SOLAR/2015-78/60

Solar Project Cost Report

Kalwall Corporation Warehouse Manchester, New Hampshire

May 31, 1978

Contracts W-31-109-ENG-38
EG-77-C-01-4049

United States Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

NOTICE

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IBM Corporation
Huntsville, AL 35805

United States Department of Energy

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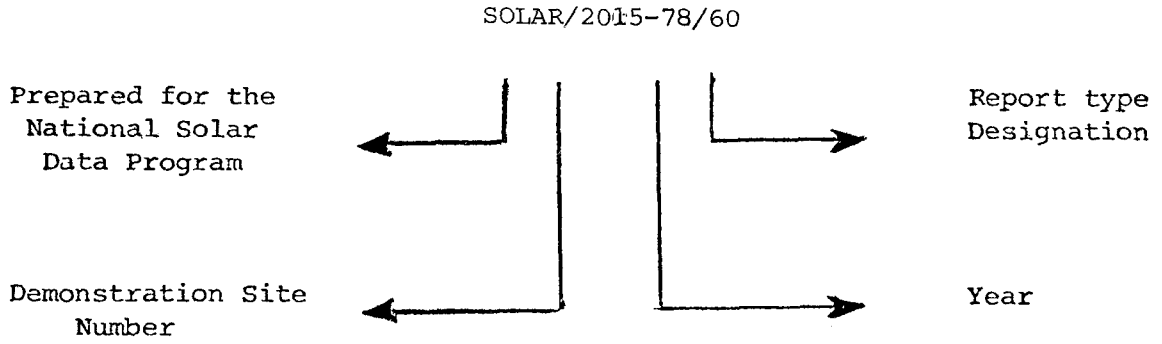
NATIONAL SOLAR DATA PROGRAM REPORTS

Reports prepared for the National Solar Data Program are numbered under a specific format. For example, this report for the Kalwall Corporation project site is designated as SOLAR/2015 78/60. The elements of this designation are explained in the following illustration:



- 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.,
  - o Monthly Performance Reports are designated by the numbers 01 (for January) through 12 (for December)
  - o Solar Energy System Performance Evaluations are designated by the number 14
  - o Solar Project Descriptions are designated by the number 50
  - o 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) or 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 projects data. Detailed analysis of this report will require reference to the "Solar Project Description" for this project, report number SOLAR/2015-78/50.

II. EXECUTIVE SUMMARY

This report provides detailed cost information for the solar space heating project at the Kalwall Corporation warehouse in Manchester, New Hampshire.

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 I. The PON request was issued in the Autumn of 1975. The Kalwall Corporation was the general construction contractor for the project.

The direct gain passive solar system was retrofitted to a 10,000 square foot warehouse section in Manchester, New Hampshire. The design used 1,750 square feet of Kalwall Corporation Sunwall Solar Window as the south wall collector aperture. The warehouse concrete slab floor and inventory provide thermal energy storage. Five 24 inch, thermostatically controlled fans are used for warm air circulation. Auxiliary space heating is provided by two hot water fan coil units.

The construction costs of this solar heating project are presented in this report. Category costs are listed by materials, labor, and subcontract costs. The subcontract costs include both materials, labor overhead and profit for mechanical and electrical subcontractors. No further breakdown of these costs could be obtained. The construction cost for this project was $10,470 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 • Delivery • Mounting on Support Structure • Collectors Connecting 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 • Painting
TOTAL PROJECT COST	

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 fitting, 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, air handling units 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, internal heat exchangers, and insulation.
- Controls: solid state controllers, thermostats, alarms, switches, wiring 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 telephone 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 the main source of data since they 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 any other pertinent cost information.

It must be emphasized that this cost information can only be assessed in relation to the detailed system description report, Solar/2015-78/50.

IV. SYSTEM DESCRIPTION SUMMARY

The following is a brief summary of the Kalwall Corporation's Solar Heated Warehouse Demonstration Project. Highlights of this site include:

- COLLECTOR TYPE: Passive direct gain window wall
- FREEZE PROTECTION: None required
- APPLICATION: Space Heating
- STORAGE TYPE: Concrete floor and warehouse contents
- NEW OR RETROFIT: Retrofit
- INSTRUMENTED FOR PERFORMANCE EVALUATION: Yes

The direct gain passive solar system was retrofitted to a 10,000 square foot warehouse in Manchester, New Hampshire. The design used 1,750 square feet of Kalwall Corporation Sunwall Solar Window as the south wall collector aperture. The warehouse concrete slab floor and inventory provide thermal storage. Five-24 inch, thermostatically controlled fans are used for warm air circulation. Auxiliary heat is provided by two hot water fan coil units.

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

V. PROJECT BACKGROUND

The Kawall Corporation Warehouse Solar Project was constructed as a result of a Kalwall Corporation proposal to ERDA (now DOE) in November, 1975. The contract with ERDA, in which the Government shared 80% of the estimated project cost, was awarded in July, 1976. Construction began in July and was substantially completed by September, 1976.

Project responsibilities were as follows:

- Owner: Kalwall Corporation
- Architect: Not applicable
- Engineer: Kalwall Corporation
- General Contractor: Kalwall Corporation
- Subcontractors:
  - A.A. Erectors
  - R.R. Keller and Associates
  - Keller Products

A major portion of the existing warehouse was partitioned off to be passively solar heated. A more weather tight overhead garage door was installed to reduce heat loss and an auxiliary fan coil unit was added in the solar conditioned space. The cost of the partition, the overhead door, the auxiliary system and the data acquistion system are not included in this cost report because they are not attributable to the solar energy system. No costs were attributed to the solar energy system for the existing floor slab, although the cost of the insulation that was added around the perimeter foundation exterior of the slab is included. The passive solar wall was formerly comprised of Kalwall panels that did not transmit as much light. The former support structure or mounting system for the wall was compatible with the new Sunwall panels and the value of the existing support structure is not included.

VI. DATA SOURCES

Cost data for the Kalwall solar energy system were collected during a visit to the site made on May 31, 1978.

Cost data were collected from a representative of the Kalwall Corporation. The primary source materials used were supplier and contractor invoices to the owner and owner invoices to the Department of Energy. A secondary source was a discussion with the Kalwall representative. Such information made it possible to apportion most of the materials and labor components to certain categories.

The various subcontractors were not contacted because the Kalwall representative was familiar with the costs incurred by the subcontractors.

VII. COST ANALYSIS BY CATEGORY

A. Introduction

In the ten sub-sections 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 sub-section, 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 that category and any unique aspects are discussed along with detailed information related to the basis of the costs. This includes the identification of costs that were either unavailable or impossible to separate from the other categories.

B. Collector Array

The south wall of the Kalwall warehouse is composed entirely of Kalwall Sunwall Solar Window panels which form the passive solar collector. The wall had originally been made of other panels, also manufactured by Kalwall, which did not transmit as much light. These original panels were removed at the beginning of the solar project and the existing mounting supports were kept since they were fully compatible with the new Sunwall construction. See Table VII-1 for collector costs.

TABLE VII-1. COLLECTOR CATEGORY COSTS-KALWALL

COMPONENT	COST, $			
	Kalwall Labor	Kalwall Material	Subcontract Labor	Subcontract Material
Removal of existing wall & installation of new solar windows	None	6320	1820*	None
SUBTOTAL	None	6320	1820	None
COLLECTOR CATEGORY TOTAL	$8140			

*It was not possible to separate the labor for removal of the old wall from installation of the new wall.

- Materials
  - o Data source - Discussion with a representative of Kalwall and DOE vouchers.
  - o Cost components - Sunwall Solar Window Panels. The support structure was existing and no costs are included for it.
- Delivery
  - o Data source - Discussion with a representative of Kalwall.
  - o Cost components - The Kalwall panels are stored in the warehouse so that no delivery costs were incurred.
- Removal of Existing Wall and Installation of New Wall
  - o Data source - Discussion with a representative of Kalwall and DOE vouchers.
  - o Cost components - A.A. Erectors was subcontracted to install the new Sunwall panels after removing the original panels. No further breakdown could be obtained.

C. Support Structure

- No New Costs Incurred. See Collector Category.

D. Piping

- All piping costs were for auxiliary heaters and are not included.

E. Ductwork

- None

F. Insulation

- None. See Storage Category.

G. Heating/Cooling Equipment

Five-24 inch propeller fans were hung from the ceiling of the warehouse along the south wall to provide air movement and improve the heat transfer between the floor and the air. See Table VII-2 for heating/cooling equipment costs.

TABLE VII-2. HEATING/COOLING EQUIPMENT CATEGORY COSTS-KALWALL

COMPONENT	COSTS, $			
	Kalwall Labor	Kalwall Materials	Subcontract Labor	Subcontract Materials
Fans	None	365	400	None
SUBTOTAL	None	365	400	None
HEATING/COOLING EQUIPMENT CATEGORY TOTAL	$765			

- Materials
  - o Data source - DOE vouchers
  - o Cost components - Five propeller fans.
- Delivery
  - o Data source - Discussion with a representative of Kalwall.
  - o Cost components - The cost of delivery could not be separated from the materials cost.
- Labor
  - o Data source - Discussion with a representative of Kalwall.

- o Cost components - R.R. Keller & Associates was associated to provide labor to install the wall partitions, the overhead door, and the fans. The cost listed under fans is estimated to be that increment of total subcontract cost attributable to the installation of the fans.

H. Storage

The existing concrete slab floor and the merchandise stored in the warehouse acts as the thermal storage in the passive solar system. The only cost associated with the storage subsystem in this retrofit was the addition of insulation at the perimeter of the concrete slab on the exterior wall. See Table VII-3 for storage costs.

TABLE VII-3. STORAGE CATEGORY COSTS-KALWALL

COMPONENT	COSTS, $			
	Kalwall Labor	Kalwall Materials	Subcontract Labor	Subcontract Materials
Insulation	485	400	None	None
Flashing	None	90	50	None
SUBTOTAL	485	490	50	None
STORAGE CATEGORY TOTAL	$1025			

- Insulation
  - o Data source - DOE vouchers
  - o Cost components - Insulation boards and labor to install it by Kalwall personnel.
- Flashing
  - o Data source - DOE vouchers and discussion with Kalwall representative.

- o Cost components - Metal flashing below collectors and over insulation was shop fabricated. Labor figure represents small amount of time provided by A.A. Erectors personnel to install flashing.

I. Controls

Each fan is separately controlled by two thermostats; one high in the space and one closer to floor level. The thermostat near the ceiling activates the fan upon a rise in temperature. The thermostat near the floor activates the fan upon a fall in temperature. See Table VII-4 for control costs.

TABLE VII-4. CONTROL CATEGORY COSTS-KALWALL

COMPONENT	COST, $			
	Kalwall Labor	Kalwall Material	Subcontract Labor	Subcontract Material
Thermostats	None	90*	**	**
SUBTOTAL	None	90	**	**
CONTROL CATEGORY TOTAL	$90			

*This cost represents the thermostats only and not wiring.
**The cost of labor for installing the controls could not be separated from the electrical power wiring work performed by a subcontractor and is included in that category.

- Materials
  - o Data source - DOE vouchers and discussion with a representative of Kalwall.
  - o Cost components - Thermostats.
- Labor
  - o Data source - Discussion with a representative of Kalwall.
  - o Cost components - The cost of labor for installing the controls could not be separated from the electrical power wiring costs and is included in the electrical power category. This work was performed by a subcontractor.

J. Electrical Power

The only power wiring in the project involved the wiring for the fans. See Table VII-5 for electrical costs.

TABLE VII-5. ELECTRICAL POWER CATEGORY COSTS-KALWALL

COMPONENT	COST, $			
	Kalwall Labor	Kalwall Material	Subcontract Labor	Subcontract Material
Electrical Wiring	None	165	285*	None
SUBTOTAL		165	285	
ELECTRICAL CATEGORY TOTAL	$450			

*Includes the labor for the installation of the controls

- Materials
  - o Data source - DOE vouchers and discussion with a representative of Kalwall.
  - o Cost components - Wiring, boxes, staples and other electrical materials.
- Labor
  - o Data source - DOE vouchers and discussion with a representative of Kalwall.
  - o Cost components - Labor for electrical power wiring of fans and installation of controls.

K. General Construction

None

VIII. TOTAL SYSTEM CONSTRUCTION COST

Table VIII-1 presents the total system construction cost summary based on costs presented in Section VII. For clarity, attention is called to the fact that the materials and labor columns include the cost of materials and equipment, and direct-labor respectively. No allowance for overhead and profit (OH&P) or general and adminstrative expenses (G&A) has been made. Charges for OH&P and G&A can vary significantly and are primarily important to the individual firms and specific project. Applying such charges to the data presented in Table VIII-1 is a straightforward matter and is left to the user. (See Section X for further discussion of OH&P).

The subcontract column of Table VIII-1 does include the OH&P of the subcontractor. It was not possible to exclude the sub-contractor's OH&P values from this column.

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

CATEGORY[a]	MATERIALS	LABOR	SUBCONTRACT	TOTAL
Collector Array	$6320	None	$1820[b]	$8140
Support Structure	None	None	None	None
Piping	None	None	None	None
Ductwork	None	None	None	None
Insulation	None	None	None	None
Heating/Cooling Equipment	365	None	400	765
Storage	485[c]	490[c]	-50-[c]	1025
Controls	90[d]	None	c	90
Electrical Power	165	None	285[c]	450
General Construction	None	None	None	None
SUBTOTAL	$7425	$490	$2555	
TOTAL MATERIALS, LABOR AND SUBCONTRACT	$10,470			

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

[b]Includes removal of old panels and installation of new panels.

[c]The only storage costs are for the insulation around the perimeter of the concrete floor slab.

[d]This cost represents the thermostats only and not wiring.

[e]The cost of labor for installing the controls could not be separated from the electrical power wiring and is included in that category.

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-KALWALL

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	4.70	5.70	79	79
Supporting Structure	-	-	-	-
Piping	-	-	-	-
Ductwork	-	-	-	-
Insulation	-	-	-	-
Heating/Cooling Equipment	0.40	0.50	7	7
Storage	0.60	0.70	10	10
Controls	0.10	0.10	<1	<1
Electrical Power	0.30	0.30	4	4
General Construction	-	-	-	-
TOTAL SYSTEM	6.00/ft^2	7.30/ft^2	100	100

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

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

[c] Costs are in 1977 dollars. See Section X for the procedure to convert to standard year.

A comparison of a breakdown of estimated construction costs to actual costs would be inappropriate because of changes in system design and it is not provided in this report.

The costs reported above are for the basic solar system only. As mentioned previously, the system is instrumented for data acquisition. The cost of the data acquisition capability is not included in this report.

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/btu) 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 these reports to remove the effect of the great variation of OH&P percentages encountered in the program.

To illustrate the problem, 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 bare costs (materials and labor) and 10% will be added to all subcontract costs to represent the cost that the General Contractor would charge for the system.

The equivalent total construction cost thus determined for the solar energy system in the Kalwall Corporation Warehouse is $12,705 in 1976 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 9, 1977) reported that the Building Cost Index escalated 7.4% from June 1976. Escalating the $12,705 cost by 7.4%, results in an equivalent construction cost, expressed in 1977 dollars of $13,645.

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