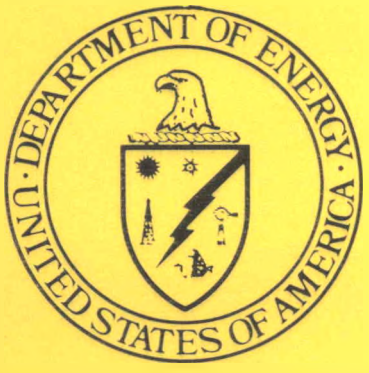
SOLAR/2056-79/60

Solar Project Cost Report

INGHAM COUNTY MEDICAL CARE FACILITY
Okemos, Michigan
August 1979



U.S. Department of Energy
National Solar Heating and Cooling Demonstration Program

National Solar Data Program

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SOLAR PROJECT

COST REPORT

for

INGHAM COUNTY

MEDICAL CARE FACILITY

OKEMOS, MICHIGAN

Prepared for
DEPARTMENT OF ENERGY
OFFICE OF ASSISTANT SECRETARY
FOR CONSERVATION AND SOLAR APPLICATIONS
NATIONAL SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

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Prepared by
MUELLER ASSOCIATES, INC.

Under Subcontract to PRC Energy Analysis Company

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NATIONAL SOLAR DATA PROGRAM REPORTS

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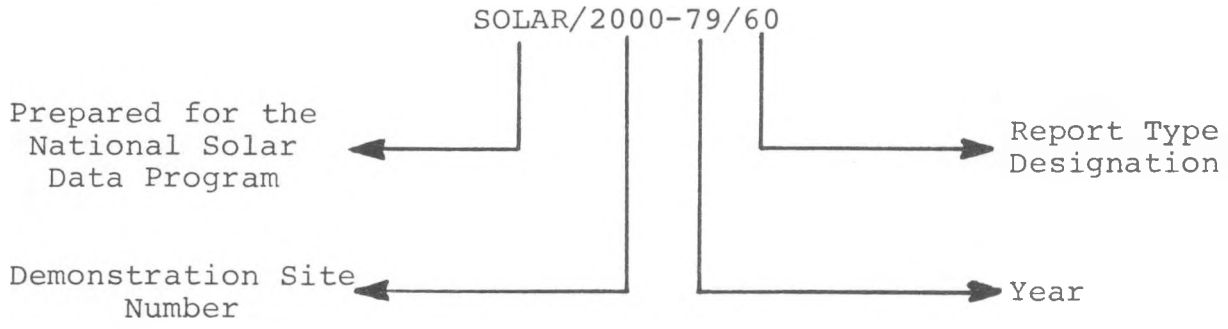

- Demonstration Site Number:
  Each project site has its own discrete number - 1000 through 1999 for residential sites and 2000 through 2999 for commercial sites.
- Report Type Designation:
  This number identifies the type of report, e.g.,
  - Monthly Performance Reports are designated by the numbers 01 (for January) through 12 (for December)
  - Solar Energy System Performance Evaluations are designated by the number 14
  - Solar Project Descriptions are designated by the number 50
  - Solar Project Cost Reports are designated by the number 60

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I. FOREWORD

The National Program for Solar Heating and Cooling is being conducted by the Department of Energy as mandated by the Solar Heating and Cooling Demonstration Act of 1974. The overall goal of the Federal Demonstration Program is to assist in the establishment of a viable solar industry and to stimulate its growth. An analysis and synthesis of the information gathered through this program will be disseminated in site-specific reports and summary documents as part of the National Solar Data Program. This cost report is a component of a larger data gathering effort to determine the costs and cost factors to satisfy the data requirements of the following:

- DOE planning and management
- Economic projections and analysis
- The solar industry infrastructure

The focus of this report is the initial installation cost of the system. No design, start-up, operating or maintenance costs are provided nor are costs for the solar data acquisition system (SDAS) and display system that may be installed in conjunction with the solar system.

Associated reports prepared by others for this specific solar demonstration project describe the system in greater detail, provide reliability and maintenance information, and describe system performance.

A similar series of reports is being developed for other solar demonstration program projects to assure widespread dissemination of project data. Detailed analysis of this report will require reference to the "Solar Project Description" for this project.

II. EXECUTIVE SUMMARY

This report provides detailed cost information for the Ingham County Medical Care Facility solar service water heating project located in Okemos, Michigan.

This Demonstration Project was funded by the U.S. Energy Research and Development Administration (ERDA, now the U.S. Department of Energy, DOE) in the Program Opportunity Notice (PON) Cycle 1. The PON request was issued in the Autumn of 1975. Bosch Mechanical Contractors, Inc., was the prime contractor for the project construction.

The solar energy system supplies service hot water for a 204 bed medical and geriatric care facility with laundry and kitchen. The system was designed at the time the building was designed. The 9,374 ft^2 of collectors were manufactured by Revere Copper and Brass, Inc., and are mounted at grade level behind the building.

Solar heated water for use in heating service water is stored in a 5,000 gallon hot water storage tank. The heaviest use of hot water occurs during the day so the requirement for thermal storage is modest.

The construction costs of this solar project are presented in this report. Category costs are listed by materials, direct labor, and subcontract costs. The subcontract costs include both materials, labor, overhead and profit for electrical, control and other minor subcontractors. No further breakdown of these costs could be obtained. Most costs incurred by the mechanical subcontractor could be disaggregated into materials and labor and were reported accordingly. The installed cost of the system was $312,825 not including prime contractor overhead and profit and general and administrative costs. Subsequent sections, especially Sections VI through VIII, provide a more detailed account of the data base and category cost components.

III. INTRODUCTION

The approach to assembling the data into solar system cost categories for every installation is to resolve the data into elements at two levels of detail, primary and secondary. Table III-1 provides an indication of the level of disaggregation associated with primary and secondary cost breakdowns.

TABLE III-1. SITE SPECIFIC COST BREAKDOWN

PRIMARY	SECONDARY
Collector Array	• Materials • Delivery • Mounting on Support Structure • Connecting Collectors to Manifold
Collector Support Structure	• Materials • Labor
Piping	• Collector Distribution System o Materials o Labor • Other Piping o Materials o Labor
Ductwork	• Collector Distribution System o Materials o Labor • Other Ductwork o Materials o Labor
Insulation	• Collector Distribution System o Materials o Labor • Other Piping/Ductwork o Materials o Labor
Heating/Cooling Equipment	• Materials • Delivery • Installation
Storage	• Materials • Delivery • Installation • Insulation
Controls	• Materials • Labor
Electrical Power	• Total
General Construction	• Roofing • Equipment Room • Architectural • Excavation • Other

In general, the primary cost breakdown follows work categories typically performed by different trades or subcontractors on building systems construction projects and are often separable, identifiable costs. The secondary cost categories represent a more detailed breakdown of the primary categories and are more difficult to obtain. This information is sought through discussions with subcontractors and suppliers, and by reviewing their records.

The following are typical examples of components comprising the cost breakdown categories listed on Table III-1.

- Collector Array: all materials provided by collector manufacturer (including tracking mechanisms, attachment fittings, hoses), labor to install collectors on support structure, labor and materials to connect collectors to supply and return manifolds, and miscellaneous specialties required for a complete array.
- Collector Support Structure: all framing, beams and columns, roof connections, fasteners and brackets required to receive collectors.
- Piping: all collector distribution and major supply and return piping, external collector manifolds, if required, pumps, expansion tanks, valves, interconnecting piping, hangers, and miscellaneous piping specialties.
- Ductwork: all ductwork connecting collectors to air handling equipment, dampers, interconnection with auxiliary systems and filter boxes.
- Insulation: all insulation - both interior and exterior - for piping and ductwork, chillers, and miscellaneous equipment, except energy storage containers.
- Heating/Cooling Equipment: absorption chillers, heat pumps, or heat exchangers used to interface with auxiliary system or to deliver energy directly to load.
- Storage: vessel or container, lining, supports, pads, internal piping, nozzles, and insulation.
- Controls: solid state controllers, thermostats, alarms switches, wiring, automatic valves and miscellaneous pneumatic or electrical devices.

- Electrical: normally an identifiable subcontract including power wiring, motor controllers, starters, conduits, disconnect switches, and miscellaneous high voltage electrical devices.
- General Construction: excavation, crane, tool and equipment rental, permits, painting, architectural modifications or additional space requirements, roofing and temporary services such as clean-up, field offices, and temporary telephones and electrical service.
- Auxiliary energy system costs are not included as part of the solar energy system costs.

Obtaining accurate total project construction cost is the focus of the data gathering effort. The costs presented do not include the contractor's overhead and profit (OH&P) or general and administrative costs. There is a general sensitivity to the publication of OH&P costs among corporations in a competitive market. Also, the bare costs (without overhead and profit) are more useful to other project planners and contractors since they could include their own overhead and profit figures.

General contractors are a main source of data since they often have the most cost information for each project. Major subcontractors are interviewed where possible to obtain more specific information pertaining to respective subsystems. Interviews are pursued with the personnel from the contracting firms who were actually on site performing the work and those that kept the cost records.

For each cost category the following types of information are sought:

- Labor type utilized
- Number of workers utilized
- Number of hours required
- Time per unit of equipment installed
- Materials cost
- Labor rates
- Delivery costs of major items
- Overhead factors
- Total costs

This information is obtained from cost files, invoices, time logs, government payment request vouchers, monthly progress reports, bills-of-materials, and the interviews.

In addition to the above data, each contractor and subcontractor is questioned concerning cost estimating techniques employed to date, recommended areas for cost reduction, final engineering cost estimates, and other pertinent cost information.

IV. SYSTEM DESCRIPTION SUMMARY

The following is a brief summary of the Ingham County Medical Care Facility solar installation. Highlights of this site include:

- COLLECTOR TYPE: Flat Plate, Double-Glazed Liquid
- FREEZE PROTECTION: Propylene Glycol Solution
- APPLICATION: Domestic Water Heating
- STORAGE TYPE: Interior Tank
- NEW OR RETROFIT: New
- INSTRUMENTED FOR PERFORMANCE EVALUATION: Yes
- SITE SPECIFIC FEATURES: Ground-mounted Collectors

The solar energy system heats service hot water for a modern, single-story, 204 bed medical and geriatric care facility in Okemos, Michigan. This hospital has both a kitchen and a laundry.

The system utilizes 504 Revere Copper and Brass, Inc., flat plate collectors which provide an effective aperture area of 9,374 square feet. The collectors are mounted on a wood and steel framework at grade level in a field behind the building.

The collectors are piped in parallel in groups of six; six of these groups are piped in series to complete a row; the 14 rows are piped in parallel. The water is pumped between the collectors and the storage tank. The 5,000 gallon insulated steel storage tank is located on the concrete floor of the mechanical room for the building. The system pumps and heat exchangers are located near the storage tank in the mechanical room. All exterior piping is insulated with fiberglass covered by an aluminum jacket.

The auxiliary system for service water heating is a No. 2 oil-fired boiler.

The solar system has been fully instrumented for data acquisition and is included in the National Solar Data Network.

V. PROJECT BACKGROUND

The Ingham Medical Facility solar project was constructed as a result of a PON I proposal to ERDA in November, 1975. The contract with ERDA which committed the Government to funding 78.7% of the estimated project cost was awarded in June, 1976. Construction of the system began in June, 1978, with the system reaching substantial completion by July, 1979, when acceptance testing was performed.

Project responsibilities were as follows:

- Owner: Ingham County Board of Commissioners
- Architect: Stein and Associates
- Engineer: Manyam and Associates
- Solar System Designer: Manyam and Associates with the assistance of Department of Electrical Engineering and System Science, Michigan State University
- Prime Contractor: Bosch Mechanical Contractors, Inc.

Four subcontractors performed major portions of the solar system construction.

- Site Preparation and Collector Support Structure: McNeilly Construction Co.
- Piping Insulation: Owens-Corning Fiberglas Corporation
- Electrical Subcontractor: Root Electric Company
- Temperature Control: Powers Regulator Company

All work was performed by union labor.

VI. DATA SOURCES

Cost data for the Ingham Medical Facility solar energy systems were collected during a visit to the site made on August 9-10, 1979, and as a result of subsequent follow-up communications.

Cost data were collected from representatives of Ingham County Board of Commissioners, Bosch Mechanical Contractors, and Manyam and Associates. The primary source materials were Owner and Prime Contractor accounting records of project costs.

The Mechanical (Prime) Contractor provided the breakdown of installation and labor requirements that could not be obtained from the Owners' data sources. This information was the basis for the apportionment of the materials and labor components attributable to certain categories.

VII. COST ANALYSIS BY CATEGORY

A. Introduction

In the ten subsections that follow, cost information is provided for the following categories of the solar system.

- Collector Array
- Support Structure
- Piping
- Ductwork
- Insulation
- Heating/Cooling Equipment
- Storage
- Controls
- Electrical Power
- General Construction

In each subsection, descriptions of the category are presented along with the cost components. A tabular presentation of the cost data actually obtained then follows. All cost data are rounded to the nearest five dollar increment. The data sources used for each cost item and any unique aspects are discussed along with detailed information related to the basis for the costs. This includes the identification of costs that were either unavailable or impossible to separate from the other categories.

B. Collector Array

The collector category includes costs associated with the purchase of collector materials, delivery, handling and mounting, and piping of the collectors.

Table VII-1 presents the construction cost breakdown for this category.

TABLE VII-1. COLLECTOR ARRAY CATEGORY COSTS - INGHAM

COMPONENT	COST, $		
	Materials	Labor	Subcontract
Materials			
Collectors	83,315		None
Collector Mounting		a	
Delivery	2,140		
SUBTOTALS	85,455		None
COLLECTOR ARRAY CATEGORY TOTAL	$85,455		

[a]Labor for mounting solar collectors is included in the Piping Category, as are labor and materials for connecting collectors to supply and return manifolds.

- Collector Array Materials
  - o Data Sources - Discussion with Owner and Mechanical Contractor.
  - o Cost Components - 504 Revere Copper and Brass, Inc., SUN-AID (model No. 79211) double-glazed, flat plate collectors.
- Collector Mounting
  - o Data Source - Mechanical Contractor records.
  - o Cost Components - Collector mounting, 133 man-days

C. Support Structure

Since the collectors at Ingham are ground-mounted, the support structure costs include the preparation of the site to receive the wood and steel framework as well as the cost of the framework itself. Cost data for this category are presented in Table VII-2.

TABLE VII-2. SUPPORT STRUCTURE CATEGORY COSTS - INGHAM

COMPONENT	COST, $		
	Materials	Labor	Subcontract
Support Structure	52,140	34,760	a
Site Preparation	9,110	6,070	a
SUBTOTALS	61,250	40,830	None
SUPPORT STRUCTURE CATEGORY TOTAL	$102,080		

[a]McNeilly Construction Co. performed some work on the support structure valued at $73,745. In this report, that cost will be treated as subcontract.

- Materials and Labor
  - o Data Source - Mechanical Contractor records.
  - o Cost Components - Wood and steel structural members, concrete foundations to support collectors and piping, and gravel to prevent weeds from growing around collectors.

D. Piping

The piping category includes piping, pumps, valves, and miscellaneous components used to transport the system fluid. Costs are shown in Table VII-3.

TABLE VII-3. PIPING CATEGORY COSTS - INGHAM

COMPONENT	COST, $		
	Materials	Labor	Subcontract
Primary (Solar) Loop	4,335	12,215	None
Collector Connections and Manifolds[a]	5,395	22,020	
Domestic Water Piping	3,205	5,310	
Pumps (3)	1,250	b	
Heat Exchangers (3)	3,660	2,000	
Backflow Preventers (2)	3,540	b	
Water Balancing and Propylene Glycol	3,805		
SUBTOTALS	25,190	41,545	None
PIPING CATEGORY TOTAL	$66,735		

[a]Includes labor for mounting solar collectors and labor and materials for connecting collectors to supply and return manifolds.

[b]Labor for installing pumps and backflow preventers included in labor for heat exchangers.

- Piping Materials
  - o Data Source - Mechanical Contractor records.
  - o Cost Components - Piping - all systems, includes fittings and all piping material costs for all piping loops in the solar system.
    - Miscellaneous hardware, pumps and most valves incorporated in piping systems.
    - Water balancing and propylene glycol.
- Labor
  - o Data Source - Mechanical Contractor records.
  - o Cost Components - Piping systems labor, installation of pipes and fittings.

E. Ductwork

No costs are attributable to the solar system in this category.

F. Insulation

The insulation category includes all insulation used in the solar system except that employed in the solar collectors and for the storage tanks. In practice, piping insulation comprises the major portion of this category. Costs are listed in Table VII-4.

TABLE VII-4. INSULATION CATEGORY COSTS - INGHAM

COMPONENT	COST, $		
	Materials	Labor	Subcontract
Insulation	11,945	17,915	a
INSULATION CATEGORY TOTAL	$29,860		

[a]This work was performed by a subcontractor, but a breakdown of material and labor was available and is provided.

- Materials
  - o Data Source - Mechanical Contractor records.
  - o Cost Components - Fiberglass pipe insulation.
- Labor
  - o Data Source - Mechanical Contractor records.
  - o Cost Component - Installation.

G. Heating/Cooling Equipment

No costs are attributed to this category in this system.

H. Storage

The storage category consists of the tanks or other devices used to store thermal energy. At Ingham, a single 5,000 gallon steel tank was used. The tank was placed on the concrete floor of the mechanical room. The tank was not insulated, although there were plans to insulate it. Costs are shown in Table VII-5.

TABLE VII-5. STORAGE CATEGORY COSTS - INGHAM

COMPONENT	COST, $		
	Materials	Labor	Subcontract
Steel Tank	7,610	2,455	None
STORAGE CATEGORY TOTAL	$10,065		

- Materials
  - o Data Source - Mechanical Contractor records.
  - o Cost Components - Tank: One 5,000 gallon, steel, cylindrical.
- Labor
  - o Data Source - Mechanical Contractor records.
  - o Cost Components - Tank installation.

I. Controls

The controls category includes all equipment in the system installed for the purpose of automatically regulating system operation. See Table VII-6 for controls cost. The cost of the automatic control valves is not included here, but is included in the Piping Category.

TABLE VII-6. CONTROLS CATEGORY COSTS - INGHAM

COMPONENT	COST, $		
	Materials	Labor	Subcontract
Automatic Temperature Controls[a]	4,275	2,010	b
CONTROLS CATEGORY TOTAL	$6,285		

[a]Does not include cost of automatic control valves.

[b]This work was performed by a subcontractor, but a breakdown of materials and labor was available and is provided.

- Materials and Labor
  - o Data Source - Mechanical Contractor records.

J. Electrical Power

The electric power category includes all components, materials and labor required to install the power distribution system for the electrical energy needed for the system. Costs are shown in Table VII-7.

TABLE VII-7. ELECTRICAL POWER CATEGORY COSTS - INGHAM

COMPONENT	COST, $		
	Materials	Labor	Subcontract
Electrical Power	6,400	3,450	a
ELECTRICAL POWER CATEGORY TOTAL	$9,850		

[a]This work was performed by a subcontractor, but a breakdown of materials and labor was available and is provided.

- Materials and Labor
  - o Data Source - Prime Contractor records.
  - o Cost Component - Materials and labor charged by Subcontractor for wiring and connecting pumps and other equipment.

K. General Construction

The general construction category includes all materials and labor consumed in the project but not directly attributable to other specific categories. No costs for building space requirements are included because much of the solar equipment was located exterior to the building. Costs are given in Table VII-8.

TABLE VII-8. GENERAL CONSTRUCTION CATEGORY COSTS - INGHAM

COMPONENT	COST, $		
	Materials	Labor	Subcontract
Job Mobilization and Cleanup	None	2,495	
GENERAL CONSTRUCTION CATEGORY TOTAL	$2,495		

- Labor
  - o Data Source - Mechanical Contractor records.
  - o Cost Components - Prime Contractor job mobilization and cleanup.

VIII. TOTAL SYSTEM CONSTRUCTION COST

Table VIII-1 presents the total system construction cost summary based on costs presented in Section VII. No allowance for Prime Contractor overhead and profit (OH&P) or general and administrative (G&A) has been made. It is important to note that at Ingham, subcontractors, especially the General Construction Contractor, were major participants in the system construction. All subcontractor costs include OH&P and G&A charges. The labor and materials breakouts presented in Section VII and in Table VII-1 represent the costs of all of the major contractors and suppliers such as the General Construction Contractor and collector supplier.

TABLE VIII-1. TOTAL SYSTEM CONSTRUCTION COST SUMMARY - INGHAM

CATEGORY[a]	MATERIALS	LABOR	SUBCONTRACT	TOTAL
Collector Array	$ 85,455	None[d]	None	$ 85,455
Support Structure	61,250	$ 40,830	e	102,080
Piping	25,190	41,545	None	66,735
Ductwork	None	None	None	None
Insulation	11,945	17,915	e	29,860
Heating/Cooling Equipment	None	None	None	None
Storage	7,610	2,455	None	10,065
Controls[b]	4,275	2,010	e	6,285
Electrical Power	6,400	3,450	e	9,850
General Construction	None	2,495	None	2,495
SUBTOTAL	$202,125	$110,700	e	$312,825
TOTAL MATERIALS, LABOR AND SUBCONTRACT	$312,825[c]			

[a]For a complete description of items included in each category, see Section VII.

[b]Includes only automatic controls. Does not include automatic or manual valves shown in Piping Category.

[c]Does not include overhead and profit or general and administrative expenses for prime contractor.

[d]Labor for mounting solar collectors is included in the Piping Category, as are labor and materials for connecting collectors to supply and return manifolds.

[e]Insulation, controls, and electrical work were performed by subcontractors, but a breakdown of materials and labor was available and is provided. $73,745 of the support structure costs were also a subcontractor cost.

IX. DISCUSSION

In this section the data are presented in formats to facilitate comparisons and further analysis of data collected at the various demonstration sites.

Table IX-1 presents the proportional composition of the total system costs and the costs per square foot of collector area for each category. It is useful to analyze the cost data unitized and apportioned in this manner, especially in comparing the costs of different systems.

TABLE IX-1. CATEGORY COSTS PER UNIT COLLECTOR AREA AND AS A PERCENT OF TOTAL COST - INGHAM

CATEGORY[a]	UNIT COST, $/FT^2 COLLECTOR AREA[c]		PERCENT OF TOTAL SYSTEM COST	
	BARE COSTS, WITHOUT OH&P	WITH OH&P[b]	BARE COSTS, WITHOUT OH&P	WITH OH&P
Collector Array	8.24	10.31	27	29
Supporting Structure	9.84	11.24	33	31
Piping	6.43	8.04	21	22
Ductwork	None	None	None	None
Insulation	2.88	3.16	10	9
Heating/Cooling Equipment	None	None	None	None
Storage	0.97[d]	1.21	3	3
Controls	0.61	0.67	2	2
Electrical Power	0.95	1.05	3	3
General Construction	0.24	0.30	1	1
TOTAL	30.16	35.98	100	100

[a] For a complete description of items included in this category, see Section VII.

[b] See Section X for the procedure used to add overhead and profit.

[c] Costs in 1977 dollars, based on net collector area of 9374 ft^2.

[d] Equates to $2.01/gallon storage.

X. SYSTEM COST FOR USE IN ANALYSIS

Detailed performance data is being acquired for this solar energy system through the National Solar Data Network. The assessment of this system's economic performance (cost/unit of energy delivered) requires a total construction cost figure that should include an overhead and profit (OH&P) factor. However, a constant OH&P factor will be applied to all bare costs in this series of reports to normalize the great variation of OH&P percentages encountered in the program.

To illustrate the necessity for this adjustment, consider two systems. System A performs well, but was installed by a contractor with a high OH&P factor. System B does not perform as well, but was installed by a contractor with a low OH&P factor. It would not be appropriate to penalize System A in an economic performance comparison of the two systems because of the installer's OH&P factor. Major variations in OH&P factors are expected due to the diversity of business firm types that contracted to install the solar demonstration systems. These include colleges and universities, engineering firms, and construction contractors. The comparison discussed above represents the extremes of conditions that can be encountered.

As a result, a need exists to "normalize" the treatment of OH&P in analysis of the cost data. For this reason, an OH&P factor of 25% will be added to all prime contractor bare costs (materials and labor) and 10% will be added to all subcontract costs to represent the cost that a prime contractor would charge. Materials purchased directly by Ingham County ($85,455 for collectors) were treated as prime contractor bare costs for the purpose of the OH&P markup.

The equivalent total construction cost thus determined for the solar energy system of the Ingham Medical Facility is $373,070 in 1978 dollars. To allow equivalent comparisons among sites, all cost data must account for the effects of inflation. Adjustment of data from all sites to a common year will eliminate inflation biases. The base year selected is 1977. The

Engineering News-Record (June 1, 1978) reported that the Building Cost Index escalated 9.6% from June, 1977. Decreasing the $373,070 cost to 90.4% of the 1978 cost results in an equivalent cost, expressed in 1977 dollars, of $337,260.

Table X-1 summarizes the various methods of representing total system cost figures discussed in this report.

TABLE X-1. SUMMARY OF TOTAL SYSTEM COST FIGURES PRESENTED IN THIS REPORT

	TOTAL WITHOUT OVERHEAD AND PROFIT (1978)	TOTAL WITH OVERHEAD AND PROFIT (1978)	TOTAL WITHOUT OVERHEAD AND PROFIT (1977)	TOTAL WITH OVERHEAD AND PROFIT (1977)
COST, $	$312,825	$373,070	$282,795	$337,260
$/SQ. FT.*	$33.37	$39.80	$30.16	$35.98

*Based on 9,374 ft^2 of collector area.