THE RELATIVE COST OF SOLAR THERMAL COLLECTOR INSTALLATIONS

Fariborz Mahjouri, PhD
Thermo Technologies
5560 Sterrett Place, Suite 115
Columbia, Maryland 21044
WWW.THERMOTECHS.COM
e-mail: mahjouri@thermotechs.com

Albert Nunez, CEM
Capital Sun Group, Ltd.
6503 81st Street
Cabin John, MD 20818-1204
www.capitalsungroup.com
e-mail: solarnrgman@juno.com

ABSTRACT

This paper will analyze the relative costs of evacuated heat pipe tube solar collectors. The source data comes from three commercial projects, the Pentagon DOD HQ in Arlington, Virginia, the Kennedy Space Center (NASA) at Cape Canaveral, Florida, and the Mid-Atlantic Social Security Administration Center in Philadelphia, Pennsylvania. All these projects were commissioned in 2003. Thermo Technologies designed and Capital Sun Group erected the Pentagon and the Social Security Center projects. Involvement with the NASA desiccant cooling system was limited to consultation and equipment supply.

This paper addresses some of the many challenges facing solar installation projects and offers a cost-breakdown of the respective projects. This analysis demonstrates that the cost of collectors is not the most significant cost element of the commercial solar projects. Further, a cost breakdown of collector itself demonstrates that material used to manufacture an advanced solar collector is negligible compared to other manufacturing and sales costs.

1. INTRODUCTION

The issue of cost and return of investment for solar water heaters has been the subject of discussion for decades. For an in depth evaluation it is important to break down the total cost of solar water heating systems by the cost elements. This will identify the major cost components and look for ways to reduce them without sacrificing system performance, durability and reliability.

Following three commercial projects are used to identify cost elements:

- The 75.6 kW domestic hot water system installed at the Pentagon in Arlington, Virginia
- The 25.2 kW solar water heating system installed at the Mid-Atlantic Social Security Administration Center in Philadelphia, Pennsylvania
- The 14.0 kW solar assisted desiccant cooling system installed at the NASA Space Flight Center, Cape Canaveral, Florida

Table 1: Cost elements of turn key solar water heating systems.

Cost Item	Weight
Collector	31%
Monitoring and Control	2%
Installation	14%
Engineering	11%
Material	5%
Bond	4%
Transportation	2%
Training	1%
Warranty	7%
Feasibility Study	10%
Roofing Warranty	4%
Change Order	8%
Total	**100%**

The collector and control system accounts for 1/3 of the total cost followed by installation costs.

2. THE EVACUATED HEAT PIPE COLLECTORS

The evacuated heat pipe solar collector is the result of extensive research, development and testing. The resulting product is a high performance, reliable and cost effective solar collector that uses advance manufacturing technologies and materials.

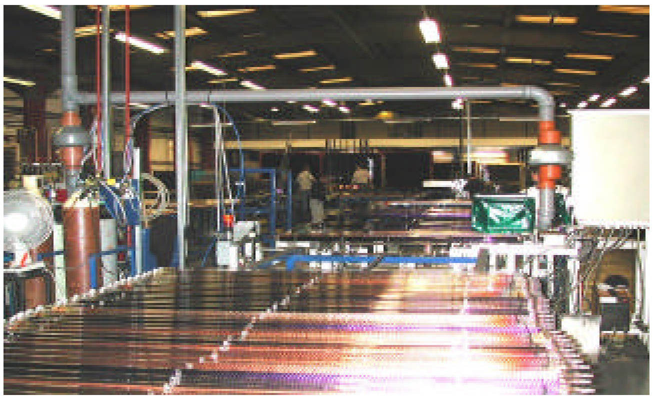

Figure 1: *Evacuated heat pipe collectors are manufactured in state-of-the art automated plants.*

Thermomax's manufacturing operations are geared to volume production and high quality assurance. Based on two locations in the United Kingdom, and a unit in Italy, Thermomax occupies over 10,000 m^2 of space for administration offices, production plants, a development laboratory and testing facilities.

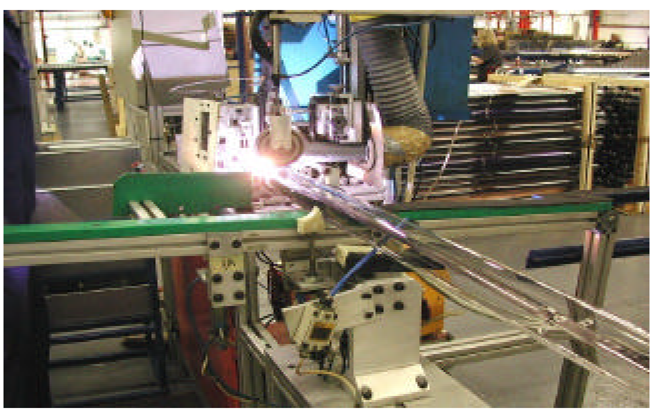

Figure 2: *Production lines of evacuated heat pipe collectors are fully automated with specialized tooling for efficient and consistent high quality.*

The plants are equipped with modern machinery and specialized tooling for high volume efficient and reliable production. Thermomax's engineering factory, in northern Italy, is involved in manufacturing the unique and sophisticated equipment needed for production and special components.

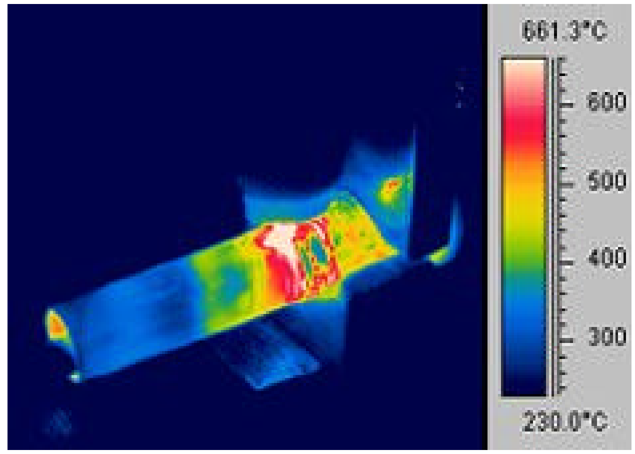

Figure 3: *Quality and performance of evacuated heat pipe tubes are monitored through infrared imagining.*

In general, the product costs are categorized as fixed and variable costs. The elements of fixed costs are:

- Factory Overhead (rent, insurance, depreciation, maintenance, R&D)
- Selling and Distribution (salaries, commissions, promotions, advertising, insurance, depreciation)
- Administration Expenses (salaries, pension, insurance, office supplies, accounting, marketing, cleaning, telephone and postage)
- Warranty

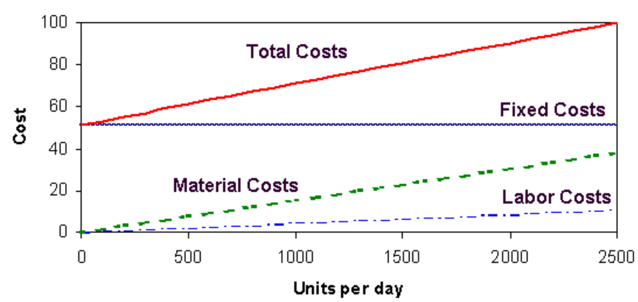

Figure 4: *Over 53% of vacuum tube production costs are fixed. Tooling, machinery, factory overhead and administration expenses do not change with production output.*

Raw material costs are much higher than the labor expenses in the fully automated vacuum tube solar collector plant as shown in Figure 4 and are thus subject to material markets fluctuation. But raw materials are not the major cost contributor of the finished product.

Figure 5: *The labor force in a state-of-the art solar manufacturing facility consists of highly skilled professional staffs who monitor the production lines and maintain computerized machinery and tools.*

The heavy investment in modern machinery that contributes significantly to the unit cost of the collector is distributed among the total number of units produced. Variable costs start to dictate the unit cost once the production volume approaches the optimum facility capacity. At this point, the cost of raw material starts to plays a role in the final production cost. The cost reduction effect of increased production volume is shown in Figure 6.

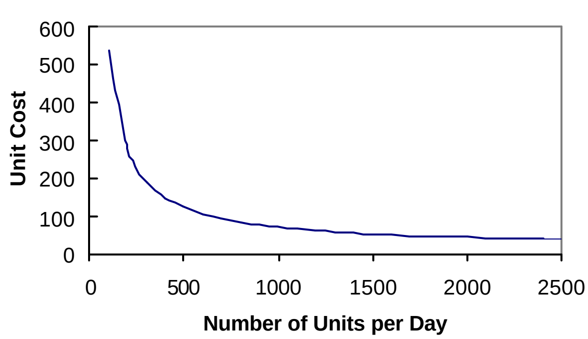

Figure 6: *Thermomax manufacturing facility is the world's most modern and Europe's largest solar vacuum tube plant. At full capacity it produces 2500 tubes in an eight-hour shift.*

3. CONTROL AND MONITORING SYSTEMS

The brain of a solar system is its control and monitoring systems. It accounts for about 2% of the total costs of the system as shown in Table 1.

The microprocessor based solar thermal controllers are sophisticated yet easy to operate. They display the status of solar system on their own LCD or on the screen of a computer. The principle is simple; they measure temperatures at the collector and storage tank. The difference is calculated and is used to record energy gain (BTU meter function) and to operate the circulation pump (delta T controller function).

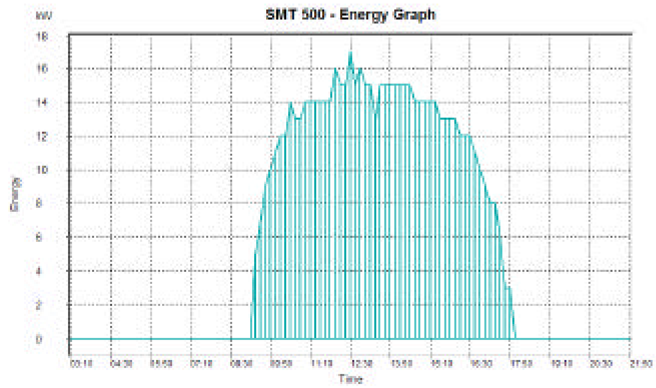

Figure 7. *SMT 500 controller records collected solar energy every 10 minutes in its internal memory while managing the optimum operation of the solar system. This data can be viewed on units LCD or downloaded to a computer for further analysis.*

To avoid overheating, the controller can be programmed to stop the circulation pump. The pump stops if the collector or tank temperature reaches the programmable high limit temperature. To prevent freezing, the controller may be programmed to activate the solar loop pump and circulate heat transfer fluid or water in the loop while freeze conditions exist.

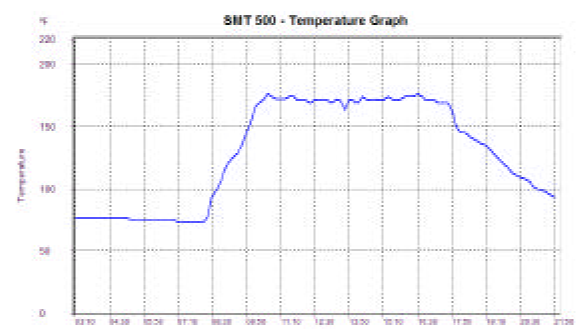

Figure 8. *SMT 500 monitors and records the collector and the tank temperatures of the solar system every 10 minutes. They can be viewed on unit's LCD or down loaded to a computer for further analysis.*

These sophisticated controllers have a diagnostic screen that shows potential problems such as sensor breakdown or circuit fault. A communication link allows the property manager to download and send all recorded data to the engineer for system performance analysis and evaluation.

4. INSTALLATION

Thermomax collectors are modular. Manifolds with tube support rails (69 lbs.) and sets of ten tubes per carton (48 lbs.) are packed in rugged corrugated boxes that meet all small package shipment weight, strength and dimensional requirements. These cartons can typically be transported to their final roof destination by buildings elevator or hoist.

Figure 9. *Thermomax collectors will be anchored on four Ballast blocks.*

Wind loading of installed system is very low because of tabular nature of the assembled collector modules.

Figure 10: *Manifolds are assembled at the job site using stainless steel hardware.*

Four (4) 70 lbs. ballast blocks can handle up to 90-mph wind for a 30-tube system installation at 38 degrees tilt angle. Therefore, installation of collector is without any roof penetration for the collector structural anchorage.

Figure 11: *After all plumbing work is completed and leak test is conducted, vacuum tubes will be inserted.*

Each leg of 30-tube manifold is bolted to ballast block with supplied stainless steel bolts and polymer anchors. Stainless steel racks and side rails are bolted to the collector front and back brackets. Tube supporting rails are positioned onto the side rails and secured with supplied stainless steel bolts and clips. Universal braces are bolted diagonally between rear struts as well as front and rear legs for reinforcement.

Figure 12: *Tubes are delivered to the job site after pipe work is completed and system is switched to manual operation.*

After all plumbing work is complete; vacuum tube collectors (Figure 12) are delivered to the roof in boxes of 10 tubes each. While the water loop circulation pump is running, tubes are unpacked and inserted through a rubber grommet into manifold and secured into the compression clamp copper chamber in super insulated header.

Figure 13: *Installation costs are 14% of the total vacuum tube system costs.*

Final inspection is conducted after all tubes are inserted to the manifolds. At this stage, the controller will be switched to automatic operation.

The modularity and installation simplicity of Thermomax tubes minimizes the installation costs. The most difficult and time-consuming part of an installation typically is positioning of ballast blocks.

5. SUMMARY

This paper identifies cost elements of direct solar water heating systems and simplicity of solar water heating installation on commercial buildings with a hot water circulation loop. These systems rely on several key design features. The diode function of heat-pipe, the superior insulation of evacuated tube, and active digital controls for successful operation and protection from freezing and overheating are all essential elements. Project participants are pleased with the relative ease of implementing this type of system and its total costs.

The cost analysis shows that 37% of total project costs are logistic expenses. Only 33% of total cost goes towards collector and system instrumentation with 14% for installation and 5 % for the balance of the system.

6. ACKNOWLEDGEMENTS

The authors would like to thank Robert Billak (retired) of the Pentagon Energy Office, John Broughton and Curt Iffinger of the NASA Energy Management Office, Robert Stiteler of Midatlantic Social Security Center, Ethan Chon and Renee Domurat of the General Services Administration for procurement of the system. Further thanks go to Anne Crawley and Dr. Andy Walker of the US Department of Energy, Federal Energy Management Program and for supporting NREL staff with the feasibility study, procurement specifications and design review.