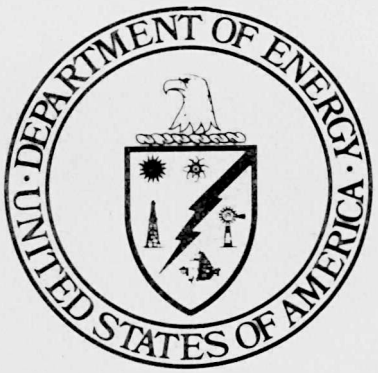
SOLAR/2066-79/60

# Solar Project Cost Report

## BILLINGS SHIPPING CORPORATION FREIGHT OFFICE

Billings, Montana
July 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

## BILLINGS SHIPPING CORPORATION FREIGHT OFFICE

BILLINGS, MONTANA

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

Under Contract Number
EG-77-C-01-2522

H. Jackson Hale, Solar Data Program Manager

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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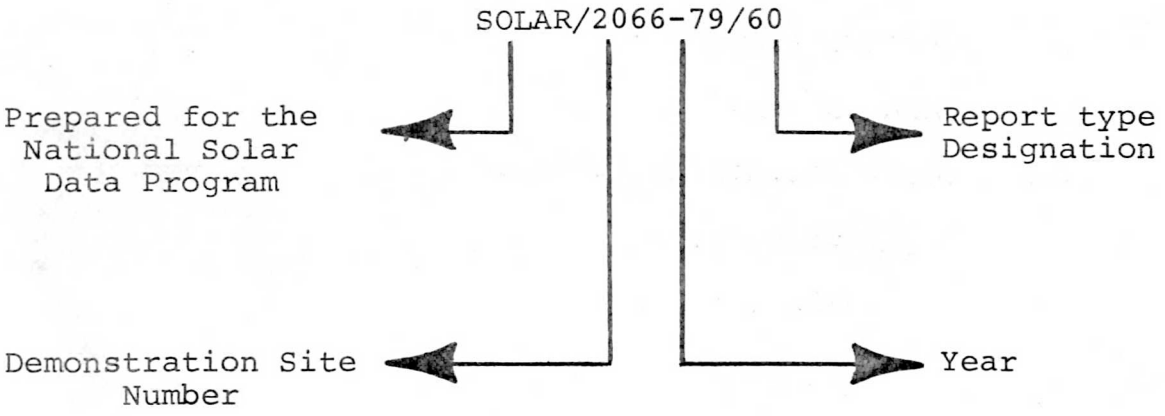


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  - Solar Project Cost Reports are designated by the number 60

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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, report number SOLAR/2066-79/50.

## II. EXECUTIVE SUMMARY

This report provides detailed cost information for the solar space heating project at the Billings Shipping Corporation Freight Office in Billings, Montana.

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 2. The proposal was submitted to ERDA in March, 1977, and the grant was awarded in May, 1977. Star Service Company was the general construction contractor for the project.

The Billings system uses 110 flat plate liquid collectors, manufactured by Lennox, having a net aperture area of 1,660 square feet. The collectors are mounted in six rows on the flat roof of the building and supply space heating to the 4,900 square foot office area.

Solar energy storage is provided by a 2,500 gallon steel water tank buried outside the building. Auxiliary heating is supplied by a gas-fired boiler.

The construction costs of this solar heating system are presented in this report. Category costs are listed for the General Contractor's materials, General Contractor's labor, and subcontract costs. The subcontract costs include materials, labor, overhead and profit costs for the collector support system, the piping and storage tank insulation, the electrical power and control wiring, and the design of the controls system. A further breakdown of these costs was obtained for the support structure and insulation subcontracts. The construction cost for this project was $64,195 not including General 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<br>• Delivery<br>• Mounting on Support Structure<br>• Connecting Collectors to Manifold |
| Collector Support Structure | • Materials<br>• Labor |
| Piping | • Collector Distribution System<br>o Materials<br>o Labor<br>• Other Piping<br>o Materials<br>o Labor |
| Ductwork | • Collector Distribution System<br>o Materials<br>o Labor<br>• Other Ductwork<br>o Materials<br>o Labor |
| Insulation | • Collector Distribution System<br>o Materials<br>o Labor<br>• Other Piping/Ductwork<br>o Materials<br>o Labor |
| Heating/Cooling Equipment | • Materials<br>• Delivery<br>• Installation |
| Storage | • Materials<br>• Delivery<br>• Installation<br>• Insulation |
| Controls | • Materials<br>• Labor |
| Electrical Power | • Total |
| General Construction | • Roofing<br>• Equipment Room<br>• Architectural<br>• Excavation<br>• 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 Billings Shipping Corporation solar installation in Billings, Montana. Major features of this system include:

- Collector - Liquid, flat plate
- Freeze Protection - Antifreeze Solution
- Application - Space heating
- Storage - Buried steel tank
- New/Retrofit - Retrofit
- Performance Evaluation Instrumentation - Yes
- Site-Specific Features - None

The Billings solar energy system utilizes an array of Lennox flat plate collectors having a gross area of 1,970 square feet (net aperture area of 1,660 square feet) to supply a portion of the heating requirements for a 4,900 square feet office area of a 43,000 square foot freight distribution building.

The collector array consists of five rows of 20 collectors each and one row of 10 collectors. The panels are bolted to a steel framework that is bolted to concrete curbs resting on the flat roof of the building. The collectors face $10^{o}$ east of south at an angle of $50^{o}$ from the horizontal. The system uses a 50 percent propylene glycol/water solution as the heat transfer medium.

The storage system consists of a 2,500 gallon steel hot water storage tank. The tank is buried approximately five feet below ground level and approximately six feet north of the building. The tank is insulated with four inches of molded polystyrene beadboard and covered with a six mil polyfilm sheet.

Space heating is provided by circulating hot water from storage or from the collectors (via the heat exchanger) to a heating coil in the air handling unit. Auxiliary heating is provided by a gas-fired boiler that supplies hot water to a heating coil downstream of the solar heating coil.

The solar energy system has been operational since November, 1978. It has been fully instrumented for performance evaluation and integrated into the National Solar Data Network.

## V. PROJECT BACKGROUND

The Billings Shipping Corporation solar energy system was constructed as a PON Cycle 2 project in ERDA's National Program for Solar Heating and Cooling of Buildings. The project grant was awarded in May, 1977, and the contract was completed in September, 1977. This contract committed ERDA to 78% funding of the project. Construction of the Billings solar system started in October, 1977 and was essentially complete by November, 1978. Both system startup and DOE acceptance testing took place in November, 1978.

The project was organized as follows:

- Owner: Billings Shipping Corporation
- Solar Designer - Architect: CTA Architects - Engineers
- Mechanical Engineer: CTA Architects - Engineers
- Project Manager: Gene Kolstad
- General Contractor: Star Service Company
- Subcontractors:
  - Support Structure: Spildie Construction
  - Insulation: E. J. Bartell's
  - Controls: Johnson Controls
  - Electrical: Sterling Electric

All work was performed by union labor.

## VI. DATA SOURCES

Cost data for the Billings Shipping Corporation solar project were collected during visits to the site and to the General Contractor's office on July 11, 1979, and through other communications with the involved parties. Most of this information came from the records and invoices of the Project Manager and the General Contractor. Additional data were obtained through telephone conversations with the subcontractors responsible for the support structure and controls and with the General Contractor.

## 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
- General Construction

In each subsection, descriptions of the category are presented along with the cost components. A tabular presentation of the cost data 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. The materials and labor columns refer to costs incurred by the General Contractor.

### B. Collector Array

The collector array category includes costs associated with the purchase, delivery, handling and mounting of the collectors on the structural frame. Costs associated with the materials and construction of the structural frame are included in the support structure category. The Lennox collectors used for this project were purchased by Billings Shipping in October, 1977, the same month in which Billings Shipping contracted Star Service for the general system construction. As such, the purchase and delivery of the collectors represent the only direct participation of the owner in the project construction. An

hourly rate of $13.30 was paid for all labor performed by the General Contractor. See Table VII-1 for collector array category cost data.

TABLE VII-1: COLLECTOR ARRAY CATEGORY COSTS - BILLINGS

| COMPONENT | COST, $ | | |
|---|---|---|---|
| | Materials | Labor | Subcontract |
| Collectors | 25,245* | --- | --- |
| Handling & Mounting | --- | 1,865 | --- |
| Subtotals | 25,245 | 1,865 | 0 |
| COLLECTOR ARRAY CATEGORY TOTAL COST | | $27,110 | |

* Purchased by Billings Shipping. The delivery cost could not be separated from the total cost of the collectors.

- Materials
  - Data source - Records and invoices of Project Manager.
  - Cost components - 110 liquid, flat plate Lennox LSC 18-1S solar collectors with a single low-iron tempered glass cover.
- Labor
  - Data source - Records of General Contractor.
  - Cost components - Unloading of collectors from tractor-trailers, lifting them to roof with lift truck, and mounting them on support structure. Approximately 140 man-hours were required for handling and mounting. The materials and labor required for the collector/header connections are included in the piping category. The General Contractor claimed that the collectors delivered were not uniform in size and that this caused unnecessary delays and problems in installation.

C. Support Structure

The support structure category consists of the structural members and subassemblies used to support the collector array. At Billings, the support structure was installed by a subcontractor.

It consists of a framework of steel angle bolted to a precast concrete pad. This pad simply rests on the flat roof of the building, necessitating only two roof penetrations for the entire system, those being for the main supply and return lines. See Table VII-2 for support structure category cost data.

TABLE VII-2: SUPPORT STRUCTURE CATEGORY COSTS - BILLINGS

| COMPONENT | COST, $ | | |
|---|---|---|---|
| | Materials | Labor | Subcontract |
| Support Structure | --- | --- | 11,830* |
| SUPPORT STRUCTURE CATEGORY TOTAL COST | | | $11,830 |

* A breakdown of the subcontractor costs was obtained as follows: Materials $8,915, Labor $2,915.

- Subcontract
  - o Data sources - Records of General Contractor and telephone conversation with support structure subcontractor.
  - o Cost components - All materials and labor required to fabricate, deliver, lift and mount, and bolt together the support structure. Approximately 250 man-hours were required to install the support structure.

D. Piping

The piping category includes piping, valves, pumps and miscellaneous equipment used to transport the system's fluids. The General Contractor identified the costs for two sections of the piping system. The first section consists of the piping and equipment carrying the glycol/water mixture (glycol loop) and the second is composed of all other parts of the piping system (storage and heat distribution loops). See Table VII-3 for piping category cost data.

TABLE VII-3: PIPING CATEGORY COSTS - BILLINGS

| COMPONENT | COST, $ | | |
|---|---|---|---|
| | Materials | Labor | Subcontract |
| Glycol Loop | 5,120 | 3,070 | --- |
| Storage & Distribution Loops | 3,735 | 2,065 | --- |
| Heat Exchanger | 1,210 | --- | --- |
| Subtotals | 10,065 | 5,135 | 0 |
| PIPING CATEGORY TOTAL COST | $15,200 | | |

- Materials
  - Data source - Records of General Contractor.
  - Cost components - All piping, pumps, valves, one Bell & Gossett shell-in-tube heat exchanger, two Grinnell heat rejectors, and three expansion tanks. The piping category includes installation labor for the controls system components. See Subsection I, Controls, of Section VII for further discussion.
- Labor
  - Data source - Records of General Contractor
  - Cost components - Installation of all piping and piping equipment. Approximately 230 man-hours and 155 man-hours were required to install the glycol loop and the storage/ distribution loops, respectively.

E. Ductwork

No costs were incurred for ductwork in the Billings project.

F. Insulation

The insulation category includes all insulation used in the solar system except that employed in the solar collectors and on the storage tank. At Billings, the insulation was purchased and installed by a subcontractor and consists of 3/4" Armaflex insulation applied to the exterior (above-roof) piping. No insulation was applied to the interior piping. See Table VII-4 for insulation category cost data.

TABLE VII-4: INSULATION CATEGORY COSTS - BILLINGS

| COMPONENT | COST, $ | | |
|---|---|---|---|
| | Materials | Labor | Subcontract |
| Insulation | --- | --- | 2,750 |
| INSULATION CATEGORY TOTAL COST $2,750 | | | |

- Subcontract
  - o Data source - Records of General Contractor
  - o Cost components - All materials and labor required for installation of the piping insulation. No further cost breakdown could be obtained.

G. Heating/Cooling Equipment

The heating/cooling equipment category for the Billings system includes the heating coils in the air handling unit. The distribution system for the building office area consists of ductwork and a single air handling unit with a four-row coil piped to the solar system and a two-row coil piped to the auxiliary boiler. See Table VII-5 for heating cooling equipment category cost data.

TABLE VII-5: HEATING/COOLING EQUIPMENT CATEGORY COSTS - BILLINGS

| COMPONENT | COST, $ | | |
|---|---|---|---|
| | Materials | Labor | Subcontract |
| Heating coils | 585 | 560 | --- |
| HEATING/COOLING EQUIPMENT CATEGORY TOTAL COST $1,145 | | | |

- Materials
  - o Data source - Records of General Contractor

- o Cost components - Four heating coils.

- Labor
  - o Data source - Records of General Contractor.
  - o Cost components - All labor required to install the four solar heating coils in the existing air handling unit for the office area, approximately 40 man-hours.

H. Storage

The storage category consists of the storage tank, tank insulation, tank gauges and devices, and required labor. At Billings, a single 2,500 gallon steel tank is used for thermal storage. This tank was initially insulated with two inches of polystyrene but an additional two inches were later added to improve thermal performance. The costs for the added insulation are included. See Table VII-6 for storage category cost data.

TABLE VII-6: STORAGE CATEGORY COSTS - BILLINGS

| COMPONENT | COST, $ | | |
|---|---|---|---|
| | Materials | Labor | Subcontract |
| Storage tank | 1,690 | 200 | --- |
| Tank insulation | --- | --- | 550 |
| Subtotals | 1,690 | 200 | 550 |
| STORAGE CATEGORY TOTAL COST $2,440 | | | |

- Materials
  - o Data source - Records of General Contractor
  - o Cost components - 2,500 gallon Empire Steel bitumen-coated water tank with connections and sensors. No further breakdown for the subcontract cost could be obtained.
- Labor
  - o Data source - Records of General Contractor

- o Cost components - Installation of the storage tank involving unloading, excavation, placement, and backfilling, approximately 15 man-hours.

I. Controls

The controls category includes all equipment in the system installed for the purpose of automatically regulating system operation. At Billings, the installation of the controls system was unusual in that it directly involved the controls subcontractor, the electrical power subcontractor, and the General Contractor. The controls subcontractor designed the controls system, provided the components to the General Contractor, and checked out the system after installation. The General Contractor installed the automatic valves, pumps, sensors, and other control components, while the electrical subcontractor did all the control wiring. The installation and wiring costs could not be isolated and are included in the piping labor and electrical power categories. See Table VII-7 for the controls category cost data.

TABLE VII-7: CONTROLS CATEGORY COSTS - BILLINGS

| COMPONENT | COST, $ | | |
|---|---|---|---|
| | Materials | Labor | Subcontract |
| Controls subcontract | --- | --- | 2,435* |
| CONTROLS CATEGORY TOTAL COST $2,435 | | | |

*Includes controls materials and checkout only. Controls labor could not be separated from piping and electrical categories.

- Subcontract
  - o Data source - Telephone conversation with controls subcontractor.
  - o Cost components - All control components (automatic valves, sensors, switches, etc.), final checkout of controls system.

J. Electrical Power Wiring

The electrical power category includes all components, materials, and labor required to install the power distribution

system for the electrical energy needed for the system. At Billings, however, the electrical power subcontractor also installed the control wiring for the system. The costs for materials, electrical wiring, and control wiring could not be separated from the total subcontract cost. See Table VII-8 for electrical power category cost data.

TABLE VII-8: ELECTRICAL POWER CATEGORY COSTS - BILLINGS

| COMPONENT | COST, $ | | |
|---|---|---|---|
| | Materials | Labor | Subcontract |
| Electrical power subcontract | --- | --- | 1,285* |
| ELECTRICAL POWER CATEGORY TOTAL COST | | $1,285 | |

* Includes control wiring.

- Subcontract
  - o Data source - Invoices of General Contractor.
  - o Cost components - Wire, conduit, switches, panels, and all labor required to wire the controls and electrical power distribution systems.

K. General Construction

The general construction category includes all costs not included in other categories but attributable to the solar energy system. At Billings, no general construction costs were incurred for the solar energy system. This is largely due to the fact that the building was designed and constructed with the expectation that the existing solar system would be retrofitted to the building. The Freight Office building was completed approximately eight months before its solar energy system was completed.

## 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 General Contractor overhead and profit (OH&P) or general and administrative expenses (G&A) has been made. It is important to note that at Billings, subcontractors were major participants in the system construction. All subcontract costs listed below include the subcontractor's OH&P and G&A. Both the materials and labor breakouts presented in Section VII and in Table VIII-1 represent the direct costs incurred by the General Contractor.

TABLE VIII-1: TOTAL SYSTEM CONSTRUCTION COST SUMMARY - BILLINGS

| CATEGORY[a] | MATERIALS | LABOR | SUBCONTRACT | TOTAL |
|---|---|---|---|---|
| Collector Array | 25,245[b] | 1,865 | None | 27,110 |
| Support Structure | None | None | 11,830 | 11,830 |
| Piping[c] | 10,065 | 5,135 | None | 15,200 |
| Ductwork | None | None | None | None |
| Insulation | None | None | 2,750 | 2,750 |
| Heating/Cooling | 585 | 560 | None | 1,145 |
| Storage | 1,690 | 200 | 550 | 2,440 |
| Controls[c] | None | None | 2,435 | 2,435 |
| Electrical Power[c] | None | None | 1,285 | 1,285 |
| General Construction | None | None | None | None |
| SUBTOTALS | 37,585 | 7,760 | 18,850 | 64,195 |
| TOTAL COST | $64,195[d] | | | |

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

[b] The collectors were purchased directly by Billings Shipping Corporation.

[c] Some controls costs are included in the piping and electrical power categories. See Section VII for further explanation.

[d] Does not include overhead and profit or general and administrative expenses.

## 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 - BILLINGS
(Based on 1,660 Sq. Ft. Collector Area)

| CATEGORY[a] | UNIT COST, $/FT.$^2$ COLLECTOR AREA[b] | | PERCENT OF TOTAL SYSTEM COST | |
|---|---|---|---|---|
| | Bare Costs | With OH&P[c] | Bare Costs | With OH&P[c] |
| Collector Array | 16.30 | 20.40 | 42 | 44 |
| Support Structure | 7.10 | 7.80 | 18 | 17 |
| Piping | 9.10 | 11.40 | 24 | 24 |
| Ductwork | 0 | 0 | 0 | 0 |
| Insulation | 1.70 | 1.80 | 4 | 4 |
| Heating/Cooling | 0.70 | 0.90 | 2 | 2 |
| Storage | 1.50[d] | 1.80 | 4 | 4 |
| Controls | 1.50 | 1.60 | 4 | 3 |
| Electrical Power | .80 | .90 | 2 | 2 |
| General Construction | 0 | 0 | 0 | 0 |
| TOTAL SYSTEM | 38.70 | 46.60 | 100 | 100 |

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

[b] Costs are in 1977 dollars.

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

[d] Equates to $1.00/gallon storage capacity.

## 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 general contractor bare costs (materials and labor) and 10% will be added to all subcontract costs to represent the cost that a general contractor would charge. In this case, the collectors purchased by Billings Shipping Corporation are treated as general contractor bare costs.

The equivalent total construction cost thus determined for the Billings Shipping Corporation solar energy system is $77,430 in 1977 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 same year in which the Billings system was primarily purchased and

constructed. Hence, no modification is required. Table X-1 summarizes the various methods of representing total system cost figures discussed in this report.

TABLE X-1: SUMMARY OF TOTAL COST FIGURES PRESENTED IN REPORT

| | TOTAL WITHOUT OVERHEAD AND PROFIT (1977) | TOTAL WITH OVERHEAD AND PROFIT (1977) |
|---|---|---|
| Total Cost | $64,195 | $77,430 |
| $/Sq. Ft.* | $38.70 | $46.60 |

* Based on 1,660 sq. ft. collector area.