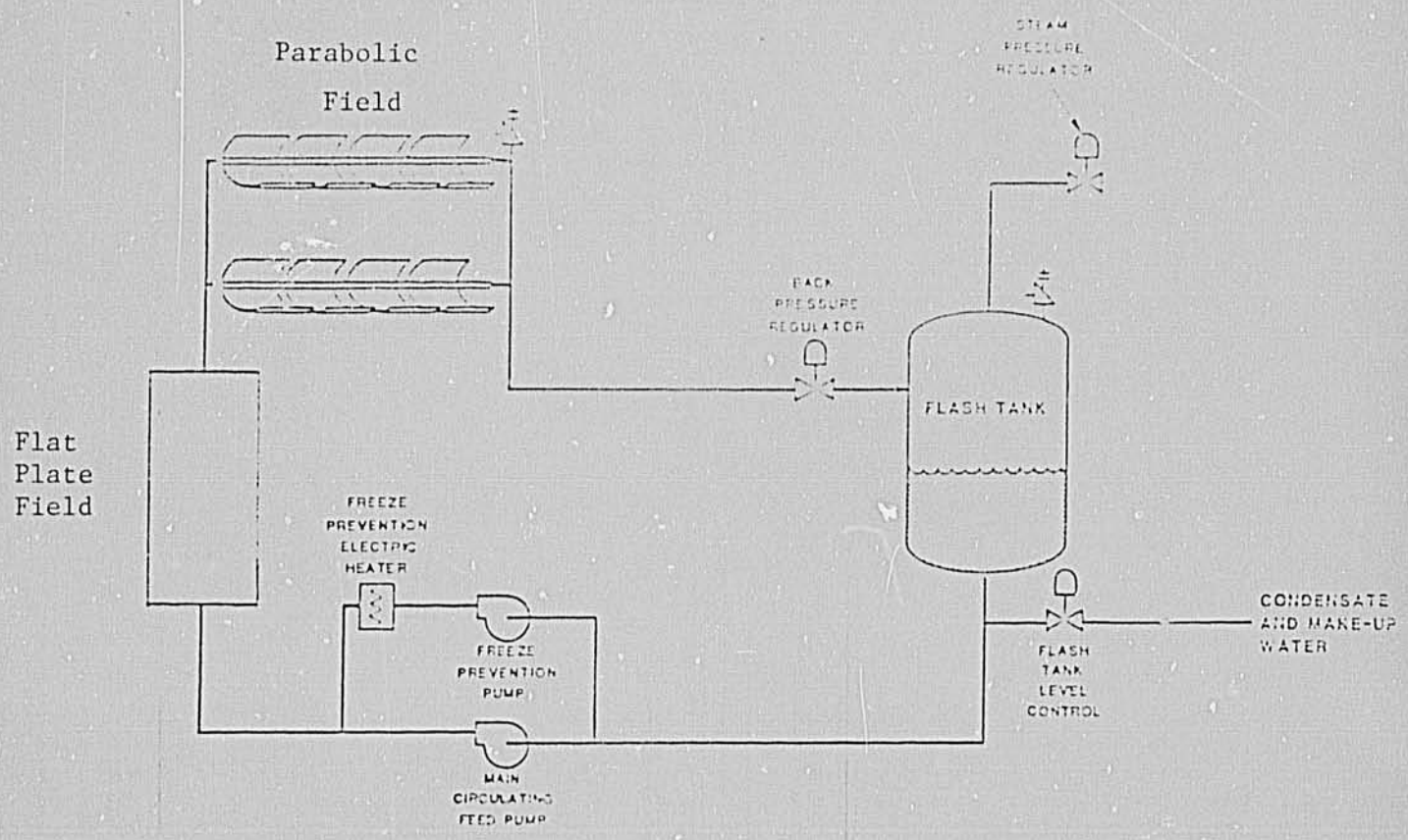

Exhibit 5.26

Schematic Diagram of a Parabolic Trough/Flat Plate

Hybrid Solar Steam System

163

EXHIBIT 5.27

EVALUATION OF THE GASOIL AND ELECTRIC OPTIONS FOR SPACE HEATING

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
MEAN TEMPRATURE (deg c)	13.2	14.2	16.6	20.2	24.2	26.7	28.2	27.8	25.4	23.4	19.2	14.8	
TEMPERATURE REQUIRED (deg C)	18	18	18	18	18	18	18	18	18	18	18	18	
TEMP. DIFFERENCE	4.8	3.8	1.4	0	0	0	0	0	0	0	0	3.2	
DAYS PER MONTH	31	28	31	30	31	30	31	31	30	31	30	31	
HEAT LOSS COEFF. (W/deg C-M2)	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	
DEGREE DAYS	157.7	115.7	69.9	14.8	1.3	0.2	0	0	0.2	1.2	19.6	109	489.6
DWELLING AREA (M2)	120	120	120	120	120	120	120	120	120	120	120	120	
AREA FRACTION	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
TIME FRACTION	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	
TOTAL HEATING LOAD (KW-HRth)	155.49	114.08	68.924	14.593	1.2818	0.1972	0	0	0.1972	1.1832	19.326	107.47	482.76
GASOIL HEATING													
HEATING EFFICIENCY	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	
GROSS ENERGY CONSUMP. (KW-HR/MO)	444.28	325.95	196.92	41.695	3.6624	0.5634	0	0	0.5634	3.3807	55.218	307.08	1379.3
GASOIL CONSUMPTION (TONNE/MONTH)	0.0374	0.0274	0.0166	0.0035	0.0003	0.0000	0	0	0.0000	0.0002	0.0046	0.0258	0.1162
ELECTRIC HEATING													
GROSS ENERGY CONSUMP. (KW-HR/MO.	155.49	114.08	68.924	14.593	1.2818	0.1972	0	0	0.1972	1.1832	19.326	107.47	482.76
ELECTRIC. CONSUMP. (KW-HR/MONTH)	172.77	126.76	76.582	16.214	1.4242	0.2191	0	0	0.2191	1.3147	21.473	119.42	536.40

Using the monthly degree-days derived earlier and assuming that one $30m^2$ room is heated for 8 hours per day we are able to calculate a typical heating load. Taking the efficiency of a gasoil heater as 35 percent, the gross energy consumption can be derived and is equivalent to a consumption of .12 Tonnes/year, per household. The analysis for the electric heating option is based on an electric resistance efficiency of 90 percent (10 percent radiation loss through windows). This results in an annual electricly consumption of 536 KW-hr/yr.

A solar space heating system was evaluated to check its applicability in Egypt. the system defined to meet the typical dwelling load consists of $3m^2$ of air or water panels. The model incorporates the heating load method used to calculate space heating requirements. The solar fraction is calculated using the SLR correlation method which is appropriate for space heating analysis. Exhibit 5.28 presents the results of the analysis. The system is configured to operate as base load with an electric heater providing backup when the load exceeds system capabilities.

The results indicate that such a system will meet 88 percent of the heating load over the year. The balance of the heating load is covered by an electric heater consuming 64 kWh/yr.

A possible system appropriate for Egyptian conditions is the hybrid solar hot water/space heating arrangement. Such a system will consist of a water heating system operating at a base load condition. The system would be oversized probably by 20 to 40 percent and will have a secondary heat transfer loop from the hot water tank to the room to be heated in winter. During the winter days, the heating loop will use the hot water gathered in the tank to heat the room. Such a joint application will be cheaper than having two different water and space heating configurations. Its technical feasibility and its effectiveness in meeting the two heating needs need to be investigated further.

EXHIBIT 5.28

EVALUATION OF THE SOLAR OPTION FOR SPACE HEATING

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
MEAN TEMPERATURE (deg c)	13.2	14.2	16.6	20.2	24.2	26.7	28.2	27.8	25.4	23.4	19.2	14.8	
TEMPERATURE REQUIRED (deg C)	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	
TEMP. DIFFERENCE	0	0	0	1.9	5.9	8.4	9.9	9.5	7.1	5.1	0.9	0	
DAYS PER MONTH	31	28	31	30	31	30	31	31	30	31	30	31	
HEAT LOSS COEFF. (W/deg C-M2)	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	
DEGREE DAYS	157.7	115.7	69.9	14.8	1.3	0.2	0	0	0.2	1.2	19.6	109	489.6
DWELLING AREA (M2)	120	120	120	120	120	120	120	120	120	120	120	120	
AREA FRACTION	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
TIME FRACTION	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	
TOTAL HEATING LOAD (KW-HR/MONTH)	155.49	114.08	68.924	14.593	1.2818	0.1972	0	0	0.1972	1.1832	19.326	107.47	482.76
TOTAL HEATING LOAD (MJ/MONTH)	559.79	410.70	248.12	52.536	4.6146	0.7099	0	0	0.7099	4.2596	69.574	386.92	1737.9
TILTED SOLAR RAD. (MJ/M2/MONTH)	479.4	542.1	657.6	626	646.5	637.5	687.6	708.4	695	679.3	586.9	531.1	7477.4
PANEL AREA (M2)	3	3	3	3	3	3	3	3	3	3	3	3	
SLR	2.5691	3.9597	7.9507	35.746	420.29	2693.8	NA	NA	2936.8	478.41	25.306	4.1178	
SOLAR FRACTION	0.7481	0.9100	1	1	1	1	NA	NA	1	1	1	0.9221	
SOLAR ENER. PROD. (MJ/MONTH)	418.79	373.75	248.12	52.536	4.6146	0.7099	0	0	0.7099	4.2596	69.574	356.81	1529.9
SOLAR ENER. PROD. (KW-HR/MONTH)	116.33	103.82	68.924	14.593	1.2818	0.1972	0	0	0.1972	1.1832	19.326	99.116	424.97
ELECTRIC LOAD	43.517	11.402	0	0	0	0	0	0	0	0	0	9.2909	64.211

5.10.1.2 Space Cooling

Space cooling due to its high cost is still considered a luxury in Egypt. Cooling is required for at least 4 months of the year. Exhibit 5.29 presents an evaluation of the use of an air conditioner in the typical Egyptian dwelling. The COP is taken to be equal to 1.8 (data from Egyptian manufacturers). The air conditioner is sized at 2.2 kW in order to meet the peak design load. Results indicate that energy consumption will be approximately 285 kWh electric for a base temperature of 25°C.

The other solar option for climatization is the intoruduction of passive designs in new building designs, and the retrofitting of existing buildings with selected passive solutions. Three low-cost appropriate passive solutions have been selected for evaluation under Egyptian conditions. These are: a) window overhangs, b) low emissivity glass and reflective film, and c) roof ponds. The analysis associated with each of the technologies is long and tedious. They are presented separately in Appendices F, G, and H.

Exhibit 5.30 presents a summary of the results for overhang analysis. Results indicate that during the summer months (May-September) solar radiation absorbed is reduced by 18.6 percent while winter solar absorption stays constant.

Exhibit 5.31 presents a summary of the roof pond analysis. The described pond has an area of 20 m^2 and a depth of 15 cm. It is situated on the roof of a building and operated in a cooling mode, i.e., with insulation cover during the day. Results indicated that the pond could dissipate 76 percent of the nighttime cooling load (assumed to be equal to 40% of the total load).

Exhibit 5.32 presents a summary of the analysis of the effect of using low emissivity glass or a thin reflective film. The specific example given is a new kind of green colored, low emissivity glass. Based on its high solar rejection, it is able to keep out 75 percent of the incoming solar radiation.

EXHIBIT 5.29

EVALUATION OF THE AIR CONDITIONER FOR SPACE COOLING

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
MEAN TEMPERATURE (deg c)	13.2	14.2	16.6	20.2	24.2	26.7	28.2	27.8	25.4	23.4	19.3	14.8	
TEMPERATURE REQUIRED (deg C)	25	25	25	25	25	25	25	25	25	25	25	25	
TEMP. DIFFERENCE	0	0	0	0	0	1.7	3.2	2.8	0.4	0	0	0	
DAYS PER MONTH	31	28	31	30	31	30	31	31	30	31	30	31	
HEAT LOSS COEFF. (W/deg C-M2)	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	
DEGREE DAYS	0.5	0.4	1.1	4	25.4	64.1	103.9	92.3	35.9	13.7	1.5	0.3	343.1
DWELLING AREA (M2)	120	120	120	120	120	120	120	120	120	120	120	120	
AREA FRACTION	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
TIME FRACTION	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
TOTAL COOLING LOAD (KW-HR/MONTH)	0.747	0.5976	1.6434	5.976	37.947	95.765	155.22	137.89	53.634	20.467	2.241	0.4482	512.59
THEORETICAL COP	0	0	0	0	0	175.29	93.125	106.42	745	0	0	0	
PRACTICAL COP	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	
AIR CONDITIONER RATING (KWth)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	
AIR CONDIT. COOL. (KW-HR/MONTH)	0.747	0.5976	1.6434	5.976	37.947	95.765	155.22	137.89	53.634	20.467	2.241	0.4482	512.59
ADDIT. A.C. NEED (KW-HR/MONTH)	0	0	0	0	0	0	0	0	0	0	0	0	0
A. C. ELEC. CONSUM. (KW-HR/MONTH)	0.415	0.332	0.913	3.32	21.082	53.203	86.237	76.609	29.797	11.371	1.245	0.249	284.77

EXHIBIT 5.30

PERFORMANCE OF OVERHANG TYPE H

TYPE H, X/H=.375, Y/H=.5	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
MONTHLY SOLAR ABSORBED MJ/M2/MO WITHOUT AN OVERHANG	327	308	282	221	188	191	195	211	258	331	325	329
MONTHLY ABSORBED WITH MJ/M2/MO OVERHANG H	327	308	260	170	145	168	162	156	218	326	325	329
PERCENT DIFFERENCE, MONTHLY	0.00	0.00	-7.80	-23.08	-22.87	-12.04	-16.92	-26.07	-15.50	-1.51	0.00	0.00
SUMMER MONTH DIFFERENCE (%)	-18.60											
WINTER MONTH DIFFERENCE (%)	-0.31											

EXHIBIT 5.31

EFFECT OF ROOF POND ON COOLING LOAD

	UNITS	
REF. DEGREE DAY TEMPERATURE	DEG C	25
DEG COOLING DAYS FOR JULY	DDs	103.9
BUILDING HT. LOSS COEFF.	W/M2/C	4.15
BUILDING FLOOR AREA	M2	120
DAYS/MONTH	DAYS/MO	31
COOLING LOAD		
MONTHLY COOLING LOAD	GJ/MO	4.471
DAILY COOLING LOAD	MJ/DAY	144.2
NIGHTTIME COOLING LOAD (40%)	MJ/DAY	57.7
DAYTIME COOLING LOAD (60%)	MJ/DAY	86.5
AREA OF ROOF POND	M2	20
DEPTH OF ROOF POND	M	0.1524
HEAT DISSIPATED AT NIGHT	W/M2	63.04
TOT. HT. DISSIPATED AT NIGHT	MJ/HR	4.54
NIGHTTIME COOLING LOAD	MJ/HR	6.01
% OF COOLING LOAD SAVED	%	0.76

EXHIBIT 5.32

EFFECT OF REFLECTIVE FILM ON ABSORBED SOLAR RADIATION

MATERIAL--SOUTHWALL CORPORATION HM-55 WITH GREEN COVER

SHADING COEFFICIENT--0.28
VISIBLE TRANSMISSION--40%
UNIT THICKNESS--3.81CM
SOLAR REJECTION--0.754

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
MONTHLY SOLAR ABSORBED WITHOUT ANY COATING	MJ/M2/MO	327	308	282	221	188	191	195	211	258	331	325	329
MONTHLY ABSORBED WITH HM-55 COATING	MJ/M2/MO	80.6	75.9	69.5	54.5	46.3	47.1	48	52	63.6	81.6	80.1	81.1
PERCENT DIFFERENCE, MONTHLY		-75.4	-75.4	-75.4	-75.3	-75.4	-75.3	-75.4	-75.4	-75.3	-75.3	-75.4	-75.3

5.10.2 Economic Analysis

5.10.2.1 Economic Analysis for Space Heating

The ability of any solar technology to compete in the market place is a function of its price compared to alternative energy systems. Exhibit 5.33 displays the economics of using gasoil or electric heaters in order to meet space heating energy requirements. The analysis is based on a capital cost of $50 and $70 respectively for the gasoil and electric heaters, and an operation and maintenance cost of 5% of capital cost. Results indicate that gasoil system annualized cost is $0.03/kWh and electric system costs is $0.08/kWh. Thus, electric systems are more expensive on a life cycle cost basis. Their expanding use in Egypt is due to the subsidized price of electricity and ther ease of use.

Solar space heating economic evaluation is presented in Exhibit 5.34. Cost of installed solar panels is taken to be $22/m^2 and operation and maintenance cost assumed to be 2 percent. Results of the evaluation indicate a price of $0.30/kWh on a life cycle basis. This result can be expected due to the short duration of the heating season and Cairo's mile climate. Clearly, solar space heating is not economical in Egypt today.

5.10.2.2 Economic Analysis for Space Cooling

It is difficult to evaluate the economics of using an air conditioner since sizes, usage patterns and start up temperatures vary significantly among users. Nevertheless, an analysis was performed using the typical dwelling cooling load. The air conditioner is taken to cost $300/kW and is sized at 2.2 kW. Life is assumed to be 5 years based on a manufacturer estimates. Exhibit 5.35 presents the economic evaluation of the air conditioner. Results indicate that cooling cost for home users is $0.39/kWh cooling.

Exhibit 5.36 describes the financial analysis results of all three passive systems. The results indicate that roof pond costs are much higher than comparable traditional air conditionings costs. Low emissivity glass

EXHIBIT 5.33

ECONOMIC EVALUATION OF GASOIL OPTIONS

GROSS ENERGY CONSUMPTION

GASOIL CONSUMPTION, (KW-HRth/YR)	1379.3
PRICE OF GASOIL, ($/GJ)	5.88
DISCOUNT RATE (%)	10
LIFE (YEARS)	10
YEARLY FUEL COST, ($/YR)	29.20
CAPITAL COST, ($)	50
OPERATION AND MAINTENANCE, 5%	2.5
ANNUAL CAPITAL COST, ($)	8.14
TOTAL ANNUAL COST, ($)	39.83
COST OF ENERGY, ($/KW-HRth)	0.029

ECONOMIC EVALUATION OF ELECTRIC OPTIONS

GROSS ENERGY CONSUMPTION

ELECTRIC CONSUMPTION, (KW-HR/YR)	536.4
PRICE OF ELECTRICITY, ($/KW-HRe)	0.05
DISCOUNT RATE (%)	10
LIFE (YEARS)	10
YEARLY FUEL COST, ($/YR)	26.82
CAPITAL COST, ($)	70
OPERATION AND MAINTENANCE, 5%	3.5
ANNUAL CAPITAL COST, ($)	11.39
TOTAL ANNUAL COST, ($)	41.71
COST OF ENERGY, ($/KW-HRe)	0.078

EXHIBIT 5.34

ECONOMIC EVALUATION OF SOLAR SPACE HEATING

PANEL AREA, M2	3
SOLAR ENERGY PRODUCED, (MJ/YEAR)	1529.9
SOLAR ENERGY PRODUCED, (KW-HR/YEAR)	424.97
PANEL COST, ($/M2)	236.81
DISCOUNT RATE (%)	10
LIFE (YEARS)	10
CAPITAL COST, ($)	710.43
OPERATION AND MAINTENANCE, 2%	14.21
ANNUAL CAPITAL COST, ($)	115.62
TOTAL ANNUAL COST, ($)	129.83
COST OF ENERGY, ($/KW-HR)	0.305

EXHIBIT 5.35

ECONOMIC EVALUATION OF AIR CONDITIONERS

TOT. COOLING LOAD, (KW-HR/YR)	512.59
A.C. ELECTRICITY CONSUMED, (KW-HR/YR)	284.77
PRICE OF ELECTRICITY, ($/KW-HR)	0.05
DISCOUNT RATE (%)	10
PRODUCT LIFE, (YEARS)	5
ELECTRICITY COST, ($/YR)	14.24
CAPITAL COST, ($)	660
OPERATION & MAINTENANCE, (2%)	13.2
ANNUAL CAPITAL COST, ($/YR)	174.11
TOTAL ANNUAL COST, ($/YR)	201.54
COST OF ENERGY, COOLING, ($/KW-HR)	0.393

Exhibit 5.36

COMPARISON OF PASSIVE OPTIONS

	Low e glass	Overhang	Pond	Thin Film
Area	3.6 m^2	----	20 m^2	3.6 m^2
Cap Cost	107.64/m^2	$50	$161.44 m^2	32.32 m^2
Energy Savings (summer months) May-Sept	786.4 MJ/m^2 2831.1 MJ	194 MJ/m^2 698.4 MJ	6668.4 MJ	2831.1 MJ
Cost of Cooling	$0.137/MJ $0.49/KWH	$0.07/MJ $0.26/KWH	$0.48/MJ $1.74/KWH	$0.041/MJ $0.15/KWH

(1) based on $15/$ft^2$ ($161.25/$m^2$)

(2) based on $10/$ft^2$ ($107.50/$m^2$)

(3) based on $3/$ft^2$ ($32.25/$m^2$)

windows are marginally uneconomical at $0.49/KWHR cooling. Overhangs are economical and so are thin films glazed on south facing windows.

The results of the passive cooling analysis are tentative and should not be construed to be accurate at this level of analysis. Based on the uncertainty regarding the cooling load and the interaction of solar heat gain and cooling requirements, it has been impossible to realistically model even the stereotypical dwelling. Due to the state of the art of the passive solar field, it is only possible to seriously analyze these options through the use of hourly or daily simulations, both of which are outside the scope of this preliminary analysis.

5.11 Incineration of Municipal Solid Waste for Electricity Generation

The Cairo area generates about 4200 tpd of refuse. Of this amount, only 1900 tpd is usable as an MSW incineration fuel (see section 5.4). The heat content of typical MSW is 2,100-2,600 Kcal/kg.

5.11.1 Application Characterization

MSW incineration systems are designed to burn raw, unprocessed waste. There are two types of systems in commercial operation today; water wall combustion and modular combustion units.

In water wall combustion, as-received refuse is transferred from a receiving pit into a furnace feed hopper by means of an overhead travelling crane (Exhibit 5.37). From the hopper, wastes are continually fed to the furnace and burned on an inclined moving grate system. Non-combustible and unburned material fall off the end of the grate into a materials recovery system. The combustion gases are used to generate steam for the production of electricity. The combustion gases leaving the boiler sections are passed through air pollution control equipment (generally electrostatic precipitators) and exhausted to the atmosphere through a stack. Boiler efficiency is typically 63 to 68 percent. Water wall combustors are custom designed systems and, hence,

Refuse-to-Energy System

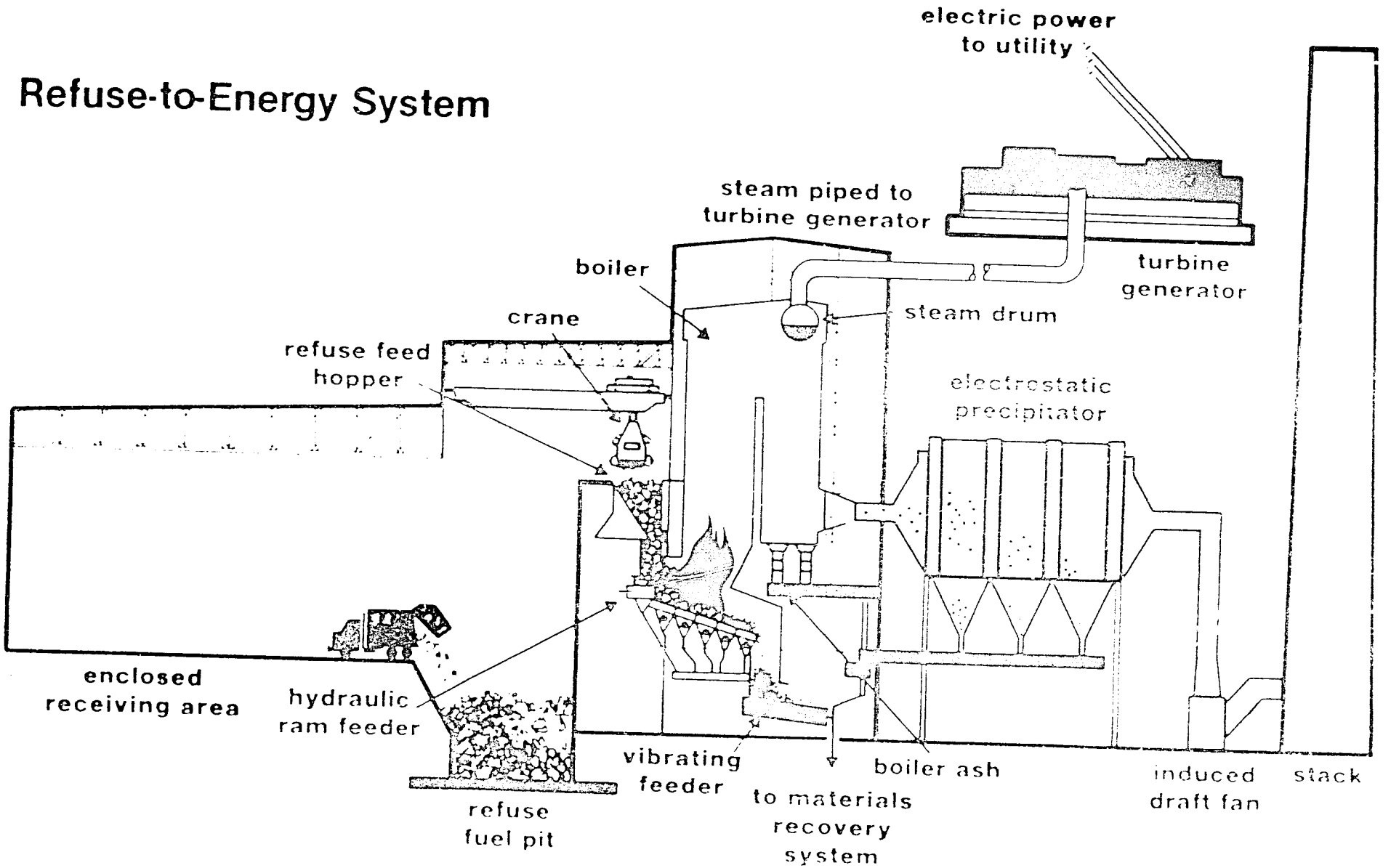

Exhibit 5.37

SOURCE: Signal Environmental Systems, Inc.

are only economical when large amounts of MSW are available (greater than 250 tpd).[17]

Modular incineration is best suited for communities generating between 50 and 250 tpd of refuse.[18] Installed systems consist of prefabricated packaged units. They are operated at sub-stoichiometric oxygen requirements by controlling combustion air flow. Typical modular combustors (Exhibit 5.38) employ a two-chamber design. As solid waste is received, it is charged into a primary refractory-lined combustion chamber, where the sub-stoichiometric combustion occurs. The heat released from the resulting partial combustion is used for endothermic volatilzation of the [illegible]ining organic compounds. The combustion gases flow into a secondary combustion chamber where they are mixed with air and fuel (natural gas or oil). If there is no immediate need for steam, hot gases in the secondary chamber are exhausted through a heat dumping stack. Attached to the second chamber is the waste heat recovery boiler for generating steam.

A currently operational water wall MSW plant is the Baltimore, Maryland RESCO facility. The plant has a capacity of 2250 tpd with an average throughput of 1800 tpd. The facility produces steam at a rate of 231,540 kg/hr at 5860 kPa and 440°C, most of which is used to drive a 60 MW steam turbine generator. The plant operates 24 hours per day, 7 days per week. An energy balance for this plant is shown in Exhibit 5.39. The plant produces approximately $.35 \times 10^{10}$ KJ/day of excess steam.

At present, there is no use for this excess steam, which could be sold or used to run a second turbine.

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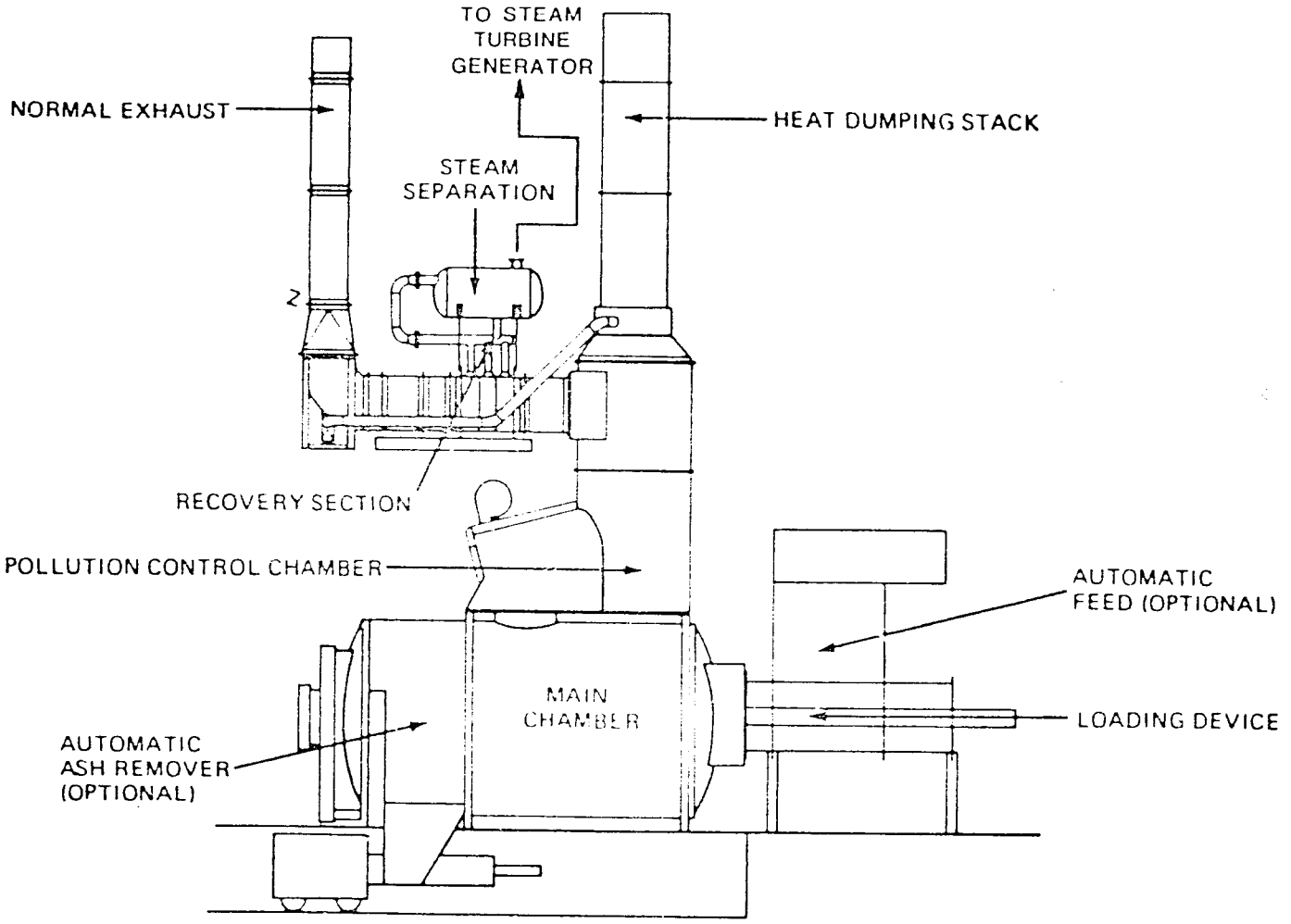
17 A Guide to Municipal Solid Wastes for Small Communities, JRB Assoc., McLean, VA, prepared for U.S. Environmental Protection Agency, March 1982.

18 Ibid.

Exhibit 5.38
TYPICAL CONTROLLED AIR, MODULAR COMBUSTOR



SOURCE: The Mitre Corporation, Resource Recovery Research, Development and Demonstration Plan, U.S. DOE, October 1979

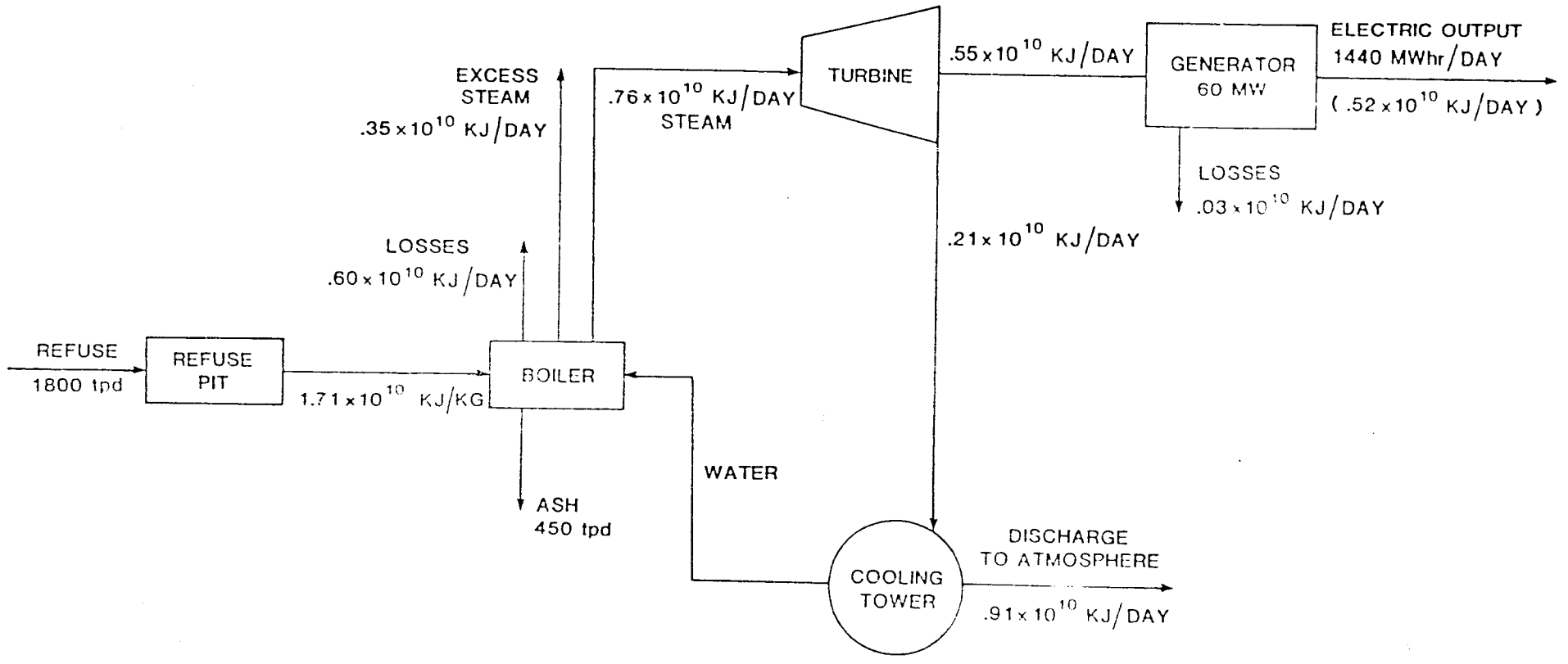


Exhibit 5.39
ENERGY BALANCE FOR BALTIMORE RESCO PLANT

* ASSUMING 4500 Btu/16 (10,441 KJ/KG) for MSW

Exhibit 5.40 shows an energy balance for a 50 tpd modular combustion system, the smallest system which is economically practical.

5.11.2 Economic Analysis

The plant, as configured in Exhibit 5.37, has a capital cost of $254 million and took 18 months to construct.[19] Since the average energy content of MSW in Egypt is about 1600 Kcal/kg (3040 Btu/lb),[20] or 68% of that used at the RESCO facility, electrical energy output at a similar plant located in Egypt would be about 980 MWh/day. Such a plant would require about 12 MWh/day for operation. Hence, the net output from an 1800 tpd MSW plant in Egypt would be about 968 MWh/day. Assuming an O&M cost of 5% of capital cost and a 20 year plant life, the levelized cost of electricity is $.12/kWh. This is higher than current world oil prices. However, since the RESCO boilers are oversized and excess steam is wasted, capital costs are higher and electricity generation is lower than obtainable in an optimally designed plant.

The plant, as configured in 5.38, has an estimated capital cost of $5.7 million. The average net output from such a plant located in Egypt would be about 40 MWh/day and the average auxiliary fuel requirements would cost about $250/day. Assuming an O&M cost of 5% of capital and a 20 year life, the levelized cost of electricity is $.07/KWh.

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19 Signal Environmental Systems, Inc.

20 El Helwagi, et al., Solid Waste Management: A Comprehensive Assessment of Problems, Planning Approach and General National Trends

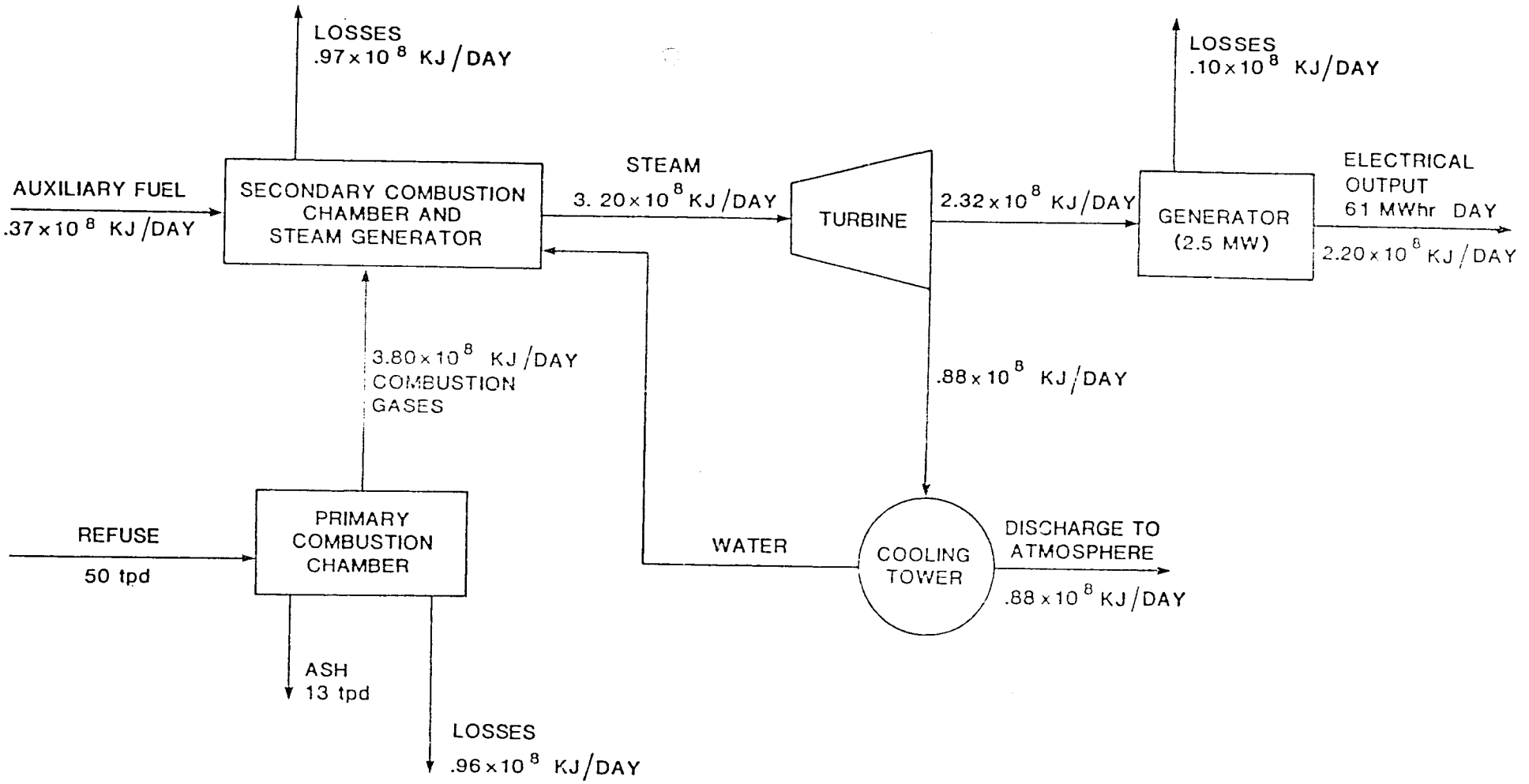


Exhibit 5.40

ENERGY BALANCE FOR A TYPICAL 50 tpd MODULAR MSW PLANT

6.0 EVALUATION CRITERIA

Eight evaluation criteria have been determined to assess the technology/application options identified in Chapter 5.0 for their relevance to Egypt. These criteria include:

- Replicability in Egypt;
- Renewable Technology Status;
- Renewable Resource Availability;
- Government Priorities;
- Renewable System Economic Feasibility;
- Current Project Status in Egypt;
- Institutional Requirements; and
- Social and Environmental Impacts

A summary description of the elements comprising each of these criteria is provided below.

6.1 Replicability in Egypt

Identifies the potential market in Egypt for the option under consideration based on technical, economic, energy, social and institutional factors.

6.2 Renewable Technology Status

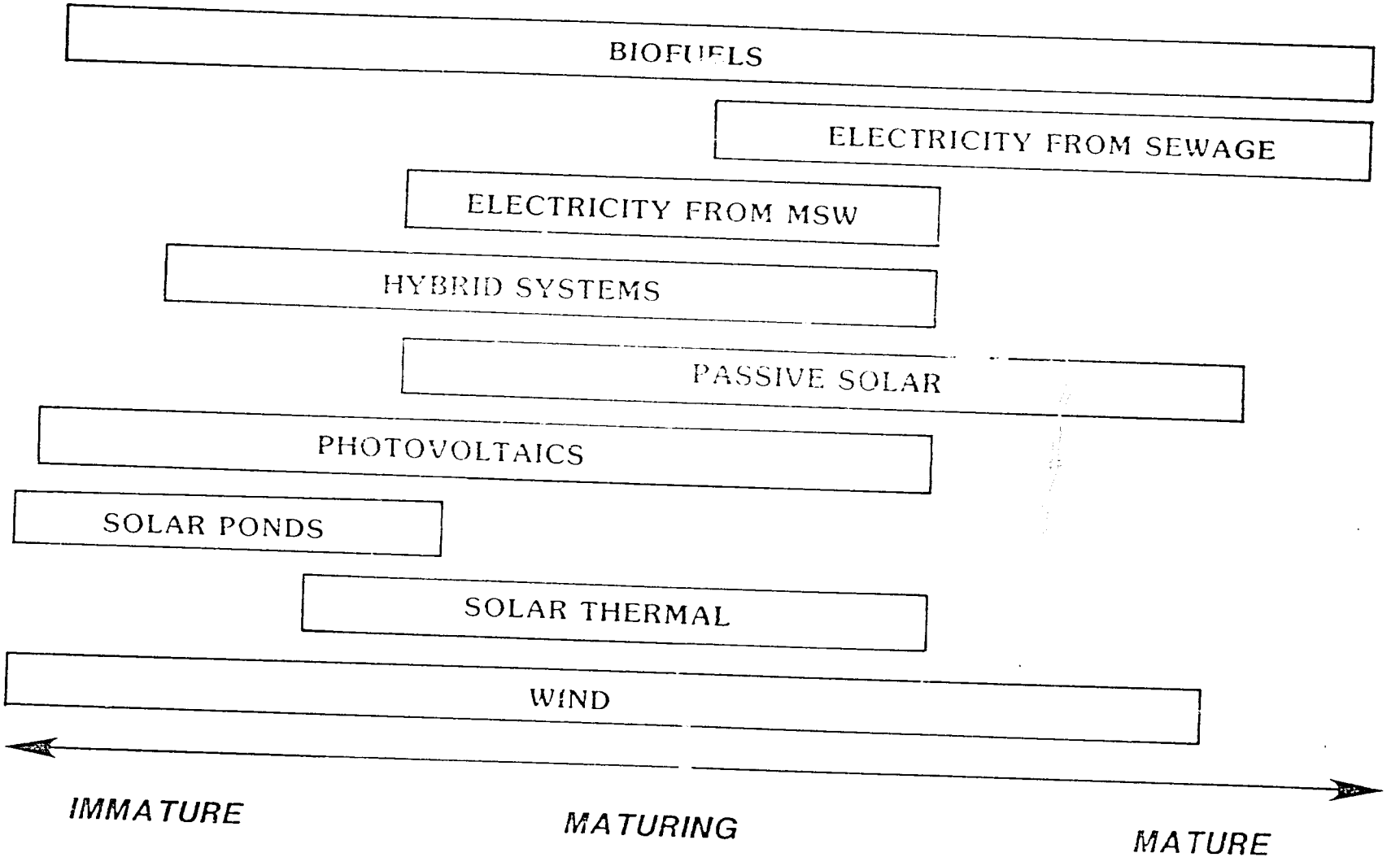
Assesses the commercial status, reliability, performance and ease of operation for the specific renewable technology under consideration. Exhibit 6.1 provides a summary chart depicting the current level of maturity of the various renewable energy technologies.

6.3 Renewable Resource Availability

Matches the technology/application option against the resource availability in the country.

Exhibit 6-1

RENEWABLE ENERGY TECHNOLOGIES STAGES OF DEVELOPMENT



6.4 Government Priorities

Compares the selected technology/application options to the major priority areas identified in the GOE Five Year Plan. For purposes of this assessment, plan priorities have been organized into two categories -- primary and secondary.

The primary priority areas have been selected and ranked on the basis of the level of investment they received in the Five Year Plan. (See Exhibit 6.2.) These priority areas include, from most important to least important:

(1) increased development of the industrial sector;

(2) expansion of the electricity, petroleum, and communication support sectors;

(3) increased housing availability and reconstruction, particularly in new communities;

(4) increased agricultural growth, with an emphasis on enhancing water supply systems, accelerating land reclamation, and increasing agricultural products; and

(5) improving health conditions in the country.

Exhibit 6.3 shows the expected production by commodity within each of the major sectors.

Secondary priority areas are those which have been designated as having a major importance in the Plan, but which have not received specific investment allocations. Among the secondary priority areas considered are: increasing employment opportunities in the industrial and agricultural sectors, improving the balance of payment situation in Egypt, and improving the balance between urban and rural development in the country.

6.5 Renewable System Economic Feasibility

Determines (1) the life cycle cost (LCC) for the renewable technology under consideration, and (2) the LCC for the competing conventional alternative(s).

EXHIBIT 6.2

EVALUATION OF GOVERNMENT PRIORITIES BASED ON PUBLIC SECTOR INVESTMENT TARGETS (1981-87)

SECTOR	RECIPIENT AGENCY	INVESTMENT (1000's of 1981/82 LE)	INVESTMENT % TOTAL
INDUSTRY	- FOOD INDUSTRY COMPANIES - SPINNING & WEAVING & CLOTHES CO. - WOOD INDUSTRY CO. - PAPER CO. - CHEMICAL INDUST. SECTOR CO. - CERAMIC, PORCELAIN & POTTERY CO. - MINERAL INDUST. SECTOR CO. - ELECTRONIC & ENGIN. INDUST. SECTOR - MINING SECTOR CO.	7,375,000	24%
SUPPORT SERVICES -ELECTRICITY	- ELEC. AUTHORITY & DISTRIB. CO. - ELEC. PROJECTS CO. - TRANSFORMERS & ELEC PROD. CO.	5,421,200	17
-PETROLEUM	- PETROLEUM PROD. CO. - REFINERY & PETROL. PROD. CO. - DISTRIBUTION CO. - TRANSPORT CO.	3,415,800	11
-COMMUNICATION	- NATIONAL AUTH. FOR COMM. - NATIONAL AUTH. FOR POST - TELEPHONE EQUIPMENT CO.	2,065,100	6

EXHIBIT 6.2 (Cont.)

EVALUATION OF GOVERNMENT PRIORITIES BASED ON PUBLIC SECTOR INVESTMENT TARGETS (1981-87)

SECTOR	RECIPIENT AGENCY	INVESTMENT (1000's of 1981/82 LE)	INVESTMENT % TOTAL
HOUSING	- NAT. AUTH, FOR SEWAGE - HOUSING & CONSTRUC. CO. - CONSTRUC. CO. - CEMENT CO. - BUILDING MATERIALS CO.	4,410,700	14
RECONSTRUCTION	- CONSTRUCTION CO. - READY-MADE CLOTHES CO.	3,294,500	10
IRRIGATION	- IRRIGATION CO.	1,882,300	6
LAND RECLAMATION	- RECLAMATION COMPANIES - AGRICULTURE COMPANIES	1,552,500	5
HEALTH	- CHEMICAL & MEDICINE CO. - MEDICINE TRADE CO.	1,171,200	4
AGRICULTURE	- AGRICULTURAL COMPANIES - ANIMAL PRODUCTION COMPANIES - FISH PRODUCTION COMPANIES	885,200	3
		31,673,500	100%

EXHIBIT 6.3

COMPARISON OF PRODUCTION IN 1981/82 WITH EXPECTED PRODUCTION IN 1986/87

SECTOR	COMMODITY	UNITS	OUTPUT 1981/82	OUTPUT 1986/87
AGRICULTURE	WHEAT	1000 MT	1,983	2,[illegible]
	BARLEY	1000 MT	127	[illegible]
	MAIZE	1000 MT	3,375	4,[illegible]
	SORGUM	1000 MT	570	[illegible]
	RICE	1000 MT	2,226	[illegible]
	BEANS	1000 MT	216	[illegible]
	VEGETABLES	1000 MT	9,186	10,[illegible]
	FRUITS & DATES	1000 MT	2,900	[illegible]
	ANIMAL MEAT	1000 MT	362	[illegible]
	CHICKEN MEAT	1000 MT	150	[illegible]
	EGGS	1000 MT	890	[illegible]
	FISH	1000 MT	155	[illegible]
	WOOL	1000 MT	55	[illegible]
	LENTIL	1000 MT	5	10
	COTTON	1000 M. QANTAR	8,360	8,[illegible]
	PEANUTS	1000 MT	33	49
	SESAME	1000 MT	19	[illegible]
	SUNFLOWER	1000 MT	15	[illegible]
	SOYABEANS	1000 MT	135	[illegible]
	LINEN SEED	1000 MT	29	[illegible]
	SUGAR CANE	1000 MT	9,255	11,[illegible]
	ONION	1000 MT	596	[illegible]
MINING	CONC. IRON ORE	1000 MT	1,800	[illegible]
	CONC. PHOSPHATE ORE	1000 MT	820	[illegible]
	TABLE SALT	1000 MT	890	[illegible]
	GYPSUM ORE	1000 MT	1,000	[illegible]
	PEBBLES	1000 CU. M.	8,500	[illegible]
	SAND	1000 CU. M.	7,100	[illegible]
COTTON GINNING & PRESSING	WOOL COTTON	1000 M. QANTAR	10,012	9,[illegible]
	COTTON SEED	1000 MT	660	[illegible]
	SKERTO	1000 M. QANTAR	205	[illegible]
FOOD, BEVERAGES & CIGARETTES	REFINED SUGAR	1000 MT	530	1,[illegible]
	MOLASSES	1000 MT	300	[illegible]
	WHITE RICE	1000 MT	1,554	1,[illegible]
	COTTON SEED OIL	1000 MT	102	[illegible]
	HYDROGENATED OIL	1000 MT	142	[illegible]
	FODDER	1000 MT	1,4[illegible]	2,[illegible]
	MACARONI	1000 MT	185	190
	DRIED ONION	1000 MT	6	[illegible]
	COTTON CAKE	1000 MT	455	[illegible]
	CIGARETTES	BILLIONS	34	[illegible]
	BEER	1000 HECTALITER	375	[illegible]
SPINNING, WEAVING & CLOTHES	COTTON SPINNING	1000 MT	257	[illegible]
	COTTON TEXTILES	1000 MT	180	[illegible]
	WOOL SPINNING	1000 MT	17	[illegible]
	WOOL TEXTILES	1000 MT	5	[illegible]
	SYNTHETIC TEXTILES	1000 MT	9	[illegible]
	SILK SPINNING	1000 MT	20	[illegible]
	SILK TEXTILES	1000 MT	18	[illegible]
	JUTE SPINNING	1000 MT	41	[illegible]
	JUTE WEAVING	1000 MT	36	[illegible]
	READY-MADE CLOTHES	1000 MT	17	[illegible]
	BLANKETS	1000 MT	9	[illegible]
LEATHER & LEATHER PRODUCTS	LEATHER SHOES	MILL. PAIRS	64	[illegible]
	RAW LEATHER	1000 MT	18	[illegible]
	TANNED LEATHER	1000 MT	22	[illegible]
	ARTIFICIAL LEATHER	1000 MT	5	[illegible]
	LEATHER PRODUCTS	1000 MT	17	[illegible]
CHEMICAL INDUSTRIES	NITRATE FERTILIZERS	1000 MT	4,000	5,[illegible]
	PHOSPHOROUS FERTILIZERS	1000 MT	500	[illegible]
	SOAP	1000 MT	270	[illegible]
	SYNTHETIC DETERGENTS	1000 MT	51	[illegible]
	COKE COAL	1000 MT	1,000	1,[illegible]
	MEDICINES	1000 MT	156	[illegible]
	MATCHES	1000 MT	66	[illegible]
METAL INDUSTRIES	ALUMINUM BLOCKS	1000 MT	100	[illegible]
	REINFORCING IRON	1000 MT	100	[illegible]
CONSTRUCTION & BUILDING	CEMENT	1000 MT	4,000	15,[illegible]
	BRICKS	MILLIONS	2,627	4,[illegible]
	FLAT GLASS	1000 SQ. M.	21	[illegible]
	TILES	1000 SQ. M.	12,500	18,[illegible]
	DOORS & WINDOWS	1000 SQ. M.	1,200	2,[illegible]

189

LCC calculations include initial capital costs, replacement costs, and operation and maintenance costs. Fuel costs used in the analysis are based on world prices, rather than the subsidized prices which exist in Egypt. The system cost analysis used for this criterion is based on the results of the option financial analyses performed in Chapter 5.0.

6.6 Current Project Status in Egypt

Reflects project activities in Egypt, either on-going or planned, that involve the technology/application option under consideration. This includes projects initiated by public, private and non-profit organizations in Egypt, as well as by foreign and multilateral donor agencies.

6.7 Institutional Requirements

Addresses the conditions in Egypt for developing, implementing and managing projects involving the specific option under consideration. Factors included in this criterion are: (1) availability of skilled labor; (2) availability of local manufacturing capability and materials; and (3) availability of local government/ private sector institutions for developing and promoting selected options on a widespread basis. For this criterion, each renewable/technology option will be judged against all three criterion elements, and a composite total score developed.

6.8 Social and Environmental Impacts

Addresses two areas -- the social and environmental effects of renewable technologies in Egypt.

Socially, this criterion examines the effect of the technology/application option on the population of Egypt. This includes an assessment of the option's impact on standard-of-living in the country, as well as how the option affects the lifestyles of local inhabitants. Environmentally, this criterion looks at the air, water, noise, and land pollution effects of the target option. For this

criterion, each renewble technology option will be judged again t both the social and environmental impact, and a composite score developed.

7.0 TECHNOLOGY/APPLICATION OPTIONS SELECTION

The previous chapters characterized renewable energy technologies and applications, selected appropriate technology/application combinations, conducted financial analyses of the selected [illegible] attributes, and evaluated the potential role for renewable energy in the Five Year Development Plan. The purpose of this section is to integrate the information from the prior sections, and use it to select candidates for renewable energy field tests.

7.1 Field Test Candidate Selection Process Description

The selection process utilizes a multi-attribute scoring scheme to assign a single numeric value to each technology/application combination being evaluated. This scheme is employed because the options have to be evaluated using a diverse set of qualitative and quantitative criteria that cannot be directly measured using a common scale (e.g. monetary value). The multi-attribute methodology enables the explicit consideration and evaluation of a variety of economic and non-economic attributes. It also allows incorporating the decision-makers preferences with regard to the relative importance of the attributes and enables technology/application combinations to be compared in a consistent and rational manner. Additionally, this technique aids in documenting the decision-making process.

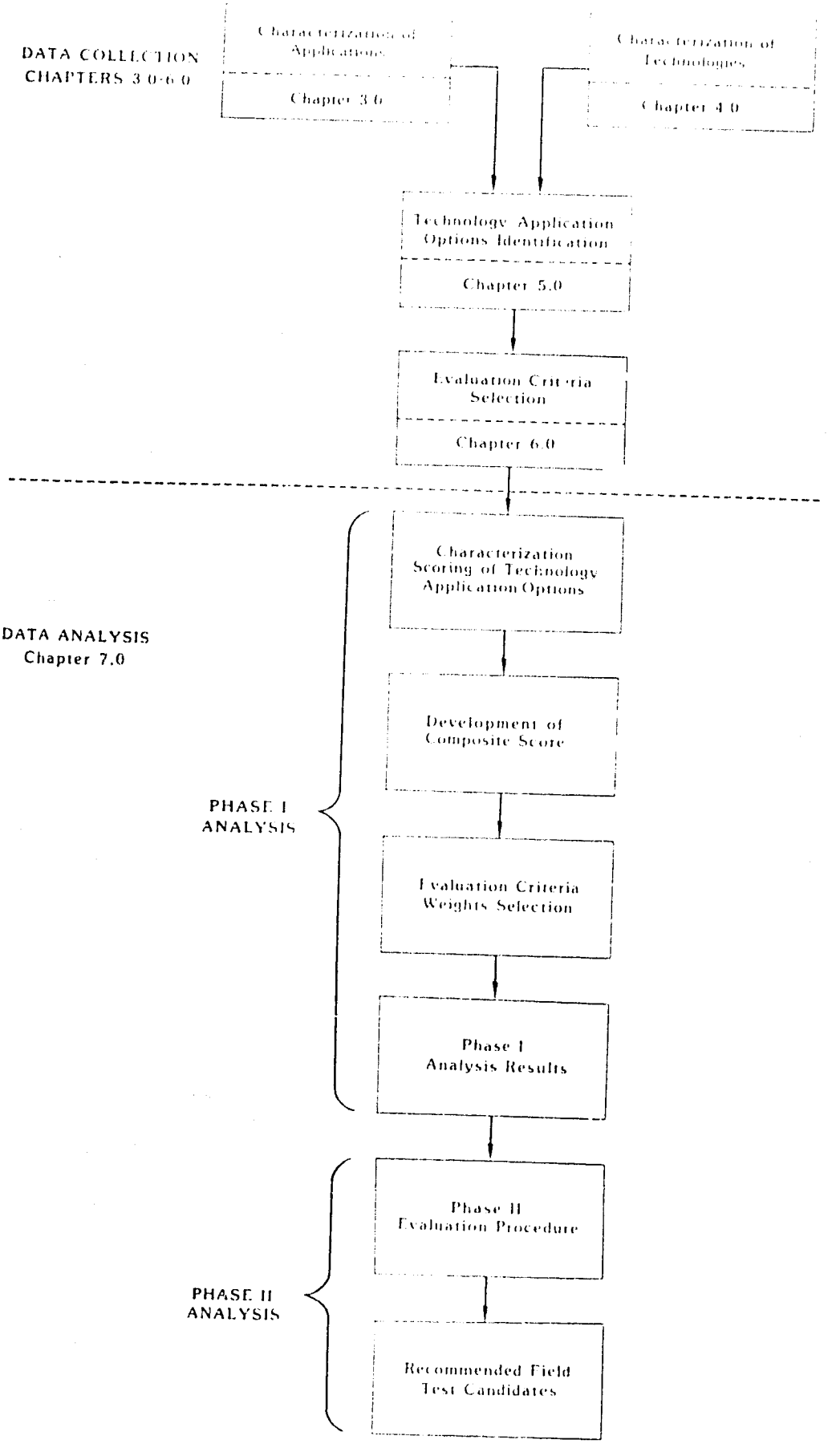
Exhibit 7.1 shows an overview of the selection process. It includes an identification of the role that each of the previous chapters played in providing data for the final option selection.

7.2 Data Collection

7.2.1 Characterization of Applications

Since the number of applications that could utilize renewable energy technologies are numerous, an informal technique was used to select a subset of applications for evaluation. The application identification process utilized

EXHIBIT 7-1
OVERVIEW OF RENEWABLE ENERGY FIELD TEST CANDIDATE SELECTION PROCESS



information from the following sources:

- o Egyptian Government Officials;
- o The Five Year Development Plan;
- o Available literature; and
- o Other data.

The selected applications were characterized in terms of energy requirements, output and the extent of its use in Egypt. Chapter 3 documented the application characterizations.

7.2.2 Characterization of Technologies

Renewable energy technologies were characterized on the basis of their technical status, market readiness, resource availability, current status in Egypt and worldwide, institutional requirements, social and environmental impacts, and research and development thrusts. Characterizations were prepared for wind, photovoltaics, high temperature solar thermal, geothermal, biomass, solar ponds municipal solid waste, and active and passive solar. Technology characterizations were documented in Chapter 4.0.

7.2.3 Technology/Application Options Identification

Options identification was based on the ability of the renewable energy technology to reasonably provide the energy required by the application. Reasonableness was defined in terms of the ease with which the technology can provide the type and quantity of energy desired as evidenced by similar applications worldwide. Technology/application options included in the planned eleven field tests were excluded from consideration.[1] Exhibit 5.1 in Section 5 showed the technology/application options identified.

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[1] PV powered irrigation is the exception to this rule. It has been included at the suggestion of Egyptian government officials, so that this technology/application option can be rated against other technologies used for similar applications.

7.2.4 Evaluation Criteria Selection

Each of the technology/application options identified above were scored against the eight evaluation criterion discussed in Chapter 6.0 using the following scales.

o Replicability in Egypt - Options which have a large market potential, and a high likelihood of being replicated in Egypt by either public or private sector organizations, received a better score than those with no significant potential for replication, as depicted below. Replicability was based on available sector data concerning (1) projected sectoral growth as determined by the GOE Five Year Development Plan, (2) number of facilities in the sector under consideration, and (3) expected end-unit energy consumption in the sectors studied.

Low Replicability	Moderate Replicability	High Replicability
0	5	10

o Renewable Technology Status - Technologies which are generally considered mature and commercially proven were given a higher score in the evaluation than those which are still in the research and development (R&D), or demonstration phase, as shown below.

Immature (R&D)	Maturing (Demonstration)	Mature (Commercial)
0	5	10

o Resource Availability - For this criterion, options for which a good renewable resource base exists in areas where potential renewable projects could be considered were given a higher score than options for which there is only a limited or undefined resource base, as identified below.

No undefined resource base	Moderate resource base	Good resource base
0	5	10

o Government Priorities - For this criterion, each option was assigned to one GOE primary priority sector category as specified in the Five Year Development Plan (e.g. industry, electricity, petroleum, communications, housing, irrigation, land reclamation, health and agriculture), as well as any secondary plan priorities it affected (e.g. employment, balance of payments and improvement in urban/rural balance). A composite score was then determined based on the option's expected contribution to government priorities in these sectors, with major contributors to primary priority objectives achieving the best scores. The scaling is shown below.

Low Contribution to major GOE Priorities	Moderate Contribution to major GOE Priorities	High Contribution to major GOE Priorities
0	5	10

o Renewable System Economic Feasibility - For this criterion, options which are cheaper today than conventional alternatives received a higher score than those which can not compete with conventional systems, even in the long term. This is shown below.

Never competitive with conventional	Competitive with conventional in future	Cheaper than conventional now/near-term
0	5	10

o Current Project Status in Egypt - For this criterion, technology/application options which have received less project emphasis in Egypt yielded a higher score than options which have substantial project activity, as shown below.

Significant project activity in Egypt	Moderate project activity in Egypt	Limited project activity in Egypt
0	5	10

This scoring reflects the intent of the GOE to identify and evaluate new and promising renewable options for Egypt, while avoiding duplication with existing projects in the country.

o Institutional Requirements - Options for which the local infrastructure currently exists (e.g. skilled personnel, manufacturing capability and local institutions) received a higher score than those for which the infrastructure must be developed, as shown below.

Limited existing infrastructure	Moderate existing infrastructure	Well developed infrastructure
0	5	10

o Social and Environmental Impacts - For this criterion, options with high social and environmental acceptance were assigned a better score than those with low acceptance in these areas, as seen below.

Low social or environmental acceptance	High social or environmental acceptance	High social and environmental acceptance
0	5	10

7.3 Data Analysis

Data analysis was conducted in two phases. Phase I involved conducting a comprehensive evaluation of the 55 technology/application options discussed in the previous sections. A listing of the 55 options is provided in Exhibit 7.2. The result of Phase I is the identification of 12 options (top 20%) which should be considered for further analysis as potential field test candidates.

Phase II involved conducting a second-level analysis of the 12 candidate

EXHIBIT 7.2

SELECTED RENEWABLE TECHNOLOGY/APPLICATION OPTIONS
CONSIDERED FOR EGYPT

SECTOR	APPLICATION	TECHNOLOGY
Agriculture	Broiler Production	Biogas Electric PV PV-Diesel Hybrid PV-Wind-Diesel Hybrid Wind Wind-Diesel Hybrid Wind-PV Hybrid
Agriculture	Cattle Feedlot	Biogas Electric PV PV-Diesel Hybrid PV-Wind-Diesel Hybrid Wind Wind-Diesel Hybrid Wind-PV Hybrid
Agriculture	Dairy Farm	Biogas Electric PV PV-Diesel Hybrid PV-Wind-Diesel Hybrid Wind Wind-Diesel Hybrid Wind-PV Hybrid
Agriculture	Egg Production	Biogas Electric PV PV-Diesel Hybrid PV-Wind-Diesel Hybrid Wind Wind-Diesel Hybrid Wind-PV Hybrid
Agriculture	Irrigation	Biogas Mechanical Pumping PV w/Battery Pumping PV w/o Battery Pumping Wind Electric Pumping Wind Mechanical Pumping
Agriculture	Land Drainage	Biogas Mechanical Pumping PV w/Battery Pumping PV w/o Battery Pumping Wind Electric Pumping Wind Mechanical Pumping
Agriculture	Livestock Watering	Biogas Mechanical Pumping PV w/Battery Pumping PV w/o Battery Pumping Wind Electric Pumping wind Mechanical Pumping
Industry	Cathodic Protection	PV
	Food Canning	Solar Thermal
	Hydrogenated Oil	Solar Thermal
	Malt Beverages	Solar Thermal
	Pharmaceuticals	Solar Thermal
	Soap & Detergents	Solar Thermal
Population Support	Commercial/Instit. Bldg.	Active/Passive Solar
	Electricity for Cities	Biogas Elec. from MSW
	Electricity for Cities	Biogas Elec. from Sewage
	Electricity for Cities	MSW Incineration/Electric
	Remote Communications	PV
	Residential Bldgs.	Active/Passive Solar

198

options resulting from Phase I. The result of this analysis is the selection of five options which are recommended to USAID and EEA as promising field test candidates.

7.3.1 Phase I Analysis

7.3.1.1 Characterization of Options and Scoring

The technology/application options were evaluated according to the eight evaluation criteria and scoring process described in Section 7.2.4. The scoring was subjective; it represents the evaluators' judgements as to how each technology/application option rates against each of the evaluation criteria. For this study, the evaluators included representatives from the project sponsor, i.e. the Egyptian Electricity Authority (EEA), and project subcontractors, i.e. Meridian Corporation and E^3I. The technology/application options were scored using all eight evaluation criteria.

7.3.1.2 Development of a Composite Score

A weighted summation technique was used to generate a single composite evaluation score for each technology/application option. The equations used to compute the composite score are as follows.

Composite Score for a technology/application option =

$$W_1 S_1 + W_2 S_2 + \ldots\ldots + W_8 S_8$$

Where: S_i = Score on a scale of 0 to 10 for the evaluation criteria "i".

W_i = Weight assigned to the evaluation criteria "i".

and $W_1 + W_2 + \ldots + W_8 = 100$

This score represents a single measure of worth of the technology/application option that reflects the relative importance of the evaluation criteria as well as the rating of the option against each evaluation criteria.

7.3.1.3 Calculation of Evaluation Criteria Weights

A procedure known as "The Metfessel General Allocation Test" was used to determine the set of weights to be used in the composite score. This technique asks the decision-makers to distribute points among the various evaluation factors under consideration. In this case, representatives from EEA, Meridian Corporation and E^3I assigned weights totalling 100 points to each of the eight evaluation criteria discussed above. In assigning a value, strict attention was given to determining the relative importance of the factors being assessed. The relative weighting for each factor, as shown in descending order of priority, is provided in Exhibit 7.3

7.3.1.4 Phase I Analysis Results

The evaluation results which compare the individual technology/application options to the evaluation criteria are presented in Exhibit 7.4. As shown in Column 9, each option has been assigned a weighted composite score which provides a single value for use in comparing the individual options. In reviewing the scores, those options with the highest values in Column 9 are considered the better candidates, on a relative scale, for possible implementation by the GOE on the basis of all the criteria evaluated.

Column 10 uses the weighted composite scores generated in Column 9, to rank order the results. As evidenced, the leading applications, in descending order, include the following:

Application	Technology
Electricity for Cities	Biogas Electricity from Sewage
Pharmaceuticals	Solar Thermal
Residential Buildings	Active/Passive Solar
Hydrogenated Oil	Solar Thermal
Commercial/Institutional Buildings	Active/Passive Solar
Electricity for Cities	MSW Incineration/Electric
Remote Communications	Photovoltaics
Soap & Detergents	Solar Thermal
Irrigation	Wind Electric
Irrigation	Wind Mechanical
Irrigation	Biogas Mechanical Pumping
Irrigation	PV without Battery

EXHIBIT 7.3

WEIGHT SELECTION USING THE METFESSEL GENERAL ALLOCATION TEST

RANK	EVALUATION CRITERIA	ASSIGNED WEIGHT
1	Replicability in Egypt	25
2	Technology Status	18
3	Resource Availability	15
4	Government Priorities	12
5	Economic Feasibility	10
6	Current Status in Egypt	10
7	Institutional Requirements	5
8	Social/Environmental Impacts	5
		100

Exhibit 7.4

RANKING OF TECHNOLOGY/APPLICATION OPTIONS BY COMPOSITE SCORE

SECTOR	APPLICATION	TECHNOLOGY	COL. 1 REPLIC. IN EGYPT	COL. 2 TECH. STATUS	COL. 3 RESOURCE AVAIL.	COL. 4 GOVT. PRIORIT.	COL. 5 ECON. FEAS.	COL. 6 CURRENT STATUS IN EGYPT	COL. 7 INSTIT. REQUIR.	COL. 8 SOCIAL/ ENVIR. IMPACTS	COL. 9 WEIGHTED COMPOSITE SCORE	COL. 10 RANK
WEIGHT ->			25	18	15	12	10	10	5	5	100	
POPULATION SUPPORT	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM SEWAGE	9	9	8	7	8	7	8	9	826	1
INDUSTRY	PHARMACEUTICALS	SOLAR THERMAL	8	7	8	8	5	8	7	8	747	2
POPULATION SUPPORT	RESIDENTIAL BLDGS.	ACTIVE/PASSIVE SOLAR	9	8	8	5	8	6	3	8	744	3
INDUSTRY	HYDROGENATED OIL	SOLAR THERMAL	8	7	8	7	5	8	7	8	735	4
POPULATION SUPPORT	COMMERCIAL/INSTIT. BLDGS.	ACTIVE/PASSIVE SOLAR	8	6	8	7	8	6	7	8	727	5
POPULATION SUPPORT	ELECTRICITY FOR CITIES	MSW INCINERATION/ELECTRIC	9	7	6	7	4	8	6	9	720	6
POPULATION SUPPORT	REMOTE COMMUNICATIONS	PV	8	8	8	6	8	4	3	8	711	7
INDUSTRY	SOAP & DETERGENTS	SOLAR THERMAL	7	7	8	7	5	8	7	8	710	8
AGRICULTURE	IRRIGATION	WIND MECHANICAL PUMPING	8	9	5	7	9	3	7	6	706	9
AGRICULTURE	IRRIGATION	BIOGAS MECHANICAL PUMPING	8	5	7	7	9	5	8	6	689	10
AGRICULTURE	IRRIGATION	WIND ELECTRIC PUMPING	8	6	5	7	8	8	5	6	682	11
AGRICULTURE	IRRIGATION	PV W/O BATTERY PUMPING	8	7	8	7	7	2	3	8	675	12
INDUSTRY	BEVERAGES	SOLAR THERMAL	6	7	8	6	5	8	7	8	673	13
INDUSTRY	FOOD CANNING	SOLAR THERMAL	5	7	8	8	5	8	7	8	672	14
AGRICULTURE	IRRIGATION	PV W/BATTERY PUMPING	8	6	8	7	5	4	3	8	657	15
AGRICULTURE	LIVESTOCK WATERING	WIND MECHANICAL PUMPING	7	9	5	5	9	3	7	6	657	15
AGRICULTURE	LIVESTOCK WATERING	BIOGAS MECHANICAL PUMPING	7	5	7	5	9	5	8	6	640	16
AGRICULTURE	LIVESTOCK WATERING	PV W/O BATTERY PUMPING	7	7	8	5	7	2	3	8	635	17
AGRICULTURE	DAIRY FARM	PV-DIESEL HYBRID	6	5	8	6	6	8	3	7	622	18
AGRICULTURE	LIVESTOCK WATERING	PV W/BATTERY PUMPING	7	6	8	5	6	4	3	8	618	19
AGRICULTURE	DAIRY FARM	BIOGAS ELECTRIC	6	6	7	6	7	5	6	6	615	20
AGRICULTURE	LIVESTOCK WATERING	WIND ELECTRIC PUMPING	7	6	5	5	6	8	5	6	613	21
POPULATION SUPPORT	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM MSW	8	7	6	7	5	9	3	8	605	22
AGRICULTURE	DAIRY FARM	WIND-DIESEL HYBRID	6	5	5	6	8	8	4	5	592	23
AGRICULTURE	DAIRY FARM	WIND-PV HYBRID	6	5	7	6	5	8	3	6	592	23
AGRICULTURE	DAIRY FARM	WIND	6	6	5	6	5	8	5	6	590	24
AGRICULTURE	DAIRY FARM	PV	6	5	8	6	1	8	3	8	577	25
AGRICULTURE	EGG PRODUCTION	BIOGAS ELECTRIC	5	6	7	2	9	5	6	6	562	26
AGRICULTURE	BROILER PRODUCTION	BIOGAS ELECTRIC	5	6	5	5	8	5	6	6	558	27
AGRICULTURE	EGG PRODUCTION	PV-DIESEL HYBRID	5	5	8	2	6	8	3	7	549	28
INDUSTRY	CATHODIC PROTECTION	PV	3	8	8	2	7	6	3	8	548	29
AGRICULTURE	DAIRY FARM	PV-WIND-DIESEL HYB.	6	4	7	6	1	9	3	6	544	30
AGRICULTURE	EGG PRODUCTION	PV-WIND-DIESEL HYB.	5	4	7	2	7	9	3	6	531	31
AGRICULTURE	EGG PRODUCTION	WIND-DIESEL HYBRID	5	5	5	2	8	8	4	5	519	32
AGRICULTURE	BROILER PRODUCTION	PV-DIESEL HYBRID	2	5	8	5	6	8	3	7	510	33
AGRICULTURE	CATTLE FEEDLOT	PV-DIESEL HYBRID	2	5	8	5	6	8	3	7	510	33
AGRICULTURE	CATTLE FEEDLOT	PV	2	5	8	5	5	8	3	8	505	34
AGRICULTURE	EGG PRODUCTION	PV	5	5	8	2	1	8	3	8	504	35
AGRICULTURE	CATTLE FEEDLOT	BIOGAS ELECTRIC	2	6	7	5	7	5	6	6	503	36
AGRICULTURE	EGG PRODUCTION	WIND-PV HYBRID	5	5	7	2	3	8	3	6	499	37
AGRICULTURE	BROILER PRODUCTION	WIND	2	6	5	5	7	8	5	6	498	38
AGRICULTURE	EGG PRODUCTION	WIND	5	6	5	2	3	8	5	6	497	39
AGRICULTURE	BROILER PRODUCTION	WIND-DIESEL HYBRID	2	5	5	5	9	8	4	5	490	40
AGRICULTURE	BROILER PRODUCTION	WIND-PV HYBRID	2	5	7	5	6	8	3	6	490	40
AGRICULTURE	CATTLE FEEDLOT	WIND-PV HYBRID	2	5	7	5	6	8	3	6	490	40
AGRICULTURE	BROILER PRODUCTION	PV-WIND-DIESEL HYB.	2	4	7	5	6	9	3	6	482	41
AGRICULTURE	CATTLE FEEDLOT	WIND	2	6	5	5	5	8	5	6	478	42
AGRICULTURE	LAND DRAINAGE	WIND MECHANICAL PUMPING	2	8	5	6	3	3	7	6	466	43
AGRICULTURE	BROILER PRODUCTION	PV	2	5	8	5	1	8	3	8	465	44
AGRICULTURE	LAND DRAINAGE	PV W/BATTERY PUMPING	2	4	8	6	1	8	3	8	459	45
AGRICULTURE	LAND DRAINAGE	PV W/O BATTERY PUMPING	2	4	8	6	1	8	3	8	459	45
AGRICULTURE	LAND DRAINAGE	WIND ELECTRIC PUMPING	2	4	5	6	3	8	5	6	434	46
AGRICULTURE	CATTLE FEEDLOT	PV-WIND-DIESEL HYB.	2	4	7	5	1	9	3	6	432	47
AGRICULTURE	CATTLE FEEDLOT	WIND-DIESEL HYBRID	2	5	5	5	3	8	4	5	430	48
AGRICULTURE	LAND DRAINAGE	BIOGAS MECHANICAL PUMPING	2	3	4	6	3	9	6	6	416	49

Applications receiving the lowest scores in the evaluation were land drainage, egg production and cattle feedlots. Exhibits 7.5 to 7.12 present the detailed assessment of the individual option evaluations for each of the eight criteria.

7.3.2 Phase II Analysis

7.3.2.1 Evaluation Procedure

In the preceding analysis, a broad-based evaluation of the potential technology/application options was performed. This analysis resulted in a relative ranking of the 55 options studied.

In the Phase II analysis, a second-tiered evaluation was performed of the 12 highest ranked options (top 20%) identified above. The purpose of this evaluation was to select from these 12, those options which are the best candidates for field testing.

To conduct the Phase II analysis, five evaluation criteria were employed. These are discussed below.

1. Scale of Potential Field Test and Required Budget - Projects which are small to moderate in scale, and within the field test budget range of EEA and USAID, are given a better rating than those that are large-scale and expensive.

2. Current Project Status in Egypt - Options that have received less project emphasis in Egypt yielded a better rating than those which have substantial project activity.

3. Commercial Status in Egypt - Technologies which are in the demonstration phase received a better rating than those which are commercially operating in Egypt today.

4. Replicability in Egypt - Options which have a large market potential and a high likelihood of being replicated in Egypt by either public or private sector organizations received a better rating than those with no significant potential for replication. Replicability is based on available sector data concerning: (1) projected sectoral growth as determined by the GOE Five Year Development Plan, (2) number of facilities in the sector under consideration, and (3) expected end-unit energy consumption in the sectors studied.

5. Resource Availability and Demand Match - Options for which a good renewable resource base exists in areas where potential renewable projects could be considered are given a better rating than options for which there is only a limited or undefined resource base.

A qualitative assessment of the 12 options was performed, using each of the above criteria. Evaluators included representatives from the Egyptian Electricity Authority, Meridian Corporation and E^3I. In reviewing the evaluation criteria it should be noted that Criteria 2, 4, and 5 are the same as those used in the first stage analysis to arrive at the 12 recommended options. Criteria 1 and Criteria 3* were added at the request of EEA.

The analysis resulted in three categories of field test candidates:

- Priority Field Test Candidates - Identifies those options which rated highest when assessed against the five evaluation criteria. These options should be considered by USAID and EEA as the best candidates for field testing under the Renewable Energy Field Testing Project.

- Secondary Field Test Candidates - Identifies those options which did not rate as highly as the priority field test candidate, but could be considered as back-up options for field testing under the Renewable Energy Field Testing Project.

- High Priority Candidates for Field Testing Under Other GOE Projects - Identifies options which ranked highly in the Phase I analysis, but were excluded for field testing under the Renewable Energy Field Testing Project because of their low rating for one or more of the Phase II evaluation criteria. Although they have been excluded here, these options are recommended highly to GOE decision-makers as potential candidates for activities being sponsored through other domestic, bilateral and/or multilateral projects.

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* Criteria 3 above, Commercial Status in Egypt, is similar in scope to the Renewable Technology Status Criteria used in the Phase I analysis. However, the scoring has been reversed. This was necessary because in the Phase I analysis a broad range of technologies were evaluated, ranging from those in the early R&D stage to those which are commercially sold and operated. The 12 field test candidates in this phase of the analysis are all relatively mature, and thus need to be evaluated at a different level. The evaluators chose to eliminate those options which are being commercially sold in the Egyptian marketplace and focus on those that are still in the demonstration phase. This will provide local Egyptian personnel with broader exposure to new renewable systems.

Exhibit 7.5

SCORING OF TECHNOLOGY/APPLICATION OPTIONS FOR OPPORTUNITY FOR REPLICABILITY CRITERIA

SECTOR	APPLICATION	TECHNOLOGY	HIGH REPLIC.	MODERATE REPLIC.	LOW REPLIC.	OPPORTUNITY FOR REPLICAB. SCORE	COMMENTS
AGRICULTURE	BROILER PRODUCTION	BIOGAS ELECTRIC	-	I	-	5	Although facilities are located in electrified areas, due to power supply
		PV	-	-	I	2	unreliability, backup diesel generators are used often since reliable power
		PV-DIESEL HYBRID	-	-	I	2	is crucial for bird survival. Biogas energy systems could replace diesels.
		PV-WIND-DIESEL HYB.	-	-	I	2	However, high capital cost systems such as wind or PV are not appropriate
		WIND	-	-	I	2	as backup power sources. (See Section 3)
		WIND-DIESEL HYBRID	-	-	I	2	
		WIND-PV HYBRID	-	-	I	2	
AGRICULTURE	CATTLE FEEDLOT	BIOGAS ELECTRIC	-	-	I	2	Low energy demand is expected at cattle feed-lots. Feed-lots are likely
		PV	-	-	I	2	to be in electrified areas
		PV-DIESEL HYBRID	-	-	I	2	
		PV-WIND-DIESEL HYB.	-	-	I	2	
		WIND	-	-	I	2	
		WIND-DIESEL HYBRID	-	-	I	2	
		WIND-PV HYBRID	-	-	I	2	
AGRICULTURE	DAIRY FARM	BIOGAS ELECTRIC	-	I	-	6	High energy demand. Reliable power supplies are needed due to milking and
		PV	-	I	-	6	milk refrigeration requirements
		PV-DIESEL HYBRID	-	I	-	6	
		PV-WIND-DIESEL HYB.	-	I	-	6	
		WIND	-	I	-	6	
		WIND-DIESEL HYBRID	-	I	-	6	
		WIND-PV HYBRID	-	I	-	6	
AGRICULTURE	EGG PRODUCTION	BIOGAS ELECTRIC	-	I	-	5	Although facilities are located in electrified areas, due to power supply
		PV	-	I	-	2	unreliability, backup diesel generators are used often since reliable power
		PV-DIESEL HYBRID	-	I	-	2	is crucial for bird survival. Biogas energy systems could replace diesels.
		PV-WIND-DIESEL HYB.	-	I	-	2	However, high capital cost systems such as wind or PV are not appropriate
		WIND	-	I	-	2	as backup power sources. (See Section 3)
		WIND-DIESEL HYBRID	-	I	-	2	
		WIND-PV HYBRID	-	I	-	2	
AGRICULTURE	IRRIGATION	BIOGAS MECHANICAL PUMPING	I	-	-	8	Irrigation requirements for crops are substantial throughout Egypt
		PV W/BATTERY PUMPING	I	-	-	8	particularly in new communities being developed in remote areas.
		PV W/O BATTERY PUMPING	I	-	-	8	
		WIND ELECTRIC PUMPING	I	-	-	8	
		WIND MECHANICAL PUMPING	I	-	-	8	
AGRICULTURE	LAND DRAINAGE	BIOGAS MECHANICAL PUMPING	-	-	I	2	Pumping facilities are large and located in areas with grid power.
		PV W/BATTERY PUMPING	-	-	I	2	Thus, replicability for decentralized renewable energy systems is low.
		PV W/O BATTERY PUMPING	-	-	I	2	
		WIND ELECTRIC PUMPING	-	-	I	2	
		WIND MECHANICAL PUMPING	-	-	I	2	
AGRICULTURE	LIVESTOCK WATERING	BIOGAS MECHANICAL PUMPING	-	I	-	7	Livestock water requirements are high and decentralized renewable
		PV W/BATTERY PUMPING	-	I	-	7	energy resources are ideal power sources.
		PV W/O BATTERY PUMPING	-	I	-	7	
		WIND ELECTRIC PUMPING	-	I	-	7	
		WIND MECHANICAL PUMPING	-	I	-	7	
INDUSTRY	CATHODIC PROTECTION	PV	-	-	I	3	Pipelines above ground or near grid, replicability is low.
	FOOD CANNING	SOLAR THERMAL	-	I	-	5	Historical growth rate of 13.3%/year expected to continue or exceed
	HYDROGENATED OIL	SOLAR THERMAL	-	I	-	8	Five Year Plan growth of 77% expected to continue
	MALT BEVERAGES	SOLAR THERMAL	-	I	-	6	Historical growth rate of 16%/year expected to continue or exceed
	PHARMACEUTICALS	SOLAR THERMAL	-	I	-	8	Growth more than doubled in Five Year Plan period
	SOAP & DETERGENTS	SOLAR THERMAL	-	I	-	7	Five Year Plan growth of 37% expected to continue
POPULATION SUPPORT	COMMERCIAL/INSTIT. BLDGS.	ACTIVE/PASSIVE SOLAR	I	-	-	8	Expanding construction in tourism/service sectors expected
	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM MSW	I	-	-	8	Urban elec. demand is rapidly increasing with migration & population growth
	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM SEWAGE	I	-	-	9	Urban elec. demand is rapidly increasing with migration & population growth
	ELECTRICITY FOR CITIES	MSW INCINERATE/ELECTRIC	I	-	-	9	Urban elec. demand is rapidly increasing with migration & population growth
	REMOTE COMMUNICATIONS	PV	I	-	-	8	Market expanding due to the need for reliable country-wide coverage
	RESIDENTIAL BLDGS.	ACTIVE/PASSIVE SOLAR	I	-	-	9	800000 new urban housing units through 2000 plus housing development in remote communities expected.

Exhibit 7.6

SCORING OF TECHNOLOGY/APPLICATION OPTIONS FOR TECHNOLOGY STATUS CRITERIA

SECTOR	APPLICATION	TECHNOLOGY	MATURE TECH-NOLOGY	MATURING TECH-NOLOGY	IMMATURE TECH-NOLOGY	TECH-NOLOGY STATUS SCORE	COMMENTS
POPULATION SUPPORT	COMMERCIAL/INSTIT. BLDGS.	ACTIVE/PASSIVE SOLAR	I	-	-	6	Technically proven but limited demonstration in commercial buildings
	RESIDENTIAL BLDGS.	ACTIVE/PASSIVE SOLAR	I	-	-	8	Technically proven and commercially proven in residential applications
POPULATION SUPPORT	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM MSW	-	-	I	2	R&D stage in the U.S. with no commercial plants
	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM SEWAGE	I	-	-	9	Technically and commercially proven worldwide
	ELECTRICITY FOR CITIES	MSW INCINERATE/ELECTRIC	-	I	-	7	Technically proven with some commercial applications
AGRICULTURE	BROILER PRODUCTION	BIOGAS ELECTRIC	-	I	-	6	Facilities of this scale for on-farm applications are in the
	CATTLE FEEDLOT	BIOGAS ELECTRIC	-	I	-	6	demonstration phase
	DAIRY FARM	BIOGAS ELECTRIC	-	I	-	6	
	EGG PRODUCTION	BIOGAS ELECTRIC	-	I	-	6	
AGRICULTURE	IRRIGATION	BIOGAS MECHANICAL PUMPING	-	I	-	5	Small biogas units commercially proven, more biogas-engine exper. needed
	LAND DRAINAGE	BIOGAS MECHANICAL PUMPING	-	-	I	3	R&D phase for large scale biogas units using animal manure
	LIVESTOCK WATERING	BIOGAS MECHANICAL PUMPING	-	I	-	5	Small biogas units commercially proven, more biogas-engine exper. needed
AGRICULTURE	BROILER PRODUCTION	PV	-	I	-	5	Agricultural applications of this scale are still in the development
	CATTLE FEEDLOT	PV	-	I	-	5	stage with limited commercial projects in place
	DAIRY FARM	PV	-	I	-	5	
	EGG PRODUCTION	PV	-	I	-	5	
INDUSTRY	CATHODIC PROTECTION	PV	I	-	-	8	Technically and commercially proven worldwide
POPULATION SUPPORT	REMOTE COMMUNICATIONS	PV	I	-	-	8	Technically and commercially proven worldwide
AGRICULTURE	IRRIGATION	PV W/BATTERY PUMPING	-	I	-	6	Technically proven with some commercial applications
	LAND DRAINAGE	PV W/BATTERY PUMPING	-	-	I	4	Facilities of this scale are in the demonstration phase
	LIVESTOCK WATERING	PV W/BATTERY PUMPING	-	I	-	6	Technically proven with some commercial applications
	IRRIGATION	PV W/O BATTERY PUMPING	-	I	-	6	Technically proven with some commercial applications
	LAND DRAINAGE	PV W/O BATTERY PUMPING	-	-	I	4	No facilities of this scale in use
	LIVESTOCK WATERING	PV W/O BATTERY PUMPING	-	I	-	6	Technically proven with some commercial applications
AGRICULTURE	BROILER PRODUCTION	PV-DIESEL HYBRID	-	I	-	5	Hybrid systems are technically proven with some commercial applications
	CATTLE FEEDLOT	PV-DIESEL HYBRID	-	I	-	5	
	DAIRY FARM	PV-DIESEL HYBRID	-	I	-	5	
	EGG PRODUCTION	PV-DIESEL HYBRID	-	I	-	5	
AGRICULTURE	BROILER PRODUCTION	PV-WIND-DIESEL HYB.	-	I	-	4	Hybrid systems are technically proven with some commercial applications
	CATTLE FEEDLOT	PV-WIND-DIESEL HYB.	-	I	-	4	
	DAIRY FARM	PV-WIND-DIESEL HYB.	-	I	-	4	
	EGG PRODUCTION	PV-WIND-DIESEL HYB.	-	I	-	4	
INDUSTRY	FOOD CANNING	SOLAR THERMAL	-	I	-	7	Low temperature industrial steam applications are technically proven
	HYDROGENATED OIL	SOLAR THERMAL	-	I	-	7	and have had moderate commercial experience
	MALT BEVERAGES	SOLAR THERMAL	-	I	-	7	
	PHARMACEUTICALS	SOLAR THERMAL	-	I	-	7	
	SOAP & DETERGENTS	SOLAR THERMAL	-	I	-	7	
AGRICULTURE	BROILER PRODUCTION	WIND	-	I	-	6	Technically proven with some commercial applications
	CATTLE FEEDLOT	WIND	-	I	-	6	Technically proven with some commercial applications
	DAIRY FARM	WIND	-	I	-	6	Technically proven with some commercial applications
	EGG PRODUCTION	WIND	-	I	-	6	Technically proven with some commercial applications
	IRRIGATION	WIND ELECTRIC PUMPING	-	I	-	6	Technically proven with some commercial applications
	LAND DRAINAGE	WIND ELECTRIC PUMPING	-	-	I	4	No facilities of this scale in use
	LIVESTOCK WATERING	WIND ELECTRIC PUMPING	-	I	-	6	Technically proven with some commercial applications
	IRRIGATION	WIND MECHANICAL PUMPING	I	-	-	9	Technically and commercially proven worldwide
	LAND DRAINAGE	WIND MECHANICAL PUMPING	I	-	-	8	Technically and commercially proven worldwide
	LIVESTOCK WATERING	WIND MECHANICAL PUMPING	I	-	-	9	Technically and commercially proven worldwide
AGRICULTURE	BROILER PRODUCTION	WIND-DIESEL HYBRID	-	I	-	5	Hybrid systems are technically proven with some commercial applications
	CATTLE FEEDLOT	WIND-DIESEL HYBRID	-	I	-	5	
	DAIRY FARM	WIND-DIESEL HYBRID	-	I	-	5	
	EGG PRODUCTION	WIND-DIESEL HYBRID	-	I	-	5	
AGRICULTURE	BROILER PRODUCTION	WIND-PV HYBRID	-	I	-	5	Hybrid systems are technically proven with some commercial applications
	CATTLE FEEDLOT	WIND-PV HYBRID	-	I	-	5	
	DAIRY FARM	WIND-PV HYBRID	-	I	-	5	
	EGG PRODUCTION	WIND-PV HYBRID	-	I	-	5	

Exhibit 7.7

SCORING OF TECHNOLOGY/APPLICATION OPTIONS FOR RESOURCE AVAILABILITY CRITERIA

SECTOR	APPLICATION	TECHNOLOGY	GOOD RESOURCE/ DEMAND MATCH	MODERATE RESOURCE/ DEMAND MATCH	LOW RESOURCE/ DEMAND MATCH	RESOURCE AVAIL-ABILITY SCORE	COMMENTS
POPULATION SUPPORT	COMMERCIAL/INSTIT. BLDGS.	ACTIVE/PASSIVE SOLAR	X	-	-	8	High solar insolation in Egypt throughout the year
	RESIDENTIAL BLDGS.	ACTIVE/PASSIVE SOLAR	X	-	-	8	High solar insolation in Egypt throughout the year
POPULATION SUPPORT	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM MSW	-	X	-	6	Good availability but need organized collection system
	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM SEWAGE	X	-	-	8	Excellent resource availability
	ELECTRICITY FOR CITIES	MSW INCINERATE/ELECTRIC	-	X	-	6	Good availability but need organized collection system
AGRICULTURE	BROILER PRODUCTION	BIOGAS ELECTRIC	X	-	-	7	Good on-farm resource availability
	CATTLE FEEDLOT	BIOGAS ELECTRIC	X	-	-	7	Good on-farm resource availability
	DAIRY FARM	BIOGAS ELECTRIC	X	-	-	7	Good on-farm resource availability
	EGG PRODUCTION	BIOGAS ELECTRIC	X	-	-	7	Good on-farm resource availability
AGRICULTURE	IRRIGATION	BIOGAS MECHANICAL PUMPING	-	X	-	7	Good on-farm resource availability
	LAND DRAINAGE	BIOGAS MECHANICAL PUMPING	-	-	X	4	Resource not easily accessible in quantity required
	LIVESTOCK WATERING	BIOGAS MECHANICAL PUMPING	X	-	-	7	Good on-farm resource availability
AGRICULTURE	BROILER PRODUCTION	PV	X	-	-	8	High solar insolation in Egypt throughout the year
	CATTLE FEEDLOT	PV	X	-	-	8	High solar insolation in Egypt throughout the year
	DAIRY FARM	PV	X	-	-	8	High solar insolation in Egypt throughout the year
	EGG PRODUCTION	PV	X	-	-	8	High solar insolation in Egypt throughout the year
INDUSTRY	CATHODIC PROTECTION	PV	X	-	-	8	High solar insolation in Egypt throughout the year
POPULATION SUPPORT	REMOTE COMMUNICATIONS	PV	X	-	-	8	High solar insolation in Egypt throughout the year
AGRICULTURE	IRRIGATION	PV W/BATTERY PUMPING	X	-	-	6	High solar insolation in Egypt throughout the year
	LAND DRAINAGE	PV W/BATTERY PUMPING	X	-	-	6	High solar insolation in Egypt throughout the year
	LIVESTOCK WATERING	PV W/BATTERY PUMPING	X	-	-	8	High solar insolation in Egypt throughout the year
	IRRIGATION	PV W/O BATTERY PUMPING	X	-	-	8	High solar insolation in Egypt throughout the year
	LAND DRAINAGE	PV W/O BATTERY PUMPING	X	-	-	8	High solar insolation in Egypt throughout the year
	LIVESTOCK WATERING	PV W/O BATTERY PUMPING	X	-	-	8	High solar insolation in Egypt throughout the year
AGRICULTURE	BROILER PRODUCTION	PV-DIESEL HYBRID	X	-	-	8	High solar insolation in Egypt throughout the year
	CATTLE FEEDLOT	PV-DIESEL HYBRID	X	-	-	8	High solar insolation in Egypt throughout the year
	DAIRY FARM	PV-DIESEL HYBRID	X	-	-	8	High solar insolation in Egypt throughout the year
	EGG PRODUCTION	PV-DIESEL HYBRID	X	-	-	8	High solar insolation in Egypt throughout the year
AGRICULTURE	BROILER PRODUCTION	PV-WIND-DIESEL HYB.	X	-	-	7	High insolation but wind availability best in coastal areas
	CATTLE FEEDLOT	PV-WIND-DIESEL HYB.	X	-	-	7	High insolation but wind availability best in coastal areas
	DAIRY FARM	PV-WIND-DIESEL HYB.	X	-	-	7	High insolation but wind availability best in coastal areas
	EGG PRODUCTION	PV-WIND-DIESEL HYB.	X	-	-	7	High insolation but wind availability best in coastal areas
INDUSTRY	FOOD CANNING	SOLAR THERMAL	X	-	-	8	High solar insolation in Egypt throughout the year
	HYDROGENATED OIL	SOLAR THERMAL	X	-	-	8	High solar insolation in Egypt throughout the year
	MALT BEVERAGES	SOLAR THERMAL	X	-	-	8	High solar insolation in Egypt throughout the year
	PHARMACEUTICALS	SOLAR THERMAL	X	-	-	8	High solar insolation in Egypt throughout the year
	SOAP & DETERGENTS	SOLAR THERMAL	X	-	-	8	High solar insolation in Egypt throughout the year
AGRICULTURE	BROILER PRODUCTION	WIND	-	X	-	5	Excellent in coastal areas, moderate in most remaining areas
	CATTLE FEEDLOT	WIND	-	X	-	5	Excellent in coastal areas, moderate in most remaining areas
	DAIRY FARM	WIND	-	X	-	5	Excellent in coastal areas, moderate in most remaining areas
	EGG PRODUCTION	WIND	-	X	-	5	Excellent in coastal areas, moderate in most remaining areas
	IRRIGATION	WIND ELECTRIC PUMPING	-	X	-	5	Excellent in coastal areas, moderate in most remaining areas
	LAND DRAINAGE	WIND ELECTRIC PUMPING	-	X	-	5	Excellent in coastal areas, moderate in most remaining areas
	LIVESTOCK WATERING	WIND ELECTRIC PUMPING	-	X	-	5	Excellent in coastal areas, moderate in most remaining areas
	IRRIGATION	WIND MECHANICAL PUMPING	-	X	-	5	Excellent in coastal areas, moderate in most remaining areas
	LAND DRAINAGE	WIND MECHANICAL PUMPING	-	X	-	5	Excellent in coastal areas, moderate in most remaining areas
	LIVESTOCK WATERING	WIND MECHANICAL PUMPING	-	X	-	5	Excellent in coastal areas, moderate in most remaining areas
AGRICULTURE	BROILER PRODUCTION	WIND-DIESEL HYBRID	-	X	-	5	Excellent in coastal areas, moderate in most remaining areas
	CATTLE FEEDLOT	WIND-DIESEL HYBRID	-	X	-	5	Excellent in coastal areas, moderate in most remaining areas
	DAIRY FARM	WIND-DIESEL HYBRID	-	X	-	5	Excellent in coastal areas, moderate in most remaining areas
	EGG PRODUCTION	WIND-DIESEL HYBRID	-	X	-	5	Excellent in coastal areas, moderate in most remaining areas
AGRICULTURE	BROILER PRODUCTION	WIND-PV HYBRID	-	X	-	7	High insolation but wind availability best in coastal areas
	CATTLE FEEDLOT	WIND-PV HYBRID	-	X	-	7	High insolation but wind availability best in coastal areas
	DAIRY FARM	WIND-PV HYBRID	-	X	-	7	High insolation but wind availability best in coastal areas
	EGG PRODUCTION	WIND-PV HYBRID	-	X	-	7	High insolation but wind availability best in coastal areas

Exhibit 7.8

SCORING OF TECHNOLOGY/APPLICATION OPTIONS FOR GOVERMENT PRIORITIES CRITERIA

SECTOR	APPLICATION	TECHNOLOGY	PRIMARY PRIORITIES: INDUSTRY	ELECTRICITY	PETROLEUM	COMMUNICATION	HOUSING	IRRIGATION	LAND RECLAM.	HEALTH	AGRICULTURE	SECONDARY PRIORITIES: EMPLOYMENT	BAL. OF PAYMENT	URB/RURL BALANCE	GOVERNMENT PRIORITIES COMPOSITE SCORE	COMMENTS
AGRICULTURE	BROILER PRODUCTION	BIOGAS ELECTRIC	-	-	-	-	-	-	-	-	I	I	-	-	5	The GOE expects increased broiler production
		PV	-	-	-	-	-	-	-	-	I	I	-	-	5	in the Five Year Development Plan
		PV-DIESEL HYBRID	-	-	-	-	-	-	-	-	I	I	-	-	5	
		PV-WIND-DIESEL HYB.	-	-	-	-	-	-	-	-	I	I	-	-	5	
		WIND	-	-	-	-	-	-	-	-	I	I	-	-	5	
		WIND-DIESEL HYBRID	-	-	-	-	-	-	-	-	I	I	-	-	5	
		WIND-PV HYBRID	-	-	-	-	-	-	-	-	I	I	-	-	5	
AGRICULTURE	CATTLE FEEDLOT	BIOGAS ELECTRIC	-	-	-	-	-	-	-	-	I	I	-	-	5	The GOE expects increased beef production
		PV	-	-	-	-	-	-	-	-	I	I	-	-	5	in the Five Year Development Plan
		PV-DIESEL HYBRID	-	-	-	-	-	-	-	-	I	I	-	-	5	
		PV-WIND-DIESEL HYB.	-	-	-	-	-	-	-	-	I	I	-	-	5	
		WIND	-	-	-	-	-	-	-	-	I	I	-	-	5	
		WIND-DIESEL HYBRID	-	-	-	-	-	-	-	-	I	I	-	-	5	
		WIND-PV HYBRID	-	-	-	-	-	-	-	-	I	I	-	-	5	
AGRICULTURE	DAIRY FARM	BIOGAS ELECTRIC	-	-	-	-	-	-	-	-	I	I	-	-	6	The GOE expects increased milk and milk products
		PV	-	-	-	-	-	-	-	-	I	I	-	-	6	production in the Five Year Development Plan
		PV-DIESEL HYBRID	-	-	-	-	-	-	-	-	I	I	-	-	6	
		PV-WIND-DIESEL HYB.	-	-	-	-	-	-	-	-	I	I	-	-	6	
		WIND	-	-	-	-	-	-	-	-	I	I	-	-	6	
		WIND-DIESEL HYBRID	-	-	-	-	-	-	-	-	I	I	-	-	6	
		WIND-PV HYBRID	-	-	-	-	-	-	-	-	I	I	-	-	6	
AGRICULTURE	EGG PRODUCTION	BIOGAS ELECTRIC	-	-	-	-	-	-	-	-	I	I	-	-	2	Although increased egg production is emphasized in
		PV	-	-	-	-	-	-	-	-	I	I	-	-	2	the Plan, the current excess supply of eggs has
		PV-DIESEL HYBRID	-	-	-	-	-	-	-	-	I	I	-	-	2	caused the GOE to down grade emphasis on this
		PV-WIND-DIESEL HYB.	-	-	-	-	-	-	-	-	I	I	-	-	2	priority
		WIND	-	-	-	-	-	-	-	-	I	I	-	-	2	
		WIND-DIESEL HYBRID	-	-	-	-	-	-	-	-	I	I	-	-	2	
		WIND-PV HYBRID	-	-	-	-	-	-	-	-	I	I	-	-	2	
AGRICULTURE	IRRIGATION	BIOGAS MECHANICAL PUMPING	-	-	-	-	-	I	-	-	I	I	-	I	7	Irrigation to improve agricultural productivity
		PV W/BATTERY PUMPING	-	-	-	-	-	I	-	-	I	I	-	I	7	and to provide water for reclaimed lands receives
		PV W/O BATTERY PUMPING	-	-	-	-	-	I	-	-	I	I	-	I	7	a high priority in the Plan
		WIND ELECTRIC PUMPING	-	-	-	-	-	I	-	-	I	I	-	I	7	
		WIND MECHANICAL PUMPING	-	-	-	-	-	I	-	-	I	I	-	I	7	
AGRICULTURE	LAND DRAINAGE	BIOGAS MECHANICAL PUMPING	-	-	-	-	-	-	I	-	-	-	-	I	6	Improved drainage in agricultural areas receives
		PV W/BATTERY PUMPING	-	-	-	-	-	-	I	-	-	-	-	I	6	a high priority in the Plan
		PV W/O BATTERY PUMPING	-	-	-	-	-	-	I	-	-	-	-	I	6	
		WIND ELECTRIC PUMPING	-	-	-	-	-	-	I	-	-	-	-	I	6	
		WIND MECHANICAL PUMPING	-	-	-	-	-	-	I	-	-	-	-	I	6	
AGRICULTURE	LIVESTOCK WATERING	BIOGAS MECHANICAL PUMPING	-	-	-	-	-	-	-	-	I	-	-	-	5	Improved access to water supplies has received
		PV W/BATTERY PUMPING	-	-	-	-	-	-	-	-	I	-	-	-	5	significant attention in the Plan
		PV W/O BATTERY PUMPING	-	-	-	-	-	-	-	-	I	-	-	-	5	
		WIND ELECTRIC PUMPING	-	-	-	-	-	-	-	-	I	-	-	-	5	
		WIND MECHANICAL PUMPING	-	-	-	-	-	-	-	-	I	-	-	-	5	
INDUSTRY	CATHODIC PROTECTION	PV	-	-	I	-	-	-	-	-	-	-	-	-	2	Pipelines are overground or near grid power
	FOOD CANNING	SOLAR THERMAL	I	-	-	-	-	-	-	-	-	-	-	-	8	Produc. doubled from 1973-79, growth to continue
	HYDROGENATED OIL	SOLAR THERMAL	I	-	-	-	-	-	-	-	-	-	-	-	7	Produc. increase from 142-250 thous. T in 1981-87
	MALT BEVERAGES	SOLAR THERMAL	I	-	-	-	-	-	-	-	-	-	I	-	6	Produc. increase from 375-480 thous. T in 1981-87
	PHARMACEUTICALS	SOLAR THERMAL	I	-	-	-	-	-	-	-	-	-	-	-	8	Produc. increase from 156-340 thous. T in 1981-87
	SOAP & DETERGENTS	SOLAR THERMAL	I	-	-	-	-	-	-	-	-	-	-	-	7	Produc. increase from 320-440 thous. T in 1981-87
POPULATION SUPPORT	COMMERCIAL/INSTIT. BLDGS.	ACTIVE/PASSIVE SOLAR	-	-	-	-	I	-	-	-	-	-	-	-	7	Major increase in tourism & service sectors
	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM MSW	-	I	-	-	-	-	-	-	-	-	-	I	7	Urban MSW management a priority
	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM SEWAGE	-	I	-	-	-	-	-	-	-	-	-	I	7	Urban sewage management a major priority
	ELECTRICITY FOR CITIES	MSW INCINERATE/ELECTRIC	-	I	-	-	-	-	-	-	-	-	-	I	7	Urban MSW management a priority
	REMOTE COMMUNICATIONS	PV	-	-	-	I	-	-	-	-	-	-	-	I	6	Rural comm. network improvement a priority
	RESIDENTIAL BLDGS.	ACTIVE/PASSIVE SOLAR	-	-	-	-	I	-	-	-	-	-	-	I	5	Housing in urban & rural areas to increase but
																climatization not specifically address in Plan

Exhibit 7.9

SCORING OF TECHNOLOGY/APPLICATION OPTIONS FOR ECONOMIC FEASIBILITY CRITERIA

SECTOR	APPLICATION	TECHNOLOGY	IN THE 1985-1990 TIMEFRAME < THAN CONVEN.	IN THE 1985-1990 TIMEFRAME = TO CONVEN.	IN THE 1985-1990 TIMEFRAME > THAN CONVEN.	IN THE 1990-1995 TIMEFRAME < THAN CONVEN.	IN THE 1990-1995 TIMEFRAME = TO CONVEN.	IN THE 1990-1995 TIMEFRAME > THAN CONVEN.	COST STATUS SCORE	COMMENTS
POPULATION SUPPORT	COMMERCIAL/INSTIT. BLDGS.	ACTIVE/PASSIVE SOLAR	-	I	-	I	-	-	8	See analysis in Section 5.10
	RESIDENTIAL BLDGS.	ACTIVE/PASSIVE SOLAR	-	I	-	I	-	-	8	See analysis in Section 5.10
POPULATION SUPPORT	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM MSW	-	-	I	-	I	-	5	See analysis in Section 5.4
	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM SEWAGE	I	-	-	I	-	-	8	See analysis in Section 5.3
	ELECTRICITY FOR CITIES	MSW INCINERATE/ELECTRIC	-	-	I	-	-	-	4	See analysis in Section 5.11
AGRICULTURE	BROILER PRODUCTION	BIOGAS ELECTRIC	I	-	-	I	-	-	8	See analysis in Section 5.6
	CATTLE FEEDLOT	BIOGAS ELECTRIC	-	I	-	-	I	-	7	See analysis in Section 5.5
	DAIRY FARM	BIOGAS ELECTRIC	-	I	-	-	I	-	7	See analysis in Section 5.5
	EGG PRODUCTION	BIOGAS ELECTRIC	I	-	-	I	-	-	9	See analysis in Section 5.6
AGRICULTURE	IRRIGATION	BIOGAS MECHANICAL PUMPING	I	-	-	I	-	-	9	See analysis in Section 5.2
	LAND DRAINAGE	BIOGAS MECHANICAL PUMPING	-	-	I	-	-	I	3	See analysis in Section 5.2
	LIVESTOCK WATERING	BIOGAS MECHANICAL PUMPING	I	-	-	I	-	-	9	See analysis in Section 5.2
AGRICULTURE	BROILER PRODUCTION	PV	-	-	I	-	-	I	1	See analysis in Section 5.1
	CATTLE FEEDLOT	PV	-	I	-	-	I	-	5	See analysis in Section 5.1
	DAIRY FARM	PV	-	-	I	-	-	I	1	See analysis in Section 5.1
	EGG PRODUCTION	PV	-	-	I	-	-	I	1	See analysis in Section 5.1
INDUSTRY	CATHODIC PROTECTION	PV	I	-	-	I	-	-	7	See analysis in Section 5.8
POPULATION SUPPORT	REMOTE COMMUNICATIONS	PV	I	-	-	I	-	-	8	See analysis in Section 5.7
AGRICULTURE	IRRIGATION	PV W/BATTERY PUMPING	-	-	I	-	I	-	5	See analysis in Section 5.2
	LAND DRAINAGE	PV W/BATTERY PUMPING	-	-	I	-	-	I	1	See analysis in Section 5.2
	LIVESTOCK WATERING	PV W/BATTERY PUMPING	-	-	I	I	-	-	6	See analysis in Section 5.2
	IRRIGATION	PV W/O BATTERY PUMPING	-	I	-	I	-	-	7	See analysis in Section 5.2
	LAND DRAINAGE	PV W/O BATTERY PUMPING	-	-	I	-	-	I	1	See analysis in Section 5.2
	LIVESTOCK WATERING	PV W/O BATTERY PUMPING	-	I	-	I	-	-	7	See analysis in Section 5.2
AGRICULTURE	BROILER PRODUCTION	PV-DIESEL HYBRID	-	-	I	I	-	-	6	See analysis in Section 5.1
	CATTLE FEEDLOT	PV-DIESEL HYBRID	-	-	I	I	-	-	6	See analysis in Section 5.1
	DAIRY FARM	PV-DIESEL HYBRID	-	-	I	I	-	-	6	See analysis in Section 5.1
	EGG PRODUCTION	PV-DIESEL HYBRID	-	-	I	I	-	-	6	See analysis in Section 5.1
AGRICULTURE	BROILER PRODUCTION	PV-WIND-DIESEL HYB.	-	-	I	I	-	-	6	See analysis in Section 5.1
	CATTLE FEEDLOT	PV-WIND-DIESEL HYB.	-	-	I	I	-	-	1	See analysis in Section 5.1
	DAIRY FARM	PV-WIND-DIESEL HYB.	-	-	I	I	-	-	1	See analysis in Section 5.1
	EGG PRODUCTION	PV-WIND-DIESEL HYB.	-	-	I	I	-	-	7	See analysis in Section 5.1
INDUSTRY	FOOD CANNING	SOLAR THERMAL	-	-	I	-	-	I	5	See analysis in Section 5.9
	HYDROGENATED OIL	SOLAR THERMAL	-	-	I	-	-	I	5	See analysis in Section 5.9
	MALT BEVERAGES	SOLAR THERMAL	-	-	I	-	-	I	5	See analysis in Section 5.9
	PHARMACEUTICALS	SOLAR THERMAL	-	-	I	-	-	I	5	See analysis in Section 5.9
	SOAP & DETERGENTS	SOLAR THERMAL	-	-	I	-	-	I	5	See analysis in Section 5.9
AGRICULTURE	BROILER PRODUCTION	WIND	-	I	-	I	-	-	7	See analysis in Section 5.1
	CATTLE FEEDLOT	WIND	-	-	I	-	I	-	5	See analysis in Section 5.1
	DAIRY FARM	WIND	-	-	I	-	I	-	5	See analysis in Section 5.1
	EGG PRODUCTION	WIND	-	-	I	-	-	I	3	See analysis in Section 5.1
	IRRIGATION	WIND ELECTRIC PUMPING	-	I	-	-	I	-	8	See analysis in Section 5.2
	LAND DRAINAGE	WIND ELECTRIC PUMPING	-	-	I	-	-	I	3	See analysis in Section 5.2
	LIVESTOCK WATERING	WIND ELECTRIC PUMPING	-	I	-	I	-	-	6	See analysis in Section 5.2
	IRRIGATION	WIND MECHANICAL PUMPING	I	-	-	I	-	-	9	See analysis in Section 5.2
	LAND DRAINAGE	WIND MECHANICAL PUMPING	-	-	I	-	-	I	3	See analysis in Section 5.2
	LIVESTOCK WATERING	WIND MECHANICAL PUMPING	I	-	-	I	-	-	9	See analysis in Section 5.2
AGRICULTURE	BROILER PRODUCTION	WIND-DIESEL HYBRID	I	-	-	I	-	-	9	See analysis in Section 5.1
	CATTLE FEEDLOT	WIND-DIESEL HYBRID	-	-	I	-	-	I	3	See analysis in Section 5.1
	DAIRY FARM	WIND-DIESEL HYBRID	I	-	-	I	-	-	8	See analysis in Section 5.1
	EGG PRODUCTION	WIND-DIESEL HYBRID	I	-	-	I	-	-	8	See analysis in Section 5.1
AGRICULTURE	BROILER PRODUCTION	WIND-PV HYBRID	-	-	I	I	-	-	6	See analysis in Section 5.1
	CATTLE FEEDLOT	WIND-PV HYBRID	-	-	I	I	-	-	6	See analysis in Section 5.1
	DAIRY FARM	WIND-PV HYBRID	-	-	I	-	I	-	5	See analysis in Section 5.1
	EGG PRODUCTION	WIND-PV HYBRID	-	-	I	-	-	I	3	See analysis in Section 5.1

Exhibit 7.10

SCORING OF TECHNOLOGY/APPLICATION OPTIONS FOR CURRENT STATUS IN EGYPT CRITERIA

SECTOR	APPLICATION	TECHNOLOGY	SIGNIFICANT PROJECT ACTIVITY IN EGYPT	MODERATE PROJECT ACTIVITY IN EGYPT	LIMITED PROJECT ACTIVITY IN EGYPT	CURRENT STATUS IN EGYPT SCORE	COMMENTS
POPULATION SUPPORT	COMMERCIAL/INSTIT. BLDGS.	ACTIVE/PASSIVE SOLAR	-	X	-	6	Test facilities been constructed & design techniques
	RESIDENTIAL BLDGS.	ACTIVE/PASSIVE SOLAR	-	X	-	6	developed in Egypt
POPULATION SUPPORT	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM MSW	-	-	X	9	No project experience
	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM SEWAGE	-	X	-	7	Plant operated in the 1930s, none at present in Egypt
	ELECTRICITY FOR CITIES	MSW INCINERATE/ELECTRIC	-	-	X	8	Incineration experience but no MSW incin./elec. gener. exp.
AGRICULTURE	BROILER PRODUCTION	BIOGAS ELECTRIC	-	X	-	5	Several organizations have ongoing R&D in small biogas units
	CATTLE FEEDLOT	BIOGAS ELECTRIC	-	X	-	5	Several organizations have ongoing R&D in small biogas units
	DAIRY FARM	BIOGAS ELECTRIC	-	X	-	5	Several organizations have ongoing R&D in small biogas units
	EGG PRODUCTION	BIOGAS ELECTRIC	-	X	-	5	Several organizations have ongoing R&D in small biogas units
AGRICULTURE	IRRIGATION	BIOGAS MECHANICAL PUMPING	-	X	-	5	Several organizations have ongoing R&D in small biogas units
	LAND DRAINAGE	BIOGAS MECHANICAL PUMPING	-	-	X	9	No project experience in facilities of this scale
	LIVESTOCK WATERING	BIOGAS MECHANICAL PUMPING	-	X	-	5	Several organizations have ongoing R&D in small biogas units
AGRICULTURE	BROILER PRODUCTION	PV	-	-	X	8	No project experience in facilities of this scale
	CATTLE FEEDLOT	PV	-	-	X	8	No project experience in facilities of this scale
	DAIRY FARM	PV	-	-	X	8	No project experience in facilities of this scale
	EGG PRODUCTION	PV	-	-	X	8	No project experience in facilities of this scale
INDUSTRY	CATHODIC PROTECTION	PV	-	X	-	6	No PV project experience for application
POPULATION SUPPORT	REMOTE COMMUNICATIONS	PV	-	X	-	4	Several organizations have commercial applications
AGRICULTURE	IRRIGATION	PV W/BATTERY PUMPING	-	X	-	4	Several organizations have ongoing projects
	LAND DRAINAGE	PV W/BATTERY PUMPING	-	-	X	8	No project experience in facilities of this scale
	LIVESTOCK WATERING	PV W/BATTERY PUMPING	-	X	-	4	Several organizations have ongoing projects
	IRRIGATION	PV W/O BATTERY PUMPING	-	X	-	2	Several organizations have ongoing projects
	LAND DRAINAGE	PV W/O BATTERY PUMPING	-	-	X	8	No project experience in facilities of this scale
	LIVESTOCK WATERING	PV W/O BATTERY PUMPING	-	X	-	2	Several organizations have ongoing projects
AGRICULTURE	BROILER PRODUCTION	PV-DIESEL HYBRID	-	-	X	8	No project experience but some ongoing research
	CATTLE FEEDLOT	PV-DIESEL HYBRID	-	-	X	8	No project experience but some ongoing research
	DAIRY FARM	PV-DIESEL HYBRID	-	-	X	8	No project experience but some ongoing research
	EGG PRODUCTION	PV-DIESEL HYBRID	-	-	X	8	No project experience but some ongoing research
AGRICULTURE	BROILER PRODUCTION	PV-WIND-DIESEL HYB.	-	-	X	9	No project experience but some ongoing research
	CATTLE FEEDLOT	PV-WIND-DIESEL HYB.	-	-	X	9	No project experience but some ongoing research
	DAIRY FARM	PV-WIND-DIESEL HYB.	-	-	X	9	No project experience but some ongoing research
	EGG PRODUCTION	PV-WIND-DIESEL HYB.	-	-	X	9	No project experience but some ongoing research
INDUSTRY	FOOD CANNING	SOLAR THERMAL	-	-	X	8	No commercial projects but substantial ongoing research
	HYDROGENATED OIL	SOLAR THERMAL	-	-	X	8	No commercial projects but substantial ongoing research
	MALT BEVERAGES	SOLAR THERMAL	-	-	X	8	No commercial projects but substantial ongoing research
	PHARMACEUTICALS	SOLAR THERMAL	-	-	X	8	No commercial projects but substantial ongoing research
	SOAP & DETERGENTS	SOLAR THERMAL	-	-	X	8	No commercial projects but substantial ongoing research
AGRICULTURE	BROILER PRODUCTION	WIND	-	-	X	8	No project experience but some ongoing research
	CATTLE FEEDLOT	WIND	-	-	X	8	No project experience but some ongoing research
	DAIRY FARM	WIND	-	-	X	8	No project experience but some ongoing research
	EGG PRODUCTION	WIND	-	-	X	8	No project experience but some ongoing research
	IRRIGATION	WIND ELECTRIC PUMPING	-	-	X	8	No project experience but some ongoing research
	LAND DRAINAGE	WIND ELECTRIC PUMPING	-	-	X	8	No project experience but some ongoing research
	LIVESTOCK WATERING	WIND ELECTRIC PUMPING	-	-	X	8	No project experience but some ongoing research
	IRRIGATION	WIND MECHANICAL PUMPING	X	-	-	3	Good experience in Egypt
	LAND DRAINAGE	WIND MECHANICAL PUMPING	X	-	-	3	Good experience in Egypt
	LIVESTOCK WATERING	WIND MECHANICAL PUMPING	X	-	-	3	Good experience in Egypt
AGRICULTURE	BROILER PRODUCTION	WIND-DIESEL HYBRID	-	-	X	8	No project experience but some ongoing research
	CATTLE FEEDLOT	WIND-DIESEL HYBRID	-	-	X	8	No project experience but some ongoing research
	DAIRY FARM	WIND-DIESEL HYBRID	-	-	X	8	No project experience but some ongoing research
	EGG PRODUCTION	WIND-DIESEL HYBRID	-	-	X	8	No project experience but some ongoing research
AGRICULTURE	BROILER PRODUCTION	WIND-PV HYBRID	-	-	X	8	No project experience but some ongoing research
	CATTLE FEEDLOT	WIND-PV HYBRID	-	-	X	8	No project experience but some ongoing research
	DAIRY FARM	WIND-PV HYBRID	-	-	X	8	No project experience but some ongoing research
	EGG PRODUCTION	WIND-PV HYBRID	-	-	X	8	No project experience but some ongoing research

Exhibit 7.11

SCORING OF TECHNOLOGY/APPLICATION OPTIONS FOR INSTITUTIONAL REQUIREMENTS CRITERIA

SECTOR	APPLICATION	TECHNOLOGY	AVAILABILITY OF SKILLED PERSONNEL	LOCAL MANUFAC-TURING CAPABILITY	LOCAL INSTI-TUTIONS	INSTITUTIONAL REQUIREMENTS SCORE	COMMENTS
POPULATION SUPPORT	COMMERCIAL/INSTIT. BLDGS.	ACTIVE/PASSIVE SOLAR	M	M	H	7	Larger scale GOE & commercial operations have better access to trained
	RESIDENTIAL BLDGS.	ACTIVE/PASSIVE SOLAR	L	L	L	3	personnel, manufac. facilities & building regulations can be enforced
POPULATION SUPPORT	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM MSW	L	L	L	3	Technology is ac R&D stage, minimal capability in Egypt
	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM SEWAGE	H	M	H	8	Technology similar to sewage treatment plants already in use in Egypt
	ELECTRICITY FOR CITIES	MSW INCINERATE/ELECTRIC	M	H	H	6	Tech. similar to combust. plants in Egypt. Organ. syst. for MSW manage
AGRICULTURE	BROILER PRODUCTION	BIOGAS ELECTRIC	M	H	H	6	Utilizes locally available material & construction techniques,
	CATTLE FEEDLOT	BIOGAS ELECTRIC	M	H	H	6	and also personnel in Egypt experienced with technology
	DAIRY FARM	BIOGAS ELECTRIC	M	H	H	6	
	EGG PRODUCTION	BIOGAS ELECTRIC	M	H	H	6	
AGRICULTURE	IRRIGATION	BIOGAS MECHANICAL PUMPING	H	H	H	8	Utilizes locally available material & construction techniques,
	LAND DRAINAGE	BIOGAS MECHANICAL PUMPING	M	H	H	6	and also personnel in Egypt experienced with technology, particularly
	LIVESTOCK WATERING	BIOGAS MECHANICAL PUMPING	H	H	H	8	with small scale systems (land drainage systems are large)
AGRICULTURE	BROILER PRODUCTION	PV	L	L	L	3	No extensive use of PV in Egypt
	CATTLE FEEDLOT	PV	L	L	L	3	
	DAIRY FARM	PV	L	L	L	3	
	EGG PRODUCTION	PV	L	L	L	3	
INDUSTRY	CATHODIC PROTECTION	PV	L	L	L	3	
POPULATION SUPPORT	REMOTE COMMUNICATIONS	PV	L	L	L	3	
AGRICULTURE	IRRIGATION	PV W/BATTERY PUMPING	L	L	L	3	No extensive use of PV in Egypt
	LAND DRAINAGE	PV W/BATTERY PUMPING	L	L	L	3	
	LIVESTOCK WATERING	PV W/BATTERY PUMPING	L	L	L	3	
	IRRIGATION	PV W/O BATTERY PUMPING	L	L	L	3	
	LAND DRAINAGE	PV W/O BATTERY PUMPING	L	L	L	3	
	LIVESTOCK WATERING	PV W/O BATTERY PUMPING	L	L	L	3	
AGRICULTURE	BROILER PRODUCTION	PV-DIESEL HYBRID	L	L	L	3	No extensive use of hybrids in Egypt
	CATTLE FEEDLOT	PV-DIESEL HYBRID	L	L	L	3	
	DAIRY FARM	PV-DIESEL HYBRID	L	L	L	3	
	EGG PRODUCTION	PV-DIESEL HYBRID	L	L	L	3	
AGRICULTURE	BROILER PRODUCTION	PV-WIND-DIESEL HYB.	L	L	L	3	No extensive use of hybrids in Egypt
	CATTLE FEEDLOT	PV-WIND-DIESEL HYB.	L	L	L	3	
	DAIRY FARM	PV-WIND-DIESEL HYB.	L	L	L	3	
	EGG PRODUCTION	PV-WIND-DIESEL HYB.	L	L	L	3	
INDUSTRY	FOOD CANNING	SOLAR THERMAL	M	H	M	7	Local manufacturing facilities & personnel can be used for technology
	HYDROGENATED OIL	SOLAR THERMAL	M	H	M	7	manufacture and use
	MALT BEVERAGES	SOLAR THERMAL	M	H	M	7	
	PHARMACEUTICALS	SOLAR THERMAL	M	H	M	7	
	SOAP & DETERGENTS	SOLAR THERMAL	M	H	M	7	
AGRICULTURE	BROILER PRODUCTION	WIND	M	M	M	5	Local manufacturing facilities & personnel can be used for technology
	CATTLE FEEDLOT	WIND	M	M	M	5	manufacture and use. However, there is more experience with
	DAIRY FARM	WIND	M	M	M	5	mechanical water pumping systems
	EGG PRODUCTION	WIND	M	M	M	5	
	IRRIGATION	WIND ELECTRIC PUMPING	M	M	M	5	
	LAND DRAINAGE	WIND ELECTRIC PUMPING	M	M	M	5	
	LIVESTOCK WATERING	WIND ELECTRIC PUMPING	M	M	M	5	
	IRRIGATION	WIND MECHANICAL PUMPING	H	H	M	7	
	LAND DRAINAGE	WIND MECHANICAL PUMPING	H	H	M	7	
	LIVESTOCK WATERING	WIND MECHANICAL PUMPING	H	H	M	7	
AGRICULTURE	BROILER PRODUCTION	WIND-DIESEL HYBRID	M	M	L	4	No extensive use of hybrids in Egypt
	CATTLE FEEDLOT	WIND-DIESEL HYBRID	M	M	L	4	
	DAIRY FARM	WIND-DIESEL HYBRID	M	M	L	4	
	EGG PRODUCTION	WIND-DIESEL HYBRID	M	M	L	4	
AGRICULTURE	BROILER PRODUCTION	WIND-PV HYBRID	L	M	L	3	No extensive use of hybrids in Egypt
	CATTLE FEEDLOT	WIND-PV HYBRID	L	M	L	3	
	DAIRY FARM	WIND-PV HYBRID	L	M	L	3	
	EGG PRODUCTION	WIND-PV HYBRID	L	M	L	3	

EXHIBIT 7.12

SCORING OF TECHNOLOGY/APPLICATION OPTIONS FOR SOCIAL & ENVIRONMENTAL IMPACTS CRITERIA

SECTOR	APPLICATION	TECHNOLOGY	EXTENT OF SOCIAL ACCEPTABILITY	EXTENT OF ENVIRON-MENTAL IMPACTS	SOCIAL & ENVIRON-MENTAL IMPACTS SCORE	COMMENTS
POPULATION SUPPORT	COMMERCIAL/INSTIT. BLDGS.	ACTIVE/PASSIVE SOLAR	H	H	8	No anticipated problems, unless lifestyle changes are needed
	RESIDENTIAL BLDGS.	ACTIVE/PASSIVE SOLAR	H	H	8	No anticipated problems, unless lifestyle changes are needed
POPULATION SUPPORT	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM MSW	H	H	8	Beneficial health impacts due to better waste control & disposal
	ELECTRICITY FOR CITIES	BIOGAS ELEC. FROM SEWAGE	H	H	9	Beneficial health impacts due to better waste control & disposal
	ELECTRICITY FOR CITIES	MSW INCINERATE/ELECTRIC	H	H	9	Beneficial health impacts due to better waste control & disposal
AGRICULTURE	BROILER PRODUCTION	BIOGAS ELECTRIC	M	H	6	Some social problems due to collection, storage & use of manure
	CATTLE FEEDLOT	BIOGAS ELECTRIC	M	H	6	Some social problems due to collection, storage & use of manure
	DAIRY FARM	BIOGAS ELECTRIC	M	H	6	Some social problems due to collection, storage & use of manure
	EGG PRODUCTION	BIOGAS ELECTRIC	M	H	6	Some social problems due to collection, storage & use of manure
AGRICULTURE	IRRIGATION	BIOGAS MECHANICAL PUMPING	M	H	6	Some social problems due to collection, storage & use of manure
	LAND DRAINAGE	BIOGAS MECHANICAL PUMPING	M	H	6	Some social problems due to collection, storage & use of manure
	LIVESTOCK WATERING	BIOGAS MECHANICAL PUMPING	M	H	6	Some social problems due to collection, storage & use of manure
AGRICULTURE	BROILER PRODUCTION	PV	H	H	8	No anticipated problems
	CATTLE FEEDLOT	PV	H	H	8	No anticipated problems
	DAIRY FARM	PV	H	H	8	No anticipated problems
	EGG PRODUCTION	PV	H	H	8	No anticipated problems
INDUSTRY	CATHODIC PROTECTION	PV	H	H	8	No anticipated problems
POPULATION SUPPORT	REMOTE COMMUNICATIONS	PV	H	H	8	No anticipated problems
AGRICULTURE	IRRIGATION	PV W/BATTERY PUMPING	H	H	8	No anticipated problems
	LAND DRAINAGE	PV W/BATTERY PUMPING	H	H	8	No anticipated problems
	LIVESTOCK WATERING	PV W/BATTERY PUMPING	H	H	8	No anticipated problems
	IRRIGATION	PV W/O BATTERY PUMPING	H	H	8	No anticipated problems
	LAND DRAINAGE	PV W/O BATTERY PUMPING	H	H	8	No anticipated problems
	LIVESTOCK WATERING	PV W/O BATTERY PUMPING	H	H	8	No anticipated problems
AGRICULTURE	BROILER PRODUCTION	PV-DIESEL HYBRID	H	M	7	No major problems other than noise & air pollution from diesel
	CATTLE FEEDLOT	PV-DIESEL HYBRID	H	M	7	No major problems other than noise & air pollution from diesel
	DAIRY FARM	PV-DIESEL HYBRID	H	M	7	No major problems other than noise & air pollution from diesel
	EGG PRODUCTION	PV-DIESEL HYBRID	H	M	7	No major problems other than noise & air pollution from diesel
AGRICULTURE	BROILER PRODUCTION	PV-WIND-DIESEL HYB.	M	M	6	Problems due to noise & air pollution from diesel & possible noise,
	CATTLE FEEDLOT	PV-WIND-DIESEL HYB.	M	M	6	TV interference and visual problems of wind machine
	DAIRY FARM	PV-WIND-DIESEL HYB.	M	M	6	
	EGG PRODUCTION	PV-WIND-DIESEL HYB.	M	M	6	
INDUSTRY	FOOD CANNING	SOLAR THERMAL	H	H	8	No anticipated problems
	HYDROGENATED OIL	SOLAR THERMAL	H	H	8	No anticipated problems
	MALT BEVERAGES	SOLAR THERMAL	H	H	8	No anticipated problems
	PHARMACEUTICALS	SOLAR THERMAL	H	H	8	No anticipated problems
	SOAP & DETERGENTS	SOLAR THERMAL	H	H	8	No anticipated problems
AGRICULTURE	BROILER PRODUCTION	WIND	M	M	6	Possible noise, TV interference and visual problems
	CATTLE FEEDLOT	WIND	M	M	6	Possible noise, TV interference and visual problems
	DAIRY FARM	WIND	M	M	6	Possible noise, TV interference and visual problems
	EGG PRODUCTION	WIND	M	M	6	Possible noise, TV interference and visual problems
	IRRIGATION	WIND ELECTRIC PUMPING	M	M	6	Possible noise, TV interference and visual problems
	LAND DRAINAGE	WIND ELECTRIC PUMPING	M	M	6	Possible noise, TV interference and visual problems
	LIVESTOCK WATERING	WIND ELECTRIC PUMPING	M	M	6	Possible noise, TV interference and visual problems
	IRRIGATION	WIND MECHANICAL PUMPING	M	M	6	Possible noise, TV interference and visual problems
	LAND DRAINAGE	WIND MECHANICAL PUMPING	M	M	6	Possible noise, TV interference and visual problems
	LIVESTOCK WATERING	WIND MECHANICAL PUMPING	M	M	6	Possible noise, TV interference and visual problems
AGRICULTURE	BROILER PRODUCTION	WIND-DIESEL HYBRID	M	M	5	Problems due to noise & air pollution from diesel & possible noise,
	CATTLE FEEDLOT	WIND-DIESEL HYBRID	M	M	5	TV interference and visual problems of wind machine
	DAIRY FARM	WIND-DIESEL HYBRID	M	M	5	
	EGG PRODUCTION	WIND-DIESEL HYBRID	M	M	5	
AGRICULTURE	BROILER PRODUCTION	WIND-PV HYBRID	M	M	6	Possible noise, TV interference and visual problems from wind a/c
	CATTLE FEEDLOT	WIND-PV HYBRID	M	M	6	Possible noise, TV interference and visual problems from wind a/c
	DAIRY FARM	WIND-PV HYBRID	M	M	6	Possible noise, TV interference and visual problems from wind a/c
	EGG PRODUCTION	WIND-PV HYBRID	M	M	6	Possible noise, TV interference and visual problems from wind a/c

7.3.2.2 Recommended Field Test Candidates

The Phase II analysis resulted in an identification of five renewable technology/application options which should be considered by USAID and EEA for field testing under the Renewable Energy Field Testing Project. These include:

- o Active/Passive Solar for Residential Buildings
- o Solar Thermal for the Pharmaceutical Industry
- o Solar Thermal for Hydrogenated Oil Industry
- o Biogas Electric from Sewage to Provide Electricity for Cities
- o Wind Mechanical Power for Small-Scale Irrigation.

Exhibit 7.13 summarizes the analysis results for each of the 12 options studied.

7.4 Next Steps

The following activities are planned:

Task 2.2.2 Renewable Technology/Application Evaluation

(a) Conduct a briefing to senior EEA officials (e.g. Drs. Sharkawi and Tablawi) to obtain their concurrence on the evaluation process and approval of the five candidate field test opt ons. The briefing will be held in mid-September 1985, and will include representatives from EEA, Meridian Corporation and E^3I.

(b) Collect detailed economic, market and technical data for each of the five selected options; develop preliminary system conceptual designs; and identify potential field test sites. Based on the detailed data collection and site analyses, the five options will be reduced to four target options which will be recommended for field testing under the Renewable Energy Field Test Project. This selection of the four options will be completed by the end of November, 1985.

Task 2.2.3 Technology Application Program Plans (TAPPs)

(a) Develop individual TAPPs for each of the four candidate field tests which provide the necessary guidance for field test implementation. These plans will include: (1) justification for undertaking the candidate field test; (2) detailed economic and market assessment of the selected option; (3) recommended site location for the field test; (4) conceptual design for the project; (5) draft Request for Proposals (RFP) for system hardware; (6) schedule and budget proposals; and (7) a listing of contacts from participating organizations. The four draft TAPPs are expected to be completed at monthly intervals beginning in March, 1986.

EXHIBIT 7.13

FIELD TEST OPTION ANALYSIS RESULTS

A. Priority Field Test Candidates

Technology	Application	Analysis Results
Active/Passive Solar	Residential Buildings	o Small-scale system requirements which satisfy budget constraints o Technically/Operationally Proven o Cost-Competitive o Available solar resource in urban areas o Substantial replicability in urban, remote and new communities; 800,000 new urban units planned by 2000 o Limited on-going projects in Egypt
Solar Thermal	Pharmaceuticals Industry	o Satisfies project budget constraints o Technically proven
	Hydrogenated Oil Industry	o Large potential for replicability in low temperature steam industrial applications o Available solar resource in industrial areas o Limited project experience in Egypt

EXHIBIT 7.13 (Cont'd)

FIELD TEST OPTION ANALYSIS RESULTS

A. Priority Field Test Candidates (Cont'd)

Technology	Application	Analysis Results
Biogas Electric From Sewage	Electricity for Cities	o Technically proven o Satisfies project budget constraints o Large market for offsetting sewage plant electricity requirements and supplying grid power o No project experience in Egypt o Good sewage colection system in place to supply resource base
Wind Mechanical	Small-Scale Irrigation Irrigation	o Small-systems which satisfy budget constraints o Simple, proven technology o No current project experience; had systems in place in late 1800's o Available wind resource in coastal and outlying areas o Large market potential in agricultural and remote areas
Photovoltaics	Remote Communications	o Commercially available technology that is sold world-wide; thus, no need to conduct demonstration project o Substantial on-going projects in military, other government and private sectors; field test will not add to knowledge base or experience of Egyptians

EXHIBIT 7.13 (Cont'd)

FIELD TEST OPTION ANALYSIS RESULTS

B. Secondary Field Test Candidates

Technology	Application	Analysis Results
Photovoltaics	Irrigation	o Substantial on-going projects in Egypt; field test will not add to knowledge base or experience of Egyptians
Solar Thermal	Soap and Detergent Industry	o Replicability potential not as high as in other solar thermal sectors studied
Wind Electric	Small-Scale Irrigation	o Technology more complex than wind mechanical systems for irrigation and not as well proven
Biogas Mechanical	Small-Scale Irrigation	o Technology more complex than wind mechanical systems for irrigation and not as well proven o Substantial on-going projects (>100) in small-scale biogas units so field test will not add to knowledge base or experience of Egyptians
Municipal Solid Waste Incineration	Electricity for Cities	o System costs prohibitive for project budget, but cost may be acceptable for other projects being considered by GOE; MSW plant estimated at about $6 million o Although waste collection systems are improving in Cairo, Alexandria and other urban areas, the current system does not provide a stable resource supply
Active/Passive Solar	Commercial Buildings	o EREDO is sponsoring projects to demonstrate active/passive solar for commercial building climatization; a field test under this project would not provide new information or training to Egyptians

Volume II: Appendices

RENEWABLE ENERGY RESOURCES
FIELD TEST PROJECT

USAID Contract No: AID-263-0123-C-00-4069-00

TASK 2.2.1 FINAL REPORT

Renewable Energy Technology/ Application Options Identification

Prepared for
EGYPTIAN ELECTRICITY AUTHORITY
Cairo, Egypt

and

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
USAID Mission: Cairo, Egypt

Submitted to
LOUIS BERGER INTERNATIONAL, INC.
Washington, D.C.

Prepared by
MERIDIAN CORPORATION
Falls Church, VA

In Association with

EGYPTIAN ELECTRICITY AUTHORITY
Cairo, Egypt

ENERGY AND ENVIRONMENTAL ENGINEERING, INC.
East Cambridge, MA

SEPTEMBER 1985

APPENDIX A

Renewable Energy

Technologies Characterizations

PAGE

APPENDIX A: RENEWABLE ENERGY TECHNOLOGY CHARACTERIZATION

A.1 Wind A-1
- A.1.1 Introduction
- A.1.2 Technology Description
  - A.1.2.1 Electric Generators and Power Conditioning Units
  - A.1.2.2 Grid-Connected Utility Systems
  - A.1.2.3 Storage Systems
- A.1.3 Resource Availability
- A.1.4 Market Readiness
- A.1.5 Economic Viability
- A.1.6 Industry Status
- A.1.7 Current R&D Thrusts
- A.1.8 Relevant Experience in Egypt Using Wind Technology

A.2 Photovoltaics A-23
- A.2.1 Operating Characteristics
- A.2.2 Technology Description
  - A.2.2.1 Types of PV Cells
  - A.2.2.2 Types of PV Collectors
- A.2.3 Resource Availability
- A.2.4 Market Readiness
  - A.2.4.1 Stand-Alone Market
  - A.2.4.2 Consumer Products
  - A.2.4.3 Grid-Connected Residential and Intermediate
  - A.2.4.4 Central Station Utility Power
- A.2.5 Economic Viability
- A.2.6 Industry Status
- A.2.7 R&D Thrusts
- A.2.8 Relevant Egyptian/Worldwide Experience in Using PV

A.3 High Temperature Solar Thermal A-45
- A.3.1 Operating Characteristics
- A.3.2 Technology Description
  - A.3.2.1 Central Receiver
  - A.3.2.2 Parabolic Dish
  - A.3.2.3 Parabolic Trough
- A.3.3 Technology Status
- A.3.4 Resource Availability
- A.3.5 Market Readiness
- A.3.6 Economic Viability
- A.3.7 Industry Status
- A.3.8 Current Solar Thermal R&D Thrusts
- A.3.9 Relevant Experience in Egypt and Other Countries Using High Temperature Thermal Technology

A.4 Geothermal A-58
- A.4.1 Operating Characteristics
- A.4.2 Technology Description
- A.4.3 Resource Availability

PAGE

A.4.4 Economic Viability
A.4.5 Industry Status
A.4.6 Current R&D Thrusts
A.4.7 Relevant Experience in Egypt Using Geothermal Technology

A.5 Biomass..... A-65
A.5.1 Operating Characteristics
A.5.2 Technology Description
A.5.2.1 Direct Combustion
A.5.2.2 Anaerobic Digestion
A.5.3 Resource Availability
A.5.4 Market Readiness
A.5.5 Economic Viability
A.5.6 Industrial Status
A.5.7 Current R&D Thrust for Technology..
A.5.8 Relevant Experience in Egypt Using Biomass Technologies
A.5.9 Worldwide Experience Using Biogas Technology

A.6 Solar Ponds..... A-83
A.6.1 Operating Characteristics
A.6.2 Technology Description
A.6.3 Resource Availability
A.6.4 Market Readiness
A.6.5 Economic Viability
A.6.6 Industry Status
A.6.7 Current R&D Thrusts
A.6.8 Relevant Experience in Egypt/Worldwide in Using Solar Pond Technology

A.7 Municipal Solid Waste..... A-91
A.7.1 Operating Characteristics
A.7.2 Technology Description
A.7.2.1 Mass Incineration
A.7.2.2 Refuse Derived Fuel (RDF)
A.7.2.3 Cogeneration
A.7.2.4 Co-Disposal
A.7.3 Resource Availability
A.7.4 Market Readiness
A.7.5 Economic Viability
A.7.6 Industry Status
A.7.7 Current R&D Thrusts for Technology
A.7.8 Relevant Experience in Egypt and Other Countries Using MSW

A.8 Passive and Hybrid Solar Heating and Cooling and Daylighting... A-102
A.8.1 Technology Description
A.8.1.1 Passive and Hybrid Solar Heating
A.8.1.2 Daylighting
A.8.1.3 Passive Solar Cooling Systems
A.8.2 Resource Availability
A.8.3 Market Readiness

PAGE

A.8.4 Economic Viability
A.8.5 Industry Status
A.8.6 Current Passive Solar R&D Thrusts
A.8.7 Relevant Egypt/Worldwide Experience in Passive Solar

PAGE

Exhibit A.1	Typical Relationship Between Power Output and Wind Speed...	A-2
Exhibit A.2	Veritical-Axis Machines.....	A-3
Exhibit A.3	Horizontal-Axis Machines.....	A-4
Exhibit A.4	Average Monthly Wind Speed for Some Localities.....	A-7
Exhibit A.5	Catalog of Representative Wind Machines -- Mechanical and Non-Grid Connected Electric.....	A-9
Exhibit A.6	Annual Energy Output for Mechanical and Non-Grid Connected Electric Machines (kWh/yr).....	A-10
Exhibit A.7	Catalog of Representative Wind Machines -- Grid Connected Electric.....	A-11
Exhibit A.8	Annual Energy Output for Grid Connected Electric Machines..	A-12
Exhibit A.9	Projected Sizes of Wind Turbines for Selected Sites in Egypt.....	A-13
Exhibit A.10	Technology Status and Technical Goals (1984 Dollars).....	A-15
Exhibit A.11	Countries Having Activities in Wind Energy.....	A-17
Exhibit A.12	Photovoltaic System.....	A-24
Exhibit A.13	Sunshine Duration, Monthly Mean Values 1972-1976.....	A-27
Exhibit A.14	Hourly Average of the Solar Irradiation on a Clear Day in Helwan (Cairo).....	A-28
Exhibit A.15	Annual Frequency of Weather Phenomena in a Selection of Met. Stations in Egypt.....	A-29
Exhibit A.16	Cloudiness, Hourly Mean Values in the Period (0600-1800).....	A-30
Exhibit A.17	Utility Market Share of PV Applications.....	A-32
Exhibit A.18	Average Module Prices.....	A-34
Exhibit A.19	Photovoltaic Shipments.....	A-35
Exhibit A.20	Photovoltaics Technology Maturity.....	A-37
Exhibit A.21	Egyptian PV Experience.....	A-39
Exhibit A.22	U.S. Department of Energy Systems.....	A-40
Exhibit A.23	PV Project Listing.....	A-41
Exhibit A.24	Solar Thermal Technology Concepts.....	A-46
Exhibit A.25	Solar Thermal Technology.....	A-47
Exhibit A.26	Countries Having Activities in Solar Thermal Technology.....	A-54
Exhibit A.27	Estimated Installation Costs for Geothermal Energy Capacity.....	A-58
Exhibit A.28	Worldwide Geothermal Projects.....	A-62
Exhibit A.29	Cycle of Biomass Energy Production.....	A-66
Exhibit A.30	Anaerobic Digester Systems.....	A-68
Exhibit A.31	Anaerobic Digester Designs.....	A-70
Exhibit A.32	Annual Biomass Resources in Egypt.....	A-72
Exhibit A.33	Estimates for Biomass Fuel Costs (in 1977 US Dollars).....	A-75
Exhibit A.34	Estimated Biomass Energy and Contemporary Reference Costs.....	A-76
Exhibit A.35	Present Biogas Units in Egypt.....	A-78
Exhibit A.36	Status of Biomass - Fueled Small Power Production, Cogeneration and Municipal Facilities in the U.S. in 1984.....	A-81
Exhibit A.37	Status of Utilities Using Biofuels.....	A-82

223

PAGE

Exhibit A.38 Schematic of a Salt-Gradient Pond with Typical Salinity and Temperature Profile..... A-84
Exhibit A.39 Countries Having Activities in Solar Pond Technology..... A-90
Exhibit A.40 Survey of MSW Technology Capital Costs..... A-96
Exhibit A.41 Manufacturers of Refractory and Waterwall Mass Incineration Systems in the U.S..... A-98
Exhibit A.42 Manufacturers of Modular Combustion Mass Incineration Systems in the U.S..... A-98
Exhibit A.43 Manufacturers of RDF Co-Fired Systems and Dedicated Boilers in the United States..... A-99
Exhibit A.44 Manufacturing of MSW Cogeneration Systems in the United States A-99
Exhibit A.45 Summary of Worldwide Inventory of Waste to Energy Systems..... A-101
Exhibit A.46 Passive Solar Heating Options..... A-103
Exhibit A.47 Daylighting Designs and Integrated Daylighting Systems..... A-105
Exhibit A.48 Passive Solar Cooling Options..... A-106
Exhibit A.49 Passive Solar Cooling - Shading Mechanisms..... A-107
Exhibit A.50 Roof Pond - Heating and Cooling Mechanisms..... A-109
Exhibit A.51 Utility-Funded Passive Solar Projects in the United States. A-114

224

A.1 Wind

A.1.1 Introduction

Wind is created primarily by the sun's unequal heating of the earth's surface and by the rotation of the planet. Wind energy conversion systems are a means of converting the wind to a useful form of energy such as mechanical power or electricity. The relationship between power output from a wind energy conversion system and wind speed is shown in Exhibit A.1. Wind systems use an inexhaustible resource, range in size from a few watts to several megawatts, and can be constructed and installed in a matter of months. Thus, wind technology is highly modular and can help increase planning flexibility and decrease the financial risks associated with large conventional generating units. In addition, wind turbines can be designed to operate safely and reliably and to be compatible with many environments and land uses.

A.1.2 Technology Description

A variety of wind turbine systems appropriate for installation in rural areas or desert communities in Egypt is currently available either commercially or in the form of working prototypes that would be readily manufactured as the market develops.

The wind turbines are generally classified into horizontal-axis and vertical-axis types. Exhibits A.2 and A.3 show different types of vertical and horizontal-axis machines. There is evidence that the ancient Egptians used horizontal-axis wind turbines as early as 3600 B.C. to pump water for field irrigation and grain grinding. The horizontal-axis machine's axis of rotation is parallel to the wind stream and the ground. They may serve both high and low torque loads. On the other hand, vertical-axis wind turbines may be powered by wind coming from any direction by being positioned perpendicular to the wind stream and the ground. Both types contain five common basic subsystems: (1) a blade or rotor which is the energy conversion device; (2) a drive train, usually including a gearbox and generator; (3) a tower that supports the rotor; (4) various turbines supporting systems including controls, electrical cables, etc.; and (5) "balance-of-station" subsystems, which depending on the application, might include ground support equipment, interconnection equipment, etc.

Many variations in configuration are possible for both vertical- and horizontal-axis concepts. There are several vertical-axis machines that are similar in design and size, ranging from 100 to 300 kilowatts (kW). In contrast, there are over 50 horizontal-axis machines which vary widely in size, from several watts to 4 megawatts (MW), and design configuration.

The majority of commercially-available mechanical systems are used for pumping water. Other mechanical systems for grinding grain and providing shaft power are currently in that development stage. The classic windmill is a well proven design available from manufacturers all over the world. Typical wheel size range from 2 to 3.5 m with about 18-20 fans per wheel. The wheel is coupled via a crank to a single-acting borehole pump. Most commercially available machines have very similar performance characteristics. With a cut in speed of around 3m/s, water output rises linearly with windspeed to around 8 m/s, the rated speed.

225

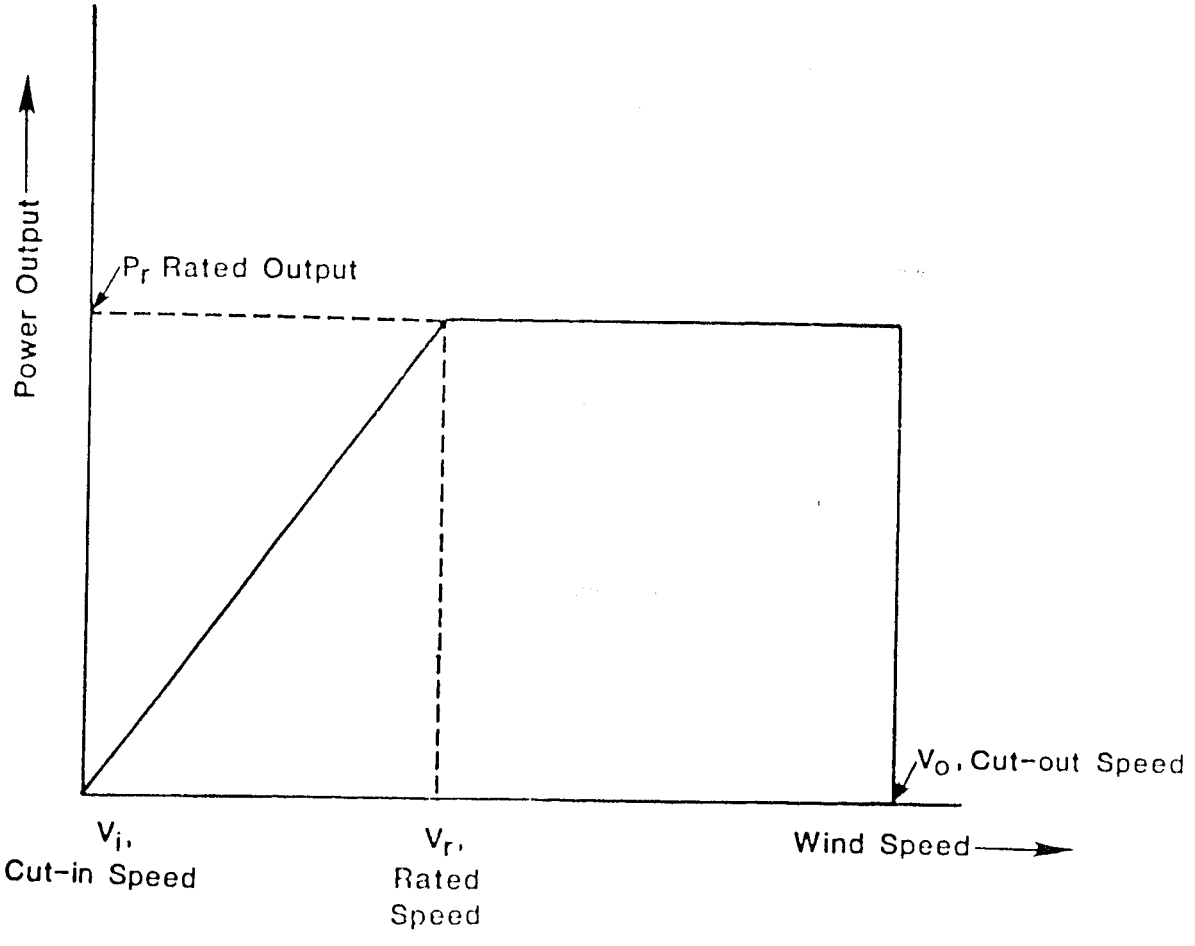


EXHIBIT A-1 TYPICAL RELATIONSHIP BETWEEN POWER OUTPUT AND WIND SPEED

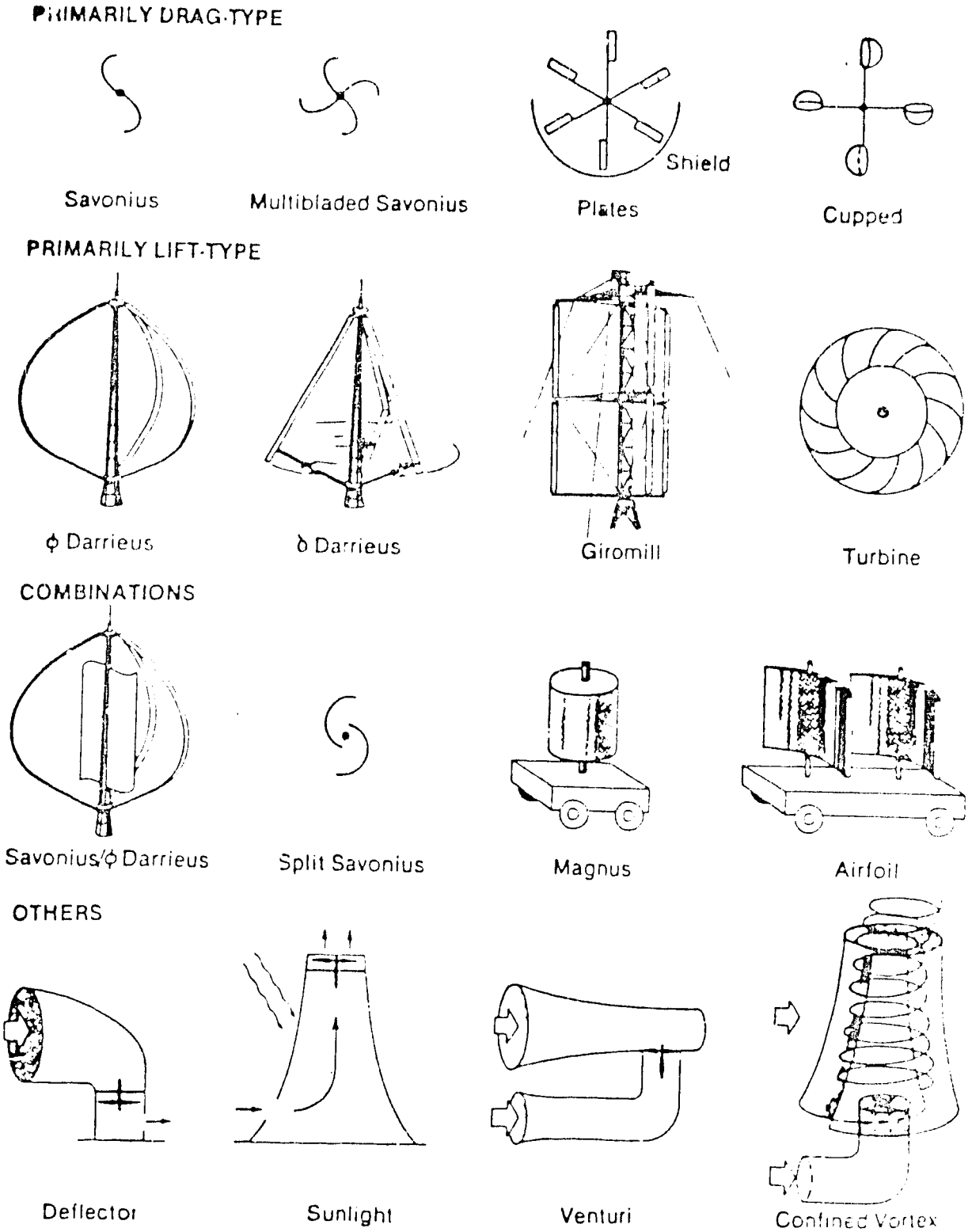


EXHIBIT A-2 VERTICAL -AXIS MACHINES

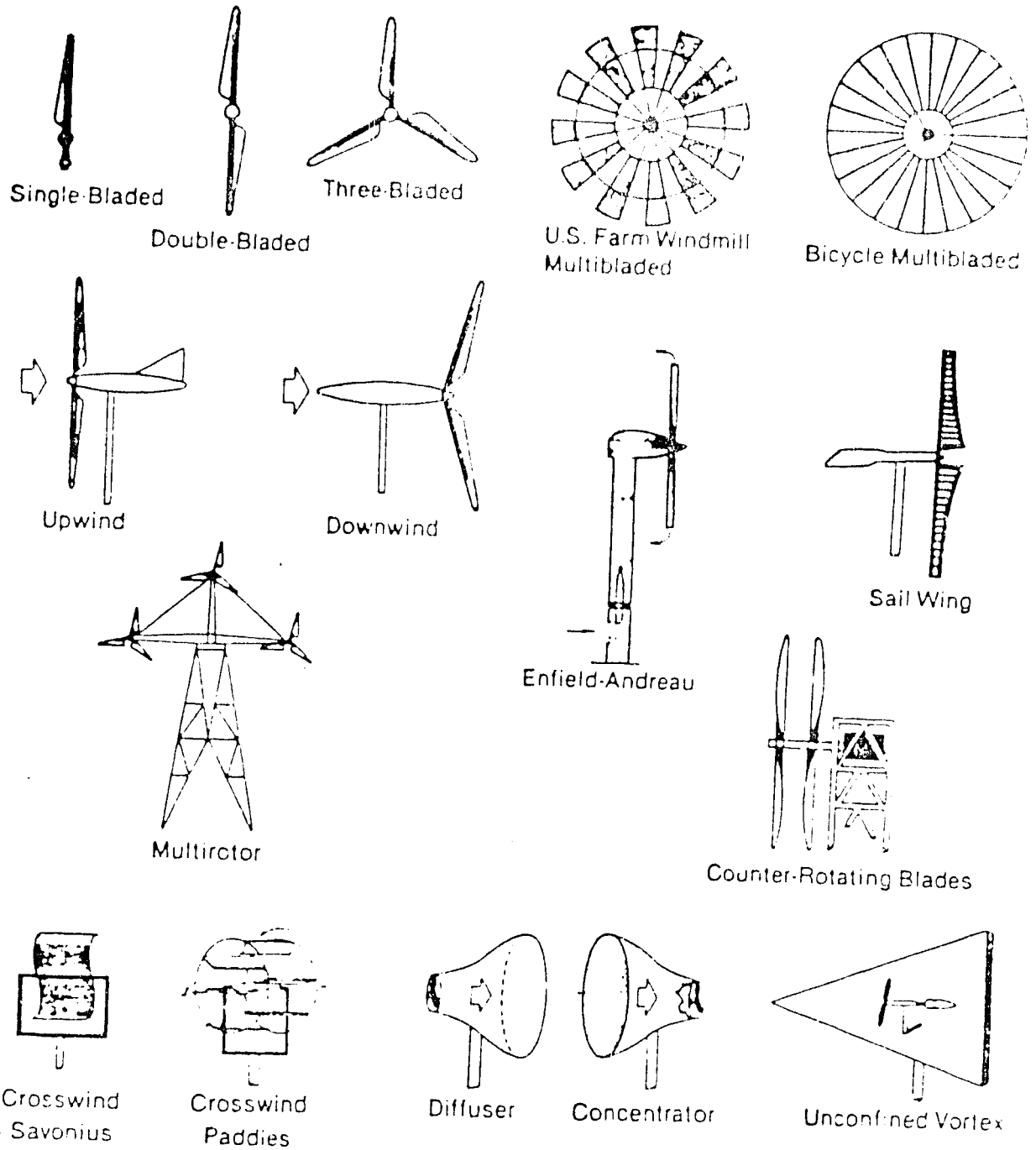


EXHIBIT A-3 HORIZONTAL-AXIS MACHINES

A.1.2.1 Electric Generators and Power Conditioning Units

The most appropriate type of wind driven electric generators to be used for off-grid operation in remote desert or rural areas is the synchronous generator either with permanent magnets or with controllable direct current field excitation. The direct current generators are excluded due to the frequent maintenance services they need over short periods of time, and also due to the unreliable commutator operation. Both reasons make the DC generators inferior to the synchronous generators for utilization in remote areas with limited availability of technically trained personnel.

If there is no mechanical or electrical constraints, the speed of the electrical generator will follow the varying speed of the wind. The resulting output voltage of the wind driven synchronous generator will be of variable magnitude and frequency. Most electrical appliances must operate at constant supply voltages. Therefore, the synchronous generator is controlled via the controllable rectifier and a DC/DC converter to maintain the output voltage constant.

The output of the generators may be utilized directly to feed loads when required, and at the same time, excess energy may be stored in a battery or any other storage system. When constant frequency AC output is needed, the DC power from the rectifier is converted to AC power using forced-commutation thyristor inverters for off-grid applications.

The generators and power conditioning units must be selected to withstand the severe operating conditions in the desert and rural areas (high ambient temperature, high humidity, sand blasts, dust accumulation, etc.).

A.1.2.2 Grid-Connected Utility Systems

There are several features which make wind energy systems attractive for use in providing grid-connected power. Systems do not have to be located in the immediate vicinity of usage, but can be placed at the most favorable wind sites. Because of the distribution of energy throughout the grid, surplus generation can be provided to other regions, thereby increasing the capacity factor of the system. Conversely, at periods of low wind, power can be supplied from other sources.

While substantial amounts of electricity may be supplied by grid-connected wind energy systems, there is a practical limit for integration. This limit is based on the mix of base load, intermediate, and peak load units available to a particular system, and the profile of demand requirement over a given 24 hour period. This value ranges between 25 and 50 percent depending upon the system.

A.1.2.3 Storage Systems

The utilization of the intermittent wind energy resource for autonomous applications becomes practical only if some means of energy storage are possible.

The conventional lead-acid battery is the most appropriate electrical energy storage device available especially for low demand communities. Other types of conventional batteries such as Nickel-Zinc, Metal-Gas and Zinc-Chlorine batteries are the other options for energy storage.

229

Wind energy conversion systems operating independently may require up to several days of energy storage capacity depending on the wind regime where these units are installed. One of the very successful solutions for the problem of long term energy storage is the use of hybrid renewable (wind-solar-biogas - conventional engines) energy systems.

Wind energy could be utilized very efficiently and economically when supplying certain types of loads e.g., water pumping, household electricity, etc. Hybrid systems of different renewable resources (solar, wind, biogas) could be used to supply the total energy requirement of a small community in a desert or in an arid region efficiently and economically with much smaller energy storage facilities. The potential proportion of energy that could be supplied by each of the three resources depends on the wind regime, solar insolation intensity, the amount and characteristics of waste (human, animal and agricultural), relative costs of each, cost of storage available or desired, and the degree of reliability required.

A.1.3 Resource Availability

At least two regions in Egypt have sufficient average daily and annual wind speeds considered high enough for the development of wind power generators. (see Exhibit A.4). Available data demonstrates that the Mediterranean Sea coast has an average annual wind speed of about 20 km/hr, and the Red Sea coast approximately 22 km/hr. Useable electric energy output in these areas is estimated to be 650 kWh per square meter of windmill swept area.

For the Mediterranean coast, as one proceeds from Marsa Matruh towards Alexandria, there is a slight improvement in the wind resource. On the North Coast the wind is suitable for small machines for irrigation, and/or providing comparatively small amounts of electricity to charge batteries. However, the prospects for placement of large machines for providing continuous power to the grid requires further study.

Concerning the Red Sea Coast, the prospects for obtaining significant amounts of commercial power from wind energy for the electric grid are more positive. The wind velocities are higher than on the Mediterranean, and proceeding north from Safaga towards Ras Gharib, velocities steadily pick up. Wind velocity decreases somewhat as the Port of Suez is reached, but remain high at least from Hurghada to Ras Gharib. In these coastal locations, the possibility of significant power being generated from the wind is high.

Despite the fact that this area is the best oil and gas producing region in Egypt, it is also the region with the best wind energy potential. It is the only region identified to date, in which banks of large wind generation systems might effectively feed the grid, though this would involve building a line from the Red Sea Coast to the Nile Valley.

Currently, Battelle Pacific Northwest Laboratories, under contract to AID/Cairo, is conducting a wind resource assessment in Egypt to update information collected in previous studies. Six sites have been selected for study, El Kasr, Um El-Rakham Village and Ras El Hekmaan on the Mediterranean Coast, and Hurghada, Ras Abu Ghusan and Zafarana on the Red Sea Coast.

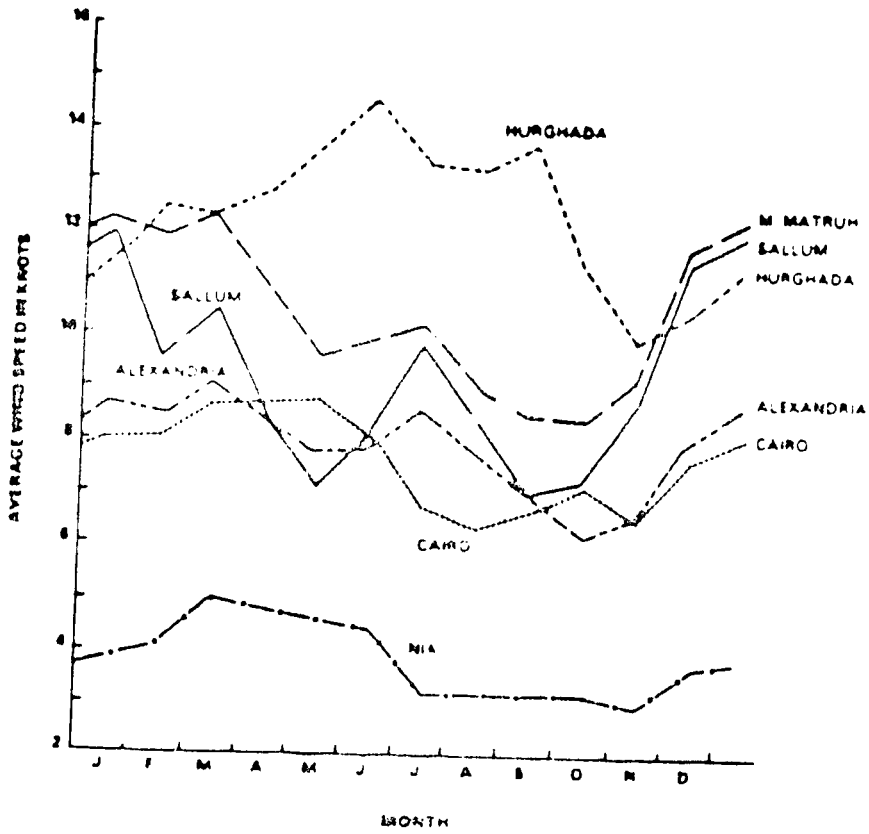


EXHIBIT A-4 AVERAGE MONTHLY WIND SPEED FOR SOME LOCALITIES

A.1.4 Market Readiness

Progress in the development of wind energy technology has been substantial. Although it is difficult to generalize about the diverse products that were available, it is estimated that the average 30-year levelized equivalent cost of electricity from wind machines was more than $1.50/kWh in the late 1970s (in constant 1984 dollars). The average 30-year levelized electricity cost from today's state-of-the-art wind machines is estimated to be 10¢ to 15¢/kWh.

Stated differently, improvements in the cost, performance, and lifetime of wind machines have already reduced the cost of wind-generated electricity more than tenfold.

Improvements in the technology have resulted in a market for grid-connected wind turbines that is many times larger than that of the small, stand-alone systems that dominated sales prior to 1973. Most of the wind machines installed in the last three years have been in wind farms in the United States, where many machines are installed at a single site to generate power for sale to electric utilities. A 1984 survey estimated that in the United States more than 8,000 units had been sold by the end of 1983, for a total capacity of more than 300 MW.

If wind turbines are to be competitive worldwide the cost of wind-generated electricity will have to be reduced by a factor of 2 to 4, from 10¢ - 15¢ to 4¢/kWh (in constant 1984 dollars). Achieving this goal will require simultaneous improvements in the cost, performance, and lifetime of both horizontal- and vertical-axis machines.

A.1.5 Economic Viability

Exhibits A.5 and A.6 provide the systems characteristics for two mechanical and eight non-grid-connected electrical machines. Exhibits A.7 and A.8 provide similar information for 10 grid-connected machines. Output figures given in these tables are presented for each of four specific annual mean wind speeds at a reference height of ten meters.

The size range of wind energy systems for rural and desert communities in Egypt may be estimated from the following data:

- Size of the community including population and area of arable land.
- Estimates for the energy needs that could be provided by wind energy systems (basic needs, long term demand, irrigation, desalination if fresh water is not available).
- The load factor or the annual energy generated by a wind energy system per installed kW. These figures are estimated from the wind velocity-duration data assuming an 8 m/s rated wind speed for the wind turbines and that the output power of the turbine at speeds higher than the rated value is constant and equal to that at the rated speed.

The values of the load factor and the kWh/installed kW are listed in Exhibit A.9 for different locations in Egypt. This table also gives the projected necessary installed power to meet the basic energy needs for 100 persons in a

232

EXHIBIT A.5

CATALOG OF REPRESENTATIVE WIND MACHINES --
MECHANICAL AND NON-GRID CONNECTED ELECTRIC

Rated Power[1] (kW)	Rated Wind Speed (k/h)	Hub Height (m)	Mean Power Output (kW)	Installed System Cost (1981$)[2] 1980-85	1986-90
.14 (1.8m dia. mechanical)	24	9	.08	$ 1,800	$ 1,800
.75 (4.3m dia. mechanical)	24	9	.45	6,600	6,600
.1 (DC)	40	10	.03	1,500	900
1.0 (DC)	40	10	.29	8,800	5,300
2.0 (AC)	40	10	.85	14,400	8,600
5.0 (AC)	40	15	1.63	24,200	14,500
10.0 (AC)	40	15	3.25	35,700	21,400
15.0 (AC)	40	15	4.88	38,000	22,800
25.0 (AC)	40	20	8.00	48,800	29,300
40.0 (AC)	23	20	14.00	74,100	44,500

[1]Mean power output calculated for an average annual wind speed at 22 km/h at referenced height of 10 m.

[2]Installed costs include all equipment and installation costs with shipping costs f.o.b. factory.

EXHIBIT A.6

ANNUAL ENERGY OUTPUT FOR MECHANICAL AND NON-GRID CONNECTED ELECTRIC MACHINES (kWh/yr.)[1]

Annual Mean Wind Speed at 10 meters (m/s)	1.8m Diameter	4.3m Diameter	Rated Power (kW)							
			0.1	1.0	2.0	5.0[3]	10.0[3]	15.0[3]	25.0[3]	40.0[2]
4.4	414	2160	86	855	1,710	5,292	10,584	15,876	27,657	44,244
5.1	522.9	2763	136	1,355	2,709	7,992	15,993	23,940	41,022	65,628
5.6	539.1	3132	176	1,755	3,510	9,959	19,917	29,880	52,902	84,636
6.0	637.2	3366	207	2,070	4,140	11,992.5	23,985	35,982	60,489	96,786
Machine Specification										
Vcut in m/sec	2.2	2.2	3.6	3.6	3.6	3.6	3.6	3.6	4.5	4.5
Vrated m/sec	6.7	6.7	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
Vcut out m/sec	15.7	15.7	17.9	17.9	17.9	17.9	17.9	17.9	17.9	17.9
hub height m	9.1	9.1	10	10	10	10	10	10	20	20

[1]A .9 availability factor has been applied to annual output values.

[2]Value expressed in thousands of gallons per year.

[3]Output values calculated at hub height by adjusting the 10 meter annual wind speed to specification hub height using a 1/7th power law.

EXHIBIT A.7

CATALOG OF REPRESENTATIVE WIND MACHINES --
GRID CONNECTED ELECTRIC

Rated Power[1] (kW)	Rated Wind Speed (kmh)	Hub Height (m)	Mean Power Output (kW)	Installed System Cost (1981$)[2] 1980-85	1986-90
1.8	63	7.3	.8	$ 9,300	$ 5,600
4.0	63	7.3	1.9	13,000	7,800
10.0	64	7.3	4.5	21,300	12,800
25.0	67.6	5.5	8.0	24,400	14,600
65.0	67.6	6[3]	25.1	133,000	79,800
95.0	77	2.7[3]	23.7	125,000	50,000
200.0	77	7.3	69.1	432,000	259,200
511.0	90	2.7[3]	66.9	500,000	235,000
2,500.0	72	18.6	944.0	6,000,000	3,500,000
4,000.0	35	24.4	860.0	7,500,000	5,000,000

[1]Mean power output calculated for an average annual wind speed of 22 km/hr mph at reference height of 10m.

[2]Installed costs include all equipment and installation costs with shipping f.o.b. factory.

[3]Reference height for vertical-axis machines.

EXHIBIT A.8

ANNUAL ENERGY OUTPUT FOR GRID CONNECTED ELECTRIC MACHINES (MWH/YR)[1]

Annual Mean Wind Speed at 10 meters (m/s)	Rated Power (kW)									
	1.8	4.0	10.0	25.0	65.0	95.0	200.0	511.0	2.5MW	4.0MW
4.4	3.2	6.6	17.7	17.3	91.8	67.8	212.4	140.4	3188	1782
5.1	4.6	9.2	24.2	30.7	135	110	331.2	272.7	4905	3690
5.6	5.3	10.7	27.7	38.2	161.6	135	403.2	356.4	5805	4815
6.0	5.9	12.1	31.0	45.4	184.3	157.3	468	432	6651	5760
V_{rated} (m/s)	11	11	11	12	12	14	14	16	12	16
hub height (m)	7	7	7	5.5	6.8	2.7	7	2.7	18	24

[1]A .9 availability factor has been applied to the annual output values.

[2]Reference height for vertical-axis machines.

desert community with available fresh underground water not deeper than 100 m. The long term future demands are also given in Exhibit A.9. It is evident from these results that a choice of units 4 or 5 kW will be a good compromise to cover the short term energy needs of 100 persons. For communities of 500 persons. Two units, 15 kW each or a single 25 kW will be adequate to supply the energy needs.

The appropriate size of the units that could supply energy for irrigation pumping is 5-10 kW for each 10 hectares, depending on the irrigation period since the energy demand for irrigation is not evenly distributed all over the year. In the future, 100 kW units may be used for each 100 hectares.

EXHIBIT A.9 PROJECTED SIZES OF WIND TURBINES FOR SELECTED SITES IN EGYPT

Site	Load Factor	Installed kW to Cover		
		Basic Needs of 100 Persons	Long Term Needs of 100 Persons	Irrigation of 10 Ha
El-Jaccoum	0.292	3.71	19.17	5.22
Alexandria	0.24	4.5	23.77	6.37
Hurghada	0.474	2.29	11.8	3.65

A.1.6 Industry Status

The wind technology industry in the United States has experienced a sustained growth. The technical feasibility of both large and small wind energy conversion systems for electricity is established. Considerable test and operational data on small machines now exists, and a data base is being established for large machines. There are currently approximately 60 U.S. manufacturers producing wind turbines. Most of the successful manufacturers sell small (less than 100 kW, rated capacity) horizontal-axis machines, although a trend appears to be developing and several companies are designing and beginning to market intermediate-sized (200-500 kW) machines.

The growth of wind farms continues to be an encouraging indicator of progress. At least 50 developers have installed wind farms to sell electricity to more than 15 utilities. The majority of wind farms applications are in California. Approximately 4700 machines totaling 230 megawatts of capacity had been installed by the end of 1983. This is up from about 1700 machines and 70 megawatts at the end of 1982.

The technology base developed over the past several years, combined with a favorable investment climate and incentives, has spawned this growing industry. However, performance and reliability have been less than adequate although these are variable across the industry.

A.1.7 Current R&D Thrusts

Research and Development (R&D) activities in the early phases of the program were driven by three main beliefs: that the extensive technology developed for the aviation industry could be borrowed directly; that the wind itself could be characterized as a steady, homogeneous flow; and that major improvements in cost-effectiveness would be achieved through advanced engineering, economies of scale, and mass production. Because of the relatively advanced state of aircraft aerodynamic technology, basic research was not stressed.

Even though wind technology has advanced significantly since 1974, further improvements are required if wind energy is to be competitive with grid-supplied power from other sources. Exhibit A.10 shows the status of current state-of-the-art technology relative to the long term goals and helps define the challenges for research and development.

Developing these opportunities for improving wind technology requires research in two parallel areas: the basic science of wind turbine dynamics, and advanced components and systems research. Wind turbine dynamics research includes studies in atmospheric fluid dynamics, aerodynamics, and structural dynamics. These activities are aimed at an improved understanding of the basic physical phenomena created by the wind turbine's interaction with its environment. Advanced components and systems research includes research on advanced concepts, supporting research, applied technology testing, and multimegawatt systems. These activities are aimed at reducing technical barriers and developing the technology base that will lead to major improvements in machine cost, performance, and lifetime. This area will involve not only R&D on individual components such as advanced airfoils and generators, but also systems analyses and testing to ensure that designs are optimized from an overall systems point of view.

Activities in both the science of wind turbine dynamics and advanced components and systems research are being conducted in parallel because the R&D activities are interrelated. Wind turbine dynamics research will provide the understanding and the tools to help identify, test, and evaluate new concepts. Similarly, advanced components and systems research will identify new concepts and design relationships that will define, in part, the analytical requirements of improved wind turbine dynamic models. In this sense, wind energy R&D is necessarily an interactive process between basic science and applied research.

EXHIBIT A.10 TECHNOLOGY STATUS AND TECHNICAL GOALS (1984 dollars)

	Current Technology[a]	Technical Goals
Annual energy production and installed costs (per m^2 of swept rotor area)	Ranging from: 300 kWh at \$600/m^2 to 800 kWh at \$1100/m^2	Ranging from: 900 kWh at \$50/m^2 to 1500 kWh at \$750/m^2
Annual operation and maintenance costs	2¢/kWh	0.5¢/kWh
Availability	85% to 95%	90%+
Life expectancy		
o Major fatigue-related parts	5 years[b]	30 years
o Balance of the primary structure	30 years[b]	30 years
30-year levelized cost of electricity	10¢ to 15¢/kWh	4¢/kWh

[a]Energy production for current machines was estimated for an annual average wind speed of 6.3 m/s to allow comparison with the long-term goals.

[b]Estimated.

A.1.8 Relevant Experience in Egypt Using Wind Technology

The following are the wind energy-related activities in Egypt.

a. The Ministry of Energy and Electricity and the University of Oklahoma, with support from the U.S. Agency for International Development (AID), have conducted a research program to measure wind speed and duration in Egypt. This program has two phases.

   Phase one started in 1972 and was basically a resource availability study. It dealt mainly with the gathering of existing wind data to select the promising areas for wind energy exploration. Phase two started in 1978 and dealt mainly with measuring wind speeds and duration in pre-selected locations. Such measurements have been taken in Marsa Matruh, Ras El Hekma, Sidi Abdel Rahman along the north coast (Mediterranean), Safaga, Hurghada and Ras Gharib along the Red Sea coast.

   Several basic studies concerning design performance of different windmills and generators suitable for electricity generation under the unsteady wind conditions are underway at Cairo, Alexandria and Helwan universities.

b. During 1978, the U.S. Agency for International Development (AID) set up a project to assess Egypt's energy resources needed to the year 2000, and the energy demand and supply options which are presently or will be available to Egypt by that time. The assessment was undertaken

jointly by the Egyptian Ministry of Electricity and the U.S. Department of Energy (DOE). The final report of this study was published in April 1979. The report stated that the cost projections for wind energy conversion in the higher wind areas of the Red Sea and Mediterranean coasts are sufficiently low that energy could be generated at costs competitive with fossil fuel fired systems. It is also reported that large scale implementation of wind systems could be a realistic option in Egypt for the 1980-1990's. Economic performance of three sizes (6,100 and 1000 kW) of wind turbines were projected for two sites in Egypt, the first is on the Red Sea coast (Hurghada) and the second is on the Mediterranean coast (Marsa Matruh). The cost of energy, based on a total system installed in Hurghada, on the Red Sea, was estimated to be 90 mills/kWh (0.06 LE/kWh) for small systems and to decrease to 30 mills/kWh (0.02 LE/kWh) for large systems.

c. A joint project between the National Research Center (NRC) of Egypt and the ITDG of the United Kindom started in 1977 to develop a design for a wind turbine-driven water pump of low lift type to be used for irrigation purposes in the local geoclimatic conditions of the Egyptian rural areas.

A second project is financed by the NRC of Egypt to develop a d.c. link inverter which could be assembled locally to operate with wind generators under the conditions prevalent in the Egyptian desert. This project includes, also, a study for operating subsynchronous induction generators in conjuction with large wind energy systems which are supposed to be interconnected with the power grid. The Mechanical Engineering Laboratory of the National Research Center and the Intermediate Technology and Development Group (ITDG) of the United Kingdom are undertaking a project to develop a new design of a wind-turbine driven water pump of the low lift type for irrigation purposes. Modification and development includes facilities for local manufacture of the prototype, site selection for installing the prototype, and preliminary testing under the field conditions. The tests aim at determining the performance capabilities and identifying the development needs.

d. A project to select and test the most suitable commercially available wind mills under Egyptian climatic conditions is underway as a joint work between the Ministry of Electricity and Cairo University. The main object is to introduce the necessary design changes in the selected type in order to facilitate its local manufacture.

Several other experimental and basic research studies on the laboratory scale are being conducted at the universities.

Exhibit A.11 is a representative list of countries having activities in wind energy.

EXHIBIT A.11 COUNTRIES HAVING ACTIVITIES IN WIND ENERGY

	Applications Which Have Been Identified for Wind	Research Being Conducted	Size of Machines Being Evaluated
AUSTRALIA AND SOUTH PACIFIC			
Australia	Electricity, irrigation	Integration of wind system into large scale grids; Vertical Axis machines; Hybrid wind/pv/diesel for small scale remote area; resource data collection	2mw, 1mw, 20-50 kw 20 twh/year 20-22kw 10% of power requirement
Indonesia	Water pumping	10m & 4.2m rotor diameter	1kW, 20 cubic/meter/ day irrigation
Kiribati	Water pumping, electricity		
New Zealand	Electricity (may be 5% by wind in 1989)	Resource assessment; wind diesel systems; darrieus evaluation	Small and large
Solomon Islands	Pumping water		
NORTH AMERICA			
Barbados	Power to process sugar cane Water pumping		
Canada		Vertical-axis machines; hybrid wind/diesel for 50 kW system; Resource Assessment, Giromill	8-50kw; 50-230 kw

EXHIBIT A.11 (Cont.)

	Applications Which Have Been Identified for Wind	Research Being Conducted	Size of Machines Being Evaluated
NORTH AMERICA (Continued)			
Dominican Republic	Water pumping, village power		
Haiti	Water pumping		
Honduras	Electricity		
Jamaica	Water pumping		
Mexico	Water pumping, electricity		
Trinidad and Tobago	Water pumping		
AFRICA			
Botswana	Pumping water; power generation	Vertical-axis wind; Rotary drive windpumps	
Cameroon	Water pumping;		
Cape Verde	Water pumping, electricity	3 meter dia. rotors 6 meter towers	
Ethiopia	Irrigation;		6-9 meter dia. turbine
Kenya	Irrigation, deep wells power generation		6 meter dia. rotors
Lesotho	Electricity		6 meter dia. rotors
Mali	Water pumping in north		

EXHIBIT A.11 (Cont.)

	Applications Which Have Been Identified for Wind	Research Being Conducted	Size of Mach Being Evaluated
AFRICA (Continued)			
Morocco	Water pumping, grinding grain		
Nigeria	Water pumping	Savonius for water pumping; vertical-axis turbine type	
Senegal	Irrigation, power generation	Savonius; 6 systems erected 1.1kw for demonstration	
Somalia	Water pumping		
South Africa	Water pumping, electricity		
Sudan	Water pumping		
Tanzania	Water pumping, electricity	Appropriate technology systems using local materials	1-20kw
Tunisia	Water pumping, irrigation		
Zambia	Water pumping, power generation		
ASIA			
China, People's Republic of	Electricity, water pumping	Very small systems for desalination and electric welding	100W-250W, 3kw-20kw, 18kw, 40kw, 55 kw

EXHIBIT A.11 (Cont.)

	Applications Which Have Been Identified for Wind	Research Being Conducted	Size of Machines Being Evaluated
ASIA (Continued)			
India	Irrigation, water pumping power generation	1-5kW darrieus; savonous rotors; 10m-diameter Cretan sail; .5kW soil type; water pumping, designs, economic studies	2kW, 10 kW
Iran	Water pumping	Laboratory scale tests on both horizontal and vertical axis systems	
Israel	Power generation	Laboratory scale tests	3m dia. turbine; 1kw
Japan	Electricity	Darrieus and Giromill systems of 30W; resource assessment; design of 3MW experimental unit.	30w, 8kw
Oman	Elecrtricity, pumping water		
Pakistan	Irrigation, electricity	Developing 16 regional rural centers for using wind and other solar	3.6m dia. rotors 7.7m dia. rotors
Philippines	Pumping water, irrigation electricity	3m rotor dia.	
Singapore		Laboratory scale horizontal-axis windmill	

EXHIBIT A.11 (Cont.)

ASIA	Applications Which Have Been Identified for Wind	Research Being Conducted	Size of Machines Being Evaluated
ASIA (Continued)			
Sri Lanka	Electricity, pump water	Developing anemometer network; resource assessment demonstration units	3M & 5M dia. water pumpers; 2kW electric
Thailand	Pumping water, irrigation, salt farming, power generation	Resource assessment horizontal-axis water pumping	
SOUTH AMERICA			
Argentina	Water pumping, electricity		
Bolivia	Water pumping		
Brazil	Water pumping, electricity		20-30 kw
Paraguay	Water pumping		
Peru	Electricity, irrigation		1kw, 100kw-4mw
Suriname			
Uruguay	Electricity, water pumping		
Venezuela	Water pumping, electricity		
EUROPE			
Austria	Electricity	"Aerodynamic Ballon"	
Bulgaria	Electricity		

EXHIBIT A.11 (Cont.)

	Applications Which Have Been Identified for Wind	Research Being Conducted	Size of Machines Being Evaluated
EUROPE (Continued)			
Denmark	Electricity, heat	Medium to large systems. Resource assessment, 1-2MW system design	Systems up to 2mw, 20,000 kwh/yr by 1995 Wind Power will be 10% electric demand
France	Electricity, water pumping	Resource assessment; laboratory scale tests for horizontal axis windmills; flexible blade windmill	Small
Germany, Federal Republic of	Electricity, heating	Resource assessments high capacity power plants, 265kW; Engineering study of 1-2MW systems evaluation of 15kW system	10kW, 15kW, 270kW, 1-2MW
Greece	Water pumping	Resource assessment	
Ireland	Electricity		
Netherlands	Electricity, export systems, storage	Detailed meteorological studies in North Sea; design and demonstration of Darrieus; large 10 tons	1.8kW Darrieus, 5-25 meter rotors
Spain	Electricity		17 m. diameter 100-110kW
Sweden	Heat generation, power generation	Large R&D effort on small and large systems; Design study of offshore system; safety analysis; guyed towers; resource assessment.	Small and large units up to 14MW. 63kW; 1-2MW

A.2 Photovoltaics

A.2.1 Operating Characteristics

PV systems are capable of supplying any electrical load ranging from a fraction of a watt to several megawatts. Be it an urban, rural or remote site, a stand-alone or grid-interactive system, PV has been proven not only feasible, but reliable.

Power at various voltage levels can be produced through the wiring of cells and modules in parallel or series configurations. A customer generally does not have a choice as to the preferred wiring of the cells within a module, so voltage can be adjusted through the arrangement of the modules and/or the use of a converter. A converter is used to step voltage up or down when module wiring cannot result in the appropriate voltage (e.g., 4 modules at 12V cannot produce power at 220V).

PV systems produce direct current (DC) power. Through the use of an inverter, however, PV can be used to supply alternating current (AC) loads. In Egypt, both AC and DC systems have been installed.

Most applications require the use of a regulator to control voltage fluctuations in system output. Regulators are essential because loads, such as batteries, converters and inverters can only tolerate certain variance in input voltage. Regulators, inverters and converters comprise what is referred to as the power conditioning system.

A.2.2 Technology Description

Photovoltaics (PV) is the direct conversion of sunlight into electricity. In a PV system (Exhibit A.12), groups of cells are mounted and interconnected to form modules (or collectors), which in turn are connected into arrays. The cells are made from semiconductor materials that are processed such that when light strikes the cells, they generate a direct electric current. This current is collected and transported by metallic contacts that are placed in a grid-like fashion on the surface of the cell. Power generated by the arrays is fed into a power conditioning system (e.g., regulator, converter, inverter). The power conditioning system "conditions" the power for interaction with the loads and/or utility grid, by controlling the magnitude of the voltage and type of current (direct or alternating).

A.2.2.1 Types of PV Cells

There are basically three generations of PV technology: ingot, ribbon and thin films. The current PV market is dominated by first generation technology - ingot cells. Second generation technology has just recently entered the marketplace, while third generation technology for the power market is mostly in the laboratory stages.

First generation technology consists primarily of single-crystal silicon cells cut from cylindrical ingots. A second type of ingot cell is made from polycrystalline silicon that is cast in the form of a cubic ingot. However,

PHOTOVOLTAIC SYSTEM

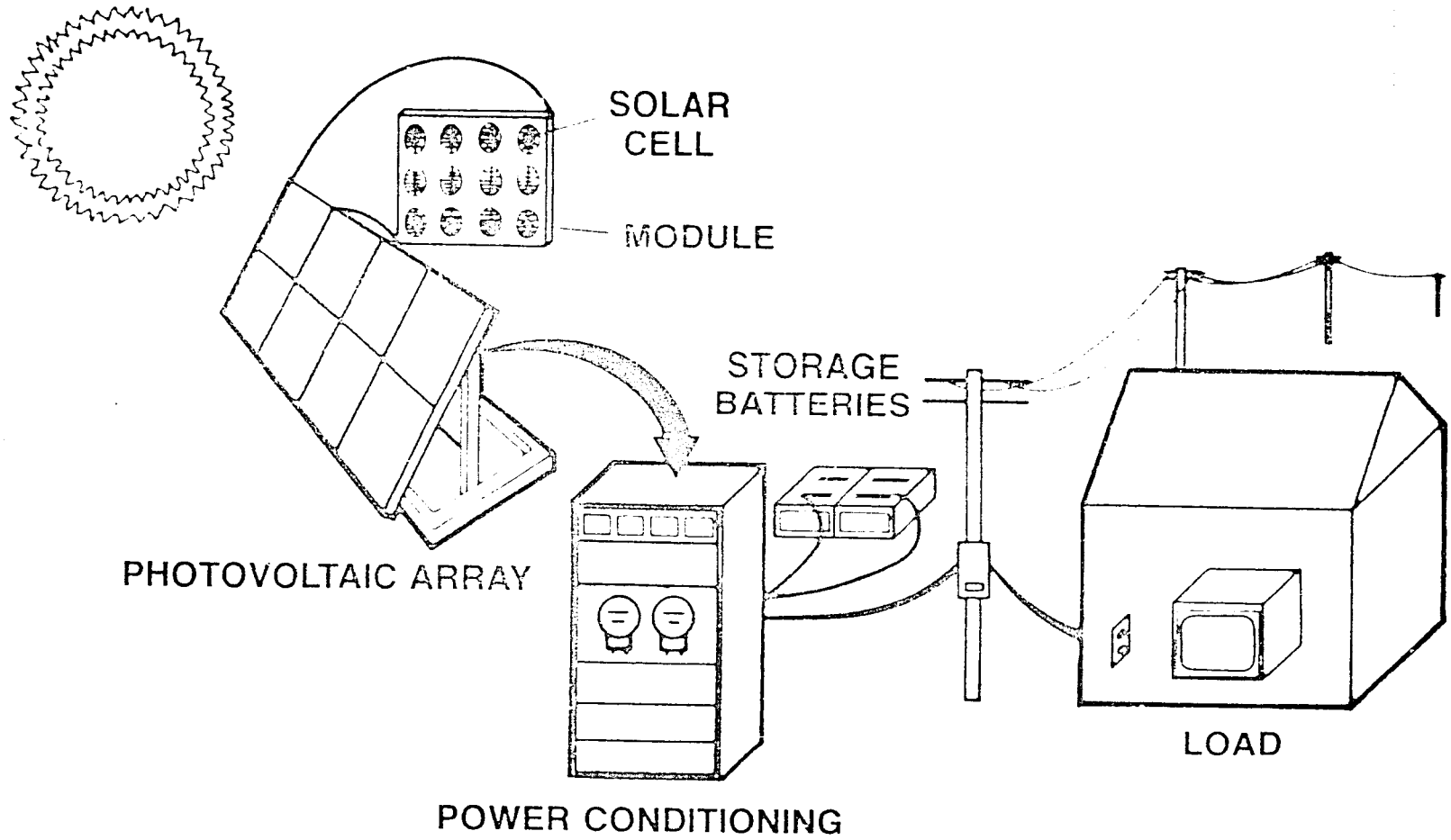


EXHIBIT A-12

due to the large material losses incurred through the slicing of ingots into wafers; the incompatibility of ingot growth to automated production processes; and the impossibility (based on inherent electronic properties of silicon) of attaining a high enough conversion efficiency to compensate for these factors, systems based on this technology will not meet long term cost goals (cost-competiveness in U.S. electrical utility market). In light of this fact, new generation technologies have emerged.

Second generation technology involves the automated production of polycrystalline silicon material in the form of a ribbon. Ribbon growth results in more efficient use of silicon feedstock and a potentially higher rate of throughput; thus far, however, this technology has exhibited lower performance characteristics than ingot cells.

While not as commercially advanced as silicon ingot and ribbon cells, thin-film cells are of interest due to their potential for much lower fabrication costs. They have the advantage of low material requirements (thin-film cells are less than one-fifth the thickness of silicon ingot cells) while lending themselves to large scale, continuous-processing techniques; however, thin-film devices have relatively low efficiencies and in some cases are unstable.

The most advanced thin-film material is amorphous silicon (a-Si). This material is the only third generation technology to have penetrated the marketplace. It has done so mostly as small cells in consumer products, for which efficiency is a minor concern. The first a-Si power module was just recently introduced (in November 1984) by ARCO Solar. Other thin films such as cadmium telluride (CdTe), copper indium diselenide ($CuInSe_2$) and gallium arsenide (GaAs) are still in the research stages.

A promising concept for thin films is multiple-junction cells. These cells consist of different thin films layered on top of each other. Each material absorbs a different region of the solar spectrum and thus results in a higher total conversion efficiency than possible for any one material.

A.2.2.2 Types of PV Collectors

There are two categories of collectors: flat plate and concentrator.

The majority of currently installed systems use flat-plate modules. They collect both direct and diffuse radiation, so tracking devices are not necessary (ARCO Solar uses tracking flat-plate systems in their megawatt-scale projects, as they feel improved performance more than compensates for increased operation and maintenance expenses). Egyptian system experience has been solely with flat-plate modules.

Concentrator collectors offer an approach to PV power generation that reduces the need for lowering the price of high-performance cells. By using lenses to focus direct sunlight onto cells, the cell area required to generate a given output can be reduced by as much as a factor of 1000. Concentrator collectors only accept direct radiation and therefore require tracking devices.

A.2.3 Resource Availability

Solar insolation in Egypt is one of the highest in the world, making photovoltaics an attractive option: yearly average solar insolation is about 5.7 kWh/m^2-day with an average of 9-11 hours of sunlight per day. The direct component of radiation represents a large fraction of the total in many areas of Egypt (diffuse radiation is generally the result of sand and dust storms, which in some cases results in cloud cover of only 4-5 days out of the year). It is therefore recommended that concentrator systems be also considered for some regions of the country.

Specific resource data for selected sites in Egypt are given in Exhibit A.13 through A.16.

A.2.4 Market Readiness

A technology is considered "ready" when it can first compete economically in a given market. This is as opposed to being "mature" - the point at which no further product development is necessary. Some of the PV technologies are ready for certain markets, but none are considered mature.

The major markets for photovoltaic systems are stand-alone; consumer products; grid-connected residential and commercial (intermediate) power; and central station utility power.

A.2.4.1 Stand-Alone Market

Stand-alone applications refer to those systems not linked to utility grids; they can be remote applications where power is otherwise unavailable or unreliable.

Remote stand-alone applications represent a market for which PV is ready. Types of applications include navigational aids, communications, rural electrification, water pumping and cathodic protection systems.

Although demonstration projects are still being conducted to verify system performance in different remote environments, PV systems for remote applications are essentially past the demonstration stage. The major manufacturers offer turnkey systems and some packaged systems for these applications. Since remote systems applications represent one of the two profitable PV markets (the other one being consumer products), certain firms have targeted their PV activities to specific applications (e.g., water pumping, navigational aids, etc.).

A.2.4.2 Consumer Products

Next to the remote systems market, consumer product applications represent the only other currently profitable photovoltaic market. They represent the only, truly, off-the-shelf PV products. Consumer products include items such as calculators, radios, watches and small toys. This market has been developed primarily by the Japanese photovoltaic industry.

EXHIBIT A.13

SUNSHINE DURATION
MONTHLY MEAN VALUES
1972-1976

Ser.	STATION	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ANNUAL
1	Sidi-Barrani	6.9	7.8	7.9	9.0	10.8	12.2	12.1	12.1	10.6	9.2	8.4	6.8	9.5
2	Marsa-Matruh	6.9	7.7	7.9	9.0	10.6	11.7	12.1	11.9	10.5	8.9	8.0	6.4	9.3
3	Alexandria	6.4	7.8	8.2	9.1	10.6	11.8	12.0	11.3	10.3	9.6	7.3	6.2	9.2
4	Damietta	7.2	8.3	8.4	9.7	11.4	12.5	12.3	11.9	10.7	9.7	8.1	6.6	9.7
5	Port-Said	7.0	7.8	8.4	9.1	11.2	12.1	12.1	11.6	10.5	9.7	8.0	6.8	9.5
6	Tahrir	7.4	7.9	8.8	9.8	11.0	12.2	12.2	11.8	10.6	9.6	7.8	7.2	9.7
7	Tanta	7.2	8.1	8.7	9.9	11.0	11.5	12.0	11.4	10.7	9.5	8.3	7.2	9.7
8	Bahteem	7.0	8.3	8.6	9.6	10.8	11.9	11.8	11.2	10.4	9.6	8.2	7.7	9.6
9	Almaza	7.6	7.8	8.6	8.9	11.2	11.9	11.4	11.4	9.5	9.4	8.2	7.6	9.5
10	Giza	7.8	8.2	8.8	9.6	11.2	12.2	12.0	11.5	10.5	9.8	8.5	7.7	9.8
11	Siwa	8.3	9.3	9.1	9.3	11.1	12.3	12.6	122.1	10.7	9.7	8.7	8.0	10.1
12	Kharga	9.1	9.7	10.2	10.4	11.5	12.2	12.4	12.0	11.0	10.6	9.9	9.5	10.7
13	Minya	8.7	9.4	9.5	10.1	11.4	12.5	12.6	12.0	10.8	10.2	9.2	8.3	10.4
14	Hurghada	9.4	9.7	9.7	10.1	11.5	12.8	12.7	12.1	11.2	10.4	9.1	9.1	10.7
15	Aswan (1975-1977)	9.4	9.2	9.4	10.6	11.8	12.4	12.3	11.6	10.9	10.5	9.6	9.6	10.6
16	El Aiwant 80-82	7.7	8.8	9.8	10.3	10.2	10.0	9.9	9.6	9.6	9.2	7.1	7.1	9.2

EXHIBIT A.14

HOURLY AVERAGE OF THE SOLAR IRRADIATION (KW/m^2)
ON A CLEAR DAY IN HELWAN (CAIRO)

Time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
6	-	-	-	0.22	0.37	0.39	0.31	0.25	0.20	-	-	-
7	-	0.36	0.56	0.58	0.61	0.63	0.61	0.57	0.57	0.53	0.45	0.16
8	0.7	0.65	0.82	0.77	0.75	0.76	0.75	0.75	0.76	0.75	0.70	0.65
9	0.86	0.82	0.95	0.87	0.84	0.83	0.81	0.84	0.85	0.86	0.84	0.82
10	0.94	0.93	0.91	0.91	0.88	0.87	0.87	0.85	0.88	0.89	0.90	0.91
11	0.97	0.97	1.04	0.93	0.91	0.90	0.87	0.89	0.91	0.91	0.93	0.93
12 (noon)	0.99	0.99	1.05	0.93	0.91	0.91	0.88	0.90	0.91	0.92	0.93	0.95

EXHIBIT A.15

ANNUAL FREQUENCY OF WEATHER PHENOMENA IN A SELECTION OF MET. STATIONS IN EGYPT

STATIONS	FREQUENCY OF DAYS OF						
	Fog (1)	Mist (2)	Total 1+2	Dust or Sand rising (3)	Dust or Sandstorm (4)	Total 3+4 (5)	Total Annual (6)
Marsa-Matruh	7.4	4.5	11.9	12.7	7.2	19.9	31.8
Alexandria	20.1	21.5	41.6	7.9	2.4	10.3	51.9
Port-Said	1.8	2.9	4.7	4.6	2.0	6.6	11.3
Cairo	19.7	25.1	44.8	11.1	3.2	14.3	59.1
Almaza	16.2	15.9	32.1	9.0	3.7	12.7	44.9
Minya	5.1	7.6	12.7	3.4	0.9	4.3	17.0
Luxor	0.1	2.0	2.1	2.7	1.5	4.2	6.3
Hurghada	0.1	1.7	1.8	4.5	1.8	6.3	8.1

EXHIBIT A.16

CLOUDINESS
HOURLY MEAN VALUES
IN THE PERIOD (0600-1800)

STATION	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ANNUAL
Sidi-Barrani	4.6	3.9	3.2	3.4	2.5	1.8	1.4	1.5	1.7	2.5	3.7	4.1	2.9
Marsa-Matruh	4.5	3.9	3.4	3.5	2.5	1.5	1.3	1.9	1.9	2.5	4.1	4.4	3.0
Alexandria	5.1	4.5	3.7	3.9	2.4	2.0	2.1	2.8	2.7	2.9	4.8	5.3	5.5
Damietta	3.3	3.6	2.8	3.1	1.6	0.8	0.7	1.2	1.3	1.6	3.1	3.4	22.
Port-Said	2.8	2.9	2.3	2.5	1.4	0.7	0.7	0.9	1.0	1.3	2.3	3.0	1.8
Tahrir	3.5	3.7	2.9	3.2	1.9	0.8	0.6	1.1	1.4	1.4	3.2	3.7	2.3
Tanta	3.2	3.3	2.6	2.6	1.6	0.8	0.9	1.3	1.3	1.4	3.1	3.2	2.1
Bahteem	2.8	3.0	2.3	2.7	1.4	0.4	0.5	0.9	1.0	1.1	2.2	2.7	1.8
Almaza	3.2	3.7	2.9	3.1	1.8	0.6	0.9	1.2	1.3	1.4	2.9	3.2	2.2
Giza	3.0	3.2	2.5	2.8	1.7	0.6	0.5	0.8	1.1	1.1	2.5	3.0	1.9
Swia	3.1	2.8	2.5	2.6	1.9	0.4	0.3	0.6	0.7	0.8	2.0	2.6	1.7
Kharga	1.8	1.8	1.3	1.6	1.1	0.2	0.2	0.2	0.2	0.2	1.0	1.3	0.9
Minya	2.3	2.4	2.1	2.3	1.5	0.3	0.2	0.3	0.4	0.4	1.7	2.0	1.3
Hurghada	2.3	2.4	2.0	2.3	1.3	0.1	0.3	0.2	0.3	0.3	1.4	2.1	1.3

A.2.4.3 Grid-Connected Residential and Intermediate

PV systems for these applications are essentially in the demonstration phases. The majority of the grid-interactive systems operating today have been sponsored by the U.S. Department of Energy (DOE).

It has been proven that PV can interface with utilities and provide utility-quality power; however, such systems are not cost effective, and therefore PV is not ready for this market at present.

At the present time, these markets are not being actively pursued by the U.S. industry. U.S. industry has targeted its efforts toward remote and central station utility applications.

A.2.4.4 Central Station Utility Power

Like the stand-alone applications, central station power systems have been developed primarily by U.S. industry. 1982 marked the beginning of private sector installation of four, megawatt-size systems to supply power to three separate California utilities.

Although megawatt-size systems take advantage of economies of scale, utility applications are still not cost effective. PV research in the U.S. is geared toward reaching cost-competitiveness in the U.S. utility market.

In summary, while PV has been proven reliable for the full-range of applications, it is only economic, and therefore "ready," for the remote systems and consumer products markets. Exhibit A.17 shows market share of the various applications for 1982 and 1983.

Egyptian exposure to photovoltaics has been primarily through stand-alone applications. Stand-alone applications will continue to be the major market in Egypt in light of Egyptian activities to develop the scarcely populated regions of the country.

PV systems offer an appropriate solution to fuel supply uncertainties and the maintenance problems of remote diesel generators. Probably the only type of maintenance that would be recommended for the Egyptian environment is to clear the modules of dust accumulation. The system can be oversized according to the length of time between visits.

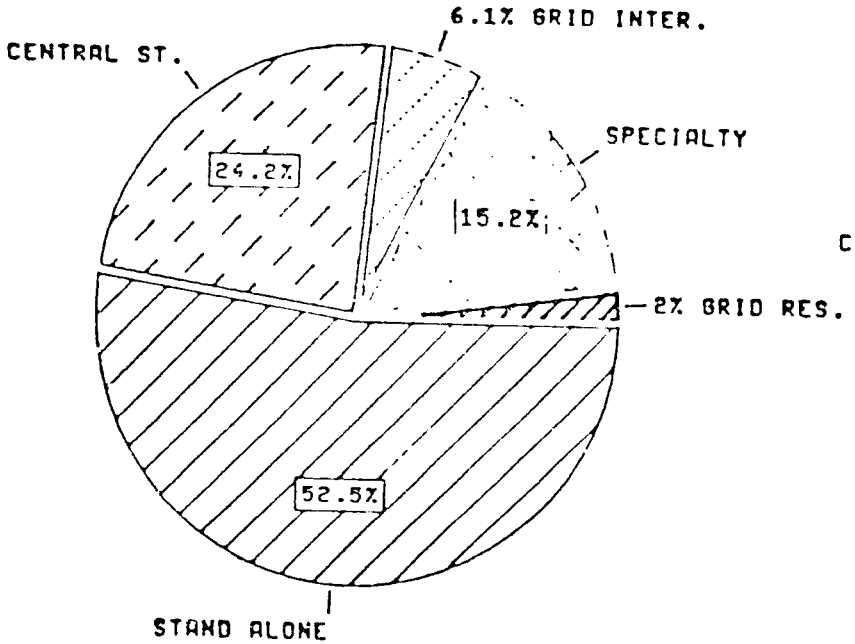
PV systems also offer the advantages of power flexibility (AC versus DC), short construction periods, easy scaleability and environmental acceptability.

Aside from the economic considerations for PV in certain applications, the major disadvantages of PV are as follows:

(1) Storage Requirements - Since PV systems can produce power only when it is sunny, storage is required to be able to use power at night and on cloudy days.

(2) Fragility - PV modules can be easily damaged by animals, stones, hail, etc.

END USE SECTORS 1982



END USE SECTORS 1983

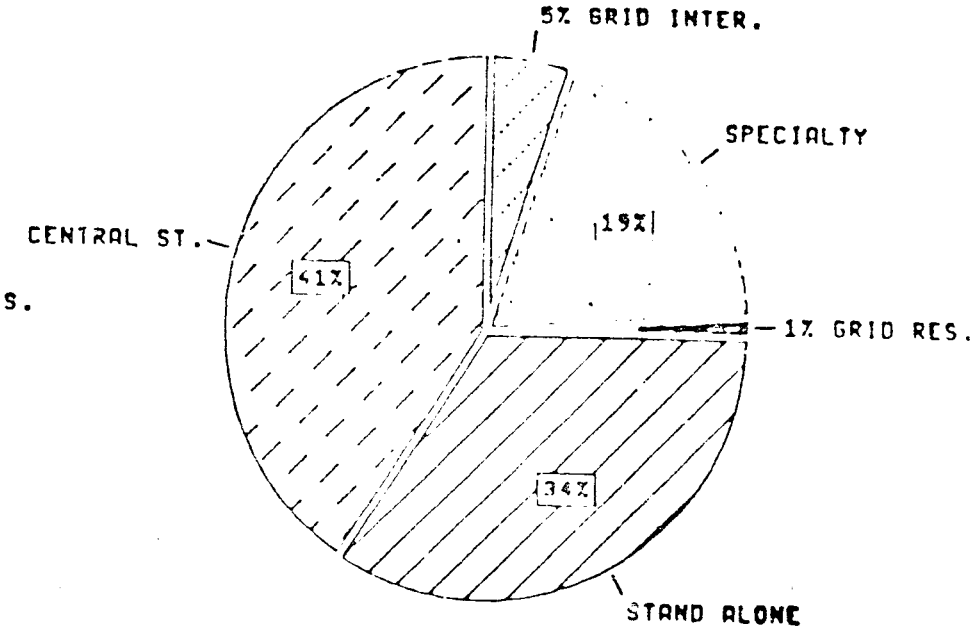


EXHIBIT A-17 UTILITY MARKET SHARE OF PV APPLICATIONS

(3) Space Requirements - Because system efficiencies are low, a large module area is necessary for large power requirements. (For example, a 1-MWp facility in California is using 8 hectares).

A.2.5 Economic Viability

Until about ten years ago, PV cells had been developed primarily for space satellite applications. High conversion efficiency was the primary concern, and costs were not a major factor. For terrestrial applications, however, expense has been the critical barrier to widespread utilization of PV.

Typically, 50 to 75 percent of PV system costs can be attributed to the modules. The remaining costs, or the balance of system (BOS), include all subsystems and components exclusive of the cells and modules that are needed for a fully functional system.

Today, PV module prices range from 5 to 12 dollars per peak watt. The range reflects the quantity of modules purchased. The $5/Wp price represents ARCO Solar's bid for Phase II of the Sacramento Municipal Utility District's (SMUD-II), 1-MWp project. In the small-to-medium-size range, prices start at approximately $7/Wp. Exhibit A.18 shows how the average PV module price has decreased since 1976.

Installed system prices range from about $10 to $30/Wp, depending upon the location and the particular application. The lowest price, $10/Wp, is for the 1-MWp, SMUD-II project. At these prices, PV is cost-competitive for many remote applications, but not for utility-interactive systems. At remote sites, PV is in competition with the extension of utility lines (which in the U.S. can cost $20,000 per mile), diesels (high O&M and fuel costs) and batteries (high initial costs).

The potential for PV applications in Egypt as a function of remoteness is as follows:

Populated Areas:

- long-term potential (late 1990's) for general city/village electrification
- immediate potential for portable equipment

Medium Remote Areas:

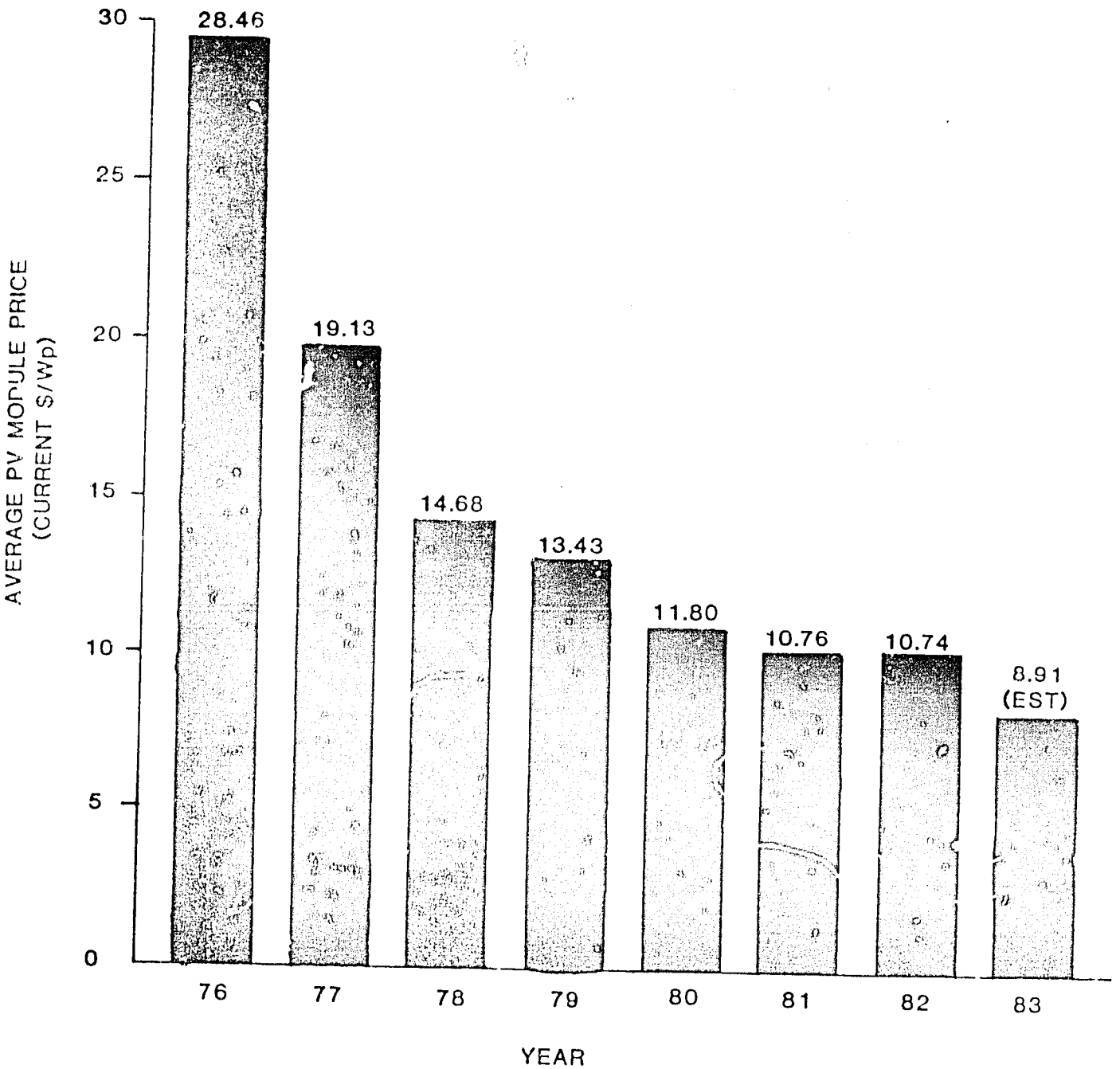
- medium-term (early 1990's) potential for most applications
- immediate potential for cathodic protection and portable applications

Remote Areas:

- immediate potential for most applications with low to moderate power requirements.

EXHIBIT A-18

AVERAGE MODULE PRICES : 1976 - 1983



DATA STRATEGIES UNLIMITED

A.2.6 Industry Status

The world leader in photovoltaic systems technology and production has traditionally been the U.S. In the past eight years, more than 75 percent of the peak capacity in the world has been installed by U.S. firms. More recently, however, the U.S. leadership position has decreased from an 85 percent market share in 1980 to 62 percent in 1983. This decrease can be largely attributed to Japan's aggressive activities in consumer product applications. Exhibit A.19 shows world shipments by geographic region.

Exhibit A.19
Photovoltaic Shipments*
(MW)

	1980	1981	1982	1983
U.S.	2.8 (85%)	4.0 (75%)	4.6 (60%)	9.6 (62%)
Japan	0.1 (2%)	0.5 (9%)	1.5 (19%)	3.3 (21%)
Europe	0.4 (12%)	0.8 (15%)	1.5 (19%)	2.4 (15%)
Other	0 (1%)	0.1 (1%)	0.2 (2%)	0.3 (2%)
Total	3.3 (100%)	5.3 (100%)	7.8 (100%)	15.6 (100%)

*Data from Strategies Unlimited

U.S and Japanese involvement in PV can be characterized by technology and application markets. The U.S. is clearly the dominant figure in first and second generation technologies. Firms have used these technologies to penetrate the remote systems and central station utility markets. On the other hand, third generation technology (in particular, a-Si) is dominated by Japan. The Japanese industry, shortly after entering the PV field, became extremely successful in the consumer products market. It has only been recently, that Japanese firms have expressed interest in the remote applications market.

Although the U.S. industry has continued to experience growth and maintain its world leadership position, it is nevertheless young and fragile. Its fragile structure, typical of young industries, is evidenced by low profitability, corporate turnover, excess capacity and high dependence on federal support.

The Japanese, however, have a smaller, but more stable PV industry. They were able to quickly capitalize on a profitable market, whereas it took many years for U.S. industry to begin to profit (and to a much lesser extent) in the remote power market.

As in the U.S., the major manufacturers in Japan are supported by large industries. The Japanese firms that are most successful in PV are the large electronic and power engineering companies: Sanyo, Sharp and Fuji accounted for approximately 70 percent of Japan's market share in 1983.

In Egypt, there is no photovoltaic industry. The manufacturers and assembly of PV cells is limited to the research scale. Laboratories at Alexandria and Ein Shams Universities produce prototypes cells and modules. PV systems are supplied by foreign firms.

The U.S. PV industry offers a wide variety of equipment to choose from: collectors made from single-crystal, polycrystalline and a-Si materials; concentrator and flat plate collectors; fixed, tiltable and tracking support structures; controllers, inverters and converters; and DC and AC end-use equipment. Individual PV system components can be obtained from respective manufacturers, or their distributors; turn-key systems can be purchased through a systems integrator or module manufacturer. Most major manufacturers also supply packaged systems for certain applications.

A.2.7 R&D Thrusts

The key thrusts of PV R&D are to reduce the cost and raise the efficiency of systems so they can be competitive in a wider variety of applications. PV systems can be divided into the modules and the balance of system (BOS).

BOS technologies are so well developed that additional significant improvements are unlikely to come from further research. Advancements in these areas will come from better designs, achieved through increased experience, and mass production. Thus, current research is directed toward improvements in the modules.

The maturity of various PV technologies is indicated in Exhibit A.20 There is a constant tradeoff between the cost and efficiency of the cells; the technologies that are most developed, so far have involved the most expensive processes.

Single-crystal silicon is the most stable and highest efficiency silicon material used in commercial PV applications. R&D efforts continue at increasing efficiency toward silicon's theoretical limits and at reducing material costs.

Cast polycrystalline silicon cells are less efficient than single-crystal cells; however, the costs involved with "growing" a single crystal are higher than for casting an ingot. R&D also concentrates on improving efficiency and reducing material costs.

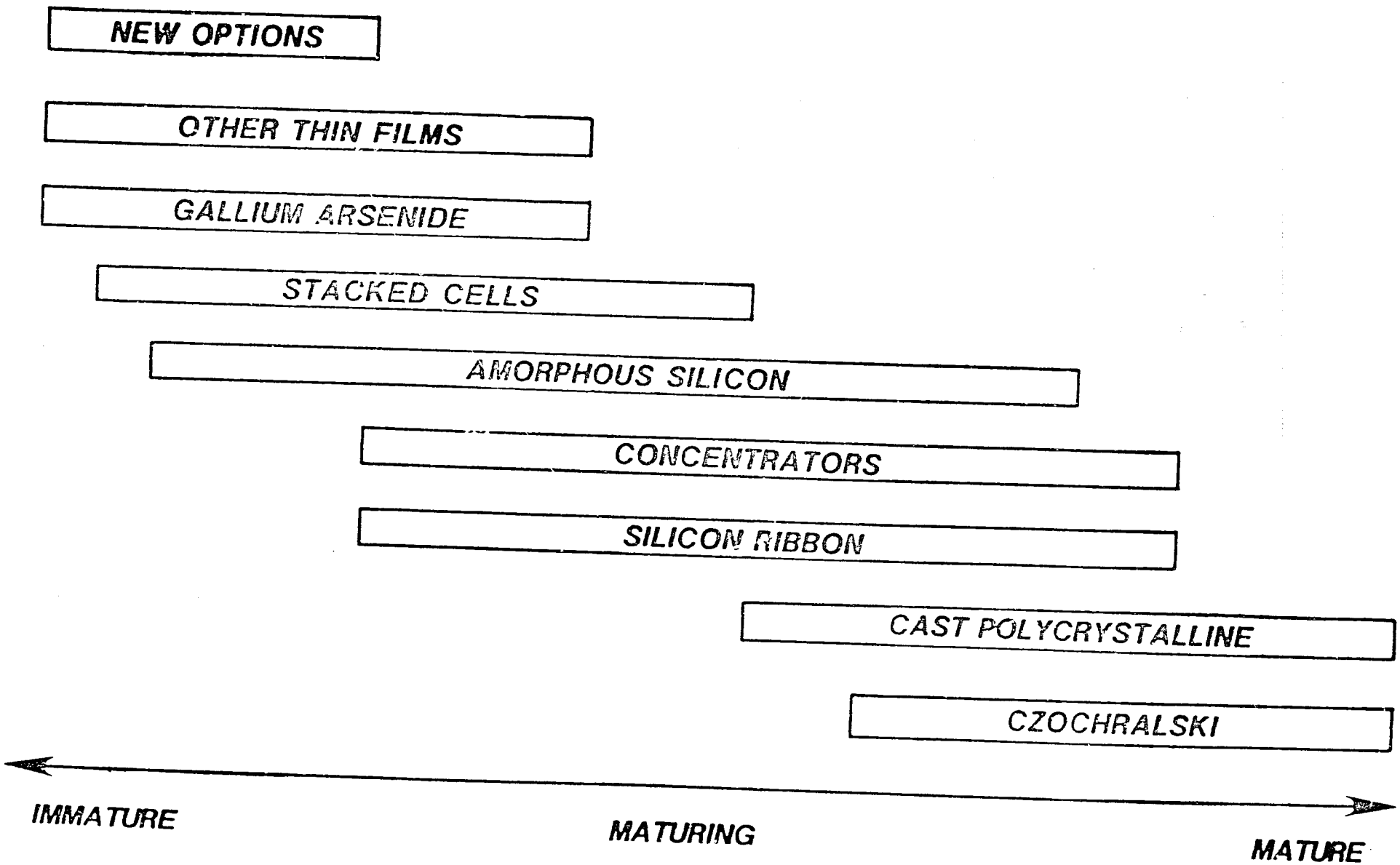
Ribbon cells offer a more automated production process; however, once again, manufacturing cost improvements have been at the sacrifice of further efficiency. R&D efforts are underway to resolve generic growth impediments and performance-limiting characteristics.

Concentrator technologies offer the opportunity to use much smaller cells (2.5 cm versus 10 cm in diameter) and generate more power per unit area. R&D in this area involves increasing concentration ratios and heat dissipation from the cells and developing improved tracking mechanisms.

A-Si technology is probably the most publicized PV material of recent years. A-Si cells use 100 times less silicon than single-crystal cells. Therefore, its potential for inexpensive products is very high. However, a-Si has the lowest efficiency and stability of any of the other more mature options. R&D in this field has been dedicated to increasing efficiency, lifetime and production automation.

PHOTOVOLTAICS

Technology Maturity



The other options in Exhibit A.20 are still in preliminary research stages. Gallium arsenide (GaAs) is looked at with promise as thin-film material in stacked cells. In single-crystal form, GaAs alloys have yielded the highest efficiency of any material to date and are extremely stable; however, GaAs is an extremely expensive material and therefore has only been used commercially for space applications. As a thin film in a stacked cell for a concentrating system, GaAs may prove to be cost-effective.

A.2.8 Relevant Egyptian/Worldwide Experience in Using PV

Egyptian PV-related activities are summarized in Exhibit A.21. In the U.S. alone, the number of PV installations has soared from just a few systems in 1974 to tens of thousands in 1984. Systems funded by the U.S. Department of Energy (DOE) are summarized in Exhibit A.22. Other U.S. Systems include five central station facilities, an estimated 6000 remote homes, and thousands of other stand-alone systems.

Along with the U.S., several other countries have strong PV research and applications experience. These countries include Japan, France, Germany, Belgium, Italy, United Kingdom, Holland, Spain, India, Australia, Canada and Brazil.

Worldwide, almost 10,000 communications systems, about 1,000 cathodic protection system, more than 5,000 navigational aids and more than 1,00 railroad aids are installed each year. In 1983, on the order of 2,500 rural eletrification system were installed. A fraction of the PV systems that have been installed in developing countries are identified in Exhibit A.23.

EXHIBIT A.21
EGYPTIAN PV EXPERIENCE

EGYPTIAN INSTITUTION	SPONSORING ORGANIZATION	PV ACTIVITY
Ministry of Electricity and Energy	French Government	o 10 kW refrigeration system (High Dam Lake)
		o Evaluation of PV cells (in cooperation with National Research Centre
		o Irrigation pump testing
	German Government	o Supply of ten PV systems (include navaids, pumps, refrigerator)
	US Government (USAID)	o Desalination, pumping, refrigeration and village electrification systems
National Research Centre		o Silicon and cadmium-sulfide cell research
		o Development of linear electric generator for PV and wind
	French Government	o Silicon cell testing and manufacture
Cairo University	U.S. Government	o Cathodic protection research
		o Theoretical PV system research
		o Amorphous silicon cell lab
Ein Shams University	French Government	o Silicon cell manufacture
University of Alexandria	Dutch Government	o Manufacture and assembly of cells and modules
Assyout University	French Government	o Cell research
Helwan University	U.S. Government	o Production and testing of cells
American University in Cairo (AUC)	U.S. Government (NSF)	o PV system testing (Basaisa)
	World Bank	o Desert development (Sadat City) - 10 kW electrification system - 5 kW pumping system

EXHIBIT A.22

U.S. DEPARTMENT OF ENERGY
SYSTEMS EXPERIMENTS

TYPE	NUMBER OF PROJECTS	AGGREGATE CAPACITY (KWp)
CENTRAL STATION	1	1,000*
GRID-CONNECTED INTERMEDIATE-SIZE	9	1,200
GRID-CONNECTED RESIDENTIAL-SIZE	8	120
FEDERAL PHOTOVOLTAIC UTILIZATION PROGRAM	3,164	600
OTHER STAND-ALONE	13	800
TOTAL	3,185	3,720

*DOE PLANS TO EXPAND THIS PROJECT TO 2,000 KWp in 1985.

EXHIBIT A.23

PV PROJECT LISTING

REGION: Africa

Country	Site	Application	Sponsor
Botswana		Pumping	USAID/Botswana/ Peace Corps
French Somaliland	Djibouti	Pumping	USAID
Gabon	Bolossoville	Rural Electrification	USDOE
	Bougandji	Rural Electrification	USDOE
	Donquila	Rural Electrification	USDOE
	Nyali	Rural Electrification	USDOE
Gambia	Gunjur	Refrigeration	CDC
	Kaur	Refrigeration	CDC
Ivory Coast	Menee	Refrigeration	USAID
	Niofouin	Refrigeration	CDC
	Zaranou	Refrigeration	CDC
Kenya	Ikutha	Refrigeration Communications Lighting Sterilization	USAID
	Kibwezi	Refrigeration Communications Lighting Sterilization	USAID
Lesotho		Lighting Communications	USAID
Liberia	Suehn	Refrigeration	USAID
Mali		Pumping	USAID
		Agri Processing	USAID
		Pumping Agri Processing Lighting	USAID/Mali/Peace Corps
		Pumping Refrigeration	
		Pumping	European Dev. Fund
		Pumping	UNDP
	Quelessebougou	Refrigeration	USAID
Mauritania		Rural Electrification	USAID

EXHIBIT A.23 (Cont.)

PV PROJECT LISTING

REGION: Africa (Cont'd)

Country	Site	Application	Sponsor
Niger		Pumping	USAID
Nigeria		Pumping	
Rwanda		Pumping	USAID/Rwanda
Senegal	Mt. Roland	Pumping Lighting Refrigeration	
Tanzania		Rural Electrification	USAID
Upper Volta	Orodara Tangaye	Refrigeration Agri Processing Pumping	USAID USAID/Upper Volta
Zaire	Kionzo	Communications Refrigeration	USAID USAID
Zimbabwe	Chikwakwa	Refrigeration Communications Lighting Sterilization	USAID
	Chiota	Refrigeration	USAID

REGION: Asia

Fiji			
India	Bhoorbaral	Refrigeration	CDC
Indonesia	Batujaja Cibung Bulang	Refrigeration Refrigeration Rural Electrification Communications	USAID USAID W. Germany USAID
Maldives	Kuluduffushi	Refrigeration	CDC
Marshall Islands	Utirik	Rural Electrification	USDOE
Pakistan	Sialkot	Rural Electrification	
Philippines		Pumping	UNDP W. Germany
Thailand	Tambon Tha Thong	Communication Refrigeration	World Bank USAID

EXHIBIT A-23 (Cont.)

PV PROJECT LISTING

REGION: Latin America/Caribbean

Country	Site	Application	Sponsor
Columbia	Bocas Del Palo	Refrigeration	CDC
Dominican Republic	Las Tablas	Refrigeration	USAID
Ecuador	Pedro Vicente Malonado	Refrigeration Communications Lighting Pumping Sterilization	USAID
	Comuna Cobos	Refrigeration	USAID
Guatemala	Tierra Blanco	Refrigeration	USAID
Guyana	Kumuka	Medical Electric Power	IADB/Guyana Ministry of Health
	Sand Creek	Medical Electric Power	IADB/Guyana Ministry of Health
	Waramuri	Refrigeration Lighting Communications Sterilization	USAID
	Schepmoed	Refrigeration	USAID
Haiti	Anse-A-Veau	Refrigeration	USAID
Honduras	Aldea Las Selvas	Refrigeration	USAID
Peru	Pucara	Refrigeration	CDC
St. Vincent & The Grenadines	Canovan	Refrigeration	USAID
	New Sandy Bay	Refrigeration	USAID

REGION: Near East

Egypt	Basaisa Village	Communications Pumping	
	Sadat City	Pumping	World Bank
	Sadat City	Communications Lighting	World Bank
Jordan		Refrigeration	USAID
		Communications	W. Germany
		Pumping	W. Germany
Morocco	Bouaboute	Refrigeration	USAID
Oman		Communications	

EXHIBIT A.23 (Cont.)

PV PROJECT LISTING

REGION: Near East (Cont'd)

Country	Site	Application	Sponsor
Saudi Arabia	Jeddah	Desalination Rural Electrification	USDOE/Saudi Arabia
Tunisia	Bir Amama	Refrigeration	USAID
	Es-Smirat	Refrigeration	USAID
	Hamman Biadha	Pumping	USAID/Tunisia
	Hamman Biadha	Communications Lighting Refrigeration	USAID/Tunisia
	Hamman Biadha	Communications Lighting Pumping Refrigeration	USAID/Tunisia
United Arab Emirates	Dubai	Lighting	Private
Yemen		Pumping	

A.3 High Temperature Solar Thermal

A.3.1 Operating Characteristics

Solar thermal systems are developing as a potentially significant energy source. Of all the solar technologies, solar thermal systems offer the greatest diversity in terms of temperature ranges, applications and storage options.

Solar thermal technology concentrates the solar flux by means of tracking mirrors or lenses onto a receiver where the solar energy is absorbed as heat. The thermal energy can be used directly for process heat applications or be converted to electricity. Collectively, existing solar thermal concepts are complementary and can address a wide range of applications including industrial and agricultural process heat, cogeneration (total energy), electrical generation, and repowering existing electric power plants.

A.3.2 Technology Description

The primary focus of the solar thermal technology is the development of three major solar thermal concentrating collector concepts: central receivers, parabolic dishes, and parabolic troughs (Exhibit A.24). Temperature capability, technology and various application options are summarized in Exhibit A.25.

A.3.2.1 Central Receiver

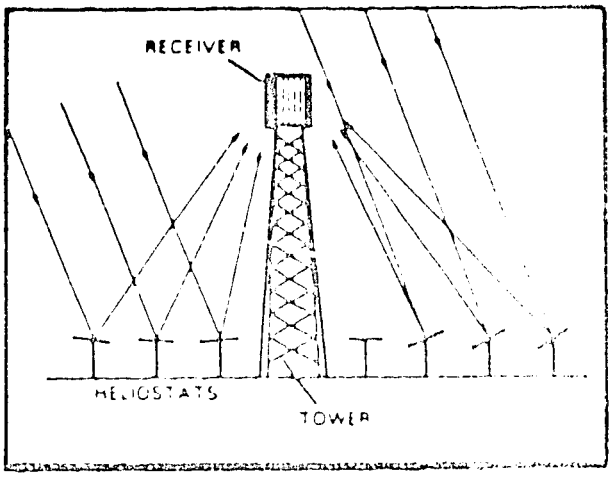
In a central receiver system, a field of heliostats (tracking mirrors) focuses sunlight at concentration ratios of several thousand times onto a receiver mounted on a tower. The concentrated energy absorbed by the receiver can be transferred as heat to a circulated working fluid to power a heat engine or provide high grade heat for industrial uses. Central receiver systems can produce working fluid temperatures up to 1700°C or more.

A.3.2.2 Parabolic Dish

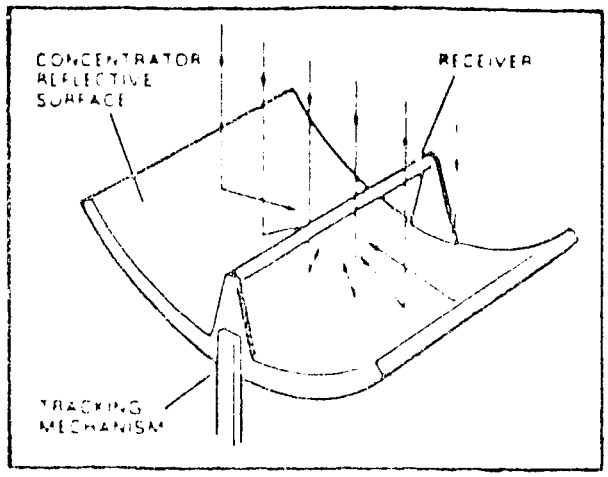
A parabolic dish is a point focusing, two axis tracking collector that focuses sunlight at concentration ratios of several thousand times onto a receiver located at the focal point of a parabolic concentrator. Energy transferred as heat to a fluid circulating through the receiver can be used directly in thermal energy applications or used to produce electrical energy through a heat engine/electric generator coupled to the receiver. A complete dish module can be used individually or in multi-module systems. Parabolic dishes can produce temperatures up to 1700°C or more.

A.3.2.3 Parabolic Trough

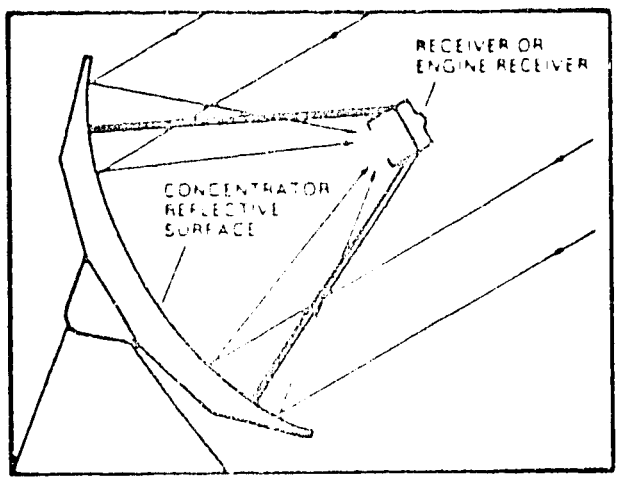
Parabolic troughs are one-axis tracking linear parabolic collectors that concentrate sunlight approximately 30 fold onto a receiver tube positioned along the focal line of the parabola. A working fluid in the receiver is heated by the concentrated sunlight and this energy is transported to the point of use by the fluid circulating in a piping system. Due to lower operating temperatures of 100°C to 315°C, troughs are usually considered to be most suitable for industrial process heat applications.



CENTRAL RECEIVER



PARABOLIC TROUGH



PARABOLIC DISH

SOLAR THERMAL TECHNOLOGY CONCEPTS

EXHIBIT A-24

SOLAR THERMAL TECHNOLOGY

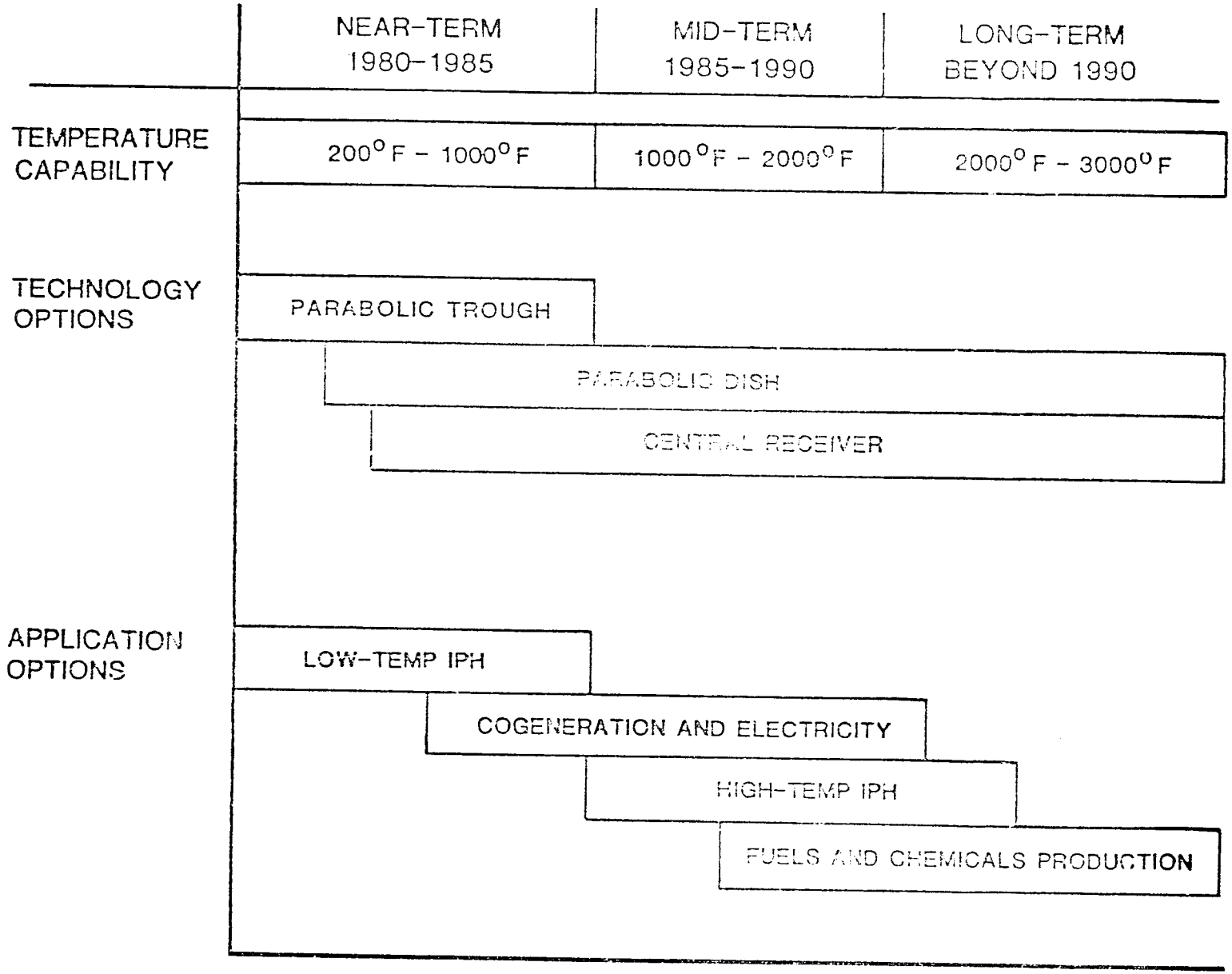


EXHIBIT A-25

IPH : Industrial Process Heat

In addition to concentrators and receivers, most solar thermal plants utilize thermal transport and have the valuable option of including thermal energy storage. Storage can improve the system's cost competitiveness and can be used to shift the plant's energy output to any time of day it is needed. Thus storage provides energy on demand, not just when the sun is shining. To complete a solar thermal system, energy conversion subsystems and balance of plants are required. Energy conversion includes equipment related to a plant's particular application, such as heat engines and heat exchangers. Balance of plant includes the control subsystem, heat rejection equipment, buildings, land, water quality equipment, and other subsystems required for plant operation.

Solar thermal systems can be built to satisfy almost any desired capacity. Dish-electric modules, each containing a heat engine, can produce as little as a few kilowatts of electricity with a single module, or fields of these modules can be assembled for larger capacity needs. Large central receiver systems are capable of generating 100 kilowatts and up to 100 megawatts of electric power with potentially inexpensive storage. Modular parabolic trough systems have been manufactured that can satisfy commercial or industrial process heat needs over a wide range of temperatures (100°C to 400°C) and capacity requirements.

A.3.3 Technology Status

The technical feasibility of solar thermal power generation has been demonstrated from time to time since the beginning of the twentieth century. One of the earliest demonstrations of solar thermal power was in Meidi, Egypt during 1913 in which parabolic trough concentrators were used to produce steam to operate 25 hp steam engine in an irrigation pumping unit.

Since 1975, first and second generation heliostats (tracking mirrors) were designed, fabricated and tested resulting in significant performance improvement, reduced manufacturing cost, and reduced mirror weight. A 10 megawatt electric central receiver pilot plant facility was constructed in the United States and is now operating and produces thermal energy at 510°C and 1465 psi using 1818 heliostats. The plant storage is designed to supply steam to the turbine at 275°C and 450 psi. The plant has produced power output as high as 12 MWe and is capable of providing electricity for a community with 10,000 houses. Several other central receiver systems have been built and operated in various countries worldwide ranging in power output from 100 kWe to few megawatts. A 500 kWe central receiver system located in Almeria, Spain was successfully constructed and operated by the International Energy Agency. Central receiver systems have been constructed and operated in Japan, Australia, Italy, USSR, and Spain. Also, a 750 kWe central receiver molten salt electric experiment in Albuquerque, New Mexico is evaluating the technical and economic feasibility of molten salt as a heat transfer fluid.

Parabolic dish technology development began in 1977. A number of parabolic dish concentrating collectors, receivers, and engines have been manufactured and tested. Parabolic dish designs are evolving toward higher operating temperatures to take advantage of their potential high solar flux concentrations. Based on the past research and development, a large scale cogeneration facility using 114 seven meter parabolic dishes was designed and constructed at Shenandoah, Georgia to supply the adjacent knitwear factory with 100-400 kWe output and process steam at 74°C for pressing fabric, and at 43°C for cooling of 35,000 square feet of floor space. The system can produce 626 kg/hr of process steam

(74°F) at 137 psi and can provide 257 tons of cooling (29°C water) for air conditioning.

Parabolic dishes can produce 15-25 kWe and can also be used as a single module in a stand-alone/remote applications. An 11 meter Vanguard dish-electric module has successfully produced up to 25 kWe at a gross efficiency of 31%, making it the most efficient solar electric device in the world. A privately funded parabolic dish project in the U.S. is near completion which will produce 4.5 MWe. In addition, several parabolic dish projects are in the planning stage in various countries such as Kuwait, Qatar, and Saudi Arabia.

The parabolic trough concept is the most highly developed of the major solar thermal technologies. It has a well defined range of applications at temperatures below 400°C. Between 1975 and 1982, over 20 parabolic trough system designs were fabricated and tested. Early trough water pumping studies, combined with trough R&D, led to three pumping (irrigation) projects at Arizona and New Mexico. These experiments established the feasibility of using solar trough technology for irrigation applications. In addition, a series of about 30 parabolic trough systems were designed, constructed and operated in the U.S. to deliver low-temperature air and water up to 100°C and steam at 182°C as well as intermediate temperature steam at 215°C. Collected process steam by these experiments was used for various applications including grain drying, car washing, concrete block curing, commercial laundry, gauze bleaching, latex production, and engine parts washing. These parabolic trough experiments proved the ability of trough technology to achieve an efficiency of 60% at 157°C for industrial process heat applications. Also, a 500 kWe parabolic trough experiment has been successfully constructed and operated at Almeria, Spain by the International Energy Agency. A few other parabolic trough projects are underway in West Germany and Japan.

A.3.4 Resource Availability

Solar energy availbility in Egypt was discussed in Section A.2.3.

A.3.5 Market Readiness

Solar thermal systems have the potential to capture a share of the industrial market with applications such as mechanical parts and car washing, bleaching, air-conditioning, potato frying, beer brewing, latex production, sterilizing, enhanced oil-recovery and oil refining. Parabolic troughs, which are mainly low- to medium-temperature systems, are ideal for this market; several complete parabolic trough systems have been installed successfully in the field giving users first-hand experience. Due to these past efforts, parabolic trough systems have entered the commercial marketplace. Other solar thermal technologies are also expected to penetrate the process heat market very soon.

The next area that solar thermal systems could be expected to penetrate is electrical generation, in hybrid systems that use solar energy to repower or retrofit a utility or industry currently using a fossil-fired system, or in stand-alone systems. Other solar thermal applications are for cogeneration and total energy systems, each of which produces both heat and electricity. Central receivers, parabolic dishes, and to some extent, parabolic troughs are all

273

potential candidates for electrical applications.

Several solar thermal systems have been constructed and successfully operated throughout the world in the past decade. Some of these systems are still producing useful heat and electrical energy for various applications; providing valuable technical information; and validating existing solar thermal technology to the potential users. Solar thermal systems providing 25 kWe to 10 MWe have been successfully operated in various countries including the United States, Japan, Australia, Spain and Italy.

A final use being studied for solar thermal systems is the production of transportable fuels and chemicals from renewable feedstocks. This technology has been investigated on a laboratory scale and several candidate processes have been identified. However, it will take many years to fully develop it on a commercial scale.

A.3.6 Economic Viability

Currently solar thermal technologies are too costly to be competitive with conventional energy sources in the U.S. Advanced components and systems with improved efficiency and lower cost are currently being developed by the solar thermal research and development community.

Parabolic trough technology has the most potential for being economically competitive in the near term (1985-1990). Total installed systems costs are about $750/kWt, making mid temperature industrial process heating using parabolic trough concentrators competitive in certain geographic locations with high insolation. Present trough concentrators are approaching a minimum cost of about. Advanced trough concentrator systems have a potential for achieving costs of about $400/kWt.

Current costs for parabolic dish systems range from $8500/kWt to $1800/kWt. Both capital and operating costs will have to be reduced considerably to make this technology option economically viable in the near future. Lower manufacturing, field installation and O&M costs and increased parabolic dish system efficiency are expected to reduce system costs to about $1300/kWe and $470/kWt by 1995.

Central receiver systems are technically feasible, however, the cost of energy from initial plants is higher than the cost of energy from existing fossil plants. Heliostats comprise approximately 50% of the central receiver system cost. Central receiver plant costs are currently about $4600/kWe and $1300/kWt. Cost is expected to come down to about $1600/kWe and $460/kWt by 1995.

Parabolic trough systems are the most nearly commercially ready of the three technologies. These systems can deliver 315°C fluid at nearly 60% nominal peak efficiency. Commercial end use sector applications now exist using trough system to deliver heat for various industrial processes. Advanced parabolic trough concentrators have a future development potential for becoming fully competitive with fossil fuel.

Parabolic dish systems and central receiver systems are not economically viable yet. Both technologies require continued research and development to reduce costs and increase efficiencies. Solar thermal systems are most attractive

in regions with good direct solar radiation over 1600 kWhr/m^2/yr.

A.3.7 Industry Status

The solar thermal industry in the United States consists of about fifty companies involved in the development and manufacturing of solar thermal components and services. They range from small high technology firms to large aerospace and petroleum companies. In the past decade, nearly all private sales and most private initiatives have been for parabolic troughs. Only recently, major private initiatives have been undertaken by the solar thermal industry to promote and verify central receiver and parabolic dish systems in the user environment. Industrial process heat and electricity generation are industry's favored markets, and most purchases in the past were made by the Government. Presently, industry is also concentrating their efforts toward stand-alone, remote solar thermal systems development. Private investments have also been made by electric utilities in solar thermal technology development. At least 15 large energy users, 6 electric utilities and 9 industrial firms using process heat, are actively involved in promoting solar thermal technologies.

Several other private companies involved in the design, production and installation of the solar thermal equipment have participated in various solar thermal projects throughout the world. In the past decade the following major solar thermal projects were undertaken worldwide:

- 500 kWe central receiver and 500 kWe parabolic trough project sponsored by the International Energy Agency and located at Almeria, Spain;
- 1 MWe central receiver and 1 MWe parabolic collector system located at Kagawa, Japan;
- 1.2 MWe central receiver CESA-1 project located at Almeria, Spain adjacent to the IEA solar thermal projects; and
- 2 MWe central receiver project located at Targassone, France.

In addition, solar thermal industry is continuing its efforts to develop innovative, reliable, low-cost, high-performance solar thermal electric and process heat components and system concepts to promote the widespread use of the various solar thermal technologies.

A.3.8 Current Solar Thermal R&D Thrusts

A major R&D need generic to all solar thermal technologies is improvement in the cost/performance ratio of the concentrator. Low-cost, high-performance concentrators will require the development of stable, lightweight, long-life reflector materials as conventional materials are heavy and expensive.

Besides the generic R&D needs, there are specific R&D needs for each technology. For trough systems, a number of technical problems remain, although a number of well-designed commercial products and systems are available. Improved foundation techniques, advanced receiver structures, advanced drives, insulated hoses, trackers and control systems, are needed to bring the trough technology to a final state of development.

For parabolic dish thermal systems, development of a technically and economically feasible energy transport system, to carry the heat energy collected by each dish concentrator in the field of concentrators to a central collection point for end use and/or storage, is the most critical technical problem. In dish-electric systems where thermal transport is not a problem, R&D is needed to develop more efficient and reliable heat engines.

For central receiver systems, development of high temperature components that can provide system operating temperatures of greater than 538°C is needed. The components include receivers, heat exchangers, and components for energy storage and transport.

Also, current R&D thrusts for solar thermal technology includes development of innovative solar thermal concentrating concepts; research on system automation for stand-alone and remote applications; and development of efficient high-temperature heat transfer fluids.

A.3.9 Relevant Experience in Egypt and Other Countries Using High Temperature Solar Thermal Technology

Egypt

a. The Solar Energy Laborarory, National Research Center (Dokki, Cairo), established in the early 1970's is the main center of solar research in Egypt. It has been involved in various experimental and moderate scale solar thermal projects:

1. A power generation project in cooperation with the U.S. under a renewable agreement (January 1975-June 1978) in which the collector array is made up of three heliostats having a total area of 108m^2, with paraboloidal concentration. Steam is produced at 220°C under a pressure of eight atmospheres. The steam drives a turbo generator (Terri turbine) capable of producing up to 5 kWe.

2. A power generating project in cooperation with West Germany (Dornier Company) under a renewable agreement (December 1976-1979) operated a site which extended over an area of 8000 m^2 with Cylindro-parabolic type collectors producing hot water at 110°C under six atmospheric pressure.

b. The Ministry of Electricity and Energy (Cairo) in 1976 formed a "Solar Energy Commission" which was replaced in 1978 by the "Supreme Council of Renewable Energy Sources," which administered several solar projects including a 5 kW/solar pump with a freezing and cooling unit.

c. The Faculty of Science of Cairo University established an educational solar energy laboratory in 1978 and also offered a solar energy course at the Master's level.

d. At the Physics Department of the American University (Cairo) work related to solar energy development has been undertaken.

276

e. In the Electrical Engineering Department of Al-Manjurah University, theoretical work on collectors for power generation has been undertaken.

f. Insolation in Egypt is recorded by the Department of Meteorology.

g. Several other experimental and basic research studies on the laboratory scale are being conducted at various Egyptian Universities.

h. Exhibit A.26 is a representative list of countries having activities in high temperature solar thermal technology.

EXHIBIT A.26 COUNTRIES HAVING ACTIVITIES IN SOLAR THERMAL TECHNOLOGY

COUNTRY	PROJECT	POWER OUTPUT	POWER SOURCE	START DATE	SPONSOR/ CLIENT
1. Australia	Solar Power Station (meeka Tharra)	100 kW	30 Concentrating Collectors	1981	State Electricity Company of Western Australia (SECWA)
2. Corsica	Solar Power Plant (Ajaccio)	300 kW	1200m^2 segmented mirror heliostats (CEA)	1982	COMES
3. Egypt	Thermal Power Project	10 kW	Cylindro Parabolic Collectors (LIEBI)	1982	Solar Energy Commission (SEC)
4. France	Solar Power Plant at Targasonne	2.5 MWe	200 heliostats each 54m^2 and array of 800m^2 Thek bowl-type collectors	1982	COMES and French Agency for the Management of Energy (FAME)
5. West Germany	Process Heat Generation	2-4 MBtu of steam.	MAN Concentrating Collectors	1982	EEC
6. Israel	2 Solar Heating Plants	-	Parabolic Trough Collectors (LUZ International)	1981-82	Gibor Textiles SHK Association
7. Italy	Solar Plant EURELIOS (Adrano, Sicily)	1 MWe	112 MBB type heliostat each 24m^2; 70 cethal type heliostat each 54m^2.	1981	Italian State Electricity Co. (ENEL)

EXHIBIT A.26 COUNTRIES HAVING ACTIVITIES IN SOLAR THERMAL TECHNOLOGY (Cont.)

COUNTRY	PROJECT	POWER OUTPUT	POWER SOURCE	START DATE	SPONSOR/ CLIENT
8. Japan	Sunshine Project (Nio-Cho)	1 MWe	807 Heliostat each $54m^2$	1981	Government
9. Japan	Solar Thermal Plant (Nio-Cho)	1 MWe	124 Parabolic Collectors	1981	Government
10. Kuwait	Solar Thermal Power/Desalination Plant	100 kW	Parabolic Collector	1981	KISR
11. Qatar	Desalination Plants	-	Parabolic Collectors	-	Industrial Development Technical Center
12. Spain	Solar Plant CESA 1 (Almeria)	1.2 MWe	300 heliostats each 40 m^2	1982	Spanish Industry Ministry
13. Spain	Central Receiver SSPS Project (Almeria)	500 kWe	93 heliostats each $40m^2$	1981	International Energy Agency (IEA)
14. Spain	Distributed Collector SSPS Project (Almeria)	500 kWe	Parabolic Trough (Acurex & Man)	1981	IEA
15. USA	Solar Test Facility (Albuquerque)	5 MWt	222 heliostats each $35m^2$	1978	Energy Department
16. USA	Solar One (Daggett, California)	10 MWe	1818 heliostats each $54m^2$	1982	Energy Department
17. USA	Industrial Process Heat Projects	Various output levels of process steam	Parabolic trough collectors	1975-1982	Energy Department

A.4 Geothermal

A.4.1 Operating Characteristics

Geothermal fluids from hot springs or wells contain beneficial heat which can be used directly or, if the temperature is high enough, be converted to electricity. Geothermal systems are very site specific; their temperature and available flow rates are dependent on the specific reservoir. Transportation of fluid over long distances is generally not cost effective. For electric generation, geothermal plants exist in sizes ranging from 50 kWe to over 100 MW. They produce AC power with standard electrical generators and are not subject to diurnal or seasonal variations.

A.4.2 Technology Description

Geothermal energy, the natural heat of the earth, has been used by man for centuries. Earliest applications used the hot waters of thermal springs for cooking, bathing, and space heating in many areas throughout the world. The production of electricity from geothermal steam was first attempted in 1904 in Larderello, Italy. Today, geothermal energy produces over 3700 MW of electricity in 15 countries and is used in countless direct applications of geothermal heat.

There are four primary technologies which produce electricity from geothermal resources: dry steam, flashed steam, binary cycle, and total flow systems.

Dry steam can be found only in a limited number of locations in the world where geothermal fluids exist naturally as water vapor. In this case, saturated steam in the reservoir is tapped by geothermal wells and becomes superheated as it flows up the well to the surface. The steam is piped to the power plant where it expands through the turbine to a condenser on the other side. The turbine shaft is hooked to a generator to produce electricity. The liquid recovered in the condenser can be disposed of on the surface, if it is environmentally acceptable, or it can be reinjected into the reservoir via an injection well. The most serious problems with electric production from vapor dominated systems are related to health effects and corrosion caused by non-condensible gases which escape from the vapor as it expands and cools.

High temperature (>150°C), liquid dominated geothermal reservoirs can be used to generate electricity with flashed steam systems. The liquid brine is flashed at the surface by reducing its pressure in a "flash vessel," where part of the water then turns into steam. In some cases, the brine actually flashes in the wellbore, thereby requiring only a steam separator at the surface. The steam phase is fed to a turbine where electricity is generated, similar to dry steam energy conversion. The liquid portion of the fluid is usually disposed of by reinjection into the ground. A major problem in flashed steam systems, especially those which utilize brine with high dissolved solids content, is the deposition of silica and calcite in the wellbore and steam distribution system.

Binary cycle (or organic Rankine cycle) technology can use medium temperature resources (90°-150°C) to generate electricity. The geothermal fluid flows, or is pumped, from the production wells into a heat exchanger where the heat is transferred to a secondary fluid, such as freon or isobutane. These fluids, with their low boiling points, will vaporize in the heat transfer process. The

280

vaporized working fluid is then expanded through the turbine and is condensed upon exit. It is subsequently returned to the heat exchanger, completing a closed cycle. The spent geothermal fluid from the heat exchanger is reinjected into the ground. The working fluid never comes into contact with the geothermal brine, eliminating corrosion problems in the power cycle. The brine is not permitted to flash into steam thus limiting the deposition of solids in the system.

Total flow geothermal systems expand the brine from the liquid phase directly without the intermediate process of flashing it into steam. By avoiding the losses in the flashing and separation processes, total flow expanders have a higher theoretical efficiency. There are a number of expander types which may be used in total flow systems, i.e. axial flow turbines, Frances turbines, Pelton wheels, helical screw expanders, etc. These systems are primarily being considered for high temperature (>150°C) applications.

The direct use of geothermal energy delivers heat from a geothermal fluid to any process requiring it. Generally, the temperature is limited to the wellhead temperature, although supplementary heating by fossil or other fuels has been used in certain cases. Most direct applications of geothermal energy use low temperature (<90°C) resources which cannot be used to generate electricity. There is no technical reason to limit direct use to this temperature range.

The advantages of geothermal energy, from a technical standpoint, lie primarily in the form of energy output and the relatively low level of sophistication of the technology. Electricity and heat derived from geothermal resources are constant, reliable supplies, suitable for local use or for connection to the grid. From a technology standpoint, oil and gas experience is directly applicable to geothermal energy extraction in drilling, well completion, and surface transport of fluids. The construction and operation of geothermal power plants is similar to that of hydroelectric or conventional steam plants.

The primary disadvantage associated with geothermal energy is related to the resource itself. Successful utilization of geothermal energy requires a reservoir of adequate size, temperature, and permeability. Often, expensive exploration programs will fail to locate resources adequate for the planned use. In addition, the use of geothermal energy for process heating applications requires the end use to be near the wells, a fact which may not be possible in some remote locations.

A.4.3 Resource Availability

Recent studies investigated the availability of geothermal energy in Egypt. These efforts found no indication of high temperature (>150°C) geothermal systems in the region. Evidence does support the possibility of medium enthalpy (>90°C) geothermal systems along the Red Sea coast.

The most favorable zones for geothermal exploration exist along the border of the Gulf of Suez. Hot springs along the eastern shore and in the Sinai have surface temperatures as high as 70°C. This zone could extend as far west as Cairo and the Favoum oasis and Wadi Natrum areas based on geochemical data, extinct geysers, and historic seismicity of these areas.

Investigations in the Western Desert do not indicate the existence of hydrothermal systems but water from deep lying aquifers could be used in direct applications of geothermal energy. Deep artesian aquifers with temperatures in the range of 35-45°C underlie much of the Western Desert. Some evidence exists that similar aquifers may exist in the Eastern Desert between the Nile and the Red Sea.

The Jebel Uwernat area of southwest Egypt has undergone thermal activity in the recent past, as evidenced by extinct geysers in the region. The remoteness of this area most likely precludes the exploitation of any geothermal resources which may exist.

A.4.4 Economic Viability

The economics of geothermal energy is strongly dependent on resource characteristics such as temperature, depth, possible flow rates, and brine chemistry. Other important cost factors include accessibility of the resource and rock hardness. Before any specific costing of a project can be performed, exploration is needed to adequately define the geothermal reservoir. A number of projects have met the debacle of investing substantial funds in drilling only to be forced to terminate the project when sufficient geothermal resources could not be located.

Exhibit A.27 gives installation cost estimates for geothermal energy extraction. These values are calculated for projects assuming resource exploration has been completed.

EXHIBIT A.27

ESTIMATED INSTALLATION COSTS FOR GEOTHERMAL ENERGY CAPACITY

(1983 $)

	Direct Use	Binary Electric	Flash Steam
Well Drilling	$6-37/kWth	$228-492/kWe	$171-369/kWe
Plant Costs	$4-15/kWth	$718-1129/kWe	$513-923/kWe
Total	$10-52/kWth	$946-1621/kWe	$684-1292/kWe
Typical Operating Factor	.4	.65	.65
Net Total Cost	$25-130/kWth	$1454-2494/kWe	$1052-1988/kWe
Project Life	10-15 yrs.	20-30 yrs.	20-30 yrs.

A.4.5 Industry Status

Ignoring vapor dominated geothermal systems, which exist in only a few places in the world, there are three technologies which can produce electricity from geothermal resources: flashed steam, binary cycle, and total flow.

Flashed steam technology is commercially proven and exists in many places throughout the world. It is primarily associated with high temperature resources (>150°C).

Binary cycle technology has been proven commercially successful in generating electricity from temperatures as low as 109°C for small scale units (<10 MW). A 50 MW demonstration project using binary technology, sponsored by the U.S. Department of Energy, is scheduled to come on-line in mid-1985 at Heber, California. Field tests have also been conducted generating electricity with wellhead temperatures as low as 81°C but these tests fell short of demonstrating commercial feasibility. Futher refinement of sub-boiling binary technology is anticipated in the near future.

Total flow systems for electric production have been subjected to considerable laboratory tests but have undergone only limited evaluation in the field and no commercial applications are imminent. Most testing has centered around systems for high temperature brines (300°C).

The direct use of geothermal energy is a commercially proven technology with innumerable projects existing throughout the world.

The structure of the geothermal industry is set by the three major phases which make up geothermal exploration and development. These are resource exploration, field development, and end-use.

The exploration for geothermal energy is performed by a wide range of organizations including small and large exploration companies, government agencies, and universities. The tools and techniques of geothermal exploration are essentially those of petroleum and mineral exploration. These include geologic mapping, geochemical sampling, remote sensing, surface geophysical techniques (such as seismic, magnetic, gravity, and electrical surveys), and test well drilling.

Geothermal field development includes well drilling and completion as well as the construction of surface fluid distribution systems. This technology is very similar to the development of an oil or gas field. Geothermal well drilling and completion, with the exception of high temperature applications (>150°C), is performed with essentially the same drilling rigs and hardware used in the petroleum industry. The surface fluid distribution system is, again, very similar to that in the oil and gas industry. As a result of these similarities between field development technology in the two industries, much of the same infrastructure has emerged. The field developers (often private or government owned oil companies) hire contractors to supply equipment and services to drill the well, much as they would in drilling for petroleum. The drilling contractors and service companies are, in most cases, the same companies which operate in the oil industry.

For electricity production, geothermal power plants are designed and built in the same manner and by the same architect/engineering firms as other energy

generating plants. Turbines, heat exchangers, and other plant components are supplied by large manufacturers which also build and sell the components of fossil, nuclear, and hydroelectric power plants. The direct use of geothermal energy generally requires nothing more than a conventional water distribution system and suitable heat exchangers.

Geothermal technology for energy extraction and utilization is very similar to conventional energy technologies which exist in Egypt. Most hardware would probably need to be imported from foreign manufacturers. Technical assistance would also be required to familiarize conventional energy personnel with geothermal technology. As geothermal energy is primarily an application of conventional technologies to a different energy source, it should be well adaptable to a country, such as Egypt, which has experience in the conventional technologies.

A.4.6 Current R&D Thrusts

A substantial amount of geothermal research is currently ongoing in the U.S., Europe, Japan, and New Zealand. Efforts include the improvement of geothermal exploration techniques, extending existing drilling technology and instrumentation to higher temperatures, increasing the understanding of the behavior of geothermal reservoirs, and handling and treating highly corrosive geothermal brines. Research is also being performed to improve energy conversion techniques. The goal of all of this research is primarily to reduce the costs associated with exploration and exploitation of geochemical resources.

In addition to R&D being performed to enhance current capabilities, major projects are underway to demonstrate the large scale use of binary energy conversion systems; to extract useful heat from low permeability, low porosity formations; and to directly tap the energy potential of shallow magma chambers.

The U.S. Department of Energy and a consortium of utilities and other organizations are building a commercial scale (50 MW) binary geothermal power plant at Heber, California, U.S.A. The objectives of the project are to demonstrate the potential of moderate temperature (below 210°C) geothermal energy to produce economic electric power with binary cycle conversion technology, and to establish schedule, cost and equipment performance, reservoir performance, and assess the environmental acceptability of such plants. The plant will be the first large-scale power generating facility in the world utilizing the binary conversion process. It is expected that information resulting from this project will be applicable to a wide range of moderate temperature hydrothermal reservoirs, which represent 80 percent of geothermal resources in the United States. Construction began in late 1983 and has progressed on schedule. Turbine roll is set for May, 1985 and full brine flow will be available by May, 1986. Following acceptance tests, the plant will undergo a two year demonstration period where extensive operational testing will be performed to provide a technology base for future full scale binary project.

Major R&D efforts are also underway in the U.S., the U.K., and other countries to extract heat from formations which contain very little or no in situ water. In this technique, two wells are drilled relatively close to each other and fractures are then artificially created in the rock to connect them. Water is pumped down one well and through the fractures, where the natural heat of the formation is transferred to the fluid. The heated water is then extracted at the second well. This is generally referred to as "hot dry rock" geothermal

and makes possible the extraction of energy in cases where sufficient water does not exist in the formation. This technology has been demonstrated as technically feasible, but many questions remain concerning economics and long term performance. It will probably be several years before commercial application is possible.

The engineering feasibility of extracting energy from molten magma chambers is another project being undertaken by the U.S. Department of Energy. The program is designed to verify the existence of selected shallow magma bodies, to develop suitable drilling technology to gain access to a magma chamber, and to develop the methods and technology for extracting the available energy. Ultimately, a well will be drilled into a shallow (<10km) magma body, and energy extraction experiments will be conducted. Work on this project commenced in early 1984. Current planning anticipates the determination of economic and engineering feasibility by 1991. Commercial application would probably not occur until the 21st century.

A.4.7 Relevant Experience in Egypt Using Geothermal Technology

There has been no effort to develop geothermal resources in Egypt to date. A number of investigations not specifically directed at geothermal exploration have provided some knowledge on development potential.

The National Science Foundation of the United States sponsored a program in the late 1970's to study "The Egyptian Section of the Afro-Arabian Plate Boundary and Tectonics of Egypt." As a part of this effort, several investigations of heat flow and thermal gradients yielded valuable information on the geothermal resource potential of Egypt. Exhibit A.28 outlines worldwide geothermal projects.

EXHIBIT A.28 WORLDWIDE GEOTHERMAL PROJECTS

North and Central America	Projects Underway	Existing Installations
Costa Rica	Deep production well drilling at Miravalles	-
Guadaloupe	6 MW plant under construction at La Bouillante	-
Guatemala	Planning 15 MW plant at Zunil for 1986	
	Exploration at Amatitlan	
Mexico	Expansion of Cerro Prieto Power Station. Drilling at Los Azufres and Los Humerus	6 operating power plants, 425 MW
Nicaragua	Drilling for Momotombo expansion. Exploration at El Hoyo	35 MW plant at Momotombo
Panama	Geothermal reconnaissance	
El Salvador	Exploration at Chipilapa	95 MW on line at Ahuachapan
United States	Approximately 80 geothermal wells drilled/year. Extensive exploration ongoing	Over 1400 MWe on-line. Over 200 direct use projects existing

Africa	Projects Underway	Existing Installations
Ascension Island	Exploration complete, funding requested for power plant construction	-
Djibouti	Drilling 6 exploration wells	-
Kenya	Expansion of Olkarie project, exploration at Eburru	2 15 MW power plants operating at Olkarie
North Yemen	Drilling geothermal exploration wells	

Asia	Projects Underway	Existing Installations
China	Expansion of Yangbajing power project	10 units, totaling 8.1 MW
	Direct use study near Beijing	
Japan	Exploration, drilling. Planning for additional power plants	8 plants operating, 105 MW Numerous direct heat applications
Thailand	Exploration drilling at San Kamphaeny	

Australia and South Pacific	Projects Underway	Existing Installations
Indonesia	Exploration and drilling in various regions	30 MW at Kamojang
	Expansion of Kamojang Power Plants	2 MW at Dieng
New Zealand	Exploration at Ohaaki and other areas	157 MW on-line at Wairakei, 10 MW at Kawerau
Philippines	Power Plant expansion, drilling, exploration	781 MW on line in 4 regions

South America	Projects Underway	Existing Installations
Argentina	Exploration well in Copahue Field	-
Peru	Shallow drilling, exploration	-

Europe	Projects Underway	Existing Installations
Azores	Exploration for low temperature resources	3 MW wellhead unit greenhouse
Denmark	Drilling for district heating demonstration at Thisted	-
Belgium	Exploration for low temperature resources	
France	Numerous direct use demonstration projects	
Germany (F.R.)	Direct use demonstration project Hot dry rock R&D at Urach	

Europe	Projects Underway	Existing Installations
Great Britan	Exploration for low temperature resources Hot dry rock R&D at Cornwall	-
Greece	Construction of 2 MW power plant at Milos Exploration on Nisyros	-
Italy	2 15 MW plants under construction	42 operating plants 472 MW
Iceland		Numerous direct use projects including district heating in Reykevik .41 MW electric capacity (Suartseugi, Krafla fields)
Sweden	Direct use heating plant construction	-
Turkey	Expansion of Kizildere field Exploration	.5 MW at Kizildere, greenhouses
USSR	Experimental hot dry rock research at Nuftekumsk and Mutnouskaya	11 MW plant at Pauzherka
Hungary	-	Numerous direct use projects
Yugoslavia		Numerous direct use projects

A.5 Biomass

A.5.1 Operating Characteristics

Biomass fuels provide almost 15 percent of the energy used worldwide, mostly through the direct combustion of wood. Half the people in the world today are using biomass to meet 90 percent of their energy needs for cooking and heating. The Egyptian rural population depends upon bio-fuels to meet 50 percent of their energy needs. In the U.S., biomass supplies almost as much energy as nuclear reactors or hydroelectric plants.

In urban areas, sewage is typically collected through existing networks and thus is available for feeding into anaerobic digesters. The biogas can either be burned in internal combustion engines to generate electricity, or the carbon dioxide removed and the methane used as fuel for automobiles or sold to local gas utilities. On-farm digesters utilize animal manure and agricultural residues to supply farm energy needs, such as heating and electricity. Family/village size units may also prove feasible in rural settings using a combination of human wastes, agricultural residues and manure. Village electricity needs can be met or the gas piped short distances to villagers' homes for use in stoves. Raw biogas typically has a heating value of about 18,600 KJ/m^3 or half that of natural gas.

The potential for local design, construction and operation of biogas production systems, including domestic, community or industrial (e.g., waste disposal) systems, is high within Egypt. Problems with digesters can often be solved relatively easily with a little basic know-how and repairs do not pose extensive requirements with respect to labor and parts. Furthermore, large energy storage systems are not necessary, as with wind and solar systems for example, since biomass resources are not intermittent in nature but can produce energy on demand.

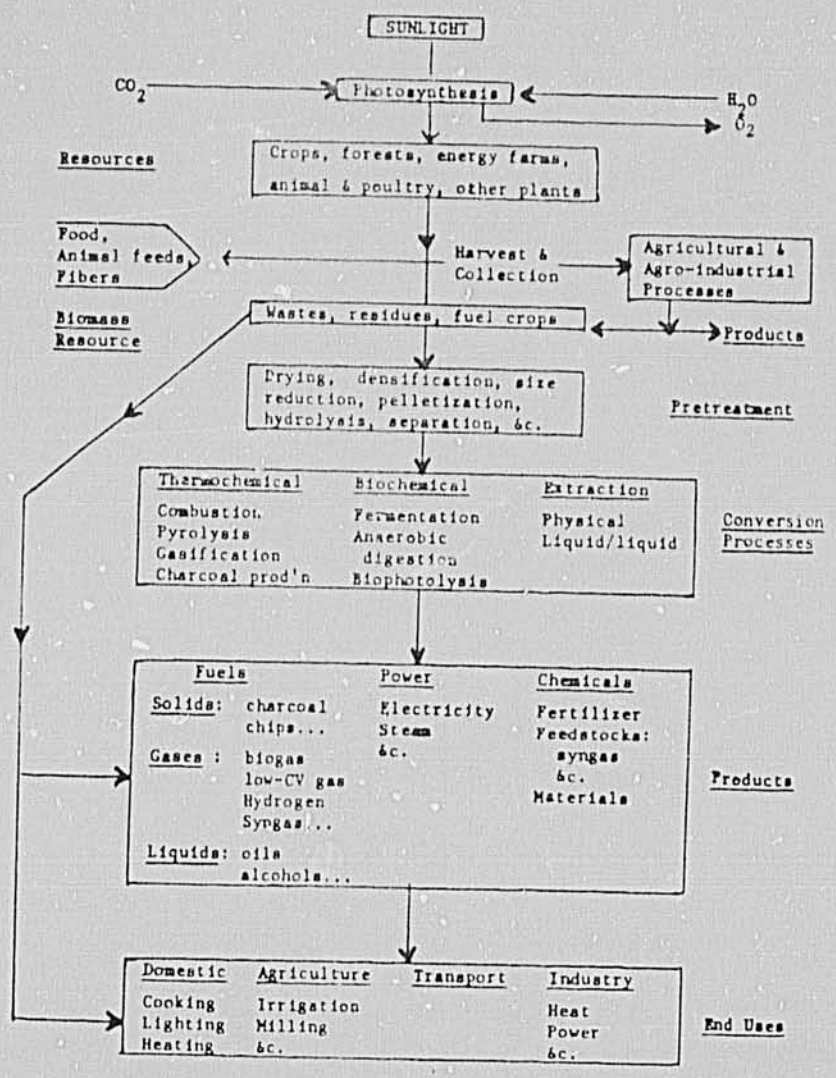
A.5.2 Technology Description

Biomass is organic matter derived from plants and animals. There is no single biomass energy technology, but a number of biomass production techniques and conversion technologies that are interrelated in various combinations. Biomass resources include wastes and by-products from industrial and agricultural processes, plus biomass produced specifically for conversion to energy. The resource base includes: (1) wood waste from sawmill and logging operations; (2) residues and wastes from agricultural, forestry and livestock operations; (3) by-products from the food processing industry; (4) grains and sugar crops; (5) municipal solid wastes and sewage; and (6) woody, herbaceous and aquatic crops grown specifically for conversion to energy.

Biomass can be converted to solid, liquid and gaseous fuels through biochemical and thermochemical processes. The resulting energy products can be used by residential, commercial and industrial consumers for heat, power and fuel; by utilities for electricity production; and the chemical industry for petrochemical substitutes. Exhibit A.29 illustrates the biomass energy production cycle.

The bio-energy technologies most used in rural areas of developing countries include the burning of agricultural wastes in open-fire stoves

EXHIBIT A-29
CYCLE OF BIOMASS ENERGY PRODUCTION



290

and ovens for cooking and heating, anaerobic digestion to produce biogas and fermentation to produce ethanol.

A.5.2.1 Direct Combustion

Combustion of biomass in open fire stoves is thermally inefficient ($\leq$ 10%), although design improvements could double the efficiencies of cooking stoves. Although agricultural residues or municipal wastes could be used as feedstocks in incinerator/steam turbine systems to produce electricity, the associated economies of scale make it uneconomical to operate small units. Thus, use of this technology is often restricted to areas of high population concentration. A possible exception involves the industrial use of residues where the feedstock components are separated for use on-site (e.g., as in processing sugarcane) leaving the residue for use as a low opportunity cost fuel.

A.5.2.2 Anaerobic Digestion

Biochemical conversion processes utilize microorganisms which break down biomass feedstocks into simpler compounds, giving off energy in the process. Anaerobic digestion and fermentation are two microbial degradation processes used for the production of bio-fuels.

Anaerobic digestion provides an energy-efficient method for converting very wet or otherwise low-quality biomass resources, such as municipal sewage and animal manure. Exhibit A.30 shows the characteristics of several anaerobic digester systems. Gaseous energy products are readily separated from the liquid component and relatively unsophisticated technologies are required. In an anaerobic digester (essentially an enclosed gas-tight tank containing an aqueous slurry of biomass material), the absence of oxygen and temperatures between 35°C and 60°C favor bacteria which decompose the feed into biogas, consisting of 50%-70% methane, with most of the remainder as carbon dioxide.

The biogas formation rate depends on the feedstock retention time, pH (optimum between 6.8 - 7.4), temperature and nature of the substrate. Cellulosic materials, such as crop residues and municipal solid waste, produce biogas more slowly than sewage sludge and animal manure. Various aquatic plants and wet food processing waste, such as those from cheese and fruit processing, are well suited for digestion.

Anaerobic digestion involves a number of different bacteria and the exact biochemical processes and relationships are not yet fully understood. The basic reactions are as follows: (1) decomposition (hydrolysis) of plant and animal matter into useable size molecules, such as sugar; (2) conversion of the decomposed matter to organic acids; and (3) conversion of the acids to methane. At least two different types of bacteria are involved. The methane-forming bacteria (methanogens) involved in step (3) above are especially sensitive to changes in temperature, pH, or the presence of toxins. The necessary bacteria may be present in the feedstock (as with cattle manure) or they may be introduced into the reactor upon start-up. Biogas production begins within a few days although complete stabilization may take months.

The energy conversion efficiency in digesters is typically about 50 percent, with the remaining energy used in bacterial cell growth and respiration and

EXHIBIT A-30
ANAEROBIC DIGESTER SYSTEMS

Type of system	Application and inputs	Scale[a]	Stage of development	Advantages	Disadvantages
Landfill	Existing and planned landfills municipal solid wastes, sewage sludge, warm climates	2×10^4 tons of waste and up (28-acre landfill)	Commercial for "as is" landfills, controlled land filling in pilot stages	Low cost, tanks not required, high loading rates possible, no moving parts	Gas generation may last only 10 years in "as is" landfills, gas usage onsite may present problems
Single-tank plug flow	All types of organics, farm and feedlot operations	Small to large	Commercial	Low cost, simple design can run high solids wastes, can have gravity feed and discharge	Low solids wastes may stratify
Multitank batch system	Can accept all types of wastes, limited application crop residues, grasses, chicken broilers, turkeys	Small to large	Commercial in Asia	Simple, low maintenance, low cost, complete digestion of materials	Gas generation not continuous, labor intensive, feed and discharge, low gas production per day
Single-tank complete mix	All types of organics sewage treatment, farm and feedlot, municipal solid wastes	Small to large	Commercial	Proven reliability, works well on all types of wastes	Greater input energy to run mixers, higher cost than plug flow
Anaerobic contact	Sewage sludge and other organics, limited application (see variable feed)	Medium to large	Commercial for sewage treatment	Smaller tank sizes, operation not overly critical	Two tanks necessary
Two or three phase	Cellulosic feedstocks	Medium to large	Pilot scale	Allows more complete decomposition, greater gas yields, greater loading rates, lower retention times	Feed rates vary with feedstocks, have not been attempted full scale, require tight controls and management of the operation
Packed bed	Dilute organics—sewage, food-processing wastes, very dilute animal wastes—industrial and commercial	Medium to large	Commercial as waste treatment technology	High loading rates possible, short retention times	Tends to clog with organic particles, limited to dilute wastes
Expanded bed	Dilute organics—sewage, food-processing wastes, very dilute animal wastes	Undetermined	Laboratory	High loading rates, low temperature digestion, high quality gas, short retention times	Not developed, high energy input to operate pumps, no operating data
Mixed bed	Sewage sludge, animal wastes, food-processing wastes—fairly dilute mixtures	Small to large	Pilot scale	Fast throughputs, high loading rates, higher solids input than packed beds	Tends to clog, high pumping energy input, no operating data
Variable feed	All types of organics, farms and feedlots	Small to medium	Conceptual—combines plug flow with anaerobic contact	Allows seasonal peaking of gas production, preserves nutrient value of material, low cost	Feed-discharge may require extra pump

[a]Scale defined as: small—0 to 30,000 gal; medium—30,000 to 80,000 gal; and large—over 80,000 gal

292

heat loss. A subsequent conversion efficiency of 30 percent can be obtained if the biogas is burned in appropriately designed burners.

Biogas production is a relatively straightforward technology. However, there is still a need to obtain detailed, reliable data from actual plant operation covering reasonably extended periods, especially when using agricultural residues as feed. Numerous possible digester designs are available. Selection of a specific design is dependent on the feedstock, availability of low-cost labor and the purpose of the digestion process. Exhibit A.31 illustrates some some of these designs.

To capture the methane gas, an inverted tank can be constructed over the digester (floating top storage) or a small pressure tank can be used to compress and store the gas. The digester tank itself may be built of steel or concrete. An agitator is often used to mix the biomass periodically, improving biogas formation rate and reducing the digester tank volume up to 50 percent. The digesters developed by the Chinese for use as family units (see Exhibit A.31) are flexible and operate in a relatively straightforward manner. Scale-up of digesters to any desired production rate can be achieved by adding modules.

A major advantage of digestion, especially when compared to dung or wood fuels, is the greater energy conversion efficiencies realized and the ability to use the resulting sludge by-product as a soil conditioner, fertilizer, and possibly as animal feed. Since the digestion process is one of waste stabilization, killing most pathogenic bacteria and parasites contained in manure and sewage, improved public health and hygiene from increased pollution control is a further benefit.

A.5.2 Fermentation

Also in an anaerobic environment, biomass can be fermented by microorganisms (yeast or bacteria) to produce alcohol. Ethyl alcohol, or ethanol, can be blended with gasoline (10 parts ethanol to 90 parts gasoline) to produce a high-octane fuel which can be used in conventional automobile engines. Ethanol can also be used for space heating or as the sole fuel in modified engines and combustion turbines. Ethanol is a key industrial chemical and is used as a solvent or reactant in the production of organic chemicals, plastics and fibers.

The production of ethanol involves: (1) treating the feedstock to produce a concentrated and sterilized sugar solution, (2) converting the sugar to ethanol and carbon dioxide through fermentation, and (3) distilling to remove ethanol from the fermented solution. Ethanol can be produced from sugar crops (sugar-cane, molasses, sweet sorghum, etc), starches (corn, potatoes, cassava, etc.), and from celluloses (wood, agricultural residues, etc.). The intensity of the required treatment process increases with starches and especially with cellulosic feedstocks. In general, processes for ethanol production from cellulostic feed-stocks are more complex and larger in scale than those from starches and sugars.

A.5.3 Resource Availability

Because of their noncommercial nature, bio-energy resources are not readily quantifiable. However, Exhibit A.32 presents estimates of the annual resource

EXHIBIT A-31
ANAEROBIC DIGESTER DESIGNS

Chinese Design of a Biogas Plant

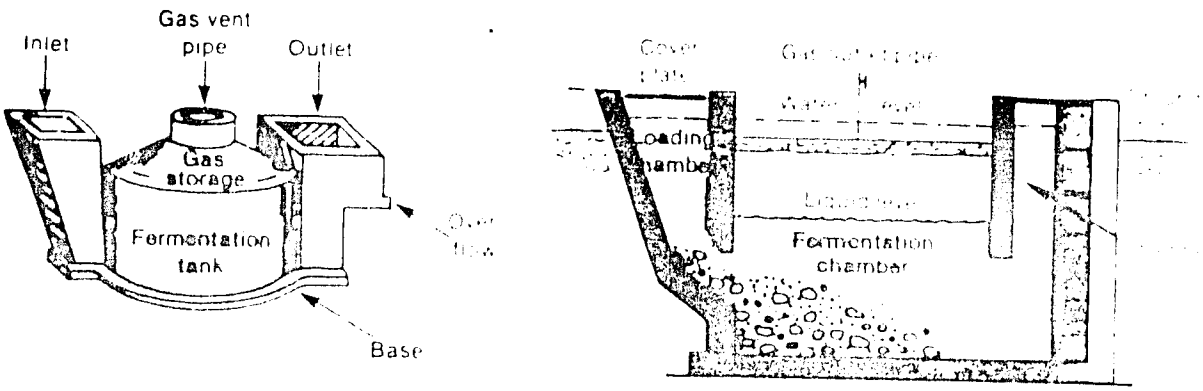
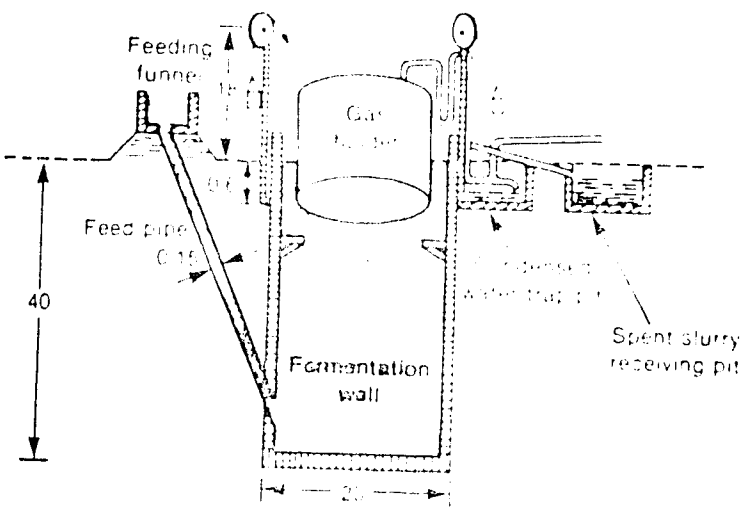


Diagram of a Gobar Gas Plant (Indian)



All dimensions in meters

Single-Tank Complete Mixed Digester

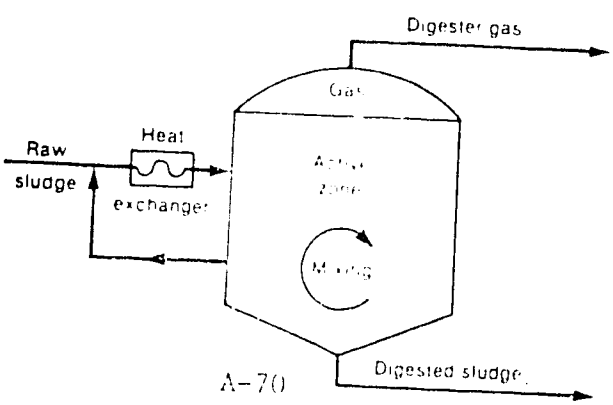
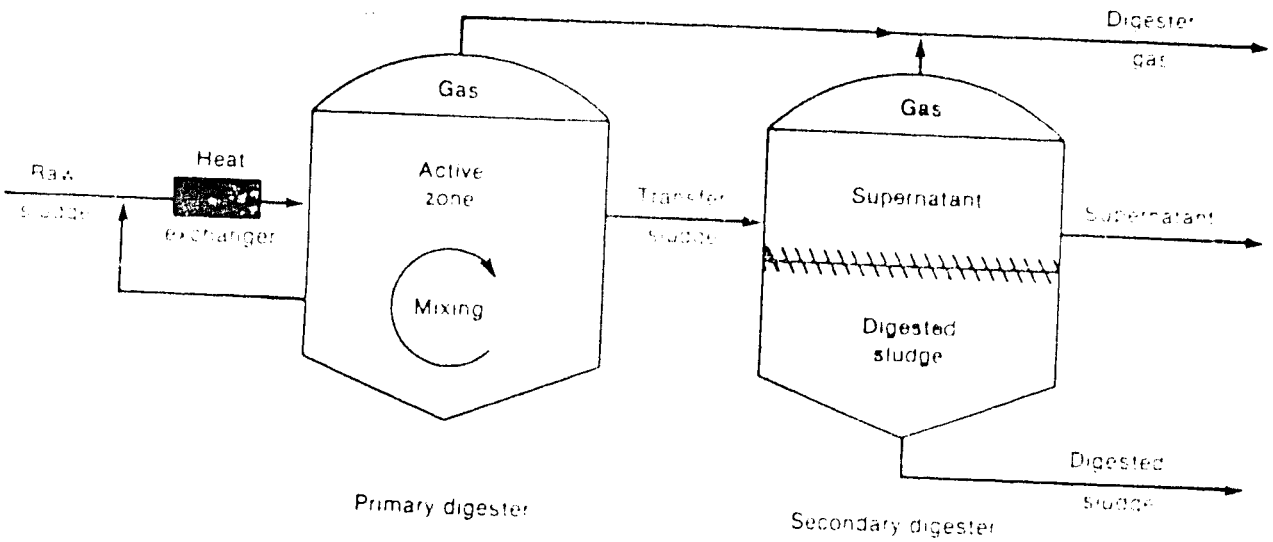
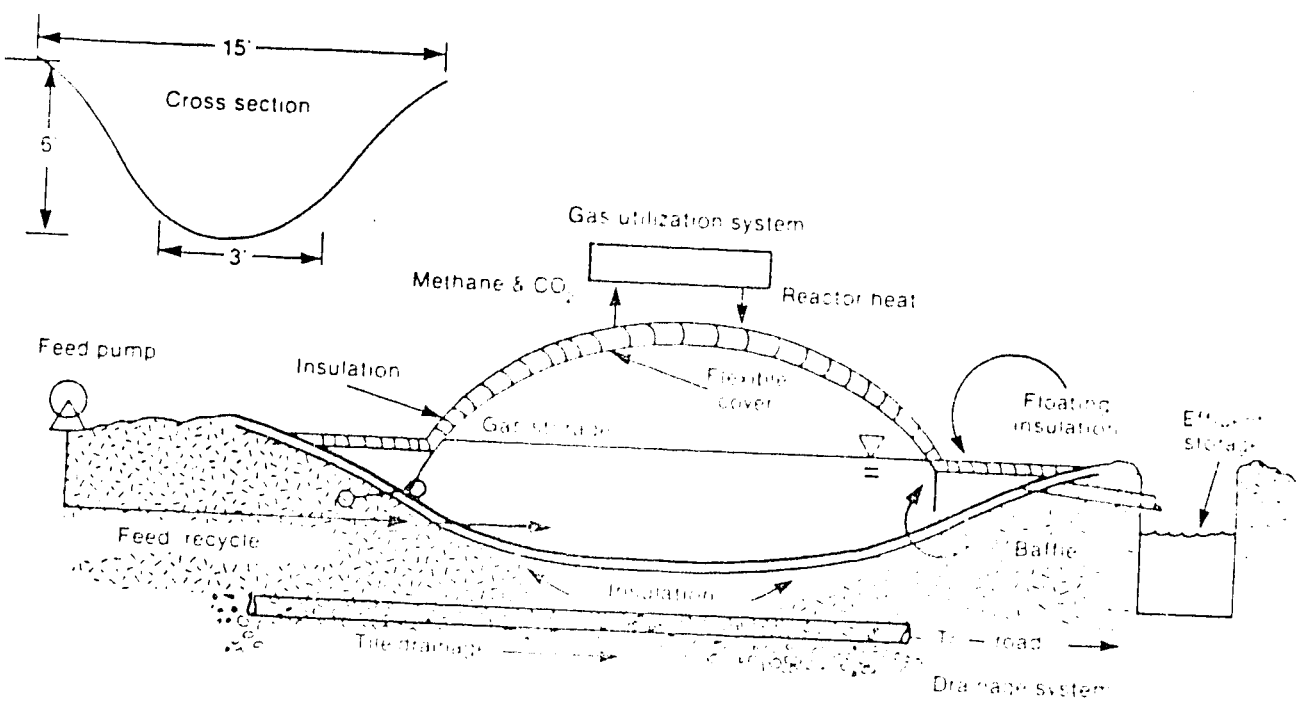


EXHIBIT 4-31 (cont'd)
ANAEROBIC DIGESTER DESIGNS (Cont'd)

Two-Stage Digester



Plug Flow Digestion System



base available to Egypt. As this exhibit indicates, the largest single biomass energy resource is agricultural residues -- approximately 20 million tons annually. The principal residues are those from cotton, sorghum, maize, sugarcane, peanuts and seasame.

EXHIBIT A.32 ANNUAL BIOMASS RESOURCES IN EGYPT

Resources	Quantity on Dry Basis, Ton Potential	Quantity on Dry Basis, Ton Utilized as Energy*	Energy[1] Content 10^{15}	Conversion Efficiency %	Net Energy Output[2] 10^{15}J
Agricultural Residues	$20x10^6$	$10x10^6$	200	8	16
Animal Excreta	$3x10^6$	$1.5x10^6$	17	8	1.4
Animal Power			96	10	10
Municipal Refuse	$2x10^6$	-	27		-
Sewage Sludge	$250x10^6$	-	29		-

* The rest is used as animal fodder and organic fertilizer.
1 = Supply; 2 = End Use

The two primary uses of the Egyptian resource base include direct burning of agricultural residues and dung cakes. Direct burning of biomass (which is only about 10 percent efficient) completely destroys the organic matter and nutrients available in the feed. Conversely, anaerobic digestion produces a residue which can be used to meet increasing demand for fertilizer and soil conditioners while also providing energy. This asset is extremely important in this region of decreasing agricultural productivity and where the present deficit in farm yard manure is more than 80 million tons per year. The use of agricultural residues for anaerobic digestion is feasible then, if combined with an active soil conservation effort. The combined energy value of agricultural residues and animal wastes in Egypt is estimated at 200 to $300x10^{15}$ J annually.

A.5.4 Market Readiness

The recent decline in the price of petroleum has not changed demand for biomass energy because, for most countries, there has not been a net decline in price. This is because the devaluation of currencies against the strong U.S. dollar has not permitted a cost reduction to be realized by countries that must buy U.S. dollars to pay for their inputs of petroleum.

Crop residues currently supply approximately one-third of the total energy consumed in Egypt. Animal wastes provide about 8 percent of the energy consumed in cooking applications. The potential energy market in Egypt consists of some 4,000 rural farm communities, encompassing about one-half of the country's

population. Digesters can often be adapted to specific conditions and end uses and implemented using locally available materials and labor. Although much of the current energy market involves large scale operations, there is considerable interest in efficient, small scale systems and there have been technical breakthroughs in the development of low-cost digesters in countries as diverse as China, Tanzania and the U.S. A market for large scale anaerobic digester systems that utilize municipal sewage is also available. This is a currently untapped market in Egypt.

According to the Egyptian national strategy, an attempt will be made to establish 400,000 digestion units by the year 2000, including 25,000 large-scale units. In constructing these units, the constraints of lack of space for digester installation and the insufficient number of animals owned by a large number of rural families will be taken into consideration. It is estimated that 6 percent of the total rural energy needs and a significant portion of fertilizer requirements can be met with this program.

Approximately 15 million liters of ethyl alcohol are produced annually by industrial fermentation of molasses produced in the sugar industry in Egypt. However, most of this is not utilized as fuel. The construction and operation of ethanol production plants is also relatively sophisticated in terms of control and especially sterilization.

A.5.5 Economic Viability

Since transporting wastes long distances is very costly, the most economic use of digesters involves on-farm systems using animal manure and agricultural wastes available on-site and urban systems using sewage. The best feedstocks are animal manure, municipal sewage, aquatics and various processing wastes. The supply of animal manure and human waste are currently the largest. Where large concentrations of agricultural residues exist, it may be feasible also to digest these.

On the average, 15 percent of the energy produced is used to heat the waste entering the digester and for the other operating requirements, e.g., pumping. Removal of the carbon dioxide and sale of the methane gas to natural gas pipelines is not feasible in small operations because: (1) gas pipelines are often not readily accessible, (2) the cost of carbon dioxide removal equipment is high, and (3) revenues from gas sales would probably be relatively low. In very large systems, production of pipeline quality gas may be feasible.

In most on-farm systems, digester energy output is sufficient to meet the energy needs of livestock operation and, in about 50 percent of the cases, also meet the farmers' home energy needs and possibly allow for net export of electricity. The most economically attractive operations are relatively large poultry, dairy, beef or swine operations (enabling economy of scale) which are relatively energy intensive (enabling the displacement of large quantities of energy bought at retail prices).

Production of electricity from small, family-size units is not economically attractive, whereas larger systems in the 10 to 100 kW range may be able to produce electric power economically. Using a larger city/village-size system also saves land which can then be used for productive purposes. The product gas can also be used to meet heating and cooking needs of the city or village.

Besides the potential for economic production of fuel and possibly electricity, digestion produces an effluent which can be used as a soil conditioner or fertilizer and as an animal feed in some cases. The valuation of the effluent is very important in assessing economic feasibility. In fact, the digested material has a higher value as fertilizer than the equivalent amount of farm yard manure. Also, nutrients which would be lost if the biomass was directly burned are recycled to the land. Furthermore, there are social benefits, such as improved health and hygiene, resulting from the anaerobic digestion of manure and sewage which should be considered in determining economic viability of such systems.

As Exhibit A.33 illustrates, the production of biogas from animal manure is quite competitive. From this table the following approximate cost ranking of the various bio-energy technologies can be derived:

increasing cost ↓

- Wood (other woody matter) to steam
- Wood (other wood matter) to chars and oil, by pyrolysis
- Biogas from animal manures
- Wood-based gasification processes
- Biogas from straws, cellulosic matter
- Electricity generation from wood
- Ethanol production from sugars
- Ethanol production from cellulose

Exhibit A.34 presents cost comparisons between selected bio-fuels and conventional fuels in various countries.

A.5.6 Industry Status

The industry varies greatly worldwide as patterns of use vary widely. Some countries have technical expertise in virtually every aspect of biomass production and conversion to energy. Useage in developing countries consists largely of gathering wood by hand for cooking and heating applications. It is estimated that about 1 billion people still do not have adequate supplies of fuelwood which prevents many small businesses and industries in developing countries from initiating more efficient biomass energy technologies.

The anaerobic digestion process is well known as it is often used in typical waste water treatment plants to stabilize sludge. Because the process uses simple equipment and requires little control, anaerobic digesters are very attractive. Private sector prospects are improving because of new reactor designs. It is predicted that in the next few years, commercially competitive digesters will be available for use on farms and feedlots, in food processing

EXHIBIT A.33

ESTIMATES FOR BIOMASS FUEL COSTS
(in 1977 US Dollars)

Process	Cost ($/GJ)
WOOD TO OIL via CATALYTIC LIQUEFACTION	5.1
WOOD TO METHANOL via GASIFICATION (OXYGEN BLOWN)*	7.3 - 9.4
AMMONIA FROM WOOD via GASIFICATION (OXYGEN BLOWN)*	8.5 -17.9
SNG PRODUCTION FROM WOOD via GASIFICATION (OXYGEN BLOWN)*	6.1 - 7.5
STEAM BY COMBUSTION OF WOOD	2.8 - 3.2
ELECTRICITY BY COMBUSTION OF WOOD	15.5 -17.7
BIOGAS FROM ANIMAL MANURE BY ANAEROBIC DIGESTION	3.8 - 8.5
SNG (METHANE) BY ANAEROBIC DIGESTION**	5.6 -13.7
BIOGAS FROM WHEAT STRAW BY ANAEROBIC DIGESTION	12.6 -22.5
ETHANOL FROM WHEAT STRAW***	50
ETHANOL FROM SUGAR CANE BY FERMENTATION	30
OIL & CHAR FROM WOOD BY PYROLYSIS	2.6 - 3.2
BIOGAS FROM KELP (SEAWEED) BY ANAEROBIC DIGESTION	19.6 -21.1
ETHANOL FROM ALGAE****	18.0 -25.5
ETHANOL FROM CORN STOVER***	18.9 -41.4

Notes:

* as opposed to air-blown gasification
** including the cost of separating CO_2 from the biogas
*** by enzymatic hydrolysis, followed by fermentation of sugars
**** by chemical (acid) hydrolysis, followed by fermentation.

The data refer to US studies at unspecified scales of operation; assumptions in deriving production costs are not known. The data should be used with circumspection and for comparison purposes only.

EXHIBIT A.[illegible]

ESTIMATED BIOMASS ENERGY AND
CONTEMPORARY REFERENCE COSTS

Country	Product	Cost ($/GJ)
Brazil (1977)	Ethanol	16.1
	Gasoline	12.3
Australia (1975)	Ethanol	16.7
	Ethanol (industrial)	18.4
Canada	Methanol (Wood)	4.2 - 9.7
New Zealand	Biogas	3.5 - 5.6
	Natural Gas (prod)	1.1
	Coal Gas (prod)	6.3
Upper Volta	Fuelwood (plantation)	25
	Kerosene	36
	Butane	31
Tanzania	Biogas	3.3
	Electricity	31.4
USA	Methanol	8.0 - 15.1
	Ethanol	14.2 - 34.1
	Medium BTU Gas	4.5 - 7
	S.N.G.	4.5 - 6.9
	Ammonia	5.5 - 10.8
	Fuel Oil	3.4 - 7.5
	Electricity	8.3 - 38.9

Approximate Reference Costs:

S.N.G.	2.8 - 4.7
Fuel Oil	2.8
Ethanol	19
Medium BTU Gas	2.8 - 4.7
Electricity	8.3 -16.6

plants, in pulp and paper mills, and in chemical manufacturing plants. At present, most systems digest manures. However, custom-designed digestion systems ranging from small to large scale are also commercially available for handling agricultural wastes, sewage and food processing wastes; some of these systems are combined with organic composting systems. China has demonstrated the use of village-size units with more than 7 million units now operating.

A remaining problem in the commercial development of anaerobic digesters is the lack of long-term, detailed and reliable economic and operating data for use in critical analyses and digester design, along with the low conversion efficiencies often associated with the process. There are, however, existing plants that are at least ten times as efficient in terms of biogas production rates as those often used in the developing countries.

A.5.7 Current R&D Thrust for Technology

The focus of biochemical conversion R&D activities in the U.S. are being directed toward the digestion of agricultural residues that are lignocellulosic and difficult to digest by other biochemical means. Pretreatment of these feedstocks, anaerobic bacteria strain selection, and nutritional factors that may improve the methane-producing capability of the cultures are being examined. The microbiology and biochemistry of digestion cultures and the genetic manipulation of bacteria in the methane production cycle are also being examined.

Feasibility of constructing biomass energy-producing facilities are also being studied. The issues being addressed include the feasibility of specific biomass energy technologies, biomass resource assessment and availability, financing alternatives, and the ability to construct and operate a facility producing biomass energy in an environmentally acceptable manner.

Other R&D areas include short-rotation woody crops and other silvicultural studies, herbaceous crops and aquatic species research, thermochemical and photobiological conversion research, and environmental studies.

A.5.8 Relevant Experience in Egypt Using Biomass Technologies

Most Egyptian R&D in the area of biomass energy emphasizes biogas production although research on improving design and efficiency of woodstoves and the development of small gasifiers is also underway. The most crucial biogas R&D involves the development of low-cost digester designs.

A national demonstration project for the development and application of village-scale digesters has been undertaken by the National Research Center (NRC) since 1979. At present there are 45 field demonstrations, most of which are household units, along with 4 larger-scale units constructed in conjuction with livestock operations. Both laboratory and pilot scale testing involving modified Chinese and Indian digester designs are being conducted utilizing cattle manure, agricultural residues and water hyacinth. The goal of this research is to demonstrate that appropriate biogas technology is technically, socially, and economically feasible in rural areas of Egypt. A number of digesters based on the Indian and Chinese designs have been installed in Egypt. Exhibit A.35 represents the details of these digesters.

EXHIBIT A.35

PRESENT BIOGAS UNITS IN EGYPT

No.	Executing Agency	Site	System Design	Size m^3	Date of Construction	Status
1	F/A Fayoum	Fayyoum	Chinese	10	1978	N/O
2	F/A Fayoum	Abu Gandeer	Chinese	10	1980	Irreg.
3	ARC	Moshtuhor	Chinese	45	1980	Irreg.
4	ARC	Moshtuhor	Indian	10	1980	Oper.
5	ARC	Moshtuhor	Indian	6	1980	Oper.
6	ARC	Moshtuhor	Indian	38	1981	Oper.
7	ARC	Moshtuhor	Indian	8	1980	Oper.
8	ARC	Toukh	Indian	8	1981	Oper.
9	ARC	Toukh	Indian	7	1981	Oper.
10	ARC	Toukh	Indian	8	1981	Oper.
11	ARC	Embaba	Chinese	10	1981	Oper.
12	ARC	Embaba	Indian	20	1981	Oper.
13	ARC	Embaba	Indian	17	1981	Oper.
14	ARC	Embaba	Indian	10	1981	Oper.
15	F/A Alexandria	Embaba	Indian	8	1981	U/C
16	Owner	Beheira	Indian	8	1981	U/C
17	NRC	Beheira	Chinese	10	1979	N/O
18	NRC	Beheira	Chinese	6	1980	Worked 8 mos.
19	NRC	Beheira	Pressurized Indian	7	1981	Oper.
20	NRC	El-Menawat	Modified-Indian	10	1981	Oper.
21	NRC	El-Menawat	Modified-Chinese	10	1981	Oper.
22	NRC	Omar Makram	Modified-Indian	8	1982	Oper.
23	NRC	Omar Makram	Modified-Indian	6	1982	Oper.
24	NRC	Omar Makram	Modified-Chinese	10	1982	Oper.

The Faculties of Agriculture in Fayoum, Minia and Assuit are currently conducting research, in conjuction with the Faculty of Engineering, Cairo University, involving an integrated renewable energy system which includes wind, solar and biogas energies.

In other research activities, anaerobic digestion of mixtures of cow dung, sewage and agricultural wastes at different ratios, organic loadings and temperatures are being examined. The effects of pre-composting, digestion, and post-composting on the survival of bacterial pollution indicators and pathogens are also being investigated. Since most digesters operate at below 10 percent solids, R&D on high-loading digesters and the use of recycle is also being undertaken.

A.5.9 Worldwide Experience Using Biogas Technology

During the past five years, significant advances on biogas production technologies have been made. Many of these developments pertain primarily to large-scale, municipal-type digesters found in urban areas. However, developing countries have taken a special interest in biogas production since the countries are largely rural and thus often have abundant animal and crop wastes available for digestion. One of the most extensive biogas programs is that of India. Thirty years of R&D has resulted in an accumulation of useful information and data, especially regarding digestion of cow manure. Several institutions have played a major role in this program: Indian Agricultural Research Institute, New Delhi; the Khadi and Village Industries Commission (KVIC), Bombay; the Gobar Gas Research Station, Ajitmal; and the Planning Research and Action Institute, Lucknow. Biogas plant designs published by KVIC utilize concrete tanks and inlet and outlet basins, with floating gas holders. These single-family units have no pumps, motors, mixing devices or other moving parts and digestion occurs at ambient temperatures.

Also operating in India, is a larger-scale plant managed by the Bharatya Agro Industries Foundation that produces 340 cu.m/day using dung from a cattle-breeding operation. A community plant has also been installed in the village of Fatah-Singh-Kapura by the Gobar Gas Research Station. The plant operates successfully on dung supplied by the villages, providing cooking gas, village lighting, water pumping and grain milling. Several other community biogas plants are being installed throughout India since these large-scale community systems have potential of being economically advantageous.

The Organization of Rural Development in the Republic of Korea has installed 25,000 digesters. However, severe winters and a non-cattle-based economy have adversely affected this program. A major campaign was conducted from 1969-1976 that encouraged the construction of biogas plants that digest both animal and human wastes.

Growing interest in Pakistan has resulted in the construction of approximately 100 biogas plants. Low winter temperatures and the high cost of imported steel for fabrication of gas-holders has generally restricted the program. The Appropriate Technology Development Organization of Pakistan has recently undertaken design and construction work on 10 cu.m capacity, fixed gas-holder digesters based on Chinese technology with an associated cost of about $590 (1976 price).

There also is an increasing interest in biogas systems in the Philippines, especially with respect to pollution control and the associated public health benefits. The National Institute of Science and Technology has installed units, including 48 digesters (22 cu.m each) at an integrated agro-industrial complex of 7,500 hogs. The resulting gas is used as fuel for canning, rendering, cooking, electricity generation and deep-well pumping.

Biogas utilization in Thailand has increased rapidly over the past several years with 225 units now operating. Plans call for the installation of 50 digesters every year. Plants have also been promoted by the Agricultural Economic Department, the Sanitation Division of the Health Department and the Applied Scientific Research Corporation. The majority of systems presently focus on waste treatment rather than energy production.

Although Indonesia has only 12 operating biogas plants at present, numerous experiments are undergoing evaluation with respect to reduced construction costs.

One of the most extensive programs is that of the People's Republic of China, with the installation of seven million plants. The destruction of bacteria contained in the waste is stressed so that the digester residue can be safely applied to crops as fertilizer.

At the end of 1984, over 50 on-farm biogas systems were operating in the U.S. and nine were operating in Canada. Most of these systems utilize cattle manure and integrated farm systems are growing in popularity. In Europe, with typically higher population densities, 500 on-farm systems were operating at the close of 1984.

By 1984, there were a large number of biomass-fueled electricity producing power plants in the U.S. that were either operating, under construction or in the planning stage. A total of nearly 200 power plants generating almost 3000 MW are expected to be on-line in the near future. Nearly 60 percent of these plants utilized agricultural residues, animal manure, MSW, landfill methane or sewage methane as the energy source. Exhibits A.36 and A.37 show the status of these plants.

EXHIBIT A.36

STATUS OF BIOMASS-FUELED SMALL POWER PRODUCTION, COGENERATION AND MUNICIPAL FACILITIES IN THE U.S. IN 1984

in Kilowatts (Number of Facilities)

FUEL	PLANNED	UNDER CONSTRUCTION	OPERATING	TOTAL
Wood Waste	238,505 KW (17)	115,630 KW (10)	850,217 KW (42)	1,204,352 KW (69)
Agricultural Residues	102,700 KW (3)	56,000 KW (3)	61,050 KW (7)	219,750 KW (13)
Animal Manure	--	10 KW (13)	925 KW (2)	935 KW (3)
SUBTOTAL	341,205 KW (20)	171,640 KW (14)	896,192 KW (50)	1,409,037 KW (84)
Municipal Solid Waste	640,450 KW (24)	286,500 KW (12)	283,610 KW (12)	1,210,560 KW (48)
Landfill Methane	39,550 KW (15)	29,650 KW (14)	20,045 KW (12)	89,245 KW (41)
Sewage Methane	164 KW (2)	2,700 KW (1)	250 KW (1)	3,114 KW (4)
SUBTOTAL	680,164 KW (41)	318,850 KW (27)	303,905 KW (25)	1,302,919 KW (93)
TOTAL	1,021,369 KW (61)	490,490 KW (41)	1,216,097 KW (76)	2,727,956 KW (178)

EXHIBIT A.37

STATUS OF UTILITIES USING BIOFUELS

in Kilowatts (Number of Facilities)

FUEL	PLANNED	UNDER CONSTRUCTION	OPERATING	TOTAL
Wood Waste	50,000 KW (1)	--	130,725 KW (8)	180,725 KW (9)
Agricultural Residues	--	--	22,500 KW (2)	22,500 KW (2)
Animal Manure	--	--	--	--
SUBTOTAL	50,000 KW (1)	--	153,225 KW (10)	203,225 KW (11)
Municipal Solid Waste	--	18,400 KW (2)	15,400 KW (3)	33,800 KW (5)
Landfill Methane	--	--	--	--
Sewage Methane	--	--	7,970 KW (2)	7,970 KW (2)
SUBTOTAL	--	18,400 KW (2)	23,370 KW (5)	41,770 KW (7)
TOTAL	50,000 KW (1)	18,400 KW (2)	176,595 KW (15)	244,995 KW (18)

A.6 Solar Ponds

A.6.1 Operating Characteristics

Solar ponds can be used to collect solar radiation and store it as heat for a variety of low temperature applications, including space heating and cooling, hot water heating, industrial process heat, crop drying, and water desalination and electricity generation.

The solar pond can be a cost effective energy alternative in areas of high insolation where land, salt and water are readily and inexpensively available. Solar ponds have technical advantages as well. Their built-in storage capability eliminates the daily fluctuations in energy supply associated with other solar energy technologies. In addition, the solar pond is the only solar technology designed to provide low temperature (below 95°C) thermal energy on a large scale. This temperature is sufficient to power an organic Rankine cycle engine to produce electricity.

A.6.2 Technology Description

A schematic of a typical salt-gradient solar pond is shown in Exhibit A.38. Pond area can range from several hundred square meters to several square kilometers. Pond depth usually varies between three and five meters, depending on the location and intended application. Pond storage capacity is dependent upon depth and can be very large. A pond is formed by excavation or embankment, or a combination thereof. The sides and bottom of a pond may or may not be lined with a plastic membrane or other impermeable liner. This is dependent upon the underlying soil conditions and the extent to which the surrounding environment requires protection against possible salt contamination.

As reflected by the name, a salt-gradient solar pond is filled with brine made of one or several salts, with the salt concentration varying from a few percent (by weight) at the surface to over twenty percent at the bottom. A typical salinity profile is also, depicted in Exhibit A.38. Normally, the surface zone (0.15 - 0.30 m) and the bottom zone (1.5 - 3.5 m) have uniform salinity, and the gradient zone (1.0 -1.5 m) has a salt concentration that increases with depth.

As solar radiation impinges on the pond surface, part of it is reflected and the remainder penetrates into and is absorbed by the pond. In an ordinary pond, when the water absorbs the incident solar radiation, its temperature increases and its density decreases. The water near the surface is readily cooled as heat is dissipated to the atmosphere. The warmer, lighter water at the bottom will then rise to the surface through natural convection. At the surface, the heat contained in the warmer water is again transferred to the ambient air. Thus an ordinary pond cannot store the solar energy that it absorbs.

In a salt-gradient pond, due to the presence of the constructed salinity gradient, natural convection is suppressed since warmer water in the lower layer has a higher salt content and, therefore, remains more dense (heavier) than water at the upper layer. In addition, the salt-gradient zone prohibits long-wave reradiation (as water is opaque to infrared radiation), and offers an effective conduction barrier (because the thermal conductivitity of water is relatively low and the gradient zone is sufficiently thick). Consequently, the

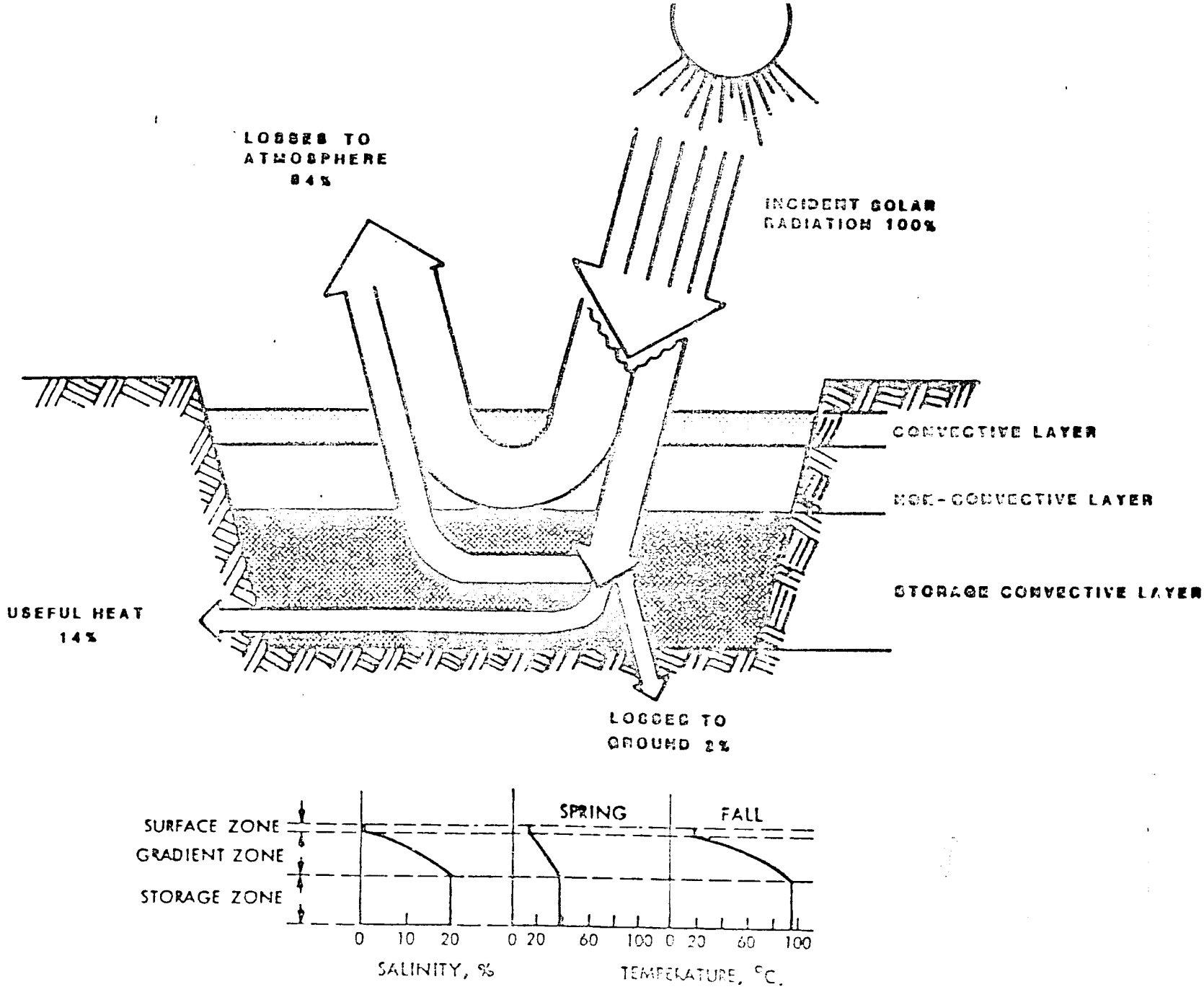


EXHIBIT A-38
SCHEMATIC OF A SALT-GRADIENT SOLAR POND WITH TYPICAL SALINITY AND TEMPERATURE PROFILE

salt-gradient zone enables the pond to trap heat in the storage zone, where the temperature is allowed to increase steadily to a level substanially above ambient. Typically, temperature in a salt-gradient pond increases with depth, varying from slightly above ambient in the surface zone to 80-100°C in the storage zone.

Both the surface and storage zone are convective and the convecting currents in the surface zone are caused by wind, evaporation, precipitation, diurnal heating and cooling, and other physical factors. The convecting currents in the storage zone, on the other hand, are induced by the buoyancy of heated bottom brine, the disturbance from heat extraction, etc. The gradient zone is stratified and nonconvective. It separates the two convective zones above and below, and prevents full-depth natural convection from occurring, thereby serving its vital insulating function.

The heat trapped in the storage zone can be extracted by means of in-pond or out-of-pond heat exchangers for both electric and thermal applications. Hot brine is withdrawn near the upper portion of the storage zone and circulated through an out-of pond heat exchanger where a working fluid receives heat from the brine to perform its designed duties. The cold brine is then returned to the pond near the bottom of the storage zone, usually on the opposite end from hot-brine withdrawl. Thermal energy extracted from the pond can be used to generate electricity or support a variety of thermal applications such as residential and commercial building space and water heating, industrial and agricultural process heating, and desalination.

The primary quantitites to be measured during the operation of a solar pond are temperature, salinity, water clarity, and thermal output. Temperature measurements are generally made by means of permanently installed thermocouples mounted in the pond and buried beneath the pond. Salinity, which changes slowly, needs to be measured less frequently at the surface and bottom of the pond. A complete salinity profile is not usually required unless operating difficulties have been observed.

Heat output of all solar thermal systems decrease as the difference between ambient and collector temperature increase and solar pond technology is no exception to this general rule. It does however differ markedly from other collectors in performance characteristics. One reason for this is that the optimum gradient zone depth, i.e., the system configuration, is different for each set of values of radiation input, heat output, and working temperature.

The most important difference between the operation of non-corrosive solar ponds and the operation of other collectors is that the solar ponds are continuously open to the environment. A given solar pond thus collects the same fraction of the incident radiation whatever the ambient temperature and solar radiation level. This fact tends to compensate for the rather low peak efficiency of solar ponds that results from absorption of the infrared portion of the spectrum near the surface. For some applications the energy per unit area provided by solar ponds may even exceed that provided by the usual flat plate collectors.

In general, theoretically 84 percent of the incident radiation on the solar pond surface escapes to the atmosphere. Out of the 16 percent balance of incident radiation collected by the solar pond, about 2 percent is lost to the ground. Thus, only approximately 14 percent of the incident radiation is

actually contributing towards the generation of heat. Actual measured collection data on experimental ponds have shown 9-12 percent pond efficiency.

It is difficult to predict the specific maintenance requirements of a normal salt-gradient solar pond. The only successfully operated ponds in the U.S. are research ponds which have not been permitted to operate in a routine energy supplying mode for extended periods of time. Salinity control, however, is a known routine maintenance requirement. Because the salt gradually diffuses upward, the salinity gradient will occasionally need adjustment through surface washing and the addition of salt to the bottom layer of the pond. For electricity generation applications, turbine/generators will require normal maintenance and repair. A major maintenance problem that has been encountered in existing ponds is leakage through the artificial liner. Such leakages are difficult to detect, difficult to locate, and difficult to repair. Avoidance of the problem by the careful selection of liners and the careful preparation of the pond bottom is the best method of addressing this problem.

Other factors which require control during pond operation are wind effects and the growth of organisms that absorb sunlight. Excessive wind can cause surface mixing and rapidly increase the solar pond upper zone thickness, thus decreasing the performance of the pond. High pond performance requires that the upper surface zone of the solar pond be maintained at the thinnest possible value (approximately 10 cm). Aerodynamic and hydrodynamic experiments have been undertaken to develop devices and/or techniques to minimize suface wave formation. Biological control is a better known procedure. Adding copper sulfate in conjunction with hydrochloric acid, or adding chlorine and bromine may suppress the growth of the unwanted light absorbing organisms in the surface zone.

A.6.3 Resource Availability

Solar energy availability in Egypt was described in Section A.2.3.

A.6.4 Market Readiness

The thermal energy of a solar pond can be used in various industrial, agricultural and residential applications. Several experimental and small scale solar ponds have demonstrated and established the feasibility for these potential applications.

Five major applications, namely space heating for residential, commercial and institutional buildings; industrial process heat; agricultural process heat; electric power; and desalination were identified as most promising in a solar pond resource assessment study conducted during the early 1980's by U.S. Jet Propulsion Laboratory.

In the residential, commercial and institutional buildings sector, solar ponds can provide thermal energy at sufficiently high temperatures for space heating and cooling and domestic water heating. The need for thermal energy in domestic water heating exists in practically every region. The availability of low cost land near buildings is a limiting factor, as vacant land is scarce and costly in most developed areas.

The need for thermal energy below 95°C is very high for industrial

process heat applications. Food, furniture, paper, chemicals, leather and primary metal processing are among the major industries to which solar ponds can be suitable energy source. Solar ponds can supply thermal energy to a number of agricultural processes: crop drying, livestock brooding, livestock waste disposal, space and water heating for livestock, farmhouse space and water heating, and irrigation pumping.

Solar pond applications in the electric power sector will be constructed mostly on a large scale (hundreds or thousands of acres in area) and at sites where the essential natural resources are available at low or no cost.

Solar ponds can also provide energy for desalination of water as they are capable of providing thermal energy to the distillation/desalination process and electrical or mechanical power to the reverse osmosis and electrodialysis processes.

A.6.5 Economic Viability

A number of factors must be considered when evaluating the technical and economic feasibility of solar ponds. They include:

1. Insolation - Because the pond is horizontal and cannot be tilted, pond sites should be located not much more than +/- 40° latitude. For example, insolation on a horizontal surface at 30° latitude is about seven percent less than at 22° N latitude (Egypt-Sudan border).

2. Land - Because the energy density of solar ponds is relatively low, land must be acquired inexpensively for ponds to retain economic viability.

3. Water - Ponds must be located where water is readily available to make up for evaporative losses.

4. Salt - A source of salt or brine must be available at a reasonable cost.

5. Aquifers - The pond should not be located near underground aquifers. Aquifers can cause both structural and thermal problems. In addition, fresh aquifers may become contaminated with salt.

6. Geophysical - The site should be fairly flat, and the underlying earth structure should be free of stresses, strains and fissures.

7. Size - Large solar ponds provide energy at a lower unit cost than small ponds. The smallest practical size for salt-gradient solar ponds varies with location and application, but is approximately 1 hectare for thermal applications and several hectares for electricity generation.

The cost of installing a solar pond varies dramatically with the cost of land, water and salt, and with the depth and size of the pond. Estimates vary from as low as $\$4/m^2$ to as high as $\$70/m^2$ for installations in the U.S. The $\$4/m^2$ estimate assumes an unlined pond with free land, water and salt, and excludes the cost of heat exchangers and turbine/generators - leaving only the cost of excavation and filling. Artificial liners will add approximately $\$10/m^2$.

311

If salt is available on site, the cost is minimal. However if it must be purchased, it can add as much as $\$25/m^2$. Water rarely costs in excess of $35¢/m^3$, and thus, adds less than $\$1/m^2$ of surface area to the cost of a 3 meter deep pond.

Because of the great variance in cost, economically attractive sites must have natural soil liners, inexpensive salt, and enough land to construct a large pond. Larger ponds are more cost effective because of economies of scale in the construction and operation of a pond. Also, perimeter losses become less significant as the size of the pond is increased. Since these cost factors are highly site specific, cost effective sites are often not near an energy consuming facility. Thus, electricity generation is an attractive alternative, as it is an efficient means of transmitting energy to the desired location.

A.6.6 Industry Status

Solar pond research and development over the past two decades has established the viability of the solar pond technology concept. Several experimental and demonstration solar pond projects were undertaken throughout the world during this period. However, only recently have solar ponds become economically viable. There are several small- and few medium-sized establishements capable of manufacturing and supplying solar pond components and subsystems.

About two dozen solar ponds, all under two acres in surface area, have been constructed and operated around the world. Pond storage temperature varies from a low of about 30°C in winter to a high of 109°C in summer. Boiling can be achieved in high-insolation locations and can be avoided by scheduled heat extraction. A variety of thermal applications have been successfully demonstrated, including pool heating, grain drying, process water heating, space and greenhouse heating, etc. The Yavne and Ein Bokek ponds in Israel have established the feasibility of peaking and baseload electric power generation. Using Rankine cycle, solar pond thermal efficiency on the order of 10 to 15 percent, and thermal-to-electrical conversion efficiency of 8 to 9 percent, have been demonstrated which are substantially below the 20 to 30 percent efficiency predicted by thermal calculations.

The solar pond industry in the U.S., during the past decade, has not been able to initiate any large scale solar pond projects. Recently, a major U.S. utility company has signed an agreement to build a 48 MWe solar pond facility by the end of 1987. This project will be initiated in 1985 and a 12 MWe solar pond unit (first of four 12 MWe units) operating as a Rankine cycle turbine generator will be installed. Several universities and research institutions are also involved in exploring better techniques to make solar ponds efficient and attractive.

A.6.7 Current R&D Thrusts

Salt-gradient solar pond research and development efforts have identified several major areas of technical uncertainties that can reduce the performance of a solar pond considerably. Current solar pond R&D efforts are addressing the following technical uncertainties:

- thickness of upper convecting zone;

317

- maintainable thickness of the nonconvecting zone;
- pond transmissivity;
- heat loss to the ground;
- maintenance requirements of the nonconvecting zone;
- heat extraction from the pond; and
- heat rejection options.

The thickness of the upper convecting zone has been recognized as having a significant impact on overall pond performance. The current state of knowledge is not sufficient to predict the thickness of the upper convecting zone.

The loss of heat from the lower convecting zone to the ground below the pond can have substantial impact on pond performance. No method of predicting the long-term thermal conductivity of the ground, the ultimate ground temperature, or the impact of thermal energy storage in the ground has been verified.

A.6.8 Relevant Experience in Egypt/Worldwide in Using Solar Pond Technology

Most of the existing experience regarding the salt-gradient solar pond technology is limited to construction and operation of few laboratory scale experimental solar ponds during past decade. There are two large-scale power generating solar pond plants in Israel which are capable of producing 150 kWe and 5MWe respectively. A large scale 48 MWe solar pond project is in its planning/design stage in the United States at present. Several other small scale experimental solar pond projects have been constructed and operated in the U.S. which have provided the industry and manufacturers with relevant experience. Egyptian experience in this technology has been limited to several small scale experiments at various Universities and Research Centers. There are other Arab and Asian countries with limited experience with the salt-gradient solar pond technology. Exhibit A.39 is a representative list of countries having activities in solar pond technology.

EXHIBIT A.39

COUNTRIES HAVING ACTIVITIES IN SOLAR POND TECHNOLOGY

COUNTRY	PROJECT	POWER OUTPUT	POWER SOURCE	START DATE	SPONSOR/ CLIENT
1. Israel	Solar Pond Electricity Station (Dead Sea)	150 kWe	Solar Pond	1980	Government
2. Israel	Solar Pond Electricity Station (Dead Sea)	5 MWe	Solar Pond	1984	Government
3. USA	Solar Pond Plant	48 MW	Solar Pond	1987 (planned)	Southern California Edison; ORMAT turbines
4. USA	Experimental Solar Ponds	-	Small Scale Solar Ponds	1974-82	Government and Laboratory scale University projects.

A.7 Municipal Solid Waste

A.7.1 Operating Characteristics

The conversion of municipal solid waste (MSW) to energy is a time-tested and well-developed concept. Several different types of technologies exist to recover energy and materials from MSW. The principal focus of this section is on MSW combustion technologies; Section A.5 discusses anaerobic digestion techniques.

MSW technologies can provide a range of outputs, depending upon the system and operational requirements. Power output can be high pressure steam or low pressure steam, to provide heat or mechanical power. Output can include electricity for process use or for sale to the electric grid.

Most of the MSW technologies discussed here are used to provide steam, which can provide heat or motive power. There are four major categories of MSW technologies available in the market. These are (1) mass incineration; (2) refuse derived fuel; (3) cogeneration; and (4) co-disposal. In general terms, the major differences these MSW conversion technologies concern:

1. the quantity and make-up of wastes handled;
2. capital and operating costs;
3. on-site energy requirements;
4. end products.

A.7.2 Technology Description

A.7.2.1 Mass Incineration

Mass incineration technologies are designed to burn raw, unprocessed waste. The mass burning system is a time-tested commercially developed system, in which waste is fed to the combustor by a hydraulic ram or gravity chute. There are four types of mass incineration systems: refractory-lined, waterwall, rotary combustor, and modular. The output from mass incineration systems is thermal energy, such as steam and/or recoverable waste. Systems can also be designed to provide electricity.

(a) Refractory Systems

The refractory-lined mass incineration system has a resistant coating, or refractory lining, in the combustion chamber that decreases heat transfer to areas outside the incinerator. This lining protects the outer shell from extreme temperature changes. The refractory-lined combustor does not recover energy in the combustion chamber. Hot combustion gases leave the chamber to an auxilliary heat exchanger or waste heat boiler, where the heat energy is recovered.

Refractory technologies require large volumes of combustion air to prevent furnace components from overheating. The major drawback of such a system is that these larger air volumes carry more particulate emissions. Control technologies for air pollution add considerably to the capital and operating cost of these systems.

The quality of the MSW burned affects both the design and required maintenance for a system. Higher quality MSW, which costs more to process, requires

315

less maintenance and a smaller combustor than a system using lower quality MSW.

(b) Waterwall Incinerator

The second mass incineration technology is the waterwall system. In the waterwall incinerator, the walls of the furnace are lined with tubes of circulating water. The water acts as a coolant and the heat transfer medium. The tubes are usually lined with a refractory coating to protect them from high temperature corrosion and erosion from air-entrained particles.

The waterwall incinerator requires less combustion air than a refractory system because the circulating water cools the furnace. The decrease in air requirements allows for a smaller incinerator and fewer emissions.

The heat recovery efficiency of a waterwall incinerator is usually higher than that of a refractory unit. The steam generated has higher temperature and and higher pressure, thus offering a broader range of potential industrial appplications.

As with refractory units, the quality of MSW burned affects both incinerator design and maintenance. The higher quality wastes require front end processing, but do not need the incinerator volume and maintenance that a system without pre-processing would require.

(c) Rotary Combustor System

The rotary combustor system is a waterwall system, in that the combustor is water-cooled, but with a major operational difference. In this system, the combustor, which is inclined, rotates. The advantages of this system over the waterwall system are that it has a higher efficiency and a lower maintenance cost. The higher efficiency can be attributed to more effective agitation in the combustion chamber from the rotation, resulting in more complete combustion and heat transfer. The lower maintenance cost is due to the absence of traveling grates and refractory linings.

The rotary combustor is generally more expensive than the waterwall incinerator of comparable size. It is best suited for larger systems, up to 300 tons per day (TPD) of input capacity.

(d) Modular Combustion Units

Modular Combustion Units (MCU) for mass incineration are pre-fabricated systems for use in small scale applications. For larger applications, up to 100 tons per day (TPD), multiple units can be used. The MCU has primary and secondary combustion chambers, with controlled air techniques for combustion of waste material.

The MCU's are shop-fabricated, including controls and instrumentation, and are typically placed on concrete foundations. A major advantage of these systems is the minimal installation and erection requirements. MCU's offer several advantages over other mass incineration systems. These systems are efficient and well suited for small scale applications; they have relatively short construction periods; there is a high level of redundency with multiple units; and there is flexibilty in sizing with multiple units.

36

A.7.2.2 Refuse Derived Fuel (RDF)

Refuse derived fuel (RDF) is processed MSW. The principal advantage of RDF over MSW is that it is more combustible, transportable, and homogeneous.

There are four types of RDF: fluff, densified, dust, and wet. Fluff RDF consists of small sized particles with a very low quantity of inert material. Densified RDF is fluff RDF mixed with binders, and then compressed. Dust RDF consists of fluff RDF mixed with embrittling agents, which is then reduced. Wet RDF is made by mixing in a wet pulper MSW and water to a slurry; non-pulpable material is removed; the pulped material is further separated and dried.

RDF is typically 50 percent to 75 percent (by weight) of incoming waste. RDF is produced from MSW through a series of processes including size segregation, size reduction and removal, and recovery of inert materials. The equipment required to process MSW into RDF depends upon the type of RDF being produced. The more processing involved, the greater the production costs.

There are two technologies capable of using RDF: co-fired boilers and dedicated boilers. Each of these systems has a smaller furnace and boiler size than mass incineration systems, due to the higher heat content of RDF. The maintenance costs associated with these systems tends to be lower than that of mass burning systems because of the higher quality of the refuse.

Co-fired systems use RDF to provide a portion of the energy input of a fossil-fuel-fired combustion system. Such systems use two fuels, RDF and a commercial fuel. Co-fired systems can produce high-temperature, high-pressure steam suitable for most industrial processes.

Dedicated boilers are designed and constructed to accept RDF as the primary fuel. The RDF dedicated boilers produce higher-temperature, higher-pressure steam than mass incineration systems. Co-fired systems, owing to their use of commercial fuels, produce higher-pressure higher-temperature steam than dedicated boilers.

A.7.2.3 Cogeneration

MSW cogeneration is the simultaneous production of thermal energy, such as process heat or steam, and electrical energy from the combustion of MSW. An MSW cogeneration system incorporates a turbine generator at the end of a waste-to-energy boiler.

In order to produce electricity, high-temperature, high-pressure steam is required to turn the turbine. Hence, refractory systems are not typically considered. The preferred systems for steam generation are the RDF and waterwall systems. Modular systems have also been used to provide steam for power generation.

The choice of a specific configuration for cogeneration can only be made on a plant-by-plant basis. This is due to specific requirements for thermal and electrical energy and other site specific characteristics.

In order to most effectively realize the advantages of cogeneration, an interconnection with the utility network can allow for the export of excess electrical

317

power. In addition, an interconnection would enable the cogenerator to purchase electrical power from the utility when the cogeneration system cannot meet total electric demand.

A.7.2.4 Co-Disposal

Co-disposal technologies are those that use an integrated approach to the disposal of MSW and sewage sludge. Co-disposal is designed to consolidate waste management at one site, which reduces landfill requirements, and saves energy. There are two approaches to co-disposal: thermal, and non-thermal. Non-thermal co-disposal relies on biological processes such as composting and anaerobic digestion. Anaerobic digestion was discussed in Section A.5. Thermal processes involve the combustion of MSW and sludge.

Three types of thermal co-disposal technologies will be discussed here: (1) RDF/sludge in a multiple hearth furnace; (2) RDF/sludge in a fluidized bed boiler; and (3) mass burning incineration.

An RDF/sludge multiple hearth furnace combusts both RDF and sludge. Sludge enters the top of a furnace and is slowly moved down a vertical stack of hearths by rabble arms. Hot gases from the combustion of RDF in the middle hearths of the furnace dry the downflowing sludge which is then combusted.

The incineration of RDF/sludge in a fluidized bed boiler combusts both RDF and sludge simultaneously. A fluidized bed boiler is a refractory-lined shell containing a bed of sand. Air is blown up through the bed, which becomes fluidized. RDF and sludge are then injected into the bed and combusted. Two advantages of fluidized bed systems are that the combustion temperatures are very high (760°-820°C), resulting in complete combustion, and emissions are low, being reduced by absorption in the bed.

Mass burning incinerators for co-disposal use energy produced from MSW to process sludge. The sludge may then be used for combustion or other purposes, such as soil conditioning or landfill cover. Mass burning co-disposal incinerators include refractory-lined systems, waterwall units, and modular units.

A.7.3 Resource Availability

Egypt has a population of 45 million people, with most of the population living along the Nile River. This high population density ensures that a sufficient quantity of MSW is available. The collection, transportation, and preparation of this waste will require an infrastructure that is either inadequate or not currently in place. The development of this infrastructure is a necessary prerequisite for MSW energy conversion in Egypt. In Egypt two cities are viable sources fo MSW: Cairo and Alexandria. The Cairo area generates about 4200 tons of MSW per day. It is estimated that 1500 tons per day are currently collected and recycled for other uses. The remaining 2,700 tons per day represent a significant resource which can be converted to energy.

The city of Alexandria generates approximately 1,700 tons of MSW per day, of which 700 tons per day are collected and recycled for other uses. Thus, there is a significant potential for energy from the remaining 1,000 tons per day.

317

The existing waste collection systems of both cities are inadequate. In Cairo, it is estimated tha 30 percent of the garbage generated is left on the streets. Larger truck fleets will be required in both cities to improve the collection of MSW as well as improve the viability of converting this waste to energy.

A.7.4 Market Readiness

The availability of MSW technologies in the market is dependent upon the state of development and degree of successful commercialization for each of the technology types. Most of the systems discussed here are in or beginning commercial operation.

Mass Incineration -- Mass incineration of MSW in refractory, modular, and waterwall systems is currently in commercial operation. These three technologies have been widely used in the United States, Europe and Japan. The rotary combustor system is a more recent development that has been in commercial operation in Japan and the United States since 1981.

RDF -- Both co-fired systems and dedicated RDF boilers have been in commercial operation since 1972 in the United States. More widespread use of RDF systems has occurred in Europe. Earlier systems were plagued with reliability problems. Systems built more recently have incorporated design changes to eliminate these problems.

Cogeneration -- MSW cogeneration technologies have been used in both Europe and the United States for over 30 years. Recent regulatory changes in the United States have encouraged cogeneration and contributed to accelerated development and increased use.

Co-disposal -- Co-disposal has been demonstrated and is commercially available in both the United States and Europe. The multiple hearth furnace has been used since the 1930's. The fluidized bed boiler has been in commercial operation in the United States since 1981. Mass burning co-disposal systems have been used in the United States since 1973.

A.7.5 Economic Viability

The cost of an MSW technology is dependent upon several factors, including: the technology type; the system size; the output; and the quality of refuse burned. A review of installed system capital costs in the United States clearly illustrates the range of costs for each of the technologies (see Exhibit A.40). It should be noted that some of these systems were installed as early as 1965, and that today's costs could be expected to be higher.

In general, modular systems tend to be less expensive than custom built systems. The economics of MSW systems are also dependent upon the level of MSW pre-processing. Pre-processed MSW does not require fuel processing systems to remove non-combustible material from the waste. Such systems tend to have lower capital equipment cost than systems using raw or unprocessed MSW.

The degree of pre-processing also impacts on system efficiency. Highly processed MSW has a higher heating value than raw waste, thus more usable energy

EXHIBIT A.40

SURVEY OF MSW TECHNOLOGY CAPITAL COSTS

Technology		Capital Cost - $1000's/TPD capacity
Mass Incineration		
- Refractory units		60 - 80
- Waterwall units		40 - 95
- Rotary combuster		60 - 80
- Modular		12 - 75
Refuse Derived Fuel		
- RDF co-firing		15 - 25
- RDF dedicated boiler		80 - 90
Cogeneration		
- Mass burning cogeneration		45 - 130
- RDF cogeneration		50 - 76
Co-Disposals		
- Modular		97 - 168
- Mass burning	MHF FBB Waterwall	16 - 136

Developed from information provided in City Currents, April 1984 (United States Conference of Mayors, Washington, DC)

can be obtained per ton of waste incinerated. MSW systems should not be evaluated on the basis of cost per ton of waste per day, but on the basis of cost per unit of usable energy. Thus, a for system of equal cost, a system which uses raw waste and requires separation systems to remove non-combustible waste, will tend to have a higher cost per unit of usable energy than a system using processed waste. The cost of obtaining processed MSW should include the costs of collecting and processing MSW.

Whether MSW technologies can compete with existing direct fired systems remains to be determined. Installed capital costs for these systems is dependent upon the technology, pre-processing equipment, system size, site specific requirements, and many other factors. In favorable circumstances MSW conversion systems can be installed for $20,000/TPD. Systems can easily cost $150,000/TPD and more. The economics of MSW technologies in Egypt can only be determined after site specific analyses.

A.7.6 Industry Status

Exhibit A.41 through A.44 list some of the manufacturers of MSW technologies. All of these manufacturers have produced systems that are in commercial operation. Many of the companies listed here are large and well-established, while others are relatively new businesses.

The larger companies (GE, Babcock & Wilcox, Combustion Engineering, among others) are international in scope with a broad range of products and services including maintenance and service contracts, and in some instances, financing.

A.7.7 Current R&D Thrusts for Technologies

MSW-to-energy conversion technologies have been in existence for over 50 years. The technological sophistication of these systems has increased dramatically over this time period, particularly in the last 15 years.

The combustion of MSW in large waterwall incinerators or in small scale modular systems are the most technologically developed technologies to date. Although these technologies have reached commercialization and others are emerging, there is still research being conducted for the purpose of minimizing emissions and improving system economics.

A.7.8 Relevant Experience in Egypt and Other Countries Using MSW

Internationally, there is a growing inventory of MSW conversion systems. The majority of these systems are in Europe, Japan, and the United States. As of 1983, there was 368 systems installed worldwide, of which 212 are European 85 are Japanese. Exhibit A.45 lists the systems by country.

The viability of MSW technologies in Egypt is dependent upon four factors: the public infrastructure; waste availability; industrial development; and experience. The success of an MSW technology program in Egypt is contingent upon the degree of development of each of these four factors.

The necessary public infrastructure for MSW technologies would include a

EXHIBIT A.41

MANUFACTURERS OF REFRACTORY AND WATERWALL
MASS INCINERATION SYSTEMS IN THE U.S.

- Combustion Engineering
  Windsor, CT
- Detroit Stoker Company
  Monroe, MI
- Consumat Systems, Inc.
  Richmond, VA
- Energy Systems, Inc.
  Hixson, TN
- Foster Wheeler Energy Corp.
  Livingston, NH
- International Boiler Works Co.
  East Stroudsburg, PA
- Johnston Boiler Co.
  Ferrysburg, MI
- Kewanee Boiler Co.
  Chesterfield, MO
- Riley Stoker Corp.
  Worcestershire, MA
- E. Keeler Co.
  Williamsport, PA
- Browning Ferris Industries
  Houston, TX
- SPM Group
  Englewood, CO

EXHIBIT A.42

MANUFACTURERS OF MODULAR COMBUSTION
MASS INCINERATION SYSTEMS IN THE U.S.

- Consumat Systems, Inc.
  Richmond, VA
- Basic Environmental Engineering, Inc.
  Glen Ellyn, IL
- Environmental Control Products, Inc.
  Charlotte, NC
- Clear Air, Inc.
  Ogden, VT
- Detroit Stoker Co.
  Monroe, MI
- E. Keeler Company
  Williamsport, PA
- Enercon Systems, Inc.
  Cleveland, OH
- Contro Division
  Meadville, PA

EXHIBIT A.43

MANUFACTURERS OF RDF CO-FIRED SYSTEMS AND DEDICATED BOILERS IN THE UNITED STATES

- Aenco, Inc.
  Albany, NY
- Combustion Engineering
  Windsor, CT
- Babcock & Wilcox
  North Canton, OH
- Foster Wheeler Corp.
  Livingston, NJ

EXHIBIT A.44

MANUFACTURING OF MSW COGENERATION SYSTEMS IN THE UNITED STATES

- Detroit Stoker Company
  Monroe, MI
- Combustion Engineering
  Windsor, CT
- Rescoe-Signal Corp.
  Hampton, NH
- Enercon Systems, Inc.
  Cleveland, OH
- E. Keeler Company
  Williamsport, PA
- Basic Environmental Engineering, Inc.
  Glen Ellyn, IL
- Browning-Ferris Industries
  Houston, TX
- General Electric Co.
  Schenectady, NY

reliable collection and transportation system to gather and bring MSW to the plant site. In Egypt, with population and transportation development heavily concentrated along the Nile River Valley, the collection and trasportation of MSW would not appear to be a major difficulty. More detailed investigations would be necessary to determine further requirements.

Another element of the public infrastructure which bears mentioning is the power system. This system can be divided into the gerneration system and the distribution system. The success of certain MSW cogeneration technologies, is dependent upon access to the utility grid, so that cogenerated power may be exported to the grid and utilized. With a developed distribution network cogenerators will be able to interconnect with the grid and provide both energy and capacity to the utility.

The availabilty of waste in Egypt is the second of the four conditions essential for MSW technology development.

The third condition necessary for successful MSW technology development in Egypt is a level of industrial development capable of utilizing the steam, heat, and power that can be provided by MSW technologies. Egypt's largest energy consuming industries are: metals, building materials, chemicals, textiles, and small scale industry. It is estimated that these industries will account for nearly 78 percent of total industrial energy use in 1985. All of these industries could benefit from steam generated from MSW.

Particular advantage of MSW-fired steam is it can displace the use of electricity in the commercial and industrial sectors. In Egypt, where total energy consumption is projected to increase at six percent per year, electric demand growth is projected at 9.9 percent per year. The displacement of electric energy with MSW derived energy can reduce the necessary investment in high cost, capital intensive electric capacity.

The final condition for MSW technology development is experience. With little direct experience with the design, construction, and operation of these technologies, Egypt would be dependent, initially, on foreign expertise. Although additional activity would be required in MSW collection and processing, Egypt appears to have the basic requirements for the use of MSW technologies.

EXHIBIT A.45

SUMMARY OF WORLDWIDE INVENTORY OF WASTE TO ENERGY SYSTEMS

Country	No. of Systems	Installed Capacity (Ton/Day)
Australia	1	520
Austria	2	1,320
Belgium	2	1,048
Brazil	2	660
Canada	3	2,800
Czechoslovakia	1	864
Denmark	35	6,348
Finland	2	640
France	26	11,858
Germany, FGR	39	23,389
Hong Kong	3	3,216
Hungary	1	1,440
Italy	24	9,997
Japan	85	44,581
Luxemborg	2	600
Monaco	1	280
Netherlands	6	8,637
Norway	8	206
Singapore	1	1,440
Spain	4	1,158
Sweden	24	5,456
Switzerland	26	7,600
United Kingdom	9	4,624
United States	55	34,870
U.S.S.R.	6	5,032
Total	368	178,584

A.8 Passive and Hybrid Solar Heating and Cooling and Daylighting

A.8.1 Technology Description

Passive solar heating and cooling technologies utilize thermal energy flows in the building system by natural means such as radiation, conduction and convection, using only energy available in the immediate system. Hybrid technologies integrate the use of other energy sources - such as electricity to power fans and pumps - to improve the heat transfer/heat flow mechanisms, but to a lesser degree than the heat transport function served in active solar systems. Daylighting involves integrating concern for maximizing use of natural lighting into building design by judicious placement of apertures and reflective surfaces.

It should be noted at the outset that the first step towards improving the way a building uses energy is energy conservation, including initial design and operations and maintenance over the period of the building's use. This involves consideration of such things as insulation, construction materials and infiltration barriers. It is the cheapest way to save energy, and will greatly enhance the efficiency of any passive solar systems which are integrated in the design.

Passive solar options are much more practicable when they are included in the initial design. While it is possible to retrofit buildings with passive solar systems, the cost can frequently be prohibitive, and the energy performance results are more difficult to predict.

A.8.1.1 Passive and Hybrid Solar Heating

The basic components of all passive solar heating systems are south-facing glass for collection, and thermal mass for heat absorption, storage and distribution. Systems have different methods of collecting, storing and distributing heat, and can be classified in three categories: direct gain, indirect gain and isolated gain. (See Exhibit A.46).

a) Direct Gain passive heating systems are the most common passive solar design. the occupied space of the residence or commercial building is directly heated by the sun.

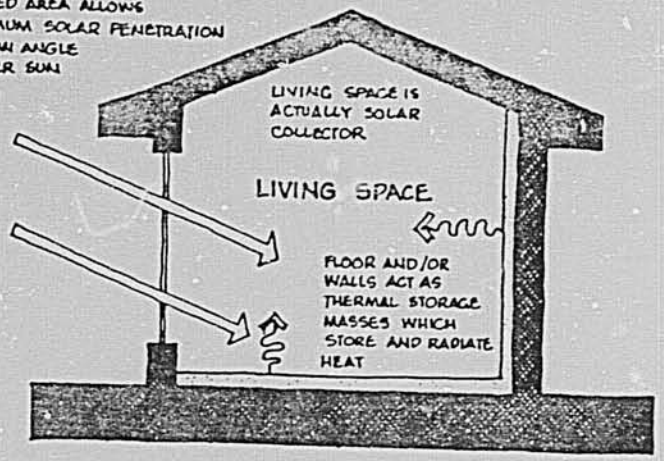
b) Indirect gain passive heating systems utilize a storage mass which collects and stores heat directly from the sun and then transfers heat to the occupied space.

c) Isolated gain passive heating systems collect and store solar radiation in a secondary space which is separate from the occupied space. Heat collected and stored in the secondary space can be vented or transferred to the occupied space by conduction through thermal mass or by convection through air between the two spaces.

These basic passive solar heating options can be assisted, by the addition of fans and heat pumps to the system, creating a hybrid system. The pumps and fans improve the distribution function by increasing the convective flow of air within or between rooms, especially when air between the rooms is stratified - on multiple levels or set apart by walls.

IN PREVENTING UNNECESSARY HEAT LOSS

LARGE SOUTH-FACING GLAZED AREA ALLOWS MAXIMUM SOLAR PENETRATION OF LOW ANGLE WINTER SUN

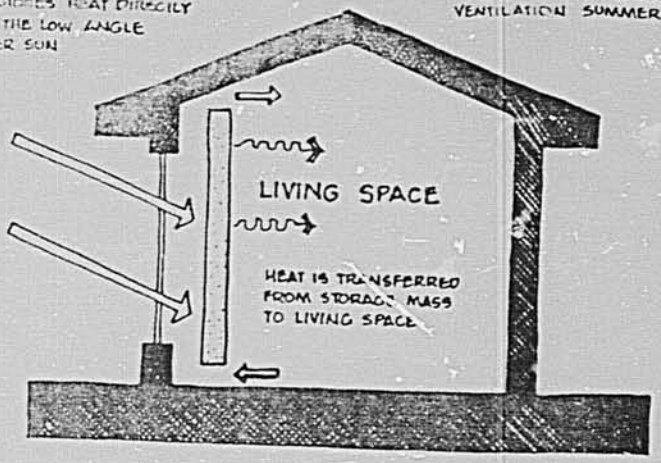


Direct Gain

IN DIRECT GAIN PASSIVE SOLAR HOMES THE OCCUPANT IS IN DIRECT CONTACT WITH THE COLLECTION, STORAGE, AND DISTRIBUTION COMPONENTS OF SOLAR HEATING

STORAGE MASS COLLECTS AND STORES HEAT DIRECTLY FROM THE LOW ANGLE WINTER SUN

INDIRECT GAIN PROVIDES THE POTENTIAL FOR INDUCED VENTILATION SUMMER COOLING

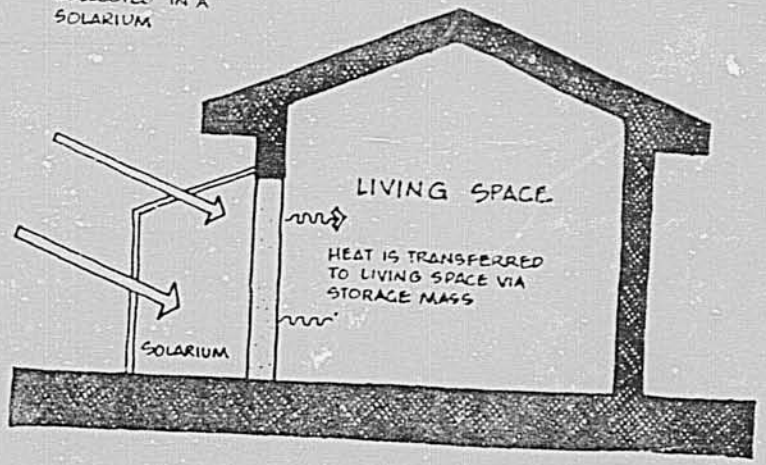


Indirect Gain

IN INDIRECT GAIN PASSIVE SOLAR HOMES THE OCCUPANT IS IN DIRECT CONTACT WITH THE STORAGE AND DISTRIBUTION COMPONENTS OF SOLAR HEATING AND NOT THE COLLECTION COMPONENT

AN ATRIUM, A SUNPORCH, A GREENHOUSE AND A SUNROOM ARE ALL EXAMPLES OF A SOLARIUM

SOLAR RADIATION IS COLLECTED IN A SOLARIUM



Isolated Gain

IN ISOLATED GAIN PASSIVE SOLAR HOMES THE OCCUPANT IS IN CONTACT WITH ONLY THE DISTRIBUTION COMPONENT OF SOLAR HEATING

EXHIBIT A-46
PASSIVE SOLAR HEATING OPTIONS

The biggest concern with passive heating systems is control. Options for controlling heat output during periods when additional heat is not desired will be discussed in the passive solar cooling systems section (A.8.1.3).

A.8.1.2 Daylighting

Daylighting involves integrating the use of glass in sout facing windows, clerestories and roof monitors, with light ballasts and shelves. Light is brought into the occupied space, then used directly or reflected as diffuse light throughout the occupied space. Light is brought into the space through windows at the level of the occupied space, or through such mechanisms as clerestories, roof monitors, or skylights at roof level. As the light enters the building it is reflected off light ballasts or light shelves placed near windows or hung beneath clerestories or skylights, and the light is reflected from the light-colored ceiling and walls. This produces a diffuse light across the occupied space at varying depths as determined by other design considerations. (See Exhibit A.47).

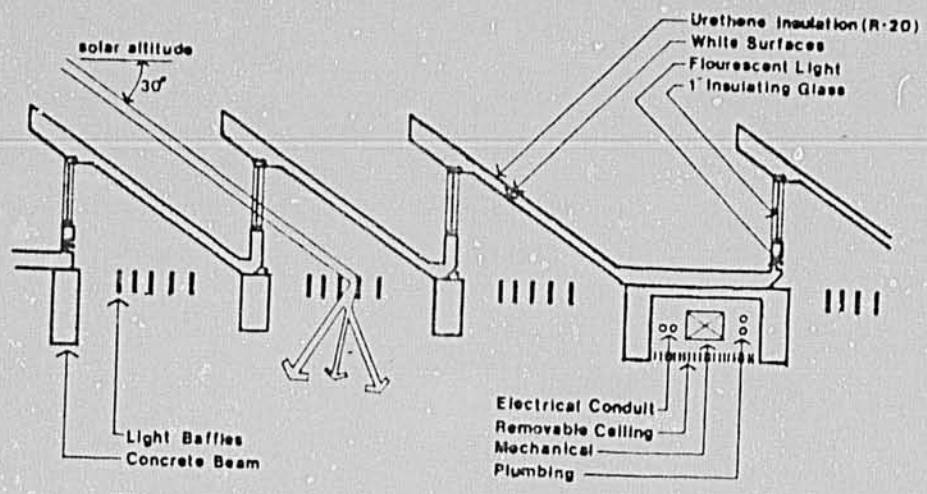
As is the case with passive solar heating systems, the key concern is control. Generally cooling loads in buildings should decrease when daylighting is integrated in the design because daylighting has a high luminous efficiency; it can provide a given amount of light with less heat than is normally produced by fluorescent fixtures. Daylighting design can save substantial amounts of electrical energy and operating costs, provide excellent lighting quality, and reduce peak loads on electric utilities. The lighting fixture layout must be designed both to complement the daylighting and also to operate as an independent system after dark. In addition, the lighting control system must be an integral part of the design. However, bringing in radiation will bring in heat as well; great care in design must be taken to prevent adverse impacts on cooling loads. Techniques for mitigating such problems will be discussed in the following section.

A.8.1.3 Passive Solar Cooling Systems

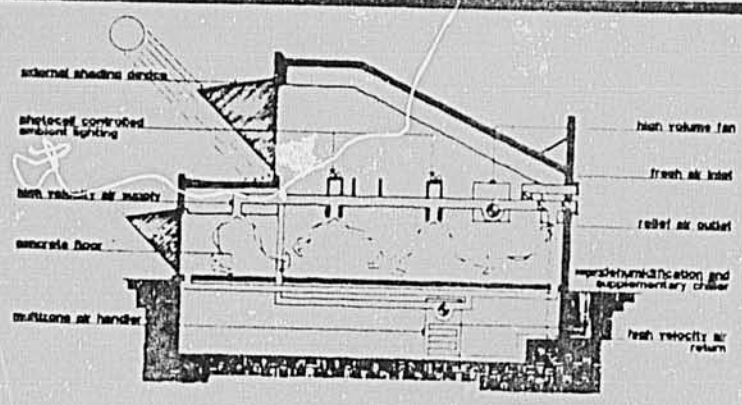
Passive solar cooling techniques, are not as much a function of equipment as of appropriate building design siting and construction techniques, and some ongoing maintenance or operation by building occupants. Techniques include load reduction, earth sheltering, roof ponds and stack effect, earth tube, natural ventilation and solar chimney designs (see Exhibit A.48). Any of these techniques may be used - one or more should be used to offset the possible overheating effects of passive heating or daylighting systems.

a) Load reduction is a defensive cooling technique, preventing the sun's rays from entering the building by shading the windows, walls or roof. Where monthly mean temperature averages are less than 27°C, controling solar heat gain can virtually eliminate the need for othe forms of cooling. The most effective shading prevents the sun from striking the building, such as overhangs and awnings, or by plantings of vegetation. Operable shading devices are even more versatile and adaptable to human comfort, but care should be taken in selection of materials. Note also that some considerable maintenance and operation of the system is required (see Exhibit A.49). Different types of glass and films for coating glass have been developed which reflect sunlight and/or heat. In most cases, use of shading options is a more desirable option because shading

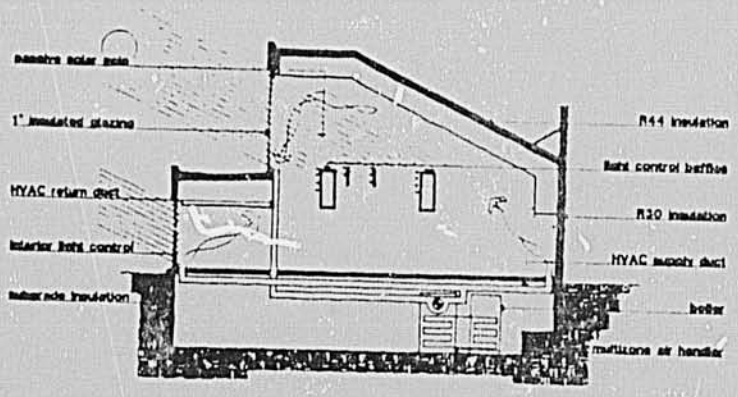
328



Clerestory design -- winter solstice.

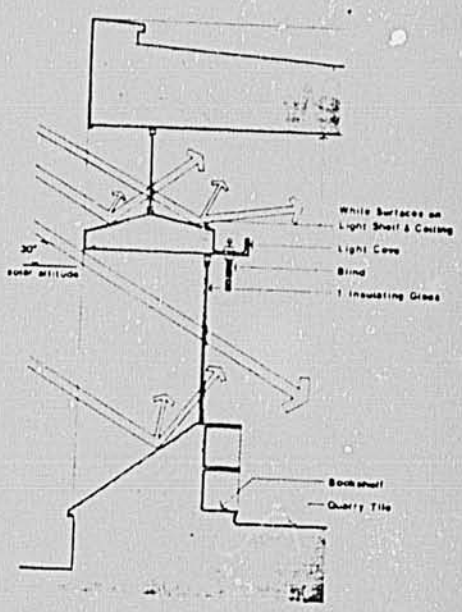


COOLING



HEATING

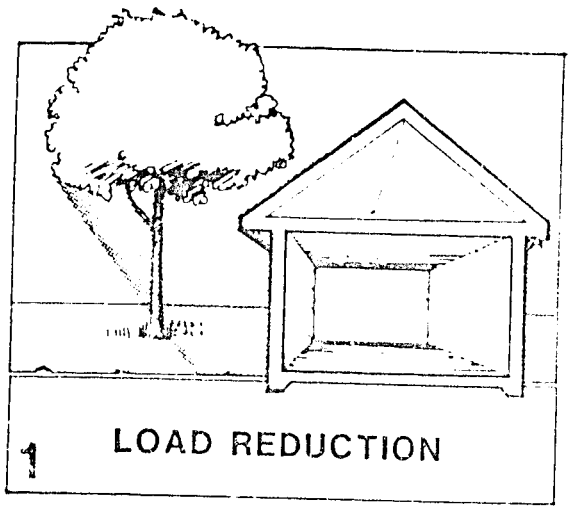
Figu The HVAC system is operating at constant volume during occupied hours. It is designed for about 45 hours/week occupancy. A time clock sets hours of operation and unoccupied period cycling conditions. A night thermostat allows for temperature setback or setup, as appropriate. The large volume ventilation fan is designed to be manually operated and may be switched on or off at will. The cooling system is controlled by inside/outside thermostats which povide the required mix of outside air ventilation and refrigeration to provide for comfort conditions.

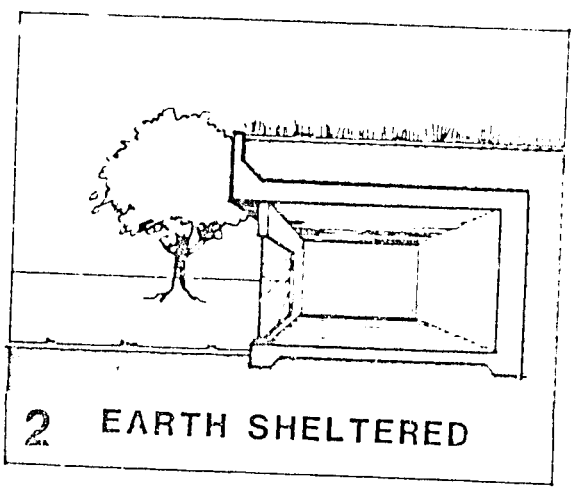


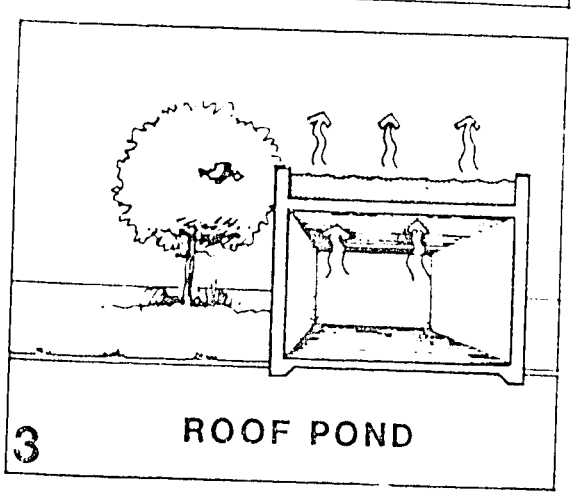
Light shelf design -- winter solstice.

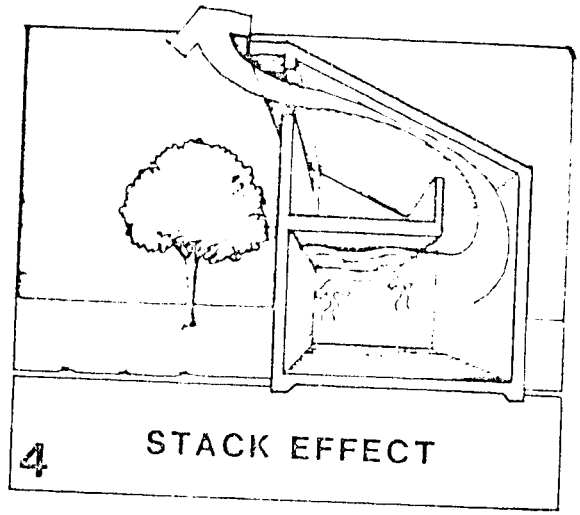
EXHIBIT A-47
DAYLIGHTING DESIGNS AND INTEGRATED DAYLIGHTING SYSTEMS

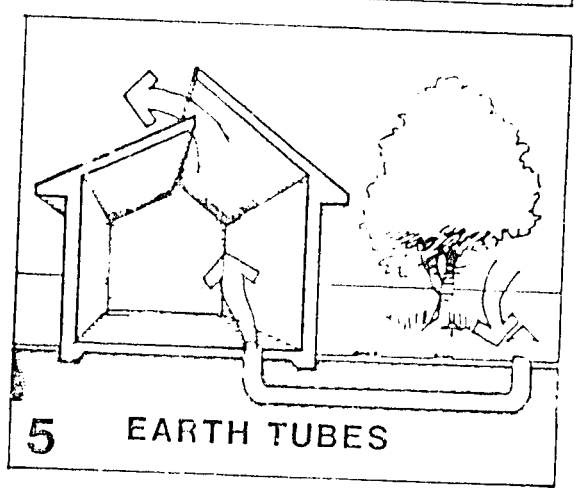
329

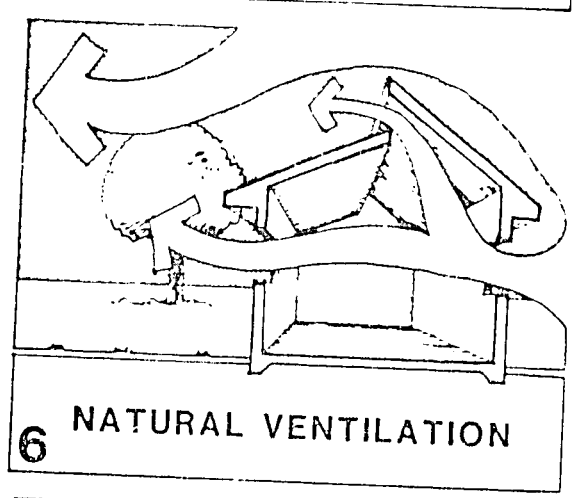












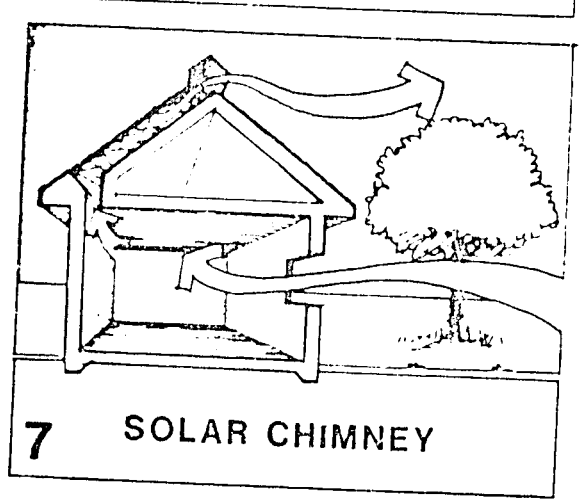
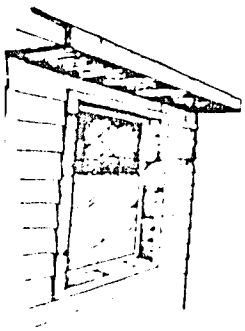
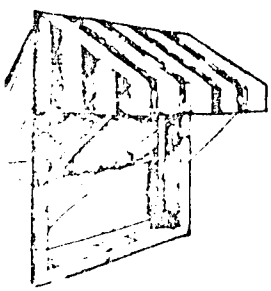


EXHIBIT A-48

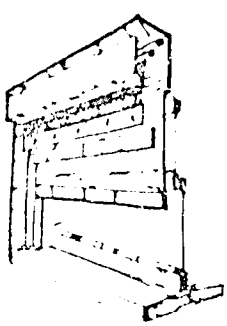
PASSIVE SOLAR COOLING OPTIONS



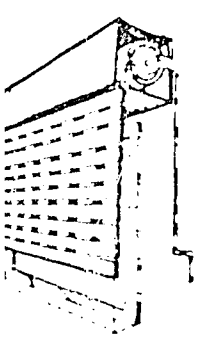
OVERHANG — When sized properly will allow low angle winter sun penetration while shading out high summer sun. An overhang will vary in size depending on its shading requirement and the latitude in which it is used.



AWNING — Simple shading device that can keep out summer sun while allowing entry of low winter sun. Appropriate where overhangs are not practical, such as the first floor windows of a two story house.



MULTI-PURPOSE SHADE — Offers several options or modes for varied conditions; including reflection, (heat gain reduction), and insulation. Has several operable shades with different characteristics in one housing.



EXTERIOR ROLL DOWN SHUTTER — Intercepts radiant solar gain outside the living space, becomes heated, and in turn reradiates heat energy back into the outside air some models reflect as well.

EXHIBIT A-49

PASSIVE SOLAR COOLING - SHADING MECHANISMS

devices are considerable more flexible for adaptation to changing seasons and climates.

b) Earth sheltered buildings are provided with additional insulation in the earth bermed along the exterior of the building, preventing heat loss in the summer and heat gain in the winter (see Exhibit A.48).

c) Roof ponds can be used for both passive heating and cooling. In the heating mode heat is collected from the sun during the day and transferred to the occupied space at night. In the cooling mode, the pond is covered in the day with a light or reflective material which prevents heat gain. The pond is uncovered in the evening to allow heat transfer from the occupied space, and evaporative cooling from the pond (see Exhibits A.48 and A.50). Stack effect, earth tubes, natural ventilation and solar chimneys are examples of convective cooling.

d) The stack effect occurs when warm air rises to the top of a tall space. An opening at the top exhausts the warmed air while openings at floor level admit outdoor air to replace it. (See Exhibit A.48)

e) Earth tubes take advantage of the stack effect, but include passing the outside air through a tube which runs underground. Because the earth is insulated this provides additional assurance that the air moving through the building will be cooled. (See Exhibit A.48)

f) Natural ventilation involves opening windows or other apertures to allow breezes to pass through a building. Proper window location enhances the process; lower inlet openings will direct the air throught the occupied area, while high inlets will create a drat above the occupants' heads. The outlet location has little effect but should be as large as possible. Land use planning also becomes important; care should be taken not to place buildings so that the flow of natural breezes is interrupted. (See Exhibit A.48)

g) The solar chimney utilizes an enclosed area near the top of the path of air flow to allow the air to become more heated. In this way the entire column of air in the chimney is hot, creating the buoyancy to enhance the air flow. (See Exhibit A.48)

Daylighting clerestories and roof monitors provide a ready source of rool level ventilation.

Dehumidification, is another passive solar cooling option. Air which has a high water vapor content, humid air, feels warmer, therefore removing humidity from the air increases the human comfort factor. Air can be dehumidified by passing it through a desicant material. The desicant material can be regenerated for further use by heating the material to allow the moisture to evaporate using solar heat or reject heat from mechanical equipment or air conditioners. This system must be considered to be still in the R&D phase.

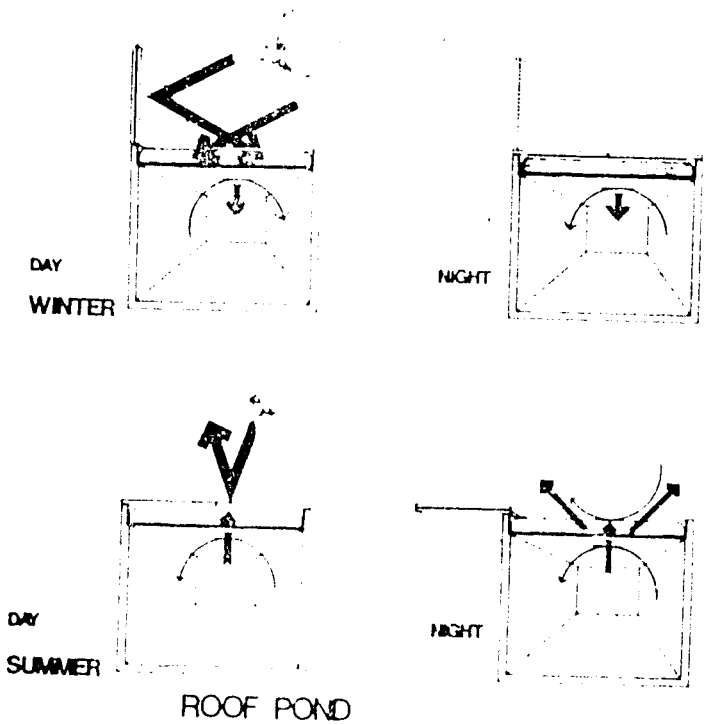


EXHIBIT A-50

ROOF POND - HEATING AND COOLING MECHANISMS

A.8.2 Resource Availability

Egypt lies in the solar belt with an annual average insolation of 800 KJ/cm^2. The direct component of solar radiation is 88 to 95 percent of the total on a clear day. Sunshine hours vary from nine to eleven hours per day, with only thirty cloudy days per year in the North.

The largest need is for cooling - cooling degree days range from 2200 in Alexandria to 3000 in Cairo. There is a significant cooling resource in the diurnal temperature swings and clear night skies which typify Egyptian climate. Lighting represents another target for passive application. Although there is nothing which can be characterized as a resource for this application, consumption trends showed that it is a significant component of energy demand.

In additional to the solar radiation, there are requirements for basic construction materials. Materials such as steel, cement, glass, and aluminum are all manufactured in Egypt. The requirement for these materials is substantial since the utilization of solar energy resources requires considerable area with collection surfaces capable of withstanding severe environmental conditions.

Support structures, towers, and storage tanks are needed in the passive solar design. These are similar in construction to the conventional equipment. These systems require various skill levels in metal forming, welding, plumbing, mechanical assembly, site preparation, concrete pouring and other labor skills common to a range of conventional systems. These skill levels are readily available in Egypt. However, special training may be required for many aspects of design, manufacture, installation, operation and maintenance. Manpower training load can be handled by the Solar Energy Laboratory at the National Research Center, Cairo University and Helwan Institute of Technology.

A.8.3 Market Readiness

Passive solar designs and technologies have great potential to increase the efficiency of residential and commercial building performance in Egypt. Generally, no new equipment market has to be developed for adoption of current passive buildings designs and technologies; it is simply a matter of developing an awareness and basic level of knowledge in the construction industry and among the consumers. Over the last twenty to thirty years this awareness has been developing in the United States. It is now to the point where it is not at all uncommon for contractors to integrate passive and energy conserving considerations into designs and development plans. Home buyers and developers are placing a growing premium on the availability of passive solar options, particularly sunspaces and skylights, and on conserving features insulation and double pave glazing.

Traditional Islamic architecture is well recognized as the origin of numerous passive solar cooling techniques. The courtyard, the high ceiling, and malkaff (wind catcher) are among the design features that have dominated Islamic buildings over the past few centuries. With the current substitution of modern design concepts, indoor comfort levels have, in many cases, deteriorated. The restoration of traditional Islamic design concepts along with the application of other passive cooling features has significant potential for improving comfort levels and reducing air conditioning demand.

When compared with contemporary modern buildings, traditional Islamic buildings found in Cairo appear to maintain more comfortable indoor temperatures. If simply for reasons of energy conservation and comfort improvement, many traditional design features are worth analyzing more fully and retaining in future construction practices. The lower initial cost of many contemporary construction techniques such as thinner roofing should be weighed against the resulting higher cooling loads and the implictions of reduced indoor comfort on productivity and general well-being.

Egypt's Five-Year Development Plan, together with it's traditional architectural styles, present a ready market for passive solar design and technologies. Prevailing construction standards include the use of concrete, mud plaster and alobe - like materials in thick walls. This thermal mass provides the good insulation properties critical to collect and store the cool temperatures generated by passive technologies, while the use of small windows prevents excessive solar heat gain during the cooling season. Design changes then would be on a relatively small scale, including relocating windows, improving ventilation, modifying roof structures to accomodate clerestories, roof monitors and skylights, and providing for shading devices. The Five-Year Development Plan goal of 5.8 million new units and 2.1 million units for upgrading or replacement implies a readily accessible target for passive design and retrofit. Because a large portion of that new building stock is directly or indirectly under the control of the Egyptian government many of the construction and design changes can be centralized in the Ministry of Housing and Reconstruction and the General Organization of Housing Cooperatives.

Passive solar technologies provide some of the most promising renewable energy options for satisfying a major portion of building energy needs. energy savings by construction of passive solar homes have been encouraging. In 1982, the estimated energy savings for passive solar homes were of the order of 2.5 trillion BTU and for passive commercial buildings were approximately 1.4 trillion BTU in the United States. The number of known buildings incorporating passive solar engineering designs has grown from a handful of research and demonstration facilities in 1977 to more than 100,000 today.

According to the brick and masonry industry, the share of passive solar designs has grown to approximately 10 percent over the last few years. Sales of window and insulating films are steadily growing based on both conservation and passive demand. The passive solar products market is expected to grow rapidly in the next few years. Surveys conducted among consumers in 1980 and 1981 reveal that energy efficiency is the most important factor for home buyers after the initial investment cost (5).

A.8.4 Economic Viability

The number of known passive buildings using the engineering principles for energy collection, storage and distribution was estimated to be 100,000 in the United States. The number of nonresidential buildings was estimated at about 7,000. It is projected that the number of passive commercial buildings would be 15,000 by 1985. The criteria for selection of passive systems by the potential users are first cost, aesthetics, reliability and maintainability. energy efficiency is increasingly becoming an important issue to home buyers. An additional $1,000 spent on energy efficient products saves $100 annually on fuel bills (effectively a 10-year payback period). The materials for passive

335

solar use represent between 5 to 15 percent of total sales volume.

A.8.5 Industry Status

Passive solar designs and technologies do not require the development of new industries or production facilities so much as the education of the construction industry and, for some applications, the building occupants. Although the government can determine design guidelines or structural formation to be used by contractors and construction companies, the fact that the efficiency of various passive solar applications depends on site specific and building use criteria requires that they also be knowledgable of the mechanics of design and technology function and form. For example, passive cooling methods present several challenges when applied to large buildings such as the multi-family and commercial structures which dominate the Egyptian building sector. Significant savings can be achieved with natural lighting and natural ventilation by increasing the exterior surface area of the building. Wise thermal design of the increased external wall area, will be required to compensate.

Including the use of high levels of insulation and thermally efficient glazing systems, analytical and performance testing experience with multi-family or commercial buildings is still quite limited.

A.8.6 Current Passive Solar R&D Thrusts

There is substantial research going on in all areas of passive solar technologies. Most of the research is directly or indirectly related to increasing the cost effectiveness of passive solar building design for heating, cooling and daylighting, and on advancing and refining current technologies.

Much of space conditioniing research is concerned with improving the ability to predict the increase in the efficiency of building energy performance associated with passive solar design. This work centers on developing predictive models - computer and graphic and on monitoring buildings to test the accuracy of those models. Research is also being done in the basic heat transfer processes particularly convection, and the development of move efficient desiccant systems and components for cooling.

Daylighting research has focused on improving the understanding of daylighting systems and their interactions with other building energy systems, and developing more sophisticated daylighting methods. Goals are to improve the cost-effectiveness reliability, and even spatial distribution of light.

An overeaching research and development thrust is in materials development, analysis and testing. R&D is being done in glazings, reflective coatings, thermal mass and desiccants.

A.8.7 Relevant Egypt/Worldwide Experience in Passive Solar

Some limited passive solar activity is taking place in Egypt. Most notable, CARE has constructed some experimental structures in Aswan. The American University in Cairo has been at the forefront of developing passive solar technologies for desert development. A large building housing the Desert

336

Development demonstration and training center was built using locally available adobe bricks. The design is based on traditional Coptic and Moslem architectural principles with prominent use of traditional domes and vaults. Government programs in the area of passive solar designs are not developed yet. Architects, engineers and building developers are generally not familiar with passive techniques.

Examples of United States projects with utilities are shown in Exhibit A.51 Additional cooperation projects are underway under the aegis of IEA in performance modeling and testing and materials research.

EXHIBIT A.51

Utility-Funded Passive Solar Projects in the United States

UTILITY	PROJECT	REASONS FOR FUNDING PROJECT
Georgia Power	• Built & instrumented 9 passive solar and energy efficient homes • Acquired and publicized performance data • Built "Future 1"; fully instrumented home with direct gain, phase-change storage, trombe wall, PV cells, etc.	• Reduce marginal cost of providing service • Share peak demand • "Total energy business" not just in generation and distribution of electrical energy
Pennsylvania Power and Light	• Built and instrumented 5 passive solar homes; acquired and publicized performance data • Incorporate direct gain, trombe wall, sunspaces double glazing, selective surfaces	• Goal to get 3% of new homes passive solar and reduce peak load by 28 MW • Prevent need for new capacity as electrical demand grows
Public Service Company of New Mexico	• Designing, building and monitoring 19-unit project to determine effect of passive solar on demand profile • Studying "forced load management" where passive homes rely on excess base-load generation for auxiliary heating requirements	• Goal to offset reduced electricity revenue from passive solar by more favorable load conditions • Use current capacity more efficiently
San Diego Gas & Electric with Southern California Gas Co.	• Built 8 two-room test stsructures to test performance of seven different passive heating and cooling techniques • 2-year experiment to identify best concepts for Southern California, most cost-effective for builders, and implications on peak load demand	• Informal assessment...on-site worker sought shelter from the hot summer sun in the house using high mass for thermal control
Pacific Power and Light	• Developed guidelines for conservation features and passive home design • Sponsoring construction of 10 homes • Publish plan book with 11 home designs aimed at the speculative market	• Attempt to produce energy-efficient, cost-effective design, combining energy conservation and passive sola design

358

EXHIBIT A.51 (Cont.)

UTILITY	PROJECT	REASONS FOR FUNDING PROJECTS
Sacramento Municipal Utility District	• Targeting technical, marketing and educational progress primarily at builders entering passive market • Conduct computer energy analysis of builder home designs • Certify homes that meet design criteria	• Planning future seminars to focus on new California energy building standards to help builders get permits for energy-efficient housing.
Tennessee Valley Authority	• Programs dealing with new construction, retrofits, modular homes, do-it-yourself activity and solar extension service information access	• Preeminent utility for helping passive solar residential market penetration
Nashville Electric Service	• Promoting energy conservation and solar through outreach services • Lending funds for solar hot water heaters • Offering low-interest loans for passive retrofits	• Reduced peak demand 75 MW or 4% per year

Source: "Solar Energy Technology Resource Book" Active and Passive Solar Technologies. July 15, 1982.

APPENDIX B

DEGREE-DAYS CALCULATIONS FOR ALEXANDRIA, CAIRO, AND ASWAN

HEATING LOAD CALCULATION FOR ALEXANDRIA

DESCRIPTION	VARIAB.	UNITS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
BASE TEMP.	Tb	deg C	18	18	18	18	18	18	18	18	18	18	18	18
MONTHLY AVG. TEMP.	Ta	deg C	13.5	14	15.6	18.3	21.4	24.2	26.1	26.7	25.3	22.8	19.3	15.2
AVG. YEAR TEMP.	Ty	deg C	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2
JANUARY MEAN TEMP.		deg C	13.5											
AUGUST MEAN TEMP.		deg C	26.7											
AVE. ANNUAL HUMIDITY		%	70											
DAYS PER MONTH	D	DAYS	31	28	31	30	31	30	31	31	30	31	30	31
HOURS PER MONTH	Hr	HOURS	744	672	744	720	744	720	744	744	720	744	720	744
CALC. FOR STD DEV.	SqT		44.89	38.44	21.16	3.61	1.44	16	34.81	42.25	26.01	6.76	0.81	25
STD DEV. Ta/Ty	SDy	deg C	4.872744	4.434267	4.020967	3.774194	3.730464	3.712876	3.511539	3.027600	2.307694	1.720729	1.531784	1.507556
STD DEV. Ta	SDa	deg C	1.382050	1.338435	1.264592	1.169906	1.077102	0.994735	0.925266	0.876732	0.869530	0.903056	0.992010	1.109301
H FACTOR	H		0.584800	0.564765	0.340863	-0.04681	-0.56694	-1.13795	-1.57060	-1.78226	-1.53277	-0.95465	-0.23325	0.453343
DIST. FUNC. OF Tb	Dh(Tb)		148.5	120.0	92.0	34.9	7.5	1.0	0.2	0.1	0.2	1.8	17.6	97.8
MONTHLY HEATING DDS	DDs	deg-days	148.5	120.0	92.0	34.9	7.5	1.0	0.2	0.1	0.2	1.8	17.6	97.8
YEARLY HEATING DDs	DDs	deg-days	521.6											

COOLING LOAD CALCULATION FOR ALEXANDRIA

DESCRIPTION	VARIAB.	UNITS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
BASE TEMP.	Tb	deg C	25	25	25	25	25	25	25	25	25	25	25	25
MONTHLY AVG. TEMP.	Ta	deg C	13.5	14	15.6	18.3	21.4	24.2	26.1	26.7	25.3	22.8	19.3	15.2
AVG. YEAR TEMP.	Ty	deg C	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2
JANUARY AVE. TEMP.		deg C	13.5											
AUGUST AVE. TEMP.		deg C	26.7											
AVE. ANNUAL HUMIDITY		%	70											
DAYS PER MONTH	D	DAYS	31	28	31	30	31	30	31	31	30	31	30	31
HOURS PER MONTH	Hr	HOURS	744	672	744	720	744	720	744	744	720	744	720	744
CALC. FOR STD DEV.	SqT		44.89	38.44	21.16	3.61	1.44	16	34.81	42.25	26.01	6.76	0.81	25
STD DEV. Ta/Ty	SDy	deg C	4.872744	4.434267	4.020957	3.774194	3.730464	3.712876	3.511539	3.027600	2.307694	1.720729	1.531784	1.507556
STD DEV. Ta	SDa	deg C	11.382050	1.328435	1.264592	1.169906	1.077102	0.994735	0.926266	0.876732	0.869530	0.903056	0.992010	1.109301
H FACTOR	H		-1.49449	-1.55316	-1.33504	-1.04559	-0.60029	-0.14683	0.213292	0.348257	0.062990	-0.43754	-1.04905	-1.58670
DIST. FUNC. OF Tb	Dh(Tb)		0.4	0.3	0.7	1.6	6.7	22.8	52.7	64.6	33.9	9.4	1.3	0.3
MONTHLY COOLING DDs	DDs	deg-days	0.4	0.3	0.7	1.6	6.7	22.8	52.7	64.6	33.9	9.4	1.3	0.3
YEARLY COOLING DDs	DDs	deg-days	194.7											

HEATING LOAD CALCULATION FOR CAIRO

DESCRIPTION	VARIAB.	UNITS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
BASE TEMP.	Tb	deg C	18	18	18	18	18	18	18	18	18	18	18	18
MONTHLY AVG. TEMP.	Ta	deg C	13.2	14.2	16.6	20.2	24.2	26.7	28.2	27.8	25.4	23.4	19.2	14.8
AVG. YEAR TEMP.	Ty	deg C	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2
JANUARY MEAN TEMP.		deg C	13.2											
AUGUST MEAN TEMP.		deg C	27.8											
AVE. ANNUAL HUMIDITY		%	56											
DAYS PER MONTH	D	DAYS	31	28	31	30	31	30	31	31	30	31	30	31
HOURS PER MONTH	Hr	HOURS	744	672	744	720	744	720	744	744	720	744	720	744
CALC. FOR STD DEV.	SqT		64	49	21.16	1	9	30.25	49	43.56	17.64	4.84	4	40.96
STD DEV. Ta/Ty	SDy	deg C	5.513701	4.958097	4.485444	4.266678	4.256011	4.158780	3.813850	3.176619	2.476067	2.127738	2.021700	1.929672
STD DEV. Ta	SDa	deg C	1.433309	1.367417	1.266499	1.147507	1.030799	0.951643	0.885439	0.854727	0.877810	0.912681	1.027440	1.148930
H FACTOR	H		0.601478	0.525174	0.198537	-0.35003	-1.08028	-1.66875	-2.05899	-2.05929	-1.53911	-1.05265	-0.21323	0.500236
DIST. FUNC. OF Tb	Dh(Tb)		157.7	115.7	69.9	14.8	1.3	0.2	.0	.0	0.2	1.2	19.6	109.0
MONTHLY HEATING DDS	DDs	deg-days	157.7	115.7	69.9	14.8	1.3	0.2	.0	.0	0.2	1.2	19.6	109.0
YEARLY HEATING DDs	DDs	deg-days	483.7											

COOLING LOAD CALCULATION FOR CAIRO

DESCRIPTION	VARIAB.	UNITS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
BASE TEMP.	Tb	deg C	25	25	25	25	25	25	25	25	25	25	25	25
MONTHLY AVG. TEMP.	Ta	deg C	13.2	14.2	16.6	20.2	24.2	26.7	28.2	27.8	25.4	23.4	18.2	14.8
AVG. YEAR TEMP.	Ty	deg C	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2
JANUARY AVE. TEMP.		deg C	13.2											
AUGUST AVE. TEMP.		deg C	27.8											
AVE. ANNUAL HUMIDITY		%	56											
DAYS PER MONTH	D	DAYS	31	28	31	30	31	30	31	31	30	31	30	31
HOURS PER MONTH	Hr	HOURS	744	672	744	720	744	720	744	744	720	744	720	744
CALC. FOR STD DEV.	SqT		64	49	21.16	1	9	30.25	49	43.56	17.64	4.84	4	40.96
STD DEV. Ta/Ty	SDy	deg C	5.513701	4.958097	4.486444	4.266678	4.256011	4.158780	3.813850	3.176619	2.476067	2.127738	2.021700	1.929672
STD DEV. Ta	SDa	deg C	11.433309	1.367417	1.266499	1.147507	1.030799	0.951843	0.885439	0.654727	0.877810	0.912681	1.027440	1.148930
H FACTOR	H		-1.47863	-1.49260	-1.19122	-0.76370	-0.13939	0.326079	0.649097	0.588368	0.083195	-0.31486	-1.03064	-1.59450
DIST. FUNC. OF Tb	Dh(Tb)		0.5	0.4	1.1	4.0	25.4	64.1	103.9	92.3	35.9	13.7	1.5	0.3
MONTHLY COOLING DDs	DDs	deg-days	0.5	0.4	1.1	4.0	25.4	64.1	103.9	92.3	35.9	13.7	1.5	0.3
YEARLY COOLING DDs	DDs	deg-days	343.0											

HEATING LOAD CALCULATION FOR ASWAN

DESCRIPTION	VARIAB.	UNITS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
BASE TEMP.	Tb	deg C	18	18	18	18	18	18	18	18	18	18	18	18
MONTHLY AVG. TEMP.	Ta	deg C	16.8	18.6	22.4	27.2	31.9	33.6	34	34.2	32	29.6	24	19.8
AVG. YEAR TEMP.	Ty	deg C	27	27	27	27	27	27	27	27	27	27	27	27
JANUARY MEAN TEMP.		deg C	16.8											
AUGUST MEAN TEMP.		deg C	34.2											
AVE. ANNUAL HUMIDITY		%	27											
DAYS PER MONTH	D	DAYS	31	28	31	30	31	30	•	31	30	31	30	31
HOURS PER MONTH	Hr	HOURS	744	672	744	720	744	720	7-4	744	720	744	720	744
CALC. FOR STD DEV.	SqT		104.04	70.56	21.16	0.04	24.01	43.56	49	51.84	25	6.76	9	51.84
STD DEV. Ta/Ty	SDy	deg C	6.444236	5.663038	5.055121	4.871531	4.871158	4.641708	4.193501	3.623659	2.901410	2.479002	2.351788	2.170881
STD DEV. Ta	SDa	deg C	11.390697	1.286625	1.136724	0.984669	0.848344	0.783809	0.742448	0.698810	0.714653	0.756205	0.910158	1.019946
H FACTOR	H		0.154977	-0.08812	-0.69521	-1.70583	-2.94280	-3.63373	-3.87055	-4.16365	-3.57661	-2.75509	-1.20357	-0.31696
DIST. FUNC. OF Tb	Dh(Tb)		70.0	31.1	5.2	0.1	.0	.0	.0	.0	.0	.0	0.7	15.2
MONTHLY HEATING DDS	DDs	deg-days	70.0	31.1	5.2	0.1	.0	.0	.0	.0	.0	.0	0.7	15.2
YEARLY HEATING DDs	DDs	deg-days	122.4											

COOLING LOAD CALCULATION FOR ASWAN

DESCRIPTION	VARIAB.	UNITS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
BASE TEMP.	Tb	deg C	25	25	25	25	25	25	25	25	25	25	25	25
MONTHLY AVG. TEMP.	Ta	deg C	16.8	18.6	22.4	27.2	31.9	33.6	34	34.2	32	29.6	24	19.8
AVG. YEAR TEMP.	Ty	deg C	27	27	27	27	27	27	27	27	27	27	27	27
JANUARY AVE. TEMP.		deg C	16.8											
AUGUST AVE. TEMP.		deg C	34.2											
AVE. ANNUAL HUMIDITY		%	27											
DAYS PER MONTH	D	DAYS	31	28	31	30	31	30	31	31	30	31	30	31
HOURS PER MONTH	Hr	HOURS	744	672	744	720	744	720	744	744	720	744	720	744
CALC. FOR STD DEV.	SqT		104.04	70.56	21.16	0.04	24.01	43.56	49	51.84	25	6.76	9	51.84
STD DEV. Ta/Ty	SDy	deg C	16.444236	5.663038	5.065121	4.871531	4.871158	4.641708	4.193501	3.623659	2.901410	2.479002	2.351788	2.170681
STD DEV. Ta	SDa	deg C	11.390697	1.286625	1.136724	0.984669	0.848344	0.783803	0.742448	0.698810	0.714653	0.756205	0.910158	1.019946
H FACTOR	H		-1.05901	-0.94004	-0.41080	0.407916	1.460816	2.003213	2.177184	2.364543	1.788305	1.092539	-0.20059	-0.91568
DIST. FUNC. OF Tb	Dh(Tb)		1.9	2.3	12.8	76.6	214.2	258.0	279.0	285.2	210.1	143.5	18.0	2.3
MONTHLY COOLING DDs	DDs	deg-days	1.9	2.3	12.8	76.6	214.2	258.0	279.0	285.2	210.1	143.5	18.0	2.3
YEARLY COOLING DDs	DDs	deg-days	1504.0											

APPENDIX C

CALCULATION OF HEAT LOSS COEFFICIENT FOR TYPICAL EGYPTIAN HOME

CALCULATION OF HEAT LOSS COEFFICIENT FOR TYPICAL EGYPTIAN HOME

I. DESCRIPTION OF MODEL

The model is a corner apartment in a five story building. The apartment is of loose construction with little or no insulation. Floor area is $120m^2$. The apartment contains four rooms of 5 x 6m each, six 1.5 x 1.5m single paned windows, and one outside door with dimensions of 1 x 2.1m.

II. THERMAL RESISTANCE VALUES

A. Outside Walls

The walls consist of a 0.20m thick cinder block with 0.013m layer of cement mortar on each side. These three materials are in series.

R for 0.20m cinder block = 0.303 $sec.m^2.{}^oC/J$

R for 0.0127m layer of cement mortar = 0.0176

R_{Tot} = 0.338 $sec.{}^oC.m^2/J$

B. Windows

Each window has a single pane with no insulation.

R inside room resistance	0.120 $sec.m^2.{}^oC/J$
R outside room resistance	0.030

R glass 0.00352

R_{Tot} window = 0.153 sec.m^2.°C/J

C. Door

The door is uninsulated.

R = 0.335 sec.m^2.°C/J

D. Roof and Basement

The apartment building has five units. Each unit compensates for 20% of the building's losses through the roof and basement.

R basement = 1.76 Sec·m^2·°C/J (A conservative value because dry earth adds to overall thermal resistance).

R roof = 0.363 sec·m^2·°C/J

The roof is pitched; outside surface air is taken to be 24.1 km/hr. The roof is constructed of asphalt shingle roofing, building paper, and 0.0159 m of plywood deck.

E. Infiltration

The apartment building is of loose constructon. The number of air changes per hour is approximately two. Outside ambient air temperature is 40.6°C; room temperature is 25°C. Heating volume of the apartment is 288m^3.

The UA for infiltration is then 193J/s.°C.

III. OVERALL UA CALCULATION

	area m^2	R sec.m^2.°C/J	UA w/°C
walls (2)	37.4	0.338	110.5
windows (6)	13.5	0.153	88.2
door (1)	1.95	0.335	5.82
roof	20% of 120m^2	0.363	66.1
basement	20% of 120m^2	1.76	34.0
infiltration			193.0

Total UA = 497.6 w/°C

Total area or the apartment is 120m^2

U_{AVE} = 4.15 w/m^2.°C

APPENDIX D

PRELIMINARY DESIGN OF A FLASH STEAM SYSTEM

PRELIMINARY DESIGN OF A FLASH STEAM SYSTEM

In a flash steam solar system, pressurized water is circulated through the collector field and flashed to low quality steam across a throttling valve into a flash, or separator tank. The flashing process is an isenthalpic process that converts the sensible heat of the water into a mixture of saturated water and steam. The quality of steam is usually less than 10 percent. From the flash tank, the saturated steam is sent to the process and the saturated water is pumped to the collector field. The pump is designed to have sufficient pressure at the outlet of the collector field to prevent boiling. To have a desired liquid level in the flash tank, boiler feedwater is fed to the pump suction (Reference 1).

The collector field outlet temperature, T_{out} is generally designed to be considerably above the steam delivery temperature to obtain reasonably good steam quality downstream of the throttling valve. A performance modifier called the flash system factor, F_F accounts for this temperature elevation.

$$F_F = \left[1 - \frac{A_c F_R U_L / M_F}{h_{fg} + C_p (T_s - T_f)} (T_s - T_f) \right]^{-1}$$

where m_c = collector loop flow rate per unit collector area
= M_c/A_c

M_c = Collector loop flow rate

A_c = Collector area

h_{fg} = Heat of vaporization of steam at its saturation temperature

C_p = Specific heat of saturated water

T_s = Steam saturation temperature

T_f = Feedwater temperature

$F_R U_L$ = Collector heat loss coefficient

Input Data:

Q_{load} = 3.3 GJ/hr

$T_{saturation}$ = 130°C

It is assumed that the irradiation on collector is 20 MJ per m^2 per day. It is also assumed that the efficiency of the parabolic trough is 40 percent which means that 40 percent of the incoming irradiation is actually transmitted through the system.

Energy collected by the water = 0.4 (20/8) MJ/m^2hr

Collector area, A_c = $\frac{3.3 \times 10^3 \text{ MJ/hr}}{1.0 \text{ MJ/m}^2\text{hr}}$

= 3300 m^2

Heat of vaporization of steam @ 130°C = 2540 KJ/Kg (Reference 8)

h_{fg} = 2.54×10^6 J/Kg × 1W-S/J

= 2.54×10^6 W-S/Kg × 1hr/3600S

= 705 W-hr/Kg

$Q_{load} = M_c \; h_{fg}$ (2)

Reference 1: Kutscher, C.F. et. al. "Design Approaches for Solar Industrial Process Heat Systems," Solar Energy Research Institute, August 1982, p. 113.

3.3×10^9 watt-sec/hr = M_c (kg/hr) (705) (3600) watt-sec/kg

$M_c = 1.3 \times 10^3$ kg/hr

$C_p = 4.26 \times 10^3$ J/kgK @ 130°C (Reference 8)

The feed water temperature is assumed as 20°C.

$$F_F = \left[1 - \frac{f_R U_L / m_c}{h_{fg} + C_p (T_s - T_f)} (T_s - T_f) \right]^{-1}$$

$$= \left[1 - \frac{0.5 / (M_c / A_c)}{h_{fg} + C_p (T_s - T_f)} (T_s - T_f) \right]^{-1}$$

$$= \left[1 - \frac{0.5\ (3300) / 1.3 \times 10^3}{\dfrac{705 + (4.26 \times 10^3)(130-20)}{3600}} (130 - 20) \right]^{-1}$$

$$= 1.20$$

$$q_c = F_F F_R \left[\eta_o I_a - U_L (T_{in} - T_a) \right] \qquad (3)$$

where q_c = annual average energy collection rate per unit of collector area during daylight hours

$F_R \eta_o$ = effective optical efficiency

I_a = available irradiation on collector

T_a = average annual daytime temperature

Reference 8: Chemical Processes, Wiley, New York, 1978, pp.2-3.

Assumptions: $T_a = 30^oC$

$I_a = 20\ MJ/m^2\text{-day}\ (0.4)$

$= \dfrac{20 \times 10^6 (0.4)}{(8\ hr/day)(3600 sec/hr)}$

$= 277.8\ watts/m^2$

$F_R\ \eta_o$ varies from 0.65 to 0.8

$F_R \eta_o = 0.72$

$q_c = 1.05\ [(0.72)(277.8) - 0.5(130-30)]$

$= 157.5\ watts/m^2$

$$Q_c = q_c\ A_c\ N_{daylight} \qquad (4)$$

where Q_c is the total annual energy collected

$N_{daylight}$ = number of daylight hours in year

= 4380 (assumed)

q_c is obtained from Figure 6.1 (Reference 7, p. 87)

Figure 6.1 plots with $F_R U_L\ (T_{in} - T_a)/F_R \eta_o\ I_b$ as abscissa and $q/F_F F_R\ o\ (I_b + 50)$ as ordinate.

$I_b = I_a$ (assumed) $T_a = 30^oC$(assumed) (Reference 7)

$$\frac{F_R U_L (T_{in} - T_a)}{F_R\ \eta_o\ I_b} = \frac{0.5(130-30)}{(0.72)(277.8)} = 0.22$$

For North-South troughs at latitude of 30°:

$$q_c/F_F F_R \eta_o (I_b + 50) = 0.56 \qquad \text{(reference 7)}$$

$$q_c = 0.56\ (1.20)(0.72)(277.8 + 50)$$

$$= 158.6\ W/m^2$$

From equation (4):

$$Q_c = (158.6)(3{,}300)(4{,}380)(3{,}600)$$

$$= 8.25 \times 10^{12}\ J/yr$$

The total annual process load is

$$Q_{load} = Q_{load}\ N_{load} \qquad (5)$$

where Q_{load} = average process load energy rate

$= 3.3 \times 10^9$ J/hr

N_{load} = number of hours process load operates during a year

= 4380 hr (assuming 60 percent)

$$Q_{load} = 3.3 \times 10^9\ (5{,}256)$$

$$= 1.454 \times 10^{13}\ J/yr$$

The solar fraction, f is calculated as

$$f = Q_c/Q_{load}$$

$$= \frac{8.25 \times 10^{12}}{1.454 \times 10^{13}}$$

$$= 0.57$$

Table 1

FINAL ANALYSIS OF A FLASH STEAM SYSTEM

PARAMETER	REMARKS	VALUE RANGE	VALUE CONSIDERED
$F_R U_L$, w/m ^{2o}K	Reference 1	0.25 - 0.75	0.5
$F_R \eta_o$	Reference 1	0.65 - 0.80	0.72
T_{in} η^oC	Input Data	130	130
Q load, GJ/hr	Data from Egypt	3.3	3.3
Collector eff.	Manufacturer	0.4	0.4
Available Energy, MJ/m^2 day	Data from Egypt	11-27	20
h_{fg}, watt-hr/kg	Reference 2	603.6	603.6
C_p, J/kg-K	Reference 3	4.26×10^3	4.26×10^3
T_f, ^oC	Guess Estimate	100	100
T_a, ^oC	Reference 1	40	40
A_c, m^2	Calculated	3,300	3,300
M_c, kg/hr	Calculated	1.5×10^3	1.5×10^3
$N_{daylight}$, hr/yr	Reference 1	4,380	4,380
N_{load}, hr/yr	Guess Estimate	5,256	5,256

APPENDIX E

HYBRID ANALYSIS

HYBRID ANALYSIS

Combination Parabolic Trough/Flat Plate Sytem

For a preliminary analysis of a hybrid solar thermal system, we have decided to use the following methodology. To raise ambient temperature 1 kg of water to 130°C steam, a quantity heat (Q_T) defined as

$$Q_T = 1\,(4.2 \times 10^3)[(100-20) + (130-100)] + 2.26 \times 10^6 \quad (1)$$
$$= 2.54 \times 10^6 \text{ J}$$

is needed. Assuming an optimum flat plate temperature is 70 °C, the maximum energy required of the flat plate system would then be

$$Q_{FP} = (1)(4.2 \times 10^3)(70-20)$$
$$= 2.1 \times 10^5 \text{ J}$$

This represents,

$$f_{FP} = \frac{2.1 \times 10^5}{2.54 \times 10^6}$$
$$= 0.083$$

fraction of the total energy requirement. Thus, we will take 8.3% from our original parabolic collector area and replace it with a flat plate system which will have an f factor equal to the parabolic system and will produce 8.3% of the total steam energy produced by the parabolic-only system. Hence

$$\text{new parabolic area} = 3300-3300(.083)$$
$$= 3026 \text{ m}^2$$

$$\text{flat plate load} = \frac{8250\ GJ(.083)}{0.57}$$

$$= 1201\ GJ$$

$$f = .57$$

Using trial and error methodology (see Figure A-1), we computed a flat plate collector area of,

$$A_{FP} = 268\ m^2$$

Now we calculate the total capital cost for this system.

$$C_{cap} = 500(3026) + 371(268)$$

$$= \$\ 1,612,428$$

This information is then entered into our program for computing annualized capital costs and overall energy cost such as shown in Table 5.10.2-1.

*** GENERAL SOLAR HEATING SYSTEM ***
** FLAT PLATE COLLECTOR **

	SOLAR GJ	LOAD GJ	OTHER GJ	AUX GJ	F
JAN	167.4	58.9	1.24	28.0	0.52
FEB	167.4	53.2	1.16	22.8	0.57
MAR	192.8	53.9	1.27	24.5	0.58
APR	188.0	57.0	1.18	23.5	0.59
MAY	181.5	58.9	1.09	27.0	0.54
JUN	173.3	57.0	0.99	28.9	0.53
JUL	183.3	58.9	1.05	25.9	0.55
AUG	186.4	58.9	1.13	23.3	0.60
SEP	189.8	57.0	1.18	21.2	0.63
OCT	167.6	58.9	1.22	22.8	0.61
NOV	182.6	57.0	1.14	25.6	0.55
DEC	156.1	58.9	1.18	29.5	0.50
YR	2136.2	693.5	13.82	301.1	0.57

1	NUMBER OF COLLECTOR PANELS....	72	
2	COLLECTOR PANEL AREA.....	3.7	M2
3	FR*UL (TEST SLOPE).....	4.5	W/M2-C
4	FR*TAU*ALPHA (TEST INTERCEPT).	.79	
5	COLLECTOR SLOPE.....	45	DEG
6	COLLECTOR AZIMUTH (SOUTH=0)...	0	DEG
7	INCIDENCE ANGLE MOD TYPE(8-10)	8	
8	NUMBER OF GLAZINGS.....	1	
9	INC ANGLE MODIFIER CONSTANT.		
10	INC ANGLE MODIFIER VALUE(S).		
	1 .999 .998 .995 .981 .953 .832		
	.7 .35 0		
11	COLLECTOR FLOWRATE/AREA.....	.015	KG/S-M2
12	COLLECTOR FLUID SPECIFIC HEAT.	4.19	KJ/KG-C
13	MODIFY TEST VALUES (1=Y,2=N)..	2	
14	TEST COLLECTOR FLOWRATE/AREA	.015	KG/S-M2
15	TEST FLUID SPECIFIC HEAT....	4.19	KJ/KG-C

Figure E-1

F-Chart Computation Which Guesses 268 m^2 for Collector Area to Match an F-factor of 0.57

361

FIGURE E-2

ECONOMIC EVALUATION OF FLAT PLATE COLLECTORS, (70 deg C)

	UNITS	YR 0	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15
PROCESS LOAD	GJ/YR	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454
COLLECTOR AREA	M2	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
ENERGY PRODUCED	GJ/YR	6793	6793	6793	6793	6793	6793	6793	6793	6793	6793	6793	6793	6793	6793	6793	6793
PRICE OF INSTALLED COLLECTOR	$/M2	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371
OPERATION & MAINTENANCE	%	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
DISCOUNT RATE	%	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
PRODUCT LIFE	YEARS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
INITIAL CAPITAL COST	US $	927500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PARTS, ($20/FT2)	US $	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAINTENANCE	$/YR	0	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.5
TOTAL COSTS	$/YR	927500	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.5
NET PRESENT VALUE	US $	1939381.															
ANNUALIZED PRESENT VALUE	$/YR	123504.															
COST OF ENERGY	$/GJ	18.18															
COST OF ENERGY	$/KWH	0.06545															
COST OF ENERGY	$/BBL	110.80															

FIGURE E-3

ECONOMIC EVALUATION OF FLAT PLATE COLLECTORS, (90 deg C)

	UNITS	YR 0	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15
PROCESS LOAD	GJ/YR	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454
COLLECTOR AREA	M2	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
ENERGY PRODUCED	GJ/YR	6504	6504	6504	6504	6504	6504	6504	6504	6504	6504	6504	6504	6504	6504	6504	6504
PRICE OF INSTALLED COLLECTOR	$/M2	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371
OPERATION & MAINTENANCE	%	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
DISCOUNT RATE	%	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
PRODUCT LIFE	YEARS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
INITIAL CAPITAL COST	US $	927500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PARTS, ($20/FT2)	US $	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAINTENANCE	$/YR	0	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.5
TOTAL COSTS	$/YR	927500	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.	13912.5
NET PRESENT VALUE	US $	1939381.															
ANNUALIZED PRESENT VALUE	$/YR	123504.															
COST OF ENERGY	$/GJ	18.99															
COST OF ENERGY	$/KWH	0.06836															
COST OF ENERGY	$/BBL	115.72															

FIGURE E-4

ECONOMIC EVALUATION OF EVACUATED TUBE COLLECTORS, (70 deg C)

	UNITS	YR 0	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15
PROCESS LOAD	GJ/YR	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454
COLLECTOR AREA	M2	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
ENERGY PRODUCED	GJ/YR	6865	6865	6865	6865	6865	6865	6865	6865	6865	6865	6865	6865	6865	6865	6865	6865
PRICE OF INSTALLED COLLECTOR	$/M2	418	418	418	418	418	418	418	418	418	418	418	418	418	418	418	418
OPERATION & MAINTENANCE	%	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
DISCOUNT RATE	%	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
PRODUCT LIFE	YEARS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
INITIAL CAPITAL COST	US $	1045000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PARTS, ($20/FT2)	US $	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAINTENANCE	$/YR	0	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675
TOTAL COSTS	$/YR	1045000	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675
NET PRESENT VALUE	US $	1058386															
ANNUALIZED PRESENT VALUE	$/YR	139150.															
COST OF ENERGY	$/GJ	20.27															
COST OF ENERGY	$/KWH	0.07297															
COST OF ENERGY	$/BBL	123.53															

FIGURE E-5

ECONOMIC EVALUATION OF EVACUATED TUBE COLLECTORS, (90 deg C)

	UNITS	YR 0	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15
PROCESS LOAD	GJ/YR	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454
COLLECTOR AREA	M2	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
ENERGY PRODUCED	GJ/YR	6685	6685	6685	6685	6685	6685	6685	6685	6685	6685	6685	6685	6685	6685	6685	6685
PRICE OF INSTALLED COLLECTOR	$/M2	418	418	418	418	418	418	418	418	418	418	418	418	418	418	418	418
OPERATION & MAINTENANCE	%	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
DISCOUNT RATE	%	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
PRODUCT LIFE	YEARS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
INITIAL CAPITAL COST	US $	1045000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PARTS, ($20/FT2)	US $	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAINTENANCE	$/YR	0	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675
TOTAL COSTS	$/YR	1045000	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675	15675
NET PRESENT VALUE	US $	1058386															
ANNUALIZED PRESENT VALUE	$/YR	139150.															
COST OF ENERGY	$/GJ	20.82															
COST OF ENERGY	$/MWH	0.07493															
COST OF ENERGY	$/MM	125.85															

FIGURE E-6

ECONOMIC EVALUATION OF PARABOLIC ONE AXIS TRACKING COLLECTORS, (90 deg C)

	UNITS	YR 0	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
PROCESS LOAD	GJ/YR	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454
COLLECTOR AREA	M2	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
ENERGY PRODUCED	GJ/YR	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5	8645.5
PRICE OF INSTALLED COLLECTOR	$/M2	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
OPERATION & MAINTENANCE	%	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
DISCOUNT RATE	%	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
PRODUCT LIFE	YEARS	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
INITIAL CAPITAL COST	US $	1125000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PARTS, (120/FT2)	US $	0	0	0	0	0	0	0	0	0	0	538200	0	0	0	0	0	0	0	0	0	0
MAINTENANCE	$/YR	0	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750
TOTAL COSTS	$/YR	1125000	18750	18750	18750	18750	18750	18750	18750	18750	18750	556950	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750
NET PRESENT VALUE	US $	1470117																				
ANNUALIZED PRESENT VALUE	$/YR	172679.																				
COST OF ENERGY	$/GJ	19.97																				
COST OF ENERGY	$/KWH	0.07190																				
COST OF ENERGY	$/EBL	121.72																				

FIGURE E-7

ECONOMIC EVALUATION OF PARABOLIC ONE AXIS TRACKING COLLECTORS, (90 deg C)

	UNITS	YR 0	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
PROCESS LOAD	GJ/YR	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454
COLLECTOR AREA	M2	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
ENERGY PRODUCED	GJ/YR	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5	8812.5
PRICE OF INSTALLED COLLECTOR	$/M2	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
OPERATION & MAINTENANCE	%	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
DISCOUNT RATE	%	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
PRODUCT LIFE	YEARS	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
INITIAL CAPITAL COST	US $	11250000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PARTS, ($20/FT2)	US $	0	0	0	0	0	0	0	0	0	0	538200	0	0	0	0	0	0	0	0	0	0
MAINTENANCE	$/YR	0	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750
TOTAL COSTS	$/YR	11250000	18750	18750	18750	18750	18750	18750	18750	18750	18750	556950	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750
NET PRESENT VALUE	US $	11470117																				
ANNUALIZED PRESENT VALUE	$/YR	1172679.																				
COST OF ENERGY	$/GJ	19.59																				
COST OF ENERGY	$/KWH	0.07054																				
COST OF ENERGY	$/BBL	119.42																				

FIGURE E-8

ECONOMIC EVALUATION OF 1990 PARABOLIC ONE AXIS TRACKING COLLECTORS

	UNITS	YR 0	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
PROCESS LOAD	GJ/YR	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454	14454
COLLECTOR AREA	M2	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
ENERGY PRODUCED	GJ/YR	9077	9077	9077	9077	9077	9077	9077	9077	9077	9077	9077	9077	9077	9077	9077	9077	9077	9077	9077	9077	9077
PRICE OF INSTALLED COLLECTOR	$/M2	392	392	392	392	392	392	392	392	392	392	392	392	392	392	392	392	392	392	392	392	392
OPERATION & MAINTENANCE	%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
DISCOUNT RATE	%	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
PRODUCT LIFE	YEARS	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
INITIAL CAPITAL COST	US $	980000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PARTS, ($20/FT2)	US $	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAINTENANCE	$/YR	0	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400
TOTAL COSTS	$/YR	980000	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400	29400
NET PRESENT VALUE	US $	1118453																				
ANNUALIZED PRESENT VALUE	$/YR	131373.																				
COST OF ENERGY	$/GJ	14.47																				
COST OF ENERGY	$/KWH	0.05210																				
COST OF ENERGY	$/BBL	88.20																				

APPENDIX F

ROOF PONDS

ROOF PONDS

1.0 DESCRIPTION

Roof ponds generally consist of an enclosed layer of water located on the roof. Roof ponds act as a collector, storage medium, heat dissipator, and radiator. Thus, this system can function in both heating and cooling capacities.

In cooling applications, insulation covers the pond during the daytime. As a result, the pond acts as a storage medium. At night, the insulation is removed and the pond radiates heat stored to the sky, thus cooling the home.(see Figure 1)

2.0 ANALYSIS

The analysis is performed on a typical Egyptian home with a floor area of $120m^2$ and an overall heat loss coefficient of 4.15 $W/m^{2o}C$. The greatest cooling need occurs in the month of July. During this month, the Cairo cooling load is calculated to be 103.9 degree days. This corresponds to a July cooling load of 4.47 GJ.

Approximately 40% of the daily cooling load occurs at night. Thus, the approximate nighttime cooling load is 6.0 MJ/hr

Table 1 details the analysis conducted. Under clear skies with low humidity and cool nighttime temperatures, a pond with a depth of 15cm can dissipate approximately 63 W/m^2 pond area.

Using these rough values, a pond with an area of 20 m^2 can account for 76% of the nighttime cooling load.

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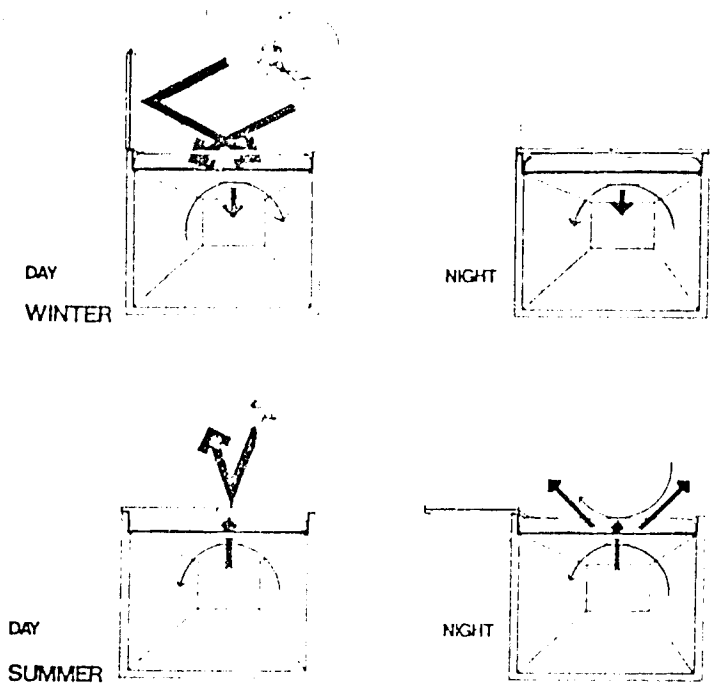
(1) Edward Mazria, The Passive Solar Energy Book, Rodale Press, Emmaus, Pennsylvania, 1979, pp. 187-199.

FIGURE 1



ROOF POND - MILD CLIMATES

TABLE 1

EFFECT OF ROOF POND ON COOLING LOAD	UNITS	
REF. DEGREE DAY TEMPERATURE	DEG C	25
DEG COOLING DAYS FOR JULY	DDs	103.5
BUILDING HT. LOSS COEFF.	W/M2/C	4.15
BUILDING FLOOR AREA	M2	120
DAYS/MONTH	DAYS/MO	31
COOLING LOAD		
MONTHLY COOLING LOAD	GJ/MO	4.471
DAILY COOLING LOAD	MJ/DAY	144.2
NIGHTLY DAILY COOLING LOAD (40%)	MJ/DAY	57.7
DAYTIME COOLING LOAD (60%)	MJ/DAY	86.5
AREA OF ROOF POND	M2	20
DEPTH OF ROOF POND	M	0.1524
AVE. HEAT DISSIPATED AT NIGHT	W/M2	63.04
TOTAL HEAT DISSIPATED AT NIGHT	MJ/HR	4.54
HOURLY NIGHTTIME COOLING LOAD	MJ/HR	6.01
PERCENTAGE OF COOLING LOAD SAVED	%	0.76

APPENDIX G

ANALYSIS OF OVERHANGS

ANALYSIS OF OVERHANGS

1.0 DESCRIPTION

Overhangs or horizontal planes projecting above a window can eliminate much of the summer sun while still letting in a large portion of the winter sun. South-facing glazing is more effectively shaded than east or west facing glazing. This is due to the east-west path of the sun which translates into a low solar altitude and shading for parts of the day for east or west facing surfaces. For the purpose of this analysis, only south facing windows and overhangs are considered.

Overhangs are characterized by two ratios; the separation, Y/H, and the overhang, X/H. (See Figure X1).(1) The separation ratio is the relation between the distance of the overhang above the window and the window height. The overhang ratio relates the projection length to the window height. The design of an overhang requires optimization of these two parameters. For example, a design that intercepts most of the summer sun will also reduce solar gains obtained in the winter months.

2.0 DESIGN PROCEDURE FOR OVERHANGS

The optimal size and location of an overhang is a function of the heating and cooling load. The design of an overhang system requires optimization of the separation and overhang ratios. Design procedures for these dimensions are dependent upon the following factors:

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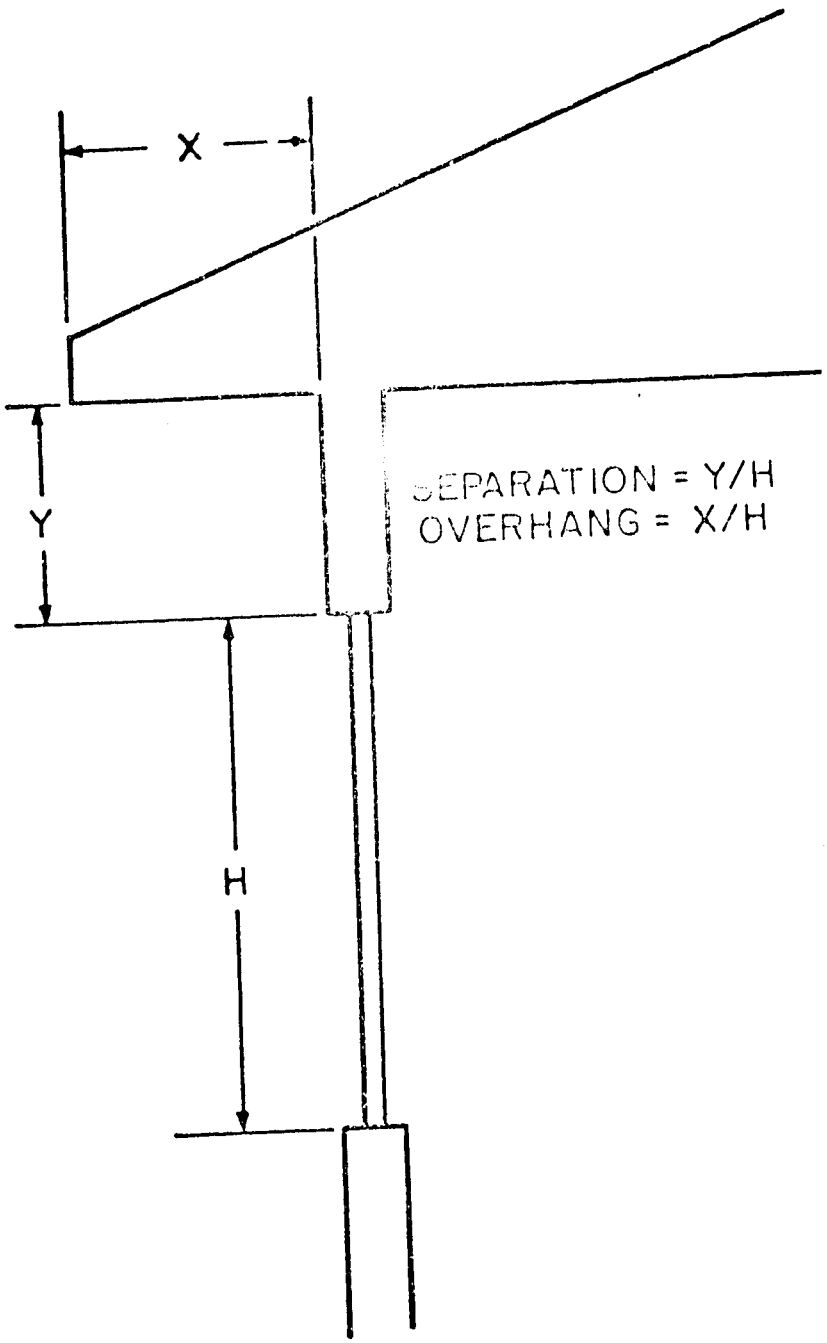
(1) Passive Solar Design Handbook, Vol. 2, Passive Solar Design Analysis, Los Alamos Scientific Laboratory, January 1980, p. C23.

FIGURE 1

OVERHANG GEOMETRY



a) Latitude

b) Number of days the window is to be shaded before and after the summer solstice

c) Number of days the window is to be unshaded before and after the winter solstice.

For example, for Cairo:

a) Latitude: 30 °

b) 50 days before and after summer solstice shaded

c) 60 days before and after winter solstice unshaded.(2)

The optimal size of the overhang is:

overhang X/H = .37

separation Y/H = .38

A graphical method was used to determine these values. Thus, an overhang of these dimensions will fully shade the window from approximately the first of May until mid August. Conversely, the window will be unshaded from the end of October until the end of February.

3.0 ANALYSIS OF OVERHANG PERFORMANCE

The method used to determine the effect of overhangs on monthly absorbed solar radiation into a building is taken from the Passive Solar Design Handbook. The analysis determines the effect of orientation, tilt, ground reflectance, reflectors, transmittance, absorbance, and overhang

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(2) Based on: Architects Handbook of Energy Practice, "Shading and Sun Control", American Institute of Architects, 1981, pp.14-18.

geometry on the monthly solar absorbed in a structure. From this value, the solar load ratio (SLR), and solar savings fraction (SSF) are calculated.

For our analysis, we took a building with a floor area of 120 m^2 and 3.6 m^2 of south facing glazing. Ten different overhang systems were analyzed with various separation and overhang ratios. See Table 1 for description of systems used.

The Lotus program was used to perform calcualations. Monthly horizontal solar radiation was provided for Cairo Center and the effects of the overhang were calculated. Fitted equations were in terms of latitude minus declination. Basically the method calculates factors for each situation and then modifies the horizontal solar into solar absorbed in the room. See Table 3 for the complete spreadsheet.

Table 2 compares the January and July performances of the ten different overhangs. The base case is one with no overhang; this is system type K.

Designs with a separation ratio of zero are not effective in Egypt's latitude. They reject 12-15% of absorbed summer solar but also cut potential winter gains by 6-25%. The primary objective is to reduce summer gain while not affecting winter gain.

Of the ten designs studied, type H performs the best. It does not affect winter gain, yet cuts July gain by 16.9%. Table 4 lists the yearly performance of Type H in terms of monthly solar absorbed. It is compared with a system with no overhang. Over the summer months (May-September) solar gain is reduced by 18.6%. Winter gain is only reduced by 0.3%. In conclusion, Type H is the best among those studied.

Table 1

DIMENSIONS OF OVERHANGS ANALYZED

TYPE	X/H (overhang)	Y/H (separation)
A	.125	0
B	.375	0
C	.125	.125
D	.375	.125
E	.125	.25
F	.375	.25
G	.125	.5
H	.375	.5
I	.25	0
J	.5	0
K	no overhang	

Table 2

	X/H ratio	Y/H ratio	JAN absorbed MJ/m 2 -mo	JUL absorbed MJ/m 2 -mo	% Difference from system with no overhang JAN	% Difference from JUL
A	.125	0	307	169	- 6.12	- 13.33
I	.25	0	286	165	- 12.54	- 15.38
B	.375	0	267	168	- 18.35	- 13.85
J	.5	0	244	171	- 25.38	- 12.31
C	.125	.125	327	171	0	- 12.31
D	.375	.125	296	167	- 9.48	- 14.36
E	.125	.25	327	173	0	- 11.28
F	.375	.25	320	165	- 2.14	- 15.38
G	.125	.5	327	182	0	- 6.67
H	.375	.5	327	162	0	- 16.92
K	no overhang		327	195	base value	base value

TABLE 4

PERFORMANCE OF OVERHANG TYPE H

TYPE H, X/H=.375, Y/H=.5	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
MONTHLY SOLAR ABSORBED MJ/M2/MO WITHOUT AN OVERHANG	327	308	282	221	188	191	195	211	258	331	325	329
MONTHLY ABSORBED WITH MJ/M2/MO OVERHANG H	327	308	260	170	145	168	162	156	218	326	325	329
PERCENT DIFFERENCE, MONTHLY	0.00	0.00	-7.80	-23.08	-22.87	-12.04	-16.92	-26.07	-15.50	-1.51	0.00	0.00
SUMMER MONTH DIFFERENCE (%)	-18.60											
WINTER MONTH DIFFERENCE (%)	-0.31											

SOLAR ENERGY ABSORBED FOR VARIOUS OVERHANGS

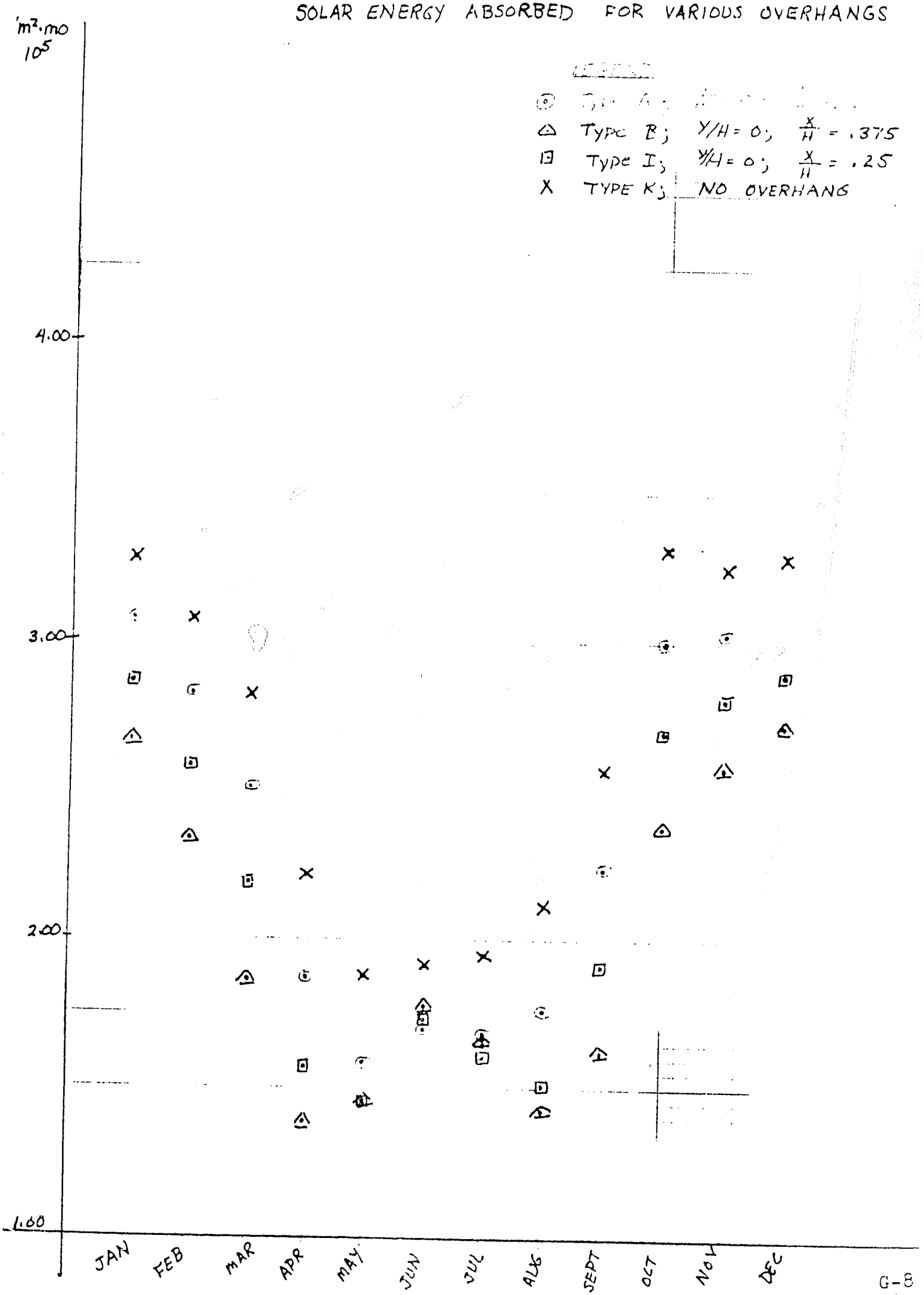

TABLE 3

LOTUS SPREADSHEET

ANALYSIS OF OVERHANGS													
BUILDING HEAT LOSS COEFF.	W/M2/C	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15
BUILDING AREA	M2	120	120	120	120	120	120	120	120	120	120	120	120
BUILDING LOAD COEFF.	W/C	498	498	498	498	498	498	498	498	498	498	498	498
BUILDING LOAD COEFF.	KJ/DEG C DAY	43027.2	43027.2	43027.2	43027.2	43027.2	43027.2	43027.2	43027.2	43027.2	43027.2	43027.2	43027.2
PROJECTED SOLAR AREA	M2	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
LCR	KJ/DD/M2	11952	11952	11952	11952	11952	11952	11952	11952	11952	11952	11952	11952
	UNITS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
HORIZ. DAILY INCIDENT SOLAR	KJ/M2/DAY	11585	15456	19129	23956	25493	27903	27422	25715	22246	17828	13054	11042
DAYS/MONTH	DAYS	31	28	31	30	31	30	31	31	30	31	30	31
MONTHLY HORIZ. SOLAR	KJ/M2/MO	359135	432768	592933	718740	790263	837090	850082	797165	667380	552668	391620	342302
MIDMONTH SOLAR DECLINATION	DEG	-21.4	-14	-2.8	9.1	18.6	23.1	21.4	14	2.8	-9.1	-18.6	-23.1
LATITUDE	DEG	30.05	30.05	30.05	30.05	30.05	30.05	30.05	30.05	30.05	30.05	30.05	30.05
(LAT. - DEC.)/100	DEG	0.5145	0.4405	0.3285	0.2095	0.1145	0.0695	0.0865	0.1605	0.2725	0.3915	0.4865	0.5315
VERTICAL VS. HORIZ. SOL. FACTOR	UNITLESS	1.318	1.073	0.775	0.537	0.423	0.401	0.406	0.468	0.652	0.933	1.220	1.381
TRANSMITTANCE VERT. WALL SOUTH FACING	UNITLESS	0.690	0.663	0.615	0.573	0.563	0.568	0.565	0.564	0.592	0.642	0.681	0.695

TABLE 3

OVERHANG RELATIONS F DIFF. GEOMETRIES			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
Y/H RATIO=0; X/H=0.125	TYPE A	UNITLESS	0.938	0.920	0.889	0.846	0.844	0.891	0.867	0.835	0.869	0.907	0.931	0.882
Y/H RATIO=0; X/H=0.375	TYPE B	UNITLESS	0.818	0.759	0.681	0.628	0.770	0.930	0.861	0.674	0.628	0.715	0.797	0.829
Y/H RATIO=0.125; X/H=0.125	TYPE C	UNITLESS	1.001	0.995	0.955	0.834	0.870	0.884	0.876	0.878	0.937	0.952	1.000	1.001
Y/H RATIO=0.125; X/H=0.375	TYPE D	UNITLESS	0.934	0.845	0.726	0.654	0.768	0.922	0.855	0.684	0.670	0.734	0.884	0.915
Y/H RATIO=0.25; X/H=0.125	TYPE E	UNITLESS	1.002	1.006	0.993	0.945	0.895	0.877	0.884	0.920	0.974	1.004	1.004	1.000
Y/H RATIO=0.25; X/H=0.375	TYPE F	UNITLESS	0.979	0.926	0.795	0.686	0.765	0.911	0.847	0.698	0.729	0.874	0.953	0.935
Y/H RATIO=0.5; X/H=0.125	TYPE G	UNITLESS	0.999	0.999	1.000	0.983	0.951	0.916	0.931	0.974	0.998	1.000	0.999	1.000
Y/H RATIO=0.5; X/H=0.375	TYPE H	UNITLESS	1.011	1.011	0.920	0.766	0.770	0.880	0.827	0.740	0.844	0.985	1.016	1.006
Y/H RATIO=0; X/H=0.25	TYPE I	UNITLESS	0.875	0.841	0.776	0.710	0.771	0.907	0.844	0.716	0.739	0.815	0.853	0.882
Y/H RATIO=0; X/H=0.5	TYPE J	UNITLESS	0.747	0.670	0.578	0.595	0.779	0.944	0.875	0.666	0.564	0.623	0.718	0.764
NO OVERHANG	TYPE K	UNITLESS	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

TABLE 3

PRODUCT OF ALL FACTORS													
TYPE A	UNITLESS	0.854	0.655	0.423	0.260	0.201	0.203	0.199	0.220	0.336	0.544	0.774	0.847
TYPE B	UNITLESS	0.744	0.540	0.314	0.193	0.183	0.212	0.198	0.178	0.243	0.428	0.662	0.796
TYPE C	UNITLESS	0.910	0.708	0.455	0.275	0.207	0.202	0.201	0.231	0.358	0.588	0.831	0.961
TYPE D	UNITLESS	0.823	0.601	0.346	0.201	0.183	0.210	0.196	0.181	0.261	0.476	0.735	0.879
TYPE E	UNITLESS	0.910	0.712	0.472	0.291	0.213	0.200	0.203	0.243	0.376	0.599	0.831	0.960
TYPE F	UNITLESS	0.891	0.659	0.378	0.211	0.183	0.208	0.195	0.184	0.282	0.524	0.800	0.947
TYPE G	UNITLESS	0.910	0.711	0.476	0.305	0.226	0.209	0.214	0.257	0.386	0.599	0.830	0.960
TYPE H	UNITLESS	0.910	0.712	0.438	0.236	0.183	0.201	0.190	0.195	0.326	0.590	0.831	0.961
TYPE I	UNITLESS	0.796	0.598	0.369	0.219	0.183	0.207	0.194	0.189	0.286	0.488	0.717	0.847
TYPE J	UNITLESS	0.679	0.477	0.275	0.183	0.185	0.215	0.201	0.176	0.218	0.373	0.596	0.733
TYPE K	UNITLESS	0.910	0.712	0.476	0.308	0.238	0.228	0.230	0.264	0.386	0.599	0.831	0.961

SOLAR ENERGY ABSORBED		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
TYPE A	KJ/M2/MO	3.07E+05	2.83E+05	2.51E+05	1.87E+05	1.59E+05	1.70E+05	1.69E+05	1.76E+05	2.24E+05	3.00E+05	3.03E+05	2.90E+05
TYPE B	KJ/M2/MO	2.67E+05	2.34E+05	1.86E+05	1.39E+05	1.45E+05	1.78E+05	1.68E+05	1.42E+05	1.62E+05	2.37E+05	2.59E+05	2.73E+05
TYPE C	KJ/M2/MO	3.27E+05	3.06E+05	2.70E+05	1.98E+05	1.64E+05	1.69E+05	1.71E+05	1.84E+05	2.39E+05	3.25E+05	3.25E+05	3.29E+05
TYPE D	KJ/M2/MO	2.96E+05	2.60E+05	2.05E+05	1.45E+05	1.44E+05	1.76E+05	1.67E+05	1.44E+05	1.74E+05	2.63E+05	2.88E+05	3.01E+05
TYPE E	KJ/M2/MO	3.27E+05	3.08E+05	2.80E+05	2.09E+05	1.68E+05	1.67E+05	1.73E+05	1.94E+05	2.51E+05	3.31E+05	3.25E+05	3.29E+05
TYPE F	KJ/M2/MO	3.20E+05	2.85E+05	2.24E+05	1.52E+05	1.44E+05	1.74E+05	1.65E+05	1.47E+05	1.88E+05	2.89E+05	3.13E+05	3.24E+05
TYPE G	KJ/M2/MO	3.27E+05	3.08E+05	2.82E+05	2.19E+05	1.79E+05	1.75E+05	1.82E+05	2.05E+05	2.57E+05	3.31E+05	3.25E+05	3.29E+05
TYPE H	KJ/M2/MO	3.27E+05	3.08E+05	2.60E+05	1.70E+05	1.45E+05	1.68E+05	1.62E+05	1.56E+05	2.18E+05	3.26E+05	3.25E+05	3.29E+05
TYPE I	KJ/M2/MO	2.86E+05	2.59E+05	2.19E+05	1.57E+05	1.45E+05	1.73E+05	1.65E+05	1.51E+05	1.91E+05	2.70E+05	2.81E+05	2.90E+05
TYPE J	KJ/M2/MO	2.44E+05	2.06E+05	1.63E+05	1.32E+05	1.46E+05	1.80E+05	1.71E+05	1.40E+05	1.45E+05	2.06E+05	2.34E+05	2.51E+05
TYPE K	KJ/M2/MO	3.27E+05	3.08E+05	2.82E+05	2.21E+05	1.88E+05	1.91E+05	1.95E+05	2.11E+05	2.58E+05	3.31E+05	3.25E+05	3.29E+05

DEG HEATING DAYS (18 C REF.)	deg-days	157.68	115.66	69.9	14.76	1.32	0.16	0.04	0.04	0.22	1.23	19.64	109
DEG COOLING DAYS (25 C REF)	deg-days	0.5	0.4	1.1	4	25.4	64.1	103.9	92.3	35.9	13.7	1.5	0.3

39

TABLE 3

S/DDs HEATING														
TYPE A	KJ/M2/DD	11.94E+03	2.45E+03	3.59E+03	1.27E+04	1.20E+05	1.06E+06	4.23E+06	4.39E+06	1.02E+06	2.44E+05	1.54E+04	2.66E+03
TYPE B	KJ/M2/DD	11.69E+03	2.02E+03	2.67E+03	9.42E+03	1.10E+05	1.11E+06	4.20E+06	3.55E+06	7.36E+05	1.92E+05	1.32E+04	2.50E+03
TYPE C	KJ/M2/DD	12.07E+03	2.65E+03	3.86E+03	1.34E+04	1.24E+05	1.05E+06	4.28E+06	4.61E+06	1.09E+06	2.64E+05	1.66E+04	3.02E+03
TYPE D	KJ/M2/DD	11.87E+03	2.25E+03	2.93E+03	9.80E+03	1.09E+05	1.10E+06	4.17E+06	3.60E+06	7.92E+05	2.14E+05	1.47E+04	2.76E+03
TYPE E	KJ/M2/DD	12.07E+03	2.66E+03	4.01E+03	1.42E+04	1.28E+05	1.05E+06	4.31E+06	4.84E+06	1.14E+06	2.69E+05	1.66E+04	3.02E+03
TYPE F	KJ/M2/DD	12.03E+03	2.47E+03	3.21E+03	1.03E+04	1.09E+05	1.09E+06	4.13E+06	3.67E+06	8.54E+05	2.35E+05	1.60E+04	2.97E+03
TYPE G	KJ/M2/DD	12.07E+03	2.66E+03	4.04E+03	1.48E+04	1.35E+05	1.09E+06	4.54E+06	5.13E+06	1.17E+06	2.69E+05	1.66E+04	3.02E+03
TYPE H	KJ/M2/DD	12.07E+03	2.66E+03	3.72E+03	1.15E+04	1.10E+05	1.05E+06	4.04E+06	3.89E+06	5.89E+05	2.65E+05	1.66E+04	3.02E+03
TYPE I	KJ/M2/DD	11.81E+03	2.24E+03	3.13E+03	1.06E+04	1.10E+05	1.08E+06	4.12E+06	3.77E+06	8.66E+05	2.19E+05	1.43E+04	2.66E+03
TYPE J	KJ/M2/DD	11.55E+03	1.78E+03	2.33E+03	8.92E+03	1.11E+05	1.13E+06	4.27E+06	3.50E+06	6.61E+05	1.68E+05	1.19E+04	2.30E+03
TYPE K	KJ/M2/DD	12.07E+03	2.66E+03	4.04E+03	1.50E+04	1.42E+05	1.19E+06	4.88E+06	5.26E+06	1.17E+06	2.69E+05	1.66E+04	3.02E+03
S/DDs COOLING													
TYPE A	KJ/M2/DD	16.13E+05	7.08E+05	2.28E+05	4.68E+04	6.24E+03	2.65E+03	1.63E+03	1.90E+03	6.24E+03	2.19E+04	2.02E+05	9.67E+05
TYPE B	KJ/M2/DD	15.34E+05	5.84E+05	1.70E+05	3.48E+04	5.70E+03	2.77E+03	1.62E+03	1.54E+03	4.51E+03	1.73E+04	1.73E+05	9.09E+05
TYPE C	KJ/M2/DD	16.54E+05	7.66E+05	2.45E+05	4.95E+04	6.44E+03	2.63E+03	1.65E+03	2.00E+03	6.66E+03	2.37E+04	2.17E+05	1.10E+06
TYPE D	KJ/M2/DD	15.91E+05	6.50E+05	1.86E+05	3.62E+04	5.68E+03	2.75E+03	1.61E+03	1.56E+03	4.85E+03	1.92E+04	1.92E+05	1.00E+06
TYPE E	KJ/M2/DD	16.54E+05	7.70E+05	2.55E+05	5.23E+04	6.63E+03	2.61E+03	1.66E+03	2.10E+03	7.00E+03	2.42E+04	2.17E+05	1.10E+06
TYPE F	KJ/M2/DD	16.40E+05	7.13E+05	2.04E+05	3.79E+04	5.68E+03	2.71E+03	1.59E+03	1.59E+03	5.23E+03	2.11E+04	2.09E+05	1.08E+06
TYPE G	KJ/M2/DD	16.53E+05	7.70E+05	2.57E+05	5.47E+04	7.04E+03	2.73E+03	1.75E+03	2.22E+03	7.17E+03	2.42E+04	2.17E+05	1.10E+06
TYPE H	KJ/M2/DD	16.54E+05	7.70E+05	2.36E+05	4.24E+04	5.70E+03	2.62E+03	1.55E+03	1.69E+03	6.06E+03	2.38E+04	2.17E+05	1.10E+06
TYPE I	KJ/M2/DD	15.72E+05	6.47E+05	1.99E+05	3.93E+04	5.71E+03	2.70E+03	1.59E+03	1.63E+03	5.31E+03	1.97E+04	1.87E+05	9.67E+05
TYPE J	KJ/M2/DD	14.88E+05	5.16E+05	1.48E+05	3.29E+04	5.76E+03	2.81E+03	1.64E+03	1.52E+03	4.05E+03	1.50E+04	1.56E+05	8.37E+05
TYPE K	KJ/M2/DD	16.54E+05	7.70E+05	2.57E+05	5.53E+04	7.40E+03	2.98E+03	1.88E+03	2.28E+03	7.18E+03	2.42E+04	2.17E+05	1.10E+06

TABLE 3

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
SLR HEATING													
TYPE A	UNITLESS	0.163	0.205	0.300	1.061	10.048	88.941	354.055	367.539	85.230	20.436	1.291	0.223
TYPE B	UNITLESS	0.142	0.169	0.223	0.788	9.175	92.877	351.672	296.900	61.564	16.095	1.105	0.209
TYPE C	UNITLESS	0.173	0.222	0.323	1.122	10.368	88.229	357.834	385.544	90.886	22.119	1.386	0.252
TYPE D	UNITLESS	0.157	0.188	0.245	0.820	9.149	92.104	349.055	300.993	66.244	17.896	1.226	0.231
TYPE E	UNITLESS	0.173	0.223	0.335	1.186	10.677	87.562	360.943	405.082	95.520	22.526	1.386	0.252
TYPE F	UNITLESS	0.170	0.206	0.269	0.860	9.147	90.983	345.950	307.405	71.460	19.681	1.335	0.249
TYPE G	UNITLESS	0.173	0.223	0.338	1.241	11.327	91.478	380.221	429.068	97.899	22.526	1.385	0.252
TYPE H	UNITLESS	0.173	0.223	0.311	0.961	9.174	87.874	337.925	325.723	82.753	22.191	1.386	0.252
TYPE I	UNITLESS	0.152	0.187	0.262	0.891	9.189	90.561	344.603	315.238	72.478	18.359	1.196	0.223
TYPE J	UNITLESS	0.129	0.149	0.195	0.747	9.278	94.215	357.201	293.047	55.319	14.024	0.995	0.193
TYPE K	UNITLESS	0.173	0.223	0.338	1.255	11.911	99.848	408.451	440.315	98.061	22.526	1.386	0.252
SLR COOLING													
TYPE A	UNITLESS	51.292	59.254	19.083	3.915	0.522	0.222	0.136	0.159	0.522	1.835	16.899	80.866
TYPE B	UNITLESS	44.715	48.878	14.184	2.909	0.477	0.232	0.135	0.129	0.377	1.445	14.465	76.016
TYPE C	UNITLESS	54.691	64.078	20.525	4.139	0.539	0.220	0.138	0.167	0.557	1.986	18.150	91.705
TYPE D	UNITLESS	49.458	54.410	15.592	3.026	0.475	0.230	0.134	0.130	0.406	1.607	16.050	83.903
TYPE E	UNITLESS	54.691	64.421	21.311	4.377	0.555	0.219	0.139	0.176	0.585	2.022	18.150	91.692
TYPE F	UNITLESS	53.525	59.666	17.063	3.174	0.475	0.227	0.133	0.133	0.438	1.767	17.478	90.400
TYPE G	UNITLESS	54.659	64.385	21.470	4.581	0.589	0.228	0.146	0.186	0.600	2.022	18.136	91.670
TYPE H	UNITLESS	54.691	64.421	19.752	3.547	0.477	0.219	0.130	0.141	0.507	1.992	18.150	91.705
TYPE I	UNITLESS	47.844	54.175	16.652	3.286	0.478	0.226	0.133	0.137	0.444	1.648	15.658	80.866
TYPE J	UNITLESS	40.829	43.148	12.401	2.755	0.482	0.235	0.138	0.127	0.339	1.259	13.025	70.019
TYPE K	UNITLESS	54.691	64.421	21.470	4.629	0.619	0.249	0.157	0.191	0.601	2.022	18.150	91.705

TABLE 3

DIRECT GAIN CORRELATION COEFF.														
G			10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
R			0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
A			0.5213	0.5213	0.5213	0.5213	0.5213	0.5213	0.5213	0.5213	0.5213	0.5213	0.5213	0.5213
B			1.0133	1.0133	1.0133	1.0133	1.0133	1.0133	1.0133	1.0133	1.0133	1.0133	1.0133	1.0133
C			1.0642	1.0642	1.0642	1.0642	1.0642	1.0642	1.0642	1.0642	1.0642	1.0642	1.0642	1.0642
D			0.6927	0.6927	0.6927	0.6927	0.6927	0.6927	0.6927	0.6927	0.6927	0.6927	0.6927	0.6927
K			1.000886	1.000886	1.000886	1.000886	1.000886	1.000886	1.000886	1.000886	1.000886	1.000886	1.000886	1.000886
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
	X CALC. HEAT													
TYPE A			0.163	0.205	0.300	1.060	10.040	88.862	353.741	367.213	85.154	20.418	1.290	0.222
TYPE B			0.142	0.169	0.223	0.788	9.167	92.795	351.361	296.637	61.510	16.081	1.104	0.209
TYPE C			0.173	0.221	0.323	1.121	10.359	88.151	357.517	385.202	90.805	22.100	1.385	0.252
TYPE D			0.157	0.188	0.245	0.819	9.141	92.023	348.746	300.726	66.185	17.880	1.225	0.231
TYPE E			0.173	0.223	0.335	1.185	10.668	87.485	360.623	404.723	95.436	22.506	1.385	0.252
TYPE F			0.170	0.206	0.268	0.859	9.139	90.902	345.643	307.133	71.397	19.663	1.334	0.249
TYPE G			0.173	0.222	0.338	1.240	11.317	91.397	379.884	428.688	97.813	22.506	1.384	0.252
TYPE H			0.173	0.223	0.311	0.950	9.166	87.796	337.625	325.434	82.680	22.171	1.385	0.252
TYPE I			0.152	0.187	0.262	0.890	9.181	90.481	344.298	314.959	72.413	18.334	1.195	0.222
TYPE J			0.129	0.149	0.195	0.746	9.269	94.132	356.885	292.787	55.270	14.012	0.994	0.193
TYPE K			0.173	0.223	0.338	1.253	11.900	99.759	408.089	439.925	97.974	22.506	1.385	0.252
TYPE A	F(X) CALC.		0.085	0.107	0.156	0.503	1.012	1.013	1.013	1.013	1.013	1.013	0.578	0.116
TYPE B			0.074	0.088	0.116	0.397	1.011	1.013	1.013	1.013	1.013	1.013	0.518	0.109
TYPE C			0.090	0.115	0.168	0.524	1.012	1.013	1.013	1.013	1.013	1.013	0.606	0.131
TYPE D			0.082	0.098	0.128	0.410	1.011	1.013	1.013	1.013	1.013	1.013	0.558	0.120
TYPE E			0.090	0.116	0.175	0.545	1.013	1.013	1.013	1.013	1.013	1.013	0.606	0.131
TYPE F			0.088	0.107	0.140	0.427	1.011	1.013	1.013	1.013	1.013	1.013	0.591	0.130
TYPE G			0.090	0.116	0.176	0.563	1.013	1.013	1.013	1.013	1.013	1.013	0.605	0.131
TYPE H			0.090	0.116	0.162	0.466	1.011	1.013	1.013	1.013	1.013	1.013	0.606	0.131
TYPE I			0.079	0.098	0.136	0.439	1.011	1.013	1.013	1.013	1.013	1.013	0.548	0.116
TYPE J			0.067	0.078	0.102	0.379	1.012	1.013	1.013	1.013	1.013	1.013	0.479	0.100
TYPE K			0.090	0.116	0.176	0.567	1.013	1.013	1.013	1.013	1.013	1.013	0.606	0.131

APPENDIX H

REFLECTIVE COATING AND LOW-EMISSIVITY GLASS

REFLECTIVE COATING AND LOW-EMISSIVITY GLASS

1.0 DESCRIPTION

Reflective films are composed of a thin metallic oxide layer. This film, when apolied to glazing, increases the amount of solar energy reflected by the window thus reducing the cooling load of the building. A clear single piece of glazing has a high emissivity; it transmits most of the incident solar radiation. Low emissivity glazings have a low absorbance, thus they reflect a large part of incident solar.

Manufacturers of these materials characterize their performance in terms of a "shading coefficient,"(SC). This coeffient is related to solar rejection by an empirical relation. Table 1 lists various products and their shading coefficients. Solar rejection, SR, is the portion of incoming solar heat that does not enter the building.

2.0 DESIGN PROCEDURE

Design of a glazing coating system involved optimization of two variables:

a) amount of visible transmission desired
b) amount of solar rejection needed.

Table 1 lists visible transmission and shading coefficient for eight systems. The data illustrates one important phenomena: in order to have a large solar rejection fraction, visible transmission is sacrificed.

TABLE 1

Type of Product	Visible Transmission	Unit thickness	SC	SR
Guardian Industries Low-E coating on green cover plate	64%	1"	.47	.5864
Guardian Industries Low-E coating on bronze cover	43%	1"	.49	.5688
Southwall Corp. HM-55 with clear cover	49%	1-1/4"	.42	.6304
Southwall Corp. HM-55 with green cover	40%	1-1/2"	.28	.7536
Clear single glazed	86%	-	-	.16
Clear double glazed	81%	-	-	.23
Reflective single glazed	20%	-	-	.64
Reflective double glazed	18%	-	-	.73

Cairo data was used to evaluate the performance of several coating systems.* The base case is a typical glazing with no overhang or coating. Visible transmission is 86% and solar rejection is 16%. A system with double glazing and low emissivity coating reduced monthly absorbed energy in July by 78%. However, visible transmission is only 14%. A more balanced system appears to be Southwall Corp HM-SS with a green cover.+ It rejected 75.4% of July absorbed energy while having a visible transmission of 40%.

Additional studies are required to determine the exact solar rejection that is optimal in Egypt. Also, more exact methods for analyzing performance need to be developed based on hourly solar data.

* See Table 2

+ See Table 3

TABLE 2

Monthly solar absorbed (MJ/m^2, mo)

JUN	191
JUL	195
AUG	211

TYPE OF MATERIAL	SOLAR REJECTION COEFFICIENT	MODIFIED SOLAR ABSORBED JULY MJ/m^2-mo	% DIFFERENCE BASE JULY VALUE	VISIBLE TRANSMISSION
Southwall Corp. HM-SS with green cover	.7536	48.0	- 75.4	40%
Reflective double glazed	.73	52.6	- 73	18%
Reflective single glazed	.64	70.2	- 64	20%
double with 1/2" air space low e (.40) coating	.78	42.9	- 78	14%
heat absorbing (double) 1/4" width	.3928	118.4	- 39	75%
Gray reflective insulating 1" width	.5864	80.6	- 59	30%

TABLE 3

EFFECT OF REFLECTIVE FILM ON ABSORBED SOLAR RADIATION

MATERIAL—SOUTHWALL CORPORATION HM-55 WITH GREEN COVER.

SHADING COEFFICIENT—0.28

VISIBLE TRANSMISSION—40%

UNIT THICKNESS—3.81CM

SOLAR REJECTION—0.7536

SOLAR ENERGY ABSORBED, MJ/M2/MO	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
GLAZING WITH NO COATING	327	308	282	221	188	191	195	211	258	331	325	329
GLAZING WITH HM-55 COATING	80.6	75.9	69.5	54.5	46.3	47.1	48.0	52.0	63.6	81.6	80.1	81.1
PERCENT DIFFERENCE, MONTHLY	-75.4	-75.4	-75.4	-75.4	-75.4	-75.4	-75.4	-75.4	-75.4	-75.4	-75.4	-75.4

TABLE 3

COOLING CALCULATIONS	SSF CALC.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
TYPE A	UNITLESS	1.0	1.0	1.0000	0.9424	0.2712	0.1148	0.0702	0.0821	0.2713	0.7141	1.0000	1.0000
TYPE B	UNITLESS	1.0	1.0	1.0000	0.8711	0.2477	0.1200	0.0697	0.0662	0.1958	0.6215	1.0000	1.0000
TYPE C	UNITLESS	1.0	1.0	1.0000	0.9526	0.2797	0.1139	0.0709	0.0862	0.2889	0.7438	1.0000	1.0000
TYPE D	UNITLESS	1.0	1.0	1.0000	0.8822	0.2470	0.1190	0.0692	0.0671	0.2107	0.6630	1.0000	1.0000
TYPE E	UNITLESS	1.0	1.0	1.0000	0.9618	0.2878	0.1131	0.0716	0.0906	0.3030	0.7506	1.0000	1.0000
TYPE F	UNITLESS	1.0	1.0	1.0000	0.8949	0.2469	0.1175	0.0685	0.0686	0.2274	0.6998	1.0000	1.0000
TYPE G	UNITLESS	1.0	1.0	1.0000	0.9686	0.3046	0.1181	0.0754	0.0960	0.3101	0.7506	1.0000	1.0000
TYPE H	UNITLESS	1.0	1.0	1.0000	0.9218	0.2476	0.1135	0.0669	0.0727	0.2634	0.7450	1.0000	1.0000
TYPE I	UNITLESS	1.0	1.0	1.0000	0.9037	0.2481	0.1170	0.0683	0.0703	0.2306	0.6727	1.0000	1.0000
TYPE J	UNITLESS	1.0	1.0	1.0000	0.8551	0.2505	0.1217	0.0708	0.0653	0.1758	0.5677	1.0000	1.0000
TYPE K	UNITLESS	1.0	1.0	1.0000	0.9701	0.3193	0.1290	0.0811	0.0986	0.3106	0.7506	1.0000	1.0000

COOLING CALCULATIONS	QAUX												
TYPE A	KJ/MO	10.00E+00	0.00E+00	0.00E+00	1.16E+08	1.96E+08	1.01E+08	6.52E+07	7.52E+07	1.96E+08	2.70E+08	0.00E+00	0.00E+00
TYPE B	KJ/MO	10.00E+00	0.00E+00	0.00E+00	1.93E+08	1.84E+08	1.05E+08	6.48E+07	6.18E+07	1.56E+08	2.81E+08	0.00E+00	0.00E+00
TYPE C	KJ/MO	10.00E+00	0.00E+00	0.00E+00	1.01E+08	2.00E+08	1.00E+08	6.58E+07	7.85E+07	2.04E+08	2.62E+08	0.00E+00	0.00E+00
TYPE D	KJ/MO	10.00E+00	0.00E+00	0.00E+00	1.83E+08	1.84E+08	1.04E+08	6.43E+07	6.26E+07	1.65E+08	2.78E+08	0.00E+00	0.00E+00
TYPE E	KJ/MO	10.00E+00	0.00E+00	0.00E+00	8.60E+07	2.03E+08	9.97E+07	6.63E+07	8.21E+07	2.10E+08	2.59E+08	0.00E+00	0.00E+00
TYPE F	KJ/MO	10.00E+00	0.00E+00	0.00E+00	1.72E+08	1.84E+08	1.03E+08	6.38E+07	6.38E+07	1.74E+08	2.73E+08	0.00E+00	0.00E+00
TYPE G	KJ/MO	10.00E+00	0.00E+00	0.00E+00	7.40E+07	2.11E+08	1.04E+08	6.96E+07	8.64E+07	2.13E+08	2.59E+08	0.00E+00	0.00E+00
TYPE H	KJ/MO	10.00E+00	0.00E+00	0.00E+00	1.43E+08	1.84E+08	1.00E+08	6.24E+07	6.73E+07	1.92E+08	2.61E+08	0.00E+00	0.00E+00
TYPE I	KJ/MO	10.00E+00	0.00E+00	0.00E+00	1.63E+08	1.85E+08	1.03E+08	6.36E+07	6.53E+07	1.76E+08	2.77E+08	0.00E+00	0.00E+00
TYPE J	KJ/MO	10.00E+00	0.00E+00	0.00E+00	2.05E+08	1.86E+08	1.06E+08	6.57E+07	6.10E+07	1.44E+08	2.80E+08	0.00E+00	0.00E+00
TYPE K	KJ/MO	10.00E+00	0.00E+00	0.00E+00	7.13E+07	2.17E+08	1.12E+08	7.43E+07	8.85E+07	2.13E+08	2.59E+08	0.00E+00	0.00E+00

TABLE 3

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
HEATING CALCULATION	SSF CALC.												
TYPE A	UNITLESS	0.0839	0.1059	0.1557	0.5023	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.5773	0.1151
TYPE B	UNITLESS	0.0730	0.0872	0.1155	0.3961	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.5175	0.1082
TYPE C	UNITLESS	0.0895	0.1146	0.1675	0.5233	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.6052	0.1307
TYPE D	UNITLESS	0.0809	0.0972	0.1270	0.4095	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.5573	0.1195
TYPE E	UNITLESS	0.0895	0.1153	0.1739	0.5446	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.6052	0.1307
TYPE F	UNITLESS	0.0876	0.1067	0.1391	0.4260	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.5905	0.1288
TYPE G	UNITLESS	0.0895	0.1152	0.1752	0.5622	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.6049	0.1306
TYPE H	UNITLESS	0.0895	0.1153	0.1611	0.4656	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.6052	0.1307
TYPE I	UNITLESS	0.0782	0.0968	0.1357	0.4382	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.5478	0.1151
TYPE J	UNITLESS	0.0666	0.0769	0.1008	0.3780	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.4783	0.0996
TYPE K	UNITLESS	0.0895	0.1153	0.1752	0.5663	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.6052	0.1307
QAUX FOR HEATING													
TYPE A	KJ/MO	17.66E+07	9.42E+07	1.30E+08	2.72E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.81E+08	1.01E+08
TYPE B	KJ/MO	16.76E+07	7.93E+07	1.02E+08	2.45E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.74E+08	9.60E+07
TYPE C	KJ/MO	18.12E+07	1.01E+08	1.38E+08	2.75E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.81E+08	1.13E+08
TYPE D	KJ/MO	17.41E+07	8.74E+07	1.10E+08	2.49E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.79E+08	1.05E+08
TYPE E	KJ/MO	18.12E+07	1.01E+08	1.42E+08	2.78E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.81E+08	1.13E+08
TYPE F	KJ/MO	17.96E+07	9.48E+07	1.19E+08	2.54E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.81E+08	1.11E+08
TYPE G	KJ/MO	18.12E+07	1.01E+08	1.43E+08	2.79E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.81E+08	1.13E+08
TYPE H	KJ/MO	18.12E+07	1.01E+08	1.34E+08	2.64E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.81E+08	1.13E+08
TYPE I	KJ/MO	17.19E+07	8.70E+07	1.16E+08	2.57E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.78E+08	1.01E+08
TYPE J	KJ/MO	16.21E+07	7.08E+07	9.02E+07	2.39E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.67E+08	8.92E+07
TYPE K	KJ/MO	18.12E+07	1.01E+08	1.43E+08	2.80E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.81E+08	1.13E+08

TABLE 3

COOLING CALCULATIONS													
	X CALC.												
TYPE A		51.25	59.20	19.07	3.91	0.52	0.22	0.14	0.16	0.52	1.83	16.88	80.79
TYPE B		44.68	48.83	14.17	2.91	0.48	0.23	0.14	0.13	0.38	1.44	14.45	75.95
TYPE C		54.64	64.02	20.51	4.14	0.54	0.22	0.14	0.17	0.56	1.98	18.13	91.62
TYPE D		49.41	54.36	15.58	3.02	0.48	0.23	0.13	0.13	0.41	1.61	16.04	83.83
TYPE E		54.64	54.36	21.29	4.37	0.55	0.22	0.14	0.18	0.58	2.02	18.13	91.61
TYPE F		53.48	59.61	17.05	3.17	0.47	0.23	0.13	0.13	0.44	1.77	17.46	90.32
TYPE G		54.61	64.33	21.45	4.58	0.55	0.23	0.15	0.19	0.60	2.02	18.12	91.59
TYPE H		54.64	64.36	19.73	3.54	0.48	0.22	0.13	0.14	0.51	1.99	18.13	91.62
TYPE I		47.80	54.13	16.64	3.28	0.48	0.23	0.13	0.14	0.44	1.65	15.64	80.79
TYPE J		40.79	43.11	12.39	2.75	0.48	0.23	0.14	0.13	0.34	1.26	13.01	69.36
TYPE K		54.64	64.36	21.45	4.63	0.52	0.26	0.16	0.19	0.60	2.02	18.13	91.62
COOLING CALCULATIONS	F(X) CALC.												
TYPE A		1.013	1.013	1.013	0.942	0.272	0.115	0.071	0.083	0.272	0.714	1.013	1.013
TYPE B		1.013	1.013	1.013	0.871	0.248	0.121	0.071	0.067	0.196	0.622	1.013	1.013
TYPE C		1.013	1.013	1.013	0.953	0.280	0.115	0.072	0.087	0.290	0.744	1.013	1.013
TYPE D		1.013	1.013	1.013	0.882	0.248	0.120	0.070	0.068	0.211	0.663	1.013	1.013
TYPE E		1.013	1.013	1.013	0.962	0.288	0.114	0.072	0.091	0.304	0.751	1.013	1.013
TYPE F		1.013	1.013	1.013	0.895	0.248	0.118	0.069	0.069	0.228	0.700	1.013	1.013
TYPE G		1.013	1.013	1.013	0.959	0.305	0.119	0.076	0.097	0.311	0.751	1.013	1.013
TYPE H		1.013	1.013	1.013	0.922	0.248	0.114	0.068	0.074	0.264	0.745	1.013	1.013
TYPE I		1.013	1.013	1.013	0.904	0.249	0.118	0.069	0.071	0.231	0.673	1.013	1.013
TYPE J		1.013	1.013	1.013	0.855	0.251	0.122	0.072	0.066	0.177	0.568	1.013	1.013
TYPE K		1.013	1.013	1.013	0.970	0.320	0.130	0.082	0.099	0.311	0.751	1.013	1.013