
by

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ABSTRACT

Designing business strategies around innovative technologies requires that interests of all stakeholders – from suppliers to end-users – be addressed. This thesis investigates why the rate of market acceptance – the rate of diffusion – is low in the United States for solar hot water (SHW) technologies appropriate for household use. Experiences from the entrepreneurial business community and innovation and diffusion literature (especially that pertaining to residential construction) provide a framework for analyses. Data include interviews with SHW industry representatives and focus group reports summarizing peoples’ viewpoints on SHW. Past and current SHW industries in the United States are described. Technical descriptions of conventional, SHW, tankless and heat pump water heating technologies are supplied to inform comparisons between them. Economic analyses, using payback period and discounted cash flow techniques, are conducted to investigate the economic competitiveness of SHW against conventional technologies. Finally, an analysis of the needs and constraints of relevant stakeholders is performed. Results indicate that SHW for a family of four over a 15-30 year time frame is economically competitive with conventional electric water heating, unless assumptions of poor water quality, low energy prices, and high SHW installation costs are made simultaneously. SHW is generally not competitive with conventional gas water heating. Results indicate that SHW systems are substantially different from, and much more complex to install than, conventional technologies, thus leading to quality variations in installed SHW systems. Factors relevant to SHW installation are therefore strong candidate targets for business model and engineering improvement efforts. Manufacturers of SHW collectors are encouraged to take larger leadership roles in ensuring industry-wide quality, as there is no guarantee that anyone else will do so. Home builders represent an attractive market for SHW, but substantial marketing efforts will likely be needed to identify and understand other specific promising markets. The general public is grossly misinformed about SHW.

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<tr>
<td>CO₂</td>
<td>Carbon dioxide, a greenhouse gas</td>
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<tr>
<td>DOE</td>
<td>Department of Energy</td>
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<tr>
<td>MSRI</td>
<td>Million Solar Roofs Initiative</td>
</tr>
<tr>
<td>PATH</td>
<td>Partnership for Advancing Technology in Housing</td>
</tr>
<tr>
<td>SEIA</td>
<td>Solar Energy Industries Association</td>
</tr>
<tr>
<td>SHW</td>
<td>Solar Hot Water. In the context of this report, this implies hot water intended for use inside the home.</td>
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1. INTRODUCTION

Solar hot water (SHW) technologies used within household hot water systems have been popular within the U.S. economy during several periods over the last 100 years. The technologies currently offered by the U.S. SHW industry are sound, as this study will show, and enable users to lower the energy consumption of their household hot water systems by substantial amounts, thus also lowering their utility bills.

Given the benefits of this technology, one might ask the question: "Why have I never heard of this technology before?" or: "Why is this industry not growing by leaps and bounds?" This thesis attempts to answer these questions, and in so doing, offers advice as to how the industry might improve its operations.

But the SHW industry is not the only industry to which such questions have ever been applied. Questions along these lines have surrounded many industries whose innovations offered clear benefits, yet experienced difficulty in gaining acceptance within their relevant markets. The process of diffusing a technology throughout society — introducing it into a relevant market and having it become accepted, used, and trusted as "mainstream" — is a process in which many barriers are encountered.

1.1.1 ISSUES FACING TECHNOLOGY-BASED FIRMS

In general terms (and by inspection), one may state that technology-based firms are faced with at least three critical areas of concern that collectively define firms within their relevant markets and bear upon their success (or lack thereof) within those markets.

First, technology-based firms are faced with technology. Without a technology to sell, the firm has nothing to offer the market. Initially, the technology may not exist at all, and the firm will have to develop it. This thesis will examine the technologies which are produced by the solar hot water industry, and show that, on the whole, they are of high quality and perform to their specifications.

Second, all firms face economic constraints. On one level, the firm must be able to produce and sell its technology such that the firm takes in more money than it expends through its operation. On another level, the technology which the firm offers must be economically worthwhile to its target users. It is the second of these economic constraints which this thesis will address, showing that in most cases (or in all, depending upon the type of
economic analysis performed), SHW technology offers economic benefits to consumers when compared to the conventional water heating technologies in use today.

Lastly, all firms face the market. That is, a firm must operate within, and sell products to, a market characterized by individual consumer preferences, states of national economies, global energy prices, technological trends, and a variety of other characterizations, most of which the individual firm has no control over. This thesis will examine the market for SHW technologies, especially in light of the people who are involved in implementing and using the technology.

1.1.2 FRAMEWORKS FOR ANALYSIS

As a significant amount of data will be reviewed and generated within this report, it is useful to have a framework to structure the analysis of that data. One such framework is that of the study of innovations. SHW technologies may themselves be considered as such, because they fit the definition of an innovation. That is, they are:

- "a non-trivial improvement...
- ... in process, product, or system...
- ... that is actually in use...
- ... and is novel to the institution developing or using it."  (Slaughter, 1998a)

Indeed, SHW technology is a non-trivial improvement to household hot water systems, and the technology is in use. And although the technology is not considered novel to the industries which manufacture and install it, solar hot water technologies are novel and unfamiliar to almost everyone else in the United States who is neither employed by, nor owns products from, the SHW industry — this means most U.S. homeowners, most U.S. home builders, most U.S. general contractors, and so on.

Furthermore, the SHW technologies examined in this report are tied to the private household environment. As such, this thesis will analyze the situation of the current U.S. SHW industry from the standpoint that its technology is an innovation for use within the residential construction industry. Lastly, because innovations are often introduced to society through entrepreneurial start-up companies and because the SHW industry is still "introducing" its innovation to the U.S. market, the SHW industry may benefit from the wisdom and rules of thumb which come from the entrepreneurial business community.
1.2 SYNOPSIS OF THE SOLAR HOT WATER INDUSTRY'S COMPETITIVE SITUATION

1.2.1 COMPETITIVE POSITION OF THE INDUSTRY

The solar hot water (SHW) industry which exists today in the United States is the fourth generation of such an industry that this country has seen. Every prior generation of the solar hot water industry which has existed within the United States (with the exception of this fourth, current, industry) has existed because the technologies they produced offered consumers either substantial measures of convenience over conventional means of heating water (during that particular time period), or because they offered consumers substantial economic benefits — either through reduced fuel usage at times when fuel prices were high, or else through government subsidies which were offered to consumers as an incentive to install solar technologies on their homes.

Use of SHW still offers consumers reduced fuel usage and, therefore, both lowers utility bills and is considered to be an "environmentally friendly" technology; but energy prices are not considered to be very high today, and so the savings which consumers derive from SHW are not as great as they may have been in the past. Thus, none of those assisting conditions apply today to the current SHW industry which applied to the three previous U.S. SHW industries in one form or another. Even so, this industry is able to stay in business. It is argued, therefore, by many people within the SHW industry (consistent throughout personal interviews), that today's (fourth) U.S. SHW industry is the healthiest one which America has seen — it is surviving by virtue of its own merits without the existence of any assisting, extenuating circumstances.

However, this lack of financial subsidies and the existence of low energy prices in today's U.S. market leaves the U.S. SHW industry in a tough competitive position: it must compete against conventional electric and natural gas water heating technologies that are well-established, familiar to consumers, technically dependable and generate few complaints. Conventional technologies can also be installed much more cheaply, more quickly and more easily than can SHW, and are simpler technologies from the homeowner's point of view. These are substantial barriers stacked against SHW, especially when one considers that both solar and conventional hot water systems deliver exactly the same product to the end-user: hot water.
1.3 OVERVIEW OF THESIS

What are the barriers facing the SHW industry, and what can be done to overcome these barriers? Are there practical solutions which exist? Answers can only be obtained by first developing a thorough understanding of the current technologies, their economics, and the motivations of the various stakeholders involved in implementing the technology. As such, this thesis will examine the history, technology, and context of the SHW industry in its initial chapters, and will then perform analyses on the economics and people of the industry within that context in the latter chapters, resulting in conclusions and recommendations in the last chapter as to what actions may realistically be undertaken by the SHW industry and/or the U.S. government to improve the industry’s health and operations.

Chapter 1 ("Introduction") introduces thesis and covers methodology of how certain calculations were made during the analyses.

Chapter 2 ("Frameworks for Analysis") will highlight issues and theoretical frameworks in the relevant literature which offer insight to the situation of the current U.S. solar hot water industry, and will serve as a guide for the thought process of this study. It focuses on literature pertaining to the diffusion of innovations (particularly in the construction industry), and anecdotes and empirical evidence from the business entrepreneurship community.

Chapter 3 ("History & Current Industry") gives a brief history of the four SHW industries which have existed, at one time or another, during the last 100 years within the United States. Following the history, a description of the current U.S. SHW market is presented. The different actors within the industry, and how they are connected to each other through the value-added chain of the industry are described.

Chapter 4 ("Water Heating Technology") describes the four basic designs of solar collector technologies used for domestic hot water heating purposes. These are: the Integrated Collector Storage (ICS) unit; the flat plate collector; the thermosiphon collector; and the evacuated tube collector. A description of these four collector technologies, how they are incorporated into a home’s domestic hot water system, and the installation procedures for installing SHW systems are given. At the end of the chapter, a tabular summary of various SHW system configurations is given, to facilitate their comparison.

Chapter 5 ("Economics of Hot Water Systems") analyzes whether purchasing a solar hot water system is economically attractive to the homeowner vis-à-vis purchasing a conventional water heater or other new innovating (water heating) technologies. This is a question whose answer depends upon several variables, namely: water quality, water usage, and energy prices. Because the economics of SHW depend on several variables, its analysis deserves careful deliberation in order to avoid erroneous conclusions which may not be generally applicable in practice. Two types of economic analyses are presented to facilitate
an understanding of the economics of SHW, and to show clearly what can realistically be expected of a SHW system, in terms of its economic performance.

The first economic analysis presented is a payback period analysis, based on nominal cash flows. This type of analysis is presented because of its simplicity and ease of comprehension. It asks the question: “Given the investment required to implement a project (SHW, in this case), how long will it take for the savings realized through that project to offset the investment which was initially required to implement it?”

Though the payback period analysis is very popular among the general public and decision-makers, it is not, in general, a very good method of analyzing the true economic value of a project because it ignores the fact that the value of money changes over time. For this reason, a more rigorous approach to economic analysis is also presented: the discounted life cycle cost analysis, which asks: Is the amount of money (which could be invested today — at a given interest rate — such that it would grow and produce payments each year equal to the savings which solar hot water provides) greater than, or less than, the investment which is required to install SHW? If that theoretical investment is less than the cost of installing SHW, then the consumer is better off not installing SHW, as s/he can generate payments in the future with that investment — those payments would be equal to the energy savings which SHW would provide, only the investment needed to generate them is less.

Chapter 6 ("Stakeholder Analysis / Distribution of Benefits") examines who the different actors — "stakeholders" — are within the SHW industry, and what it is that they want or require. The relevant stakeholders in the SHW industry are those people or groups of people that stand to gain something from the use of SHW technologies and are in a position to affect the functioning of the industry. Specifically, these stakeholders include governments, industry associations, and those who are involved at different points along the value-added chain of the industry: parts suppliers, manufacturers, distributors, specialty contractors, plumber, home builders and homeowners. The issues which face the SHW industry may be viewed differently by different stakeholders. This type of analysis is useful to identify areas of friction within an industry which may slow creative processes or the development of solutions and strategies needed to achieve market acceptance of the industry’s products.

Additionally, one must consider the distribution of benefits among the stakeholders, and the opportunities they have to reap those benefits. Who gets what out of the industry? Lack of incentives or an inability to reap benefits from feasible efforts may explain why solutions to problems are slow to develop or be created.

Chapter 7 ("Conclusions") looks back at the entirety of this report and draws conclusions from the analyses performed in the latter chapters, in reference to the context presented in the initial chapters. The conclusions offer advice to both the SHW industry and the U.S. government as to which issues today deserve attention with regard to creating a better SHW industry tomorrow.
1.4 SOURCES OF DATA

1.4.1 INTERVIEWS

The bulk of the information contained in this thesis comes from interviews conducted with people who are connected to the U.S. solar hot water industry in one form or another. Specifically, these people include:

Management personnel at solar hot water collector manufacturing companies:

- American Energy Technologies, Ltd. Cove Springs, FL
- Solar Development, Inc. Riviera Beach, FL
- Solahart Industries Pty. Ltd. Longwood, FL
- Sun Earth, Inc. Honolulu, HI
- Sun Systems, Inc. Scottsdale, AZ
- Sun Trapper Solar Systems, Inc. San Antonio, TX
- Thermal Conversion Technology Sarasota, FL

Solar hot water installers/contractors:

- All Solar Power, Inc. Tampa, FL
- Aztec Solar Sacramento, CA
- Bergquam Energy Systems Sacramento, CA
- Energy Conservation Services Gainesville, FL
- Greenlaw Solar Group Sarasota, FL
- Solar Development, Inc. Riviera Beach, FL

Solar hot water equipment distributors:

- Solar City Tampa, FL
- Solar Wholesale Phoenix, AZ

Solar energy industry representatives / Solar energy research institutions:

- Florida Solar Energy Industries Association Crystal River, FL
- Florida Solar Energy Center Cocoa, FL

U.S. Department of Energy


Other

- A.D. Little (heat pump experts) Cambridge, MA
- Chip Bercher Wisconsin Public Service 414-433-5518
- Sustainable Technologies Australia Australia, Tel: (06)-299-1592
It should be noted that not all interviewees commented on all matters which are covered by this study.

Reliability and validity of data from interviews has been assured by a fair degree of cross-validation between the different data collected from different interviews. Representativeness of manufacturers' perspectives has been assured by interviewing a variety of SHW manufacturers, including all of the possible industry leaders. No numerical data was obtainable which could identify particular manufacturers as positive leaders in overall U.S. sales of their technology. However, possibilities as to which manufacturers might be industry leaders were identified by asking all interviewees (manufacturers, industry associations, etc.) which U.S. manufacturers are leaders within the industry. General (but not total) consensus between interviews led to the identification of two probable market leaders for sales of solar collectors used in active solar hot water systems:

- American Energy Technologies
- Sun Earth, Inc.

Additionally, the probable market leader for ICS units was determined to be:

- Thermal Conversion Technology (for ICS designs)
- Solahart was the only manufacturer of thermosiphon systems that was reachable for comment.

### 1.4.2 STAKEHOLDER ANALYSIS

Data as to peoples' viewpoints for use in the stakeholder analysis come largely from interview data. However, use of external focus group reports was also made. These were conducted by outside parties with no connection to this study. The sources from which interview data came are as follows:

<table>
<thead>
<tr>
<th><strong>Stakeholder analyzed</strong></th>
<th><strong>Data source</strong></th>
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<tbody>
<tr>
<td>Solar hot water collector manufacturers</td>
<td>personal interviews</td>
</tr>
<tr>
<td>Distributors / Wholesalers</td>
<td>personal interviews</td>
</tr>
<tr>
<td>Specialty SHW installers/contractors</td>
<td>personal interviews, (NAHB Research Center, 1998)</td>
</tr>
<tr>
<td>Trade contractors (plumbers, etc.)</td>
<td>(NAHB Research Center, 1998)</td>
</tr>
<tr>
<td>Home Builders</td>
<td>(NAHB Research Center, 1998)</td>
</tr>
<tr>
<td>Home-buying consumers</td>
<td>(FOCUS Marketing Services, 1998)</td>
</tr>
<tr>
<td>DOE: U.S. Government</td>
<td>personal interviews</td>
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</table>
1.5 METHODS OF ECONOMIC ANALYSES

Two types of economic analyses are performed in this study. The details of how they are performed are described below:

1.5.1 PAYBACK PERIOD ANALYSIS

Nominal values for costs relating to both conventional hot water systems and solar hot water systems are summed over time, assuming both systems are installed on the same date. The payback period is measured starting at the time when a hot water system is installed; at that point in time when the costs accruing from a conventional hot water system grow to a value equal to, or greater than, the accrued costs of a solar hot water system, the payback period ends. The solar system is then said to have "paid for itself."

1.5.1.a Equivalent Compounding Rates of Growth

Once payback periods have been obtained, they can be used as a basis for understanding how the savings benefits of owning a SHW systems compare with compounding interest rates. Consider an investment, S, to be the difference in cost of installing a solar hot water system versus installing a conventional hot water system. If:

\[ R = \frac{1}{(\text{payback period})} \]

then R is the fixed percentage of S "paid back" by the solar system every year through the savings it produces. Then,

\[ 30(S)R \]

is the total sum saved by the solar system over a 30-year lifetime. But to understand a compounding rate of interest, such as one which would be applied to a bank or money market account, one must account for the fact that S is not recaptured at the end of the period under examination with a solar system, as it would be with a financial investment — S was used to purchase equipment. Thus, one must compare:

\[ S, \text{ as it grows to become: } [30(S)R - S] \]

If the simple, overall growth of the investment is of interest. Or, alternatively, one must consider:

\[ S, \text{ as it grows to become: } [30(S)R - S] / (1 - \text{tax rate}) \]

If one considers the scenario to be that of a tax-deferred investment. (S is subtracted from both figures, because no profit is made by the consumer unit S has been paid back by the system.) Specifically:

\[ S(1 + r)^{30} = S(R)30 - S \quad \text{(for the simple growth case); and} \]

\[ S(1 + r)^{30} = [S(R)30 - S] / (1 - \text{tax rate}) \quad \text{(for the tax deferred investment case)} \]

where r is the compounding rate of growth, assuming a 30-year period of analysis.
1.5.2 DISCOUNTED LIFE CYCLE COST ANALYSIS

The discounted life cycle cost analysis calculates the amount of money which would need to be invested today (at an assumed interest rate), such that all costs relating to a project over its life time could be paid for with that investment plus the cash flows generated by the investment over time? Thus, all future costs become “discounted” according to the following logic: in order to be able to pay a cost of $100 at some point in the future, a sum of less than $100 must be invested today, which will grow to the required $100 amount by the required point in time.

The rate at which money grows is denoted as “r,” the “discount rate.”

Specifically, the amount of money which must be invested today, in order to grow to a required amount at a required date, is:

\[
\text{Today's Investment} = \frac{\text{Amount of money required in a future year}}{(1 + r)^t}
\]

where \( r \) = discount rate
\( t \) = time at which future amount of money is required (in years)

This investment is also termed a “present value.”

There may be a number of future costs which will need to be covered in different years in the future. A present value can be calculated for each required payment from each future year. When all of these present values are summed, the “net present value” of all future costs is the result. This paper will refer to this amount as the discounted life cycle cost of the hot water system. As an equation, this reads:

Discounted (30-year) life cycle cost =
\[
[\text{present value of all costs from year 1}] + \\
[\text{present value of all costs from year 2}] + ... \\
[\text{present value of all costs from year 30}]
\]

The most economically attractive system is then the system whose discounted life cycle cost is lowest, since all costs which will accrue from this system over its lifetime could be covered by making the smallest investment today.
2. FRAMEWORKS FOR ANALYSIS

"The technology is not important...
... although you must have technology.
The manufacturing is not important...
... although you must have manufacturing.
The only important requirement is:
Are there customers for what it is that you are going to make?
Who is going to buy the darn thing?"

— Robert Shillman, President, Chairman, CEO of Cognex, Inc.
(Keynote address to course 15.975: "Starting and Running a High-Tech Company,"
Massachusetts Institute of Technology, January 1998)

2.1.1 INTRODUCTION - A NEED FOR MARKETING

People, and the decisions they make, drive markets and economies. Technology by itself will do nothing except lie on the floor, in a warehouse, or sit idly on a desk.

Of the three topical issues which face technology-based companies (technology, economics, and the market in which the firm operates — see Chapter 1: Issues Facing Technology-Based Firms), it is understanding the market which can be the most “messy” and difficult for a company to fully grasp.

Understanding the economics of a business is fairly straightforward to understand once sufficient data has been collected. And the data is often available: the firm can analyze its own costs of operation versus the revenues it brings in, can survey the market to see what consumers are paying for its own products, as well as what they are paying for competing products. A careful analysis of such data will usually result in a fair understanding of the economic environment in which the firm is doing business.

Likewise, a firm’s understanding of its technology is usually also quite complete. Firms must often engineer the products they sell from scratch, thus affording them a full understanding of that technology. In general, management will have control over, and access to, fuller descriptions of their firm’s technology (or that technology which is licensed from other companies) than will anyone else in the industry. Not only will that technology
likely be well-documented within the firm, but the firm will also have daily contact and experience in producing or using that technology.

Thus, that information which is necessary in order to obtain a reasonably full understanding of the economics and/or technology behind a company are usually accessible to the firm and under its control.

An understanding of the market in which a company operates, however, cannot be gained in nearly such a straightforward manner. The market is comprised, among other things, of a complex mix of people (users, suppliers, distributors, influential politicians, etc.), their thoughts and their actions. And these people may not regularly share or wish to share their personal thoughts or communicate their actions to other individuals or entities. Getting good marketing information is difficult.

2.1.1.a The Data in Support of Marketing

A false understanding of the market in which a firm operates can have severe consequences. The entrepreneurship community is replete with stories of start-up companies who produced high quality products for markets which those companies did not understand. As such, those products did not adequately meet the needs and constraints of the users for which they were intended — though the technology was admirable — and the companies ultimately failed (personal interviews, 1998).

These problems are not new to the business world. As such, many people have offered advice as to how to avoid them. Alfred Ehrenfeld wrote forty-three years ago: “Too many products are developed to satisfy the desires, urges, and hunches of people within the company, rather than to meet the specific needs of the market external to the company” (Ehrenfeld, 1955). This is backed up by a warning offered by MacRae Ross, in his 1991 paper “Seventeen Deadly Marketing Mistakes:”

“Deadly Marketing Mistake Number 1: Thinking that technology sells itself.”

(Ross, 1991)

Grabowski (1998) compared the “Marketing to Engineering Ratios” (M/E) of firms over the 1980’s and 1990’s, covering a range of startup and Fortune 500 companies. The market-to-engineering ratio (M/E) is defined as:

\[
M/E = \frac{\text{Expenditures on marketing, exclusive of promotional costs}}{\text{Expenditures on engineering and product development}}
\]

Marketing, in this context, does not include promotional or advertising costs. The marketing numerator of equation 2.1 “includes such things as quantification of needs, understanding the potential customer, developing business models, payback calculations,
primary and secondary market research, market segmentation, food-chain analysis, and competitive intelligence" (Grabowski, 1998).

The data (Figure 2.0-A) revealed that companies whose products had enjoyed great success in their markets had all employed a M/E ratio of 1.0 or greater — on average, successful companies actually spent twice as much money doing research on their relevant markets (on the needs, preferences, and constraints of their target users in order to determine what the features of their products should be) as they spent on developing and engineering the products themselves! Conversely, those companies who had performed dismally and ultimately went out of business had employed a M/E ratio of 0.1 or lower. In fact, the average M/E ratio of these failed companies was roughly 0.04, indicating that they spent only one twenty-fifth as much money on market, product, and business model development as they did on engineering and developing their products.

Source: (Grabowski, 1998)

There can be no doubt from Grabowski's data, that marketing — understanding a relevant market, how it operates, who the people are who act within it and what it is they need or want — is crucial towards developing a successful business. But how can the people leading an industry sift through all of the "messiness" of real-life markets?

The diffusion and innovation literature offers us some guiding frameworks and experiences to draw from. Specifically, this chapter will look at:

- manufacturers of SHW collectors, classification of their technology, and models for how they may diffuse throughout a market;
- potential adopters of SHW;
- consideration regarding all of the people needed to implement and install SHW.
2.2 MANUFACTURERS AND THEIR TECHNOLOGY

Manufacturers lie at the heart of any manufacturing industry. Without them, no industry exists: they are the reason everything happens. They require a full understanding of their own position within the industry, and of the implications that their technologies have on the people who use them if they are to steer their industries along a prosperous course.

It is a reasonable assumption that manufacturers understand fully the functioning of the technologies they produce — in the SHW industry, the manufacturers have designed the technology themselves — but the extent to which their technologies alter the worlds of the other people involved in implementing and using that technology may not always be obvious.

2.2.1 CLASSIFICATION OF INNOVATIONS

It is people who are responsible for implementing and trying out new technologies. Hence, manufacturers must consider what those people face when viewing an innovation, as this may affect the way in which (or the rate at which ) people adopt new technologies from manufacturers. A tool useful for understanding just how much a technology is deviating from the norm is offered by Henderson & Clark (Henderson and Clark, 1990). They propose a system by which innovations may be classified according to their novelty to the environments in which they are used. Four classifications of innovations are proposed: incremental, modular, architectural, and radical (Table 2.1-A).

<table>
<thead>
<tr>
<th>Linkages between components within system</th>
<th>Core concepts of system</th>
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<tr>
<td></td>
<td>Reinforced</td>
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<td>Overturned</td>
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<tr>
<td>Unchanged</td>
<td>Incremental Innovation</td>
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<td>Modular Innovation</td>
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<td>Changed</td>
<td>Architectural Innovation</td>
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<td>Radical Innovation</td>
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Source: (Henderson and Clark, 1990)

Incremental innovations are those innovations which do not overturn the basic concepts of a system, and also leave the linkages between the components of that system intact. An example might be an improved tank lining for conventional water heaters. While the quality of the tank lining may be improved, the concept of the water heating system remains the
same (it is contained in one tank, and is fueled by electricity or gas), and no re-configuration within the hot water system or home is required.

Modular innovations overturn the concepts upon which a system is based, but do not require a change in the linkages between components of that system. An example of this might be a completely redesigned hot water heating tank which heats water by using a heat pump, but which still employs the traditional cold-in and hot-out plumbing, plus one electrical, connections. Such a unit could simply be “swapped” with a conventional electric water heater: although the new water heating system would be based upon a different concept — that of taking energy from the surrounding air to heat household water — it would require nothing new as far as the linkages are concerned in hooking it up to the household.

Architectural innovations require different linkages within a system, but do not overturn the concepts upon which the system is based. For instance, one may imagine using smaller versions of conventional electric hot water heaters in every room in the house where hot water is required. (Assume that the heaters could be powered by wall outlets; this is admittedly an unreasonable assumption!) Such a system would be employing conventional tank designs and concepts, but would configure the system in a completely different arrangement, as plumbing connections between points within the system would have to be redone.

Radical innovations overturn both the core concepts upon which a system is based as well as change the linkages between components within that system. SHW is an example of a radical innovation. This is readily seen, even prior to a detailed analysis of SHW technologies. The concept of receiving a portion of the energy needed to heat water from the sun overturns current dominant concepts of water heating. Additionally, the use of SHW technology requires substantial changes in the linkages within a home’s hot water system: at the very least, some connection must be made between the solar collector outside the home, and the rest of the hot water system which is inside the home. This linkage by itself is significant, but it also implies that a penetration of the home envelope must be made, as well.

In this light, SHW technologies upset everything to which people have become accustomed, as far as household water heating is concerned. Not only are the concepts and operation of the technology different, but so are the linkages through which that technology is incorporated into the home environment. Upsetting so much of what is standard may mean that the SHW industry faces a significant lack of trust and/or lack of technical ability by would-be users and installers.

2.2.1.a Configurational Technology

A quick consideration can confirm that SHW technologies may be considered a configurational innovation, as well a radical one. Configurational technologies require a fair
amount of customization with each new implementation. For instance, a SHW system, at
the very least, must involve a solar collector outside of the home, plus components which
link and connect it to the home's hot water system inside the house. As few houses are
exactly alike, it is reasonable to assume that every installation job will be slightly different,
requiring certain tricks of the trade for some jobs, but not for all. In this way, SHW
systems are configurational technologies.

2.2.2 MODELS OF DIFFUSION

Once an understanding of an innovation has been developed, in terms of what the
innovation means to, and what it expects of, its would-be users, leaders of an industry will
have to choose an appropriate business model for diffusing — spreading — their innovation
into its particular target markets. As such, it would be helpful for any manufacturer to
know the paths by which their technology may diffuse throughout a market. Different types
of technologies often diffuse throughout markets according to different patterns (Slaughter,
1998a):

- The traditional “centralized” model of diffusion is that by which manufacturers simply
  send their products out into markets where consumers buy them. The rate at which
  consumers adopt new products under this model is similar to those seen in medicine:
  “contagion” rates of infection within populations.
- The “decentralized” model relies on the communication of the users amongst themselves.
  Information about, and encouragement to try, new products, methods, or services are
  communicated by “word of mouth” within a given relevant market or industry.
  Manufacturers may decide to capitalize on this pattern of diffusion, but they must be able to
  count on the technical competence and credibility of the adopters, as the adopters become
  the chief source of advertising for the manufacturer.
- The next model is the “evolutionary” model, whereby the manufacturer continues to make
  changes to the same product over time as the user’s needs continue to be served. Software
  is a good example here.
- The “configurational” model is one by which many different components or technologies
  exist in the market which complement each other. As such, different users come and
  assemble the technologies together indifferent ways to make similar end-products, each of
  which is slightly different from the other.
2.3 UNDERSTANDING THE PEOPLE IN THE INDUSTRY

2.3.1 ADOPTERS OF TECHNOLOGY

Who are the people that are likely to adopt innovations first? This was the subject of Edwin Mansfield's work, which investigated the rate at which industrial robots were adopted by firms within the United States and Japan. He concluded that the adoption of robots by firms was chiefly a function of firm size: "Large firms... begin using [robots] more quickly than small ones, because they tend to be more involved in operations suitable for the use of robots, they have more resources and are better able to take the risks than their small rivals, and robots tend to be more profitable for firms that can introduce them in large quantities." (Mansfield, 1989)

Rose and Jostow (1990) looked at the historical diffusion of new electrical generation technologies into usage by electric utilities. They uncovered two other factors of importance: (1) that the risks to large firms were diversified through the large numbers of projects the firms operated, thus making them feel safer in trying out new products; and (2) the large numbers of generation facilities which large firms owned required that new generation facilities be purchased more frequently as the old facilities wore out — large firms have opportunities to adopt new technologies more often than do small firms. (Rose and Jostow, 1990)

2.3.1.a Who to Target as an Adopter?

For the case of the SHW industry, this leaves us with the following questions: Are adopters of SHW concerned about any particular risks? Is the best adopter for the technology a single individual, or a large firm? Consideration of: a) opportunities to adopt, b) financial resources, and c) risks each party is willing to take may all be important. Clearly, it is best for the manufacturer to find people who have many opportunities to adopt (i.e. buy) a particular innovation, are not financially constrained, and are willing to take the risk of trying out a new technology.

2.3.1.b Champions of Innovations in Large Firms

If large firms are chosen as the ideal adopters, manufacturers may be on the lookout for an individual inside of a targeted firm to champion the process of introducing that technology into the firm. Getting innovations into an organization or firms can be characterized as a multi-step process — one which can be time-consuming and resource-intensive (Slaughter, 1998b). Thus, there may be an unwillingness by potential users to try SHW, simply because no one wants to go through the time and effort required to learn about the technology, what the risks are, push for permission to try it out from upper management, etc.
For this reason, large, risky and innovative projects are often undertaken by firms solely because of one "champion" within the company who wants to make something new and exciting happen. These are often people who have the technical competence needed to understand and master the fear of something new or unusual (Nam and Tatum, 1997).

2.3.2 IMPLEMENTATION OF INNOVATIONS

- "The greater the configurational nature of the technology (i.e., the more it is composed of selections of components to meet local requirements) the greater the chances of [its] failure ... Asymmetric distribution of knowledge between the users and suppliers are also typical of the situation..."
- "All components are potentially of importance; not just the purely technological ones."

(Fleck, 1994)

These statements were made by Fleck in his study of company-wide computer information systems and the successes (and lack thereof) of their implementation into companies who decided to adopt them. Though this technology is completely unrelated to the SHW industry at first glance, it is surprising how compatible these statements sound when applied to the SHW industry.

2.3.2.a Acceptance of Technology

Do those people who are expected to be the users and implementers of a new technology have the skills which are required to make effective use a configurational technology, requiring specialized knowledge of how the system works as a whole? Cainarca et al (1989) investigated the rate at which flexible factory automation technologies were being adopted across manufacturing industries. Use of these technologies was not as simple as merely purchasing and installing new machinery. Rather, making effective use of the technology required users to acquire substantial new skills and knowledge. More importantly, a completely different way of viewing manufacturing processes was needed by everyone involved in the activities on the manufacturing floor (Cainarca et al, 1989).

If the requirements for SHW's successful implementation are similar to those of flexible factory automation, then the SHW industry has much more to worry about than simply identifying appropriate markets and advertising to them — issues of education and training may have to be seriously addressed, both of SHW installers as well as users. Alternatively, solar hot water technologies may have to be redesigned and further simplified so as to reduce the amount of learning which is required of users or installers of the technology.

2.3.2.b Stakeholders Along the Value-Added Chain

Cainarca's work drew attention to the fact that some technologies are quite demanding of those people that use them, in that the technology may require old habits to be changed and new skills to be learned. Henderson and Clark's work (see Manufacturers of Technology,
above) established a framework by which innovations could be classified according to the changes their implementation required of their surrounding environments, thus offering a rough gauge as to just how much a technology altered conventional ways of doing things.

But to which groups of people do these considerations matter? Need one examine only the end-users of a technology? There are a variety of actors — stakeholders — who act at different points along the value-added chain within any industry. Afuah and Bahram (1995) argue that each stakeholder may view an innovation differently, and that some parties may refuse to cooperate if they are expected to go out of their way too much, possibly creating bottlenecks or inefficiencies within the industry. Therefore, the viewpoints and interests of every stakeholder involved at every step of the value-added chain must be taken into consideration when an innovating firm is developing its strategies to diffuse its technology throughout a market.

Interestingly, it has been found that, within the residential construction industry, of all the stakeholders which are typically employed in the implementation of an innovation, it is the cooperation of plumbers which is often the hardest to solicit (Ventre, 1979).

2.3.2.b.i Appropriability and Complementary Assets

When considering the viewpoint of any particular stakeholder, two questions are worth posing in trying to understand that stakeholder’s behavior. They are:

- How is the stakeholder able to appropriate the benefits of those services performed or technologies delivered? (Usually, benefits come in the form of money paid for products delivered or services rendered.) The stakeholder must have a means of ensuring that s/he will be able to reap those benefits, or else they may consider the situation too risky and will not cooperate (Teece, 1988). For example, why would a company adopt an innovation, if they had to shoulder all of the risks involved? Would they likely want some sort of guarantee from the innovator?

- What are the complementary assets which a stakeholder needs in order to reap benefits from their efforts? In other words, the stakeholder may be confident that they are in a position to appropriate benefits from their efforts, but they may not be in control of the means (complementary assets) necessary to extract those benefits. Lack of distribution channels is an example — if a firm cannot distribute its product, it is unlikely that anyone will ever buy it, and no benefits will accrue to that firm (Teece, 1988).

2.3.3 RISKS FROM COMPETING PRODUCTS

The closer a product is tied to the specific needs of an individual end-user, the more risky is the position of those people who manufacture that product. Should the end-user’s needs change, a manufacturer working closely with that customer will certainly need to alter his/her product to address those changing needs. Parts suppliers, on the other hand, may not need to change their businesses at all in such an event, as the components which they sell may be wholly unaffected by the changing needs of an end-user. And as an alternative,
part suppliers may be able to quickly leave one industry to supply another if their parts are generic enough (Christiansen and Rosenbloom, 1995).

Thus, it is the people with the most specialized technology (i.e. SHW manufacturers) who are at the greatest risk of becoming obsolete if newer, better products come along which end-users prefer. They must therefore be on the lookout for such dangers.

### 2.3.4 HELP FROM THE GOVERNMENT

Governments can be a tremendous help to an industry, providing needed information, subsidies, and technical R&D support to it. However, the U.S. federal government has a poor record of picking technological “winners” (Nelson and Langlois, 1983). Experiences within the SHW industry during the 1970’s and 1980’s, and what happened at the end of the tax credits, attest to this fact. The failure by the federal government to create a strong, healthy solar industry during that period may make it wary of becoming closely involved in the solar industries again.

However, concerns regarding global warming and international efforts to address this issue appear to be motivating the federal government into action on energy efficiency issues in general. In addition to MSRI (launched in 1997), President Clinton emphasized energy efficiency in his 1998 State of the Union address, and has just initiated the PATH program (see: Government Influences, Chapter 3).

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### 2.4 SUMMARY

“The creative effort required to achieve effective implementation is not always fully appreciated by the people directly involved in introducing new technology” (Fleck, 1994). Clearly, there may be a great many issues facing the SHW industry other than purely technical or economic ones. Coordinating the roles of the people involved — everyone through the supply chain and down to the user — deserves careful consideration. Different people work under different constraints, and each has talents which afford them a different potential role in the SHW industry. By definitions within this chapter, SHW is a radical technology. This likely places several groups of stakeholders out of their normal “comfort zones” — they have neither training nor experience to guide them in using SHW technology for the first time.

To combat any fears or hesitations which stakeholders may have due to their lack of experience, industry leaders may have to alter the business models they use, putting more effort into educational or assistance efforts whereby they assist the installation process or assuage fears about the unknowns surrounding SHW.
3. HISTORY AND CURRENT INDUSTRY

In Short: The three prior solar hot water industries which existed in the United States enjoyed either strong economic or convenience-of-lifestyle advantages over the conventional hot water heating technologies prevalent at the time. Today's solar hot water systems offer consumers no increase in convenience at a time when energy prices are fairly low. Hence, the SHW is left in a much more entrepreneurial position: it must make in-roads against established technologies at a time when people have little incentives to seek alternatives. This given, careful consideration must be given to the needs of all parties whom SHW involves, so as to remove as many barriers against SHW as possible.

3.1 PAST SHW INDUSTRIES

The history of the commercial solar hot water industry in the United States dates back to the end of the 19th century. During the late 1800's, hot water for household uses was traditionally obtained by heating it on a stove. It would then have to be carried to wherever it was to be used, which was a painstaking and laborious process.
3.1.1 THE FIRST U.S. SHW INDUSTRY

In 1891, however, Clarence Kemp introduced the Climax solar water heater in southern California. This was mounted on the roof of a home and consisted of a metal water tank painted black, and enclosed in a wooden box with a glass lid. Water was pumped up to the tank via local water pressure, and towards the middle of a typical afternoon, water in the tank would become hot enough to use for household purposes. The hot water could then be utilized by turning on a hot water tap inside the home which was connected to the Climax heater.

This offered several advantages over heating water on the stove. For one, no extra work had to be done to get hot water — one needed only to wait until the water was hot enough. Additionally, the water came from a tap, and did not have to be carried. Lastly, men no longer “needed” their wives to heat water for them — they could get by quite easily on their own for a while if the rest of the family was away (Butti and Perlin, 1980).

This increased convenience and a number of technical improvements to subsequent models led to a high market success of the Climax, and sales spread out as far as Arizona by 1905. For a $25 investment needed to purchase the heater, California residents saved roughly $9 per year in avoided coal purchases. One disadvantage to this heater, however, was the fact that water in the tank lost its heat during the night (Butti and Perlin, 1980).

The success of the Climax attracted entrepreneurs into the business, and in 1909 William J. Bailey introduced a system which provided hot water long into the evening. It was named the Day and Night heater. This design used a large insulated hot water tank which would be located on an upper floor of the home. Water continually (during the day) drained from the tank through an outlet pipe in its bottom, out of the house, onto the roof, and into a solar collector housed in a wooden box with a glass cover. As the water entered one side of the collector, it flowed across its width through narrow black-painted tubes. The water heated while flowing through these tubes, causing it to rise (due to natural convection) out of the outlet on the other side of the collector box. It then rose up a pipe leading back to the top of the hot water tank inside the home. In this way, the system continually added energy to the (heated) water in the tank. (Butti and Perlin, 1980)

The big benefit to this system was the fact that the water stayed hot long after dark because it was stored in an insulated tank inside the home, and was even warm in the morning — all with no extra effort by anyone in the household. The heater provided roughly 75% of the heat needed to heat the water, and could be hooked up to a supplemental heater inside the house.

Technical improvements on the principles governing the Day and Night led to the creation of the Sun Coil solar water heater (named so, because of the zigzag arrangement of the
pipes inside the collector). This used an alcohol-water mixture for the fluid which circulated between the collector and the tank, plus a heat exchanger in the tank through which the mixture could flow, thereby heating the water inside. This allowed their adoption even in northern California, where damage to collectors due to freezing of water had previously been a problem. By 1920, the Sun Coil was the dominant design on the market, with sales reaching Arizona and Hawaii. (Butti and Perlin, 1980)

But between 1920 and 1930, large natural gas discoveries were made in California, reducing gas prices by 75%. This made natural gas water heaters an economic possibility. More importantly, hot water could be guaranteed at all hours and could be delivered at a constant temperature, chosen by the homeowner. This enormous increase in convenience and control, plus aggressive marketing and free gas water heater installations offered by the gas utilities, led to the widespread adoption of gas water heaters and the demise of California’s solar hot water industry. (Butti and Perlin, 1980)

3.1.2 THE SECOND U.S. SHW INDUSTRY

During that same 1920’s period however, Florida began to adopt solar water heating technologies. There were no cheap supplies of natural gas or coal in Florida at that time, and electricity prices of 7 cents/kWh (roughly ten times the cost of prices seen in the 1980’s, with inflation taken into account) made solar hot water an economic choice for consumers to make. H.M. Carruthers purchased rights to market the Sun Coil water heater in 1923. By 1925, his solar water heaters were well-established in the market, and by 1938, ten solar water heater companies were competing in Florida. By 1941 a total of 25,000-60,000 collectors had been installed in Florida. Roughly half of Miami was using solar water heating at that time, and 80% of all new homes were constructed with solar water heaters pre-installed. (Butti and Perlin, 1980)

But between 1948 and 1958, the cost of copper increased to three times its 1928 prices. Consequently, the prices of solar water heaters rose from $350 to $550. At the same time, the price of electricity dropped from 4 cents/kWh to 3 cents/kWh, and utilities began aggressively marketing electric water heaters. This led to the eventual demise of Florida’s solar hot water industry, leaving only repairmen to fix the existing systems left over from the industry’s boom during the 1930’s and early 1940’s. (Butti and Perlin, 1980)

3.1.3 THE THIRD U.S. SHW INDUSTRY

With the convenience of electric and natural gas water heaters, and little economic reasons to seek out alternatives to them, solar energy did not enjoy much attention until the oil embargo of 1973. As energy prices soared during the embargo, solar became not only a strategic variable with which the government could reduce its dependence on foreign oil,
but the economics of solar energy once again began to look favorable, thus giving rise to the third U.S. SHW industry.

The Solar Energy Act of 1974 was enacted (P.L. 93-473). In 1978, solar hot water truly began to receive serious attention by the federal government with its passing of the National Energy Act, comprised of five bills, including the Energy Tax Act which created a 30% tax credit applied to the first $2,000, and a 20% tax credit applied to the next $8,000 above that initial $2,000, spent by private homeowners on solar thermal technologies to improve their homes. In 1980, the Crude Oil Windfalls Profits Act amended the provisions of the Internal Revenue Service Code, allowing homeowners to take a tax credit of 40% (up to $4,000) for expenditures on solar heating and cooling technology.

In 1979, President Carter proposed a bold goal for the United States: to form 20% of its total energy portfolio from solar and renewables by the year 2000. With that target goal in mind, the DOE reorganized its solar program in 1980 into four subprograms, whose individual goals were to foster the development of real world applications for their various solar technology areas of responsibility: Solar Applications for Buildings, Solar Applications for Industry, Solar Power Applications, and Alcohol Fuels. (Löf, 1993, p.212).

With all of this excitement surrounding solar energy — 21 states by 1980 were offering some form of solar tax deduction or credit (Whittington, 1985) — and especially due to the solar tax credits, the solar hot water industry again became active: by 1984, U.S. production of solar collectors for solar hot water had grown to between 9 and 12 million square feet per year (Department of Energy, 1995). However, profiteers attracted by the tax credits and offering inferior technology also sprang into action during this time. The technology they offered, and the problems those technologies caused — either mechanical malfunctions, a failure to provide water heating by any significant amount, or both — earned the solar hot water industry as a whole a bad reputation, lowering consumer confidence in the technology and increasing confusion about it.

With the tax credits in place up until 1985, the solar hot water industry with all of the products being offered within it — good and bad alike — remained active up until that time. Once those subsidies ceased to exist, sales within the industry collapsed almost overnight. "We were selling about one-hundred units per week, and didn’t sell any at all the next," said one distributor when describing the weeks before and after the disappearance of the tax credits (personal interviews, 1998). Any manufacturers of systems which were of inferior quality quickly disappeared from the industry altogether, and in that sense, the end of the tax credits were a help to the industry. However, the suddenness with which the credits were removed caused some manufacturers of quality systems to go out of business as well, since they were not able to adapt to the new market conditions quickly enough.
3.2 CURRENT SHW INDUSTRY

The SHW industry which has existed since the end of the tax credits is the current (and fourth) U.S. SHW industry. The technologies which are now produced within it come from several reputable manufacturers, who are all genuinely committed towards their industry and establishing a good reputation for it.

3.2.1 BENEFITS OF SHW

The benefits which SHW offers to consumers stem from the energy savings which the systems provide. With a SHW system installed on a home, homeowners gain a portion of the energy needed to heat water from the sun, thereby requiring that less energy be purchased from utilities. Consumers' utility bills are therefore lowered — by amounts varying roughly between $15 and $30 per month (assuming 75% energy savings over yearly conventional fuel costs of $250 to $500, as explained in Chapter 5). Aside from this financial benefit, consumers may also enjoy the fact that, because they are substituting energy from the sun for energy from a utility, they are contributing less to environmental problems (which result in part from a utility's use of either fossil or nuclear fuels), and are also better cushioned against price increases by utilities.

3.2.2 OVERALL MARKET ENVIRONMENT

Despite these benefits, and the SHW industry's commitment to provide quality products, the industry faces a tough market.

According to many SHW manufacturers, U.S.-based solar hot water collector manufacturers have only stayed in business since the end of the tax credits because of sales abroad and markets created through electric utility demand-side management programs which incorporated solar hot water. But the oncoming deregulation of the electricity generation industry is a disincentive for utilities to invest in such programs, since sales of electricity will no longer be limited geographically: utilities therefore have little incentive to control loads within a given geographic area, as there is no guarantee that these people will remain customers. As such, many utility-sponsored solar hot water programs have been dropped, and overall industry sales have declined (personal interviews, 1998).

However, many states are including "systems benefit charges" into the structures of their deregulation legislation. These are essentially taxes charged on electricity bills which would then be used to continue "green" (or environmental) technology pilot programs or to subsidize their costs of implementation. Most states have not yet finalized this type of legislation, so it is not certain how much money will be raised for these technologies through such a charge, or whether those moneys will be made available to technologies such as SHW. (Tellus Institute, 1998)
3.2.3 TECHNOLOGY TRENDS
Active flat plate and ICS solar hot water systems are the most commonly types of SHW equipment purchased today (personal interviews, 1998). Thermosiphon systems are likely the third most purchased design of solar hot water equipment. Active evacuated tube collectors are the newest technology for household water heating and also currently the most expensive SHW technology; as such, they currently rank lowest in sales by U.S. homeowners.

3.2.4 SPECIFIC BARRIERS AGAINST SHW
Further counting against the SHW industry is the fact that the benefits it provides — lower energy bills, increased independence from utilities, and decreased impact on the environment — are all more elusive and less tangible than those factors which are readily apparent upon installing a SHW system, including: high up-front installation costs ($1,500 - $3,500), an increase in the complexity of the home’s hot water system (SHW systems use conventional water heating technology, plus the additional components of the SHW system), the possibility of roof leaks resulting from the mounting of solar collectors on the roof of the home, and problems with the aesthetics of a system’s visibility on the home. (As it turns out, these last two concerns relating to the collector’s mounting and appearance on the roof are generally not a concern or problem with consumers after installation, but are a source of concern with consumers before hand.) (FOCUS Marketing Services, 1998)

Further hindering the SHW industry is the confusion which surrounds it. To begin with, consumers often do not even know that a SHW industry exists and that it offers quality technologies (FSEC personal interviews, 1998). Second, SHW technologies vary significantly from one to another in design and operation, making the question of “what is solar hot water technology?” inherently complex to answer. These problems are then compounded by the low education and advertising budgets available within the SHW industry (this view was shared across all personal interviews conducted), resulting in little outreach being done to educate the public about what SHW is, to promote sales of the technology, or otherwise call attention to its existence.

Despite all of these problems however, there exist some signs of hope for the industry.

3.2.5 PROGRAMS ASSISTING SHW
3.2.5.a Solar Rating and Certification Corporation
Today’s SHW industry benefits from the existence of the Solar Rating and Certification Corporation (SRCC), which acts as central evaluation group for identifying which solar products are of good quality and which ones are not, thus providing an important means of quality assurance and signaling to the general public. This organization emerged out of efforts begun by solar hot water manufacturers and the Solar Energy Industries Association
(SEIA) during the tax credits period (1978 to 1985), whose goal was the creation of mechanisms which could signal to consumers the quality of solar products.

The Florida Solar Energy Center (FSEC) began a solar water heating certification program in 1978, and started certifying solar hot water systems in 1980. Their certification programs evolved during the early 1980’s, collaborating with similar efforts going on in California, and culminated in the institutionalization of those certification standards with SEIA’s creation of the Solar Rating and Certification Corporation (SRCC) program. FSEC was awarded sole stewardship of the SRCC program for the United States in 1997 (Florida Solar Energy Center, 1997a).

To receive SRCC certification that a solar hot water system is of good quality today, the SRCC requires systems to pass OG-100 Standards, which apply to the quality of the solar collector unit itself, determined by subjecting solar collectors to a variety of physical tests (exposure over a range of temperatures, pressures, and structural stresses) to establish that they are strong, sturdy products which will not rapidly fail (Solar Rating & Certification Corporation, 1995). Systems must also meet OG-300 Standards, which set standards as to what the minimum proper functioning of solar hot water systems should be, and how the different components making up an overall solar hot water system must perform and/or interact, including the solar collector itself, the solar hot water tank (if applicable), and all of the necessary plumbing, valves and controls. The OG-300 Standards also provide ratings which indicate the level of energy which a system can reasonably be expected to provide. These ratings are based on TRNSYS computer software, which simulates a variety of weather conditions for the particular system being certified; use of the software also checks that the sizes of the different system components are appropriate for use in their particular system configurations. (Solar Rating & Certification Corporation, 1997)

3.2.5.b Government Influences and Incentives

The current SHW industry enjoys little special financial support for solar technology from the federal government, though the passage of a current federal tax credit proposal on 15% of the cost against installing a SHW system (up to $1,000) would change this. In addition, there are other programs which promote household energy efficiency and solar energy in ways less direct than cash subsidies, structured to allow the most attractive products to evolve and be selected through natural market mechanisms, as opposed to championing individual technologies before their individual practical uses to the (complex and diverse) U.S. energy economy are understood. Of particular note is the Energy Star Program, operated through the DOE, and the Million Solar Roofs Initiative, in which the DOE is the lead participating federal agency.

3.2.5.b.i The Energy Star Program

This program seeks to promote the construction of new homes that will use 30% less energy than those built in accordance with the current national Model Energy Code.
Through this program, builders are offered the “stamp of approval” by the U.S. government and preferred financing for homes which meet the high energy efficiency standards. Homeowners benefit over the long term by paying less money in energy bills.

3.2.5.b.ii Million Solar Roofs Initiative (MSRI)

Perhaps more interesting to the SHW industry, is this Presidential initiative, which has a goal to install solar technologies (both thermal and photovoltaic) on the roofs of one million U.S. buildings. The MSRI is often described by the government as a “top-down, bottom-up” initiative (United States, Department of Energy, 1998). The intended meaning here is to convey the fact that the program will be “top-down,” inasmuch as it will be federally facilitated, but that the majority of actual solar activity which will ensue will be “bottom-up” initiated, as it will be local actors — installers, schools, demonstration programs — who will initiate the installation of solar technologies because they choose to do so, for one reason or another, without federal subsidies or advertising. These efforts will be assisted through MSRI via the information which it will distribute, and the financing infrastructure it is currently working to create.

Information assimilated and distributed through MSRI will include details about incentives or loan programs applicable to solar technologies which already exist through federal and/or state government programs. This may “create” solar incentives, in effect, by uncovering information about existing incentives to people who otherwise would not know to take advantage of them. MSRI will also act as a networking hub, through which different parties involved in solar energy (interested consumers, installers, manufacturers) can find each other more easily, thus locating those skills, technology, or information that they require.

Finally, the federal government through MSRI has set a target for itself to install solar technologies on the roofs of 20,000 federal buildings. The first outputs of MSRI, such as initial information dissemination, will probably begin sometime in late 1998.

3.2.5.b.iii Partnership for Advancing Technology in Housing (PATH)

This is a new initiative from the White House, but has yet to see any money allocated for use. The program proposes a goal of lowering the energy usage of new homes by 50%, and of existing homes by 30%. To do this, the Department of Housing and Urban Development is partnering with industry to find ways of achieving the set forth goals. The program proposes a five year tax credit package of $6.3 billion for purchases of, and research and development on, energy efficient technology.
3.3 SHW INDUSTRY STRUCTURE

There is no standardization in the organization of the value-added chain for the current U.S. solar hot water industry. The industry’s value-added chain looks different from region to region, but a general value-added chain for the industry is given in Figure 4.3-A (the creation and installation of any SHW system will follow some combination of the routes indicated), along with the more important additional influences which act upon the industry:

Figure 4.3-A: Structure of the Current SHW Industry

From Figure 4.3-A, one can see that there are a variety of routes by which SHW equipment may come to be installed on an end-user’s home. Of particular note however, is the fact that all equipment is installed through specialty contractors, regardless of the path of equipment up until that point.

3.3.1 VALUE-ADDED CHAIN

Specialty Suppliers sell specialty products to manufacturers and distributors. Examples include selective coating materials which are coated onto collector components to enhance solar absorption; tube and fin absorber components (for active or thermosiphon collectors) — usually pre-coated with a selective absorption coating; 80-gallon hot water tanks, designed for solar use; and specialty valves.

Manufacturers The number of U.S.-based SHW system manufacturers is not large. When manufacturers were asked who the other “players” in the market were, they typically listed three or four firms other than themselves. In total, seven manufacturing firms
were interviewed. Industry directories such as “Solar Thermal Water Heating: The U.S. Industry” (published by SEIA) list perhaps twenty manufacturers in total. These firms typically do all of the manufacturing required for producing solar collector units, using widely-available stock materials for their production, with the exception of those parts obtained through specialty suppliers.

Additionally, manufacturers often sell “valve kits” which include all of the necessary valves required for an installation. Active system manufacturers will sometimes sell “appliances” which combine several of the system’s components (such as a pump, an drain back tank, and a controller) into one unit.

**Wholesalers** may specialize in the wholesale of many types of solar equipment and other “green” or energy efficient products; they often carry the components necessary for installing that equipment, but do not usually carry pipes and fittings, as these are available from plumbing supply houses or other non-specialty sources. They are usually not fiercely loyal to any one particular brand of product, but it is important to them that they feel the products they sell are of high quality, so they drop and add products to their catalog from time to time, according to their feelings of how the quality levels of particular brands change over time (personal interviews, 1998).

**Distributors** usually specialize in the wholesale of many types of solar equipment and can be an important link in the value-added chain. Like wholesalers, they wish to sell only products that are of high quality. They sell solar collectors to local specialty contractors and, importantly, sometimes pre-assemble some system components (such as pre-attaching valves to sections of pipe to ensure the proper orientation of parts with respect to each other) and/or offer pre-packaged “kits” containing all components and parts which a specialty contractor would need to complete an installation job (personal interviews, 1998).

**Specialty Contractors** are currently the only people who install SHW systems, and usually must have a license or special training to do so (depending upon the state). They often install solar pool heating systems as a large part of their business, since the demand for domestic SHW systems is low in most areas. When systems require it, contractors will pre-assemble or test parts of the SHW system on their own premises before going to an installation site. If kits are not available, then they must purchase system components separately from specialty suppliers and “stock” warehouses such as plumbing supply stores or Home Depot. On the whole, these contractors are small companies which act independent from manufacturers. Occasionally however, they may be loyal to, or teamed up with, one particular manufacturer.

**Home Builders / Electric Utilities** can be important influential parties to the SHW industry. They can be intermediate parties who make the decision to purchase SHW systems for their customers. Importantly, a decision by either one utility or one
home builder can lead to the sale of many SHW systems. Also, customers of these companies may trust the suggestion to buy a SHW system more if it came from a utility or a home builder than they would if it came from someone in the SHW industry, since utilities and home builders have no specific loyalty to the SHW industry and, as businesses serving the public, will only want to enter into agreements which benefit both them and their customers. Having these industries do the research on which types of solar systems make best sense for their customers, and on which brands of solar equipment are to be trusted, saves customers the time and effort of having to do so themselves — a process which, today, would be quite confusing for the average home owner, due to the variety of technology and system configurations available.

Electric utility programs which included SHW installation programs have been a significant source of sales for the SHW industry (FSEC personal interviews, 1998); these lead chiefly to the sales of retrofit installations on existing homes. Home Builders could be an important source of sales for the SHW industry, as they are responsible for the building of hundreds of thousands of new homes every year.

Consumers represent the largest pool of potential users of domestic SHW, of course. However, they are widely dispersed geographically, and their individual attitudes and needs/constraints likely vary widely from household to household. They would be essentially one-time-only customers for the SHW industry, buying systems only once every 30 years or so, and have no loyalties to any specific manufacturer over another.

3.3.2 EXTERNAL INFLUENCES

Government influence cannot be ignored.

- Economic instruments such as subsidies can alter the economics of a market (and did so in the solar hot water industry during the tax credit years).
- Statements by government agencies and high ranking officials, or the purchasing decisions they make for their departments can have a tremendous influence in how the public perceives an industry.
- Decisions regarding energy policy can indirectly affect an industry. The uncertainty surrounding states’ plans to deregulate electric utilities created a good deal of confusion and uncertainty within electric utilities, leading them to drop some of their demand-side management programs, some of which included SHW installation programs (FSEC personal interviews, 1998).
- Public educational programs can have the effect of indirect advertising for an industry.
- The federal government can also affect an industry through the setting of building codes. However, interviews conducted revealed that building codes in most locations are not a serious hindrance to the industry, with the exception of Dade
County in Florida, where stringent hurricane codes make the installation of solar collectors difficult (SEIA interviews, 1998).

*M:Market forces* are also of importance (to any industry). In the case of solar hot water, the chief market force is energy prices, with environmental factors as a (distant) secondary consideration (FOCUS Marketing Services, 1998).

*Solar Rating and Certification Corporation* is the body which provides all official services which ensure the quality of products and services within the SHW industry, such as the certifying of manufacturers’ solar collectors and of designs for the layout and configuration of SHW systems.
4. WATER HEATING TECHNOLOGY

**In Short:** Four fundamentally different SHW collector technologies exist. All of these technologies can be incorporated into the household environment in a number of ways, making use of many different components to form the balance of the full hot water system — leaving many opportunities for mistakes to be made. By way of the literature referred to in Chapter 2, SHW is both a radical and configurational technology, wholly different in its concepts and integration into the household. This is a significant barrier facing SHW. Heat pump water heating technologies, on the other hand, are less energy than SHW technologies, but are much simpler to install — they may therefore be a serious competitor to SHW in the future.

There are basically four types of solar hot water collector technologies which are on the market today. They are: the active flat plate collector, the integrated collector-storage (ICS), the evacuated tube collector, and the thermosiphon collector. In describing these technologies as well as conventional and emerging ones, this chapter essentially pursues two goals:

- To provide an understanding of the issues involved with each technology;
- To provide a basis for comparing the technologies against each other, especially in light of the frameworks given in Chapter 2 for classifying technologies as incremental, modular, architectural, or radical.

4.1 COMMON CONCEPTS AND COMPONENTS

There are concepts and terms to which almost all solar hot water systems refer or utilize. Descriptions of these concepts and components are described here.

4.1.1 VOCABULARY SPECIFIC TO SOLAR HOT WATER

*Passive* SHW systems described as passive are able to function on their own without external controls or mechanization (pumps, temperature sensors, etc.); sunlight and/or household water pressure and/or the natural ability of warm water to rise
relative to cooler water is all that is required for a passive system to function properly.

*Active*  SHW systems described as active require the use of external sensors, pumps or other mechanization in order for the system to function.

*Open ("direct")*  SHW systems described as open, or direct, heat household potable water directly in the solar collector. The term “open” is used because the two parts of the system (the collector, and the hot water tank which stores hot water) are “open” to each other, allowing the same water to flow from one to the other (Figure 4.1-A).

*Figure 4.1-A: Open ("direct") SHW System*

*Closed ("indirect")*  SHW systems described as “closed” heat one fluid within the solar collector, and then uses a heat exchanger at the hot water tank which allows the fluid from the collector to transfer its heat to the potable water in the tank. The term “closed” is used because the two parts of the system are “closed” to each other: the collector contains one fluid, while the water tank contains water, and the two do not mix (Figure 4.1-B).
Figure 4.1-B: Closed ("indirect") SHW System

Selective Coatings  With the exception of evacuated tube SHW heaters, all other SHW technologies examined here use metal components inside of a collector box to capture the sun’s energy and transmit it to a fluid (either water or a heat transfer fluid). These components are copper tubes, copper fins, or a combination of the two. These components invariably have a black coating on them which is specifically designed to accomplish two things: (1) they absorb a high portion of the incoming solar radiation efficiently without reflecting it back out to the atmosphere, thus capturing a high amount of solar energy for water heating, and (2) they are poor emitters of infrared (heat) radiation, which means they act almost as a layer of insulation, decreasing the amount of heat energy which can leave the collector through radiative processes. Manufacturers typically use one of three coatings:

HiSorb, by Soltec, Inc.: a “semi-selective” coating with absorptivity characteristics similar to that of Black Chrome, but significantly worse emissivity characteristics, decreasing its capability to retain the energy it absorbs. However, HiSorb is significantly cheaper to apply on a square foot basis than black chrome or Black Crystal, and is still used today by manufacturers who are trying to lower their costs, or on systems where the speed of thermal absorption is not a crucial factor in the system’s good performance.

Black Chrome: among the highest performing coatings and is likely the most commonly one used throughout the industry today. It has an absorptivity of roughly 97%, and emissivity roughly 15%. On the negative side, it is a very toxic substance, rubs off easily from the surfaces to which it is applied, and is more expensive than selectively-absorbing paints. Compared to semi-selective coatings such as HiSorb, black chrome can add between $2.50 and $3.50 of cost per square
foot of collector size, or between $100 and $140 to the cost of a 40-square-foot collector.

Black Crystal: potentially the highest performing selective coating on the market — a new patented substance developed by Energy Laboratories, Incorporated. It has an absorptivity comparable to that of black chrome and a better emissivity (between 9% and 12%), but is cheaper and much less toxic (if at all). Additionally, it is not easily rubbed off of the surfaces to which it is applied. The technology is used by Thermafin Manufacturing (Jacksonville, FL) to make copper tube and fin absorber components suitable for flat plate and thermosiphon collector designs, available for purchase by any solar collector manufacturer.

Glazing: All collectors (with the exception of evacuated tube designs) are contained in box-like structures, whose bottoms and sides are usually made of aluminum, in which the components designed for absorbing solar energy are arranged. To increase the efficiency at which these components absorb energy and transmit it to other parts of the system, it is desirable to shield them from elements such as wind, rain or cold air which can cool them off, which would lower the amount of energy that could be used to heat the household water supply. Yet, sunlight must also be able to shine on those components. To accomplish both goals, a sheet of glass is used as the top of the collector box.

4.1.2 VOCABULARY COMMON TO PLUMBING INDUSTRY

There are many basic plumbing components which are common to the systems described in this chapter, used in the connective plumbing which ties the collectors into the hot water tank and household hot water supply system.

*bypass valve* enables water to be routed either to solar collector or to conventional heater

*check* restricts water flow to one direction only. Used to ensure hot water does not, by natural convection, rise up to a collector when the collector is cold, where the hot water would cool and lose energy

*shut-off valve* stops water from flowing between two parts of the system

*freeze “dribble” valve* as temperatures cool, this valve opens to the atmosphere, allowing water to slowly leak out before it freezes

*tempering valve* mixes household cold water with hot water from the hot water tank to prevent scalding
**drain valve** allows solar collector to be drained

**temp/pressure relief valve** guards against conventional tank over-pressure or over-temperature

## 4.2 SHW COLLECTOR UNITS

### 4.2.1 FLAT PLATE COLLECTOR

Water or another heat transfer fluid can be used in flat plate collectors which are part of a closed system design; only water can be used in an open system design.

**Figure 4.2.-A: Schematic of Flat Plate Collector**

Copper tubes (typically 1/2” ID) welded to thin copper fins are arranged horizontally within the collector box. A fluid (water or heat transfer fluid) is pumped by an external source up to the collector and enters it through the (vertically) lower end of the collector. The fluid
then flows sequentially through each copper tube horizontally across the collector’s width, flowing with each pass through the next higher tube. In so doing, the fluid absorbs the heat captured from the sun’s radiation by the copper fins.

These fins are coated with a black selective coating to ensure that they absorb and retain a high percentage of the incoming solar radiation. The flat plate collector industry shows a strong preference for using Black Chrome or Black Crystal, due to their superior absorptivity and emissivity qualities. The tubing is typically attached to the underside of the fins to prevent casting of shadows by the tubing on the fins as the sun’s position changes throughout the day. The fluid flowing through the collector continues to absorb heat from the copper fins until it finally exits the collector from its highest tube and enters a pipe running from the collector to inside the home.

The collector boxes are made from aluminum or aluminum alloys. The chief benefit of using these materials is that they are rust-proof, thus removing the possibility of this type of failure completely. The bottoms and sides of the boxes are lined with an insulation material which ensures that heat loss through those panels is minimized. Glazing is a single sheet of glass.

The fluid in systems incorporating flat plate collectors flows in a cycle, heating up as it flows through the collector, then flowing back into the household where it deposits its energy into a hot water tank, the fluid is later pumped back up to the collector to gain more energy, and the cycle repeats.
4.2.2 EVACUATED TUBE COLLECTOR

In the evacuated tube collector unit mounted on the roof, water or a heat transfer fluid is heated when using a closed system design; only water can be used in an open system design.

Figure 4.2-B: Schematic of Evacuated Tube Collector
These systems differ quite substantially from the other systems examined in this report, in that there is no collector box. They are instead based on a technology concept originally pioneered by NASA, and use evacuated glass tubes as the collectors (typically 6 to 7 feet in length, and 3 to 5 inches in diameter), arranged vertically along the roof's surface (Figure 4.2-B). Running up the middle of each evacuated glass tube (but not touching the tube's walls), there is a thinner copper tube which is sealed at both ends. Inside each copper tube, between one and two ounces of commercial refrigerant (such as R718) sits at its bottom. With the sun's heat, this refrigerant boils and rises up to the top tip of the copper tube, which sticks out of the top end of the evacuated tube, bringing it in contact with a fluid (water or other heat transfer fluid) that is flowing across the top tips of all of the evacuated tube collectors. Thus, the fluid is heated by the hot gaseous refrigerant, which itself cools in losing energy, thus condensing and dripping back down to the bottom of the copper tube, where the cycle will begin again.

The fluid being heated by the tips of the evacuated tubes flows in a cycle: after being heated up by the evacuated tubes, it flows back into the household where it deposits its energy into a hot water tank. The fluid is then later pumped back up to the evacuated tubes to gain more energy, and the cycle repeats.

One advantage of this collector design, is that they are essentially thermal diodes — that is, they can transfer heat in only one direction, making it physically impossible for the system to malfunction such that heat is removed from the stored hot water. In order for this to happen, heat would have to be transferred from the fluid flowing across the top tips of the evacuated tubes to the refrigerant. But this would keep the refrigerant in a hot gaseous state at the top of the tubes, never able to transport that heat away to any other place. Thus, this scenario is impossible.
4.2.3 INTEGRATED COLLECTOR-STORAGE (ICS)

The ICS unit heats water only, in an open system design.

**Figure 4.2-C: Schematic of ICS Unit**

In these systems, both functions of water heating and storage are combined in one unit — hence the name: Integrated Collector-Storage, or ICS. Large copper tubes (typically 4” ID) treated with a selective absorption coating are connected in series in the collector box — their length oriented horizontally, like those of an active flat plate system — and have a total combined volume of 30 to 50 gallons, depending on system design. All tubes remain full of water at all times. Water is warmed while it sits in the tubes, absorbing the sun's energy (during the day) until the hot water is turned on inside the house. This causes the warm water from the collector to flow sequentially through each of the copper tubes, flowing sequentially from lower tubes to higher tubes. The warmed water then finally emerges from the highest of the collector tubes, and flows through a pipe into the household. The entire ICS unit is housed in a box comprised of aluminum on its bottom and sides (eliminating rust as a potential problem), with double glazing (a sheet of glass as one layer, a sheet of clear Teflon as the other) forming the top of the box.
To minimize heat losses, foamed insulation is packed underneath and between collector tubes. Double glazing is used to minimize heat losses through the top of the collector box.

4.2.4 THERMOSIPHON COLLECTOR

Inside thermosiphon collectors, water or another heat transfer fluid can be heated when using a closed system design; only water is heated when using an open system design.

In these systems, water storage and heating are uniquely tied together. A precise description of how the two interact however, is given under the SHW SYSTEM DESIGN section of this chapter. In this section, the components of the solar collector are merely described.

Several designs currently exist for thermosiphon solar collectors, but all thermosiphon collectors rely on the principle that warmer fluids rise relative to cooler fluids. Because of thermosiphon systems are designed to take advantage of this fact, they are able to operate without the aid of any external pumps or mechanization.

The most common design of a thermosiphon collector is somewhat similar to the design of a flat plate collector. Inside the collector box (constructed of aluminum for the bottom and walls of the box, with glass glazing on the top), tubes welded to fins (similar to those in a flat plate collector) are arranged either vertically or horizontally. Figure 4.2-D

Figure 4.2-D: Schematic of a Thermosiphon Collector

![Diagram of a Thermosiphon Collector](image-url)
The fluid flowing through these tubes does not flow sequentially through each tube however, as it would in a flat plate collector. Instead, each tube is open at either of its ends to larger end-tubes oriented along the collector’s sides or bottom. Fluid then enters the collector through an inlet near the bottom of the collector into one end-tube, and exits the collector through from the other end-tube.

When the sun is shining, fluid begins to warm as soon as it enters the collector. It then rises through the collector, due to the tendency of warmer fluids to rise relative to cooler fluids, making one pass either across the collector’s width or up its length through the collector tubes, depending upon their orientation.

The warm water then leaves the collector near through an exit located in one of the end-tubes near the top of the collector. It flows up into a hot water storage tank, which is usually mounted on the roof, situated above the collector. There, the fluid deposits its heat energy into the tank, where water is continually warmed by this process throughout the day.

4.3 SOLAR HOT WATER SYSTEMS

The first part of this chapter gave a technical description of the four different SHW collector technologies which are available to the U.S. market. This section looks at how those technologies are incorporated into fully-operational hot water systems within a household. This, then, brings into discussion yet more components and technologies, which can be combined with the four collector designs in various combinations to form a variety of hot water systems, each with its specific strengths and weaknesses.

This section presents descriptions of the general principles which stand behind the operation of these different types systems. As the reader will see, the individual strengths and weaknesses which characterize different SHW systems leaves the typical end-user with an enormous variety of system characteristics to choose from — many more than a home owner has to deal with when choosing a conventional gas or electric water heater. To facilitate a comparison between the different SHW systems, they are compared next to one another at the end of this chapter in a tabular format (Tables 4.6-A and 4.6-B), allowing quick reference to the relevant issues associated with each design and an easy comparison among them.
### 4.3.1 ACTIVE CIRCULATING LOOP SOLAR SYSTEMS

Active circulating systems can use either water or other heat transfer fluid in their closed configurations, or water only in their open configurations. In either case, fresh water from the household supply is introduced into the hot water tank. The solar system then heats that water in different ways, depending upon its configuration.

<table>
<thead>
<tr>
<th><strong>In an Open (&quot;direct&quot;) Loop Configuration</strong></th>
<th><strong>In a Closed (&quot;indirect&quot;) Loop Configuration</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water is drawn from the bottom of the tank and is pumped through an isolation ball valve up to the solar collector. The water then passes through the collector, gaining heat energy from the sun as it passes through.</td>
<td>Potable household water remains in the hot water tank the entire time and is not circulated through the collector. A heat transfer fluid (water or propylene glycol) is pumped around a loop comprised of the solar collector at one end, where the fluid absorbs heat. The fluid then passes back towards the hot water tank at the other end of the loop via a drain valve, a check valve, and an isolation ball valve.</td>
</tr>
<tr>
<td>The water then passes out of the collector, back through a check valve, and an isolation ball valve, and is introduced to the middle of the hot water tank.</td>
<td>At the hot water tank, the fluid flows through a coil that is either immersed in, or wrapped around, the hot water tank. As it flows through this coil, potable water inside the tank is warmed and the fluid in the coil cools. The fluid is then pumped back up to the solar collector via an isolation ball valve and a drain valve, and the cycle repeats.</td>
</tr>
</tbody>
</table>

All systems (except drain back systems) should have an air vent and a pressure relief valve located near the top of the solar collector, typically as part of the piping assembly at the point where the circulating fluid exits the collector. When hot water is demanded by the household, hot water is drawn from the top of the hot water tank, which contains its own heating elements (electric or gas) to act as a backup source of heat for the system (Figure 4.3-A).
Figure 4.3-A: Schematic of an Active SHW System  
(open system shown)

Source: (Florida Solar Energy Center, 1997b)

NOTE: while the system shown in this diagram uses an active flat plate collector, an array of evacuated tube collectors could be substituted in the flat plate collector’s place.

4.3.1.a Components Common to all Active Systems

4.3.1.a.i Pumps
All active systems use a pump which is responsible for circulating water around the tank-collector loop.
- Drain back systems require larger pumps, because fluid must be lifted up to the collector.
- System which only circulate (but do not lift) fluids use smaller pumps.

4.3.1.a.ii Hot water tanks
Hot water tanks play an important role in active systems. Since fluids are constantly circulated to the solar collectors in small volumes in active systems (the collectors do not hold more than 3-5 gallons of fluid, typically), these systems rely on having a place to store the heat energy which is collected by the fluid when passing through the collector. A major concern is that the hot water tank has to be sized properly, given the size of the collector on the roof. Larger collectors will collect a larger amount of energy more quickly than smaller
collectors will; if the collector is too large, given the size of the hot water tank being used, the water tank’s temperature will be raised well above the temperature at which the household demands hot water. This can greatly lower the useful lifetime of the hot water tank, creating additional costs to the homeowner in the form of replacement costs. A rule of thumb is to size the tank assuming at least 1.25 gallons per square foot of collector area.

Generally, two types of situations exist when an active system is being installed:

Condition 1: System is sized according to household hot water needs:
To meet the hot water demands for a family of 3-4 people, active solar systems designed to take maximum advantage of the sun’s energy typically employ collectors of the following types:
- flat plate collectors having approximately 40 - 60 square feet of collector area; or
- roughly 30 evacuated tube collectors;
plus a new hot water tank. These systems, when functioning properly, will supply roughly 70% to 85% of the household’s hot water energy needs. In order to avoid tank overheating problems, tanks with 80 to 120 gallons are used, thus requiring the purchase of a new hot water tank when the system is installed (since common hot water tanks are only 40 to 50 gallons in size).

Condition 2: Retrofit installation: system is sized according to size of the home’s existing hot water tank
Doing this avoids the need to purchase a specialized solar hot water tank at the time of installation. Collectors suitable for retrofit around a household’s existing 50 gallon (retrofitting to a 40 gallon tank is not recommended) gas or electric hot water tank include:
- flat plate collectors with approximately 32 square feet of surface area;
- (evacuated tubes are not worthwhile on this small scale)

4.3.1.b Other Components
There are other components used in active systems which are not common to all system configurations, and may or may not be needed for the functioning of the solar hot water system. Some of these components and their system configurations are described below:

Temperature Sensor + Controller The temperature sensor compares the temperatures of water exiting the solar collector against water at various heights inside of a hot water tank. These readings are sent to the controller.

Based on readings from the temperature sensor, the collector decides to turn the pump on or off. In general, fluid should not be circulated if the fluid exiting the collector is colder than the water in the hot water tank, as this would cool water in the tank. Therefore, the pump is typically turned on when the water exiting the
collector is 10-20 °F above that of the water at the bottom of the hot water tank, and is turned off when that difference reaches 3-5 °F. However, it may be necessary to circulate warm fluid up to the collector if the temperature inside the collector is too cold, or it may be necessary to stop circulation of fluid, if the temperature inside the hot water tank is too hot, or it may be necessary to begin circulation if the fluid in the collector is too hot, and may boil.

This type of system is highly optimal from a thermal efficiency standpoint, as "smart" decisions can be made by the sensor at any time, allowing the system to adapt to a wide variety of solar and system conditions.

**Photovoltaic Pump** An alternative to the Sensor + Collector system design, is to switch the pump on and off according to the amount of solar energy available. This can be accomplished with a photovoltaic (PV) array attached to the SHW collector. When sufficient sunlight is present, the PV panel begins powering the pump, and fluid is circulated through the solar collector. Use of a PV array will not work for a drain back system, although it is used often in open loop configurations. Choice of the PV components must be made carefully.

**Drain Back Tank** To avoid all of the problems that often surround the fluid which is heated though the collector (e.g., freezing, boiling, glycol fluid becoming acidic), some systems incorporate the use of a drain back tank. This is a necessary component for active systems in which water is the fluid that circulates through the collector in locations where freezing is a possibility. Drain back tanks are small and able to accommodate the total volume of fluid which is in the collector — about 5-10 gallons. As soon as the pump ceases to circulate fluid through the collector-tank loop, the fluid in the collector drains into the drain back tank, thus protecting it from freezing or boiling conditions on the roof. Circulation can begin again at any time later, when the pump starts to circulate fluid again. Use of a drain back tank requires than 3/4" piping be used.

The advantages and disadvantages of active systems are summarized in Table 4.3-A.

**Table 4.3-A: Key Characteristics of Active Circulating Loop Systems**

<table>
<thead>
<tr>
<th>Freeze Protection Issues</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some freeze protection is provided through freeze dribble valves.</td>
<td></td>
</tr>
<tr>
<td>Poor freeze protection. If using an active system whose pumps switch on and off according to temperature sensors, warm water from the hot water tank may be circulated up to the collector if sensors indicate that the water in the collector is</td>
<td></td>
</tr>
</tbody>
</table>
getting too cold, but this lowers systems efficiency and (more importantly) is subject to mechanical failure, nor would it work if electricity went out in a storm.

<table>
<thead>
<tr>
<th>If propylene glycol is circulating fluid:</th>
<th>High freeze protection. Propylene glycol will freeze only under severely cold conditions.</th>
</tr>
</thead>
</table>

**Overall Advantages**

<table>
<thead>
<tr>
<th>Low energy loss</th>
<th>Hot water is stored in an insulated hot water tank, thereby minimizing heat losses while hot water is standing.</th>
</tr>
</thead>
<tbody>
<tr>
<td>High efficiency</td>
<td>Because these systems (with the exception of the PV-powered configuration) are controlled by a “smart” device which turns the circulation system on and off depending upon temperature readings, this type of system is able to operate in a near-optimum manner, compared with other systems with no such controls.</td>
</tr>
</tbody>
</table>

**Overall Disadvantages**

<table>
<thead>
<tr>
<th>More vulnerable to mechanical failure</th>
<th>Because this system relies on mechanical pumps, the system does not work at all if the pumps fail.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject to clogging</td>
<td>In areas with poor water quality, mineral deposits are deposited on walls of piping and valves. Poor quality valves (or poorly-installed valves) are subject to jamming and clogging as the layers of these minerals deposits thicken.</td>
</tr>
<tr>
<td>Typically requires a new 80-gallon hot water tank</td>
<td>Systems can be configured to fit onto a home’s existing hot water tanks, but the energy saving these systems provide are not as high, because the 40-50 gallon household tank limits are not optimized for storing hot water with a high difference in temperature between its bottom and top, which benefits active solar systems.</td>
</tr>
</tbody>
</table>
4.3.2 PASSIVE SOLAR SYSTEMS

Passive SHW systems (ICS, or else thermosiphon designs) function essentially as pre-heat systems for the household’s conventional hot water tank. In theory, passive systems could operate in the absence of a conventional hot water heaters, as they incorporate their own methods of storing the water they heat. But this would require users to tailor their hot water usage habits to the availability of sunlight. Because the quality of life in the U.S. demands that almost unlimited hot water be available at any time of the day or night, conventional water heaters are always used in combination with passive systems to ensure that hot water is always available.

With U.S. passive systems, fresh water from the household supply is introduced first to the passive water heater. There, the water will be heated for a time, until hot water is demanded from within the household. This will cause hot water for household use to be drawn from the conventional hot water tank, and warm water to be drawn from the passive water heater and introduced into the conventional hot water heater. There, it will be heated to the appropriate temperature for the household. Thus, passive systems reduce the energy needs of a household’s conventional hot water tank by raising the temperature of the water introduced into that tank. The conventional water heater therefore has less work to do, heating water from temperatures delivered by the passive system—say, at 110°—up to 140° (a temperature range of only 30°); without the passive system, the conventional water heater would have to heat water from groundwater temperatures of, say, 60° up to 140° (a much larger temperature range of 80°).

4.3.2.a ICS System

Hot water demands of a typical 3-4 person household can be adequately supplemented by an ICS unit with a volume of 40 gallons. This could supply 70% to 90% of a household’s hot water energy needs in sunny climates if people used most of their hot water during the day and early evening when water in the ICS is hottest; this figure probably more realistically lies around 55% to 65% however, given peoples’ actual patterns of hot water usage (personal interviews, 1998). An ICS is usually hooked up to a conventional 40 gallon hot water heating tank to ensure that hot water is always available at a constant temperature.
ICS systems are passive, and use only water. Whereas circulating systems (flat plate, thermosiphon, evacuated tube) circulate a small amount of fluid between a hot water tank and the collector to continually gain more energy, this is not so with an ICS. Fresh cold water is introduced to the ICS unit via household water pressure. Between 30 and 50 gallons of water reside in an ICS unit (depending upon its size), and will remain there until hot water is demanded from within the household. During its time in the ICS unit, water gains energy from the sun. When hot water is demanded within the household, hot water is drawn from the hot water inside the conventional hot water tank inside of the home. This, in turn, draws warm water from the ICS unit down to the hot water heater inside of the house, where it will be heated to the temperature at which the conventional heater has been set to operate. The water is not recirculated back to the ICS at any point.

Source: Thermal Conversion Technology, 1997

Water is supplied to the system from household water supplies through the supply shut off valve (1) (Figure 4.3-B). This water stream will then split into two flows: the first is directed to the tempering valve (4) where it is mixed with hot water exiting the tank (for use by the homeowner) to prevent scalding; the second flow continues through valves 2B, 5B and 6 and enters the ICS unit (10) through its (vertically) lowest entry point. After progressing through successively higher storage tubes in the ICS, water emerges and flows through piping to valve 5A, 3, 2A and enters the hot water tank (7) through its cold water inlet. Hot water for use in the household emerges from the hot water tank through the hot water outlet and mixes with cold water at the tempering valve (4), finally proceeding through household plumbing for use by the homeowner.

The hot water tank contains its own heating elements (electric or gas) which bring the pre-heated water from the ICS unit up to household hot water temperatures.
The advantages and disadvantages to the ICS system are listed in Table 4.3-B.

<table>
<thead>
<tr>
<th>Freeze Protection Issues</th>
<th>Key Characteristics of the ICS System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeze protection in the ICS is good. The possibility of water freezing inside of it is fairly low, and will occur only at night when there is no sun to warm the system. Because the copper tubes containing the water inside the unit are large, arranged close to each other and have insulation packed between them, only the water near skyward-facing tube walls are actually exposed to the nighttime air temperatures. This, plus the large thermal mass of the 30-50 gallons of (warm) water give ICS systems a good deal of freeze protection, easily enough to last through a 15 °F night. However, pipes which run from the inlet/outlet ports of the unit through the roof and into the house are susceptible to freezing, and must be insulated with 1.5 inches of insulation in the coldest climates.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall Advantages</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplicity</td>
<td>There are no mechanical or control devices which are needed to make this system work. Failure due to mechanical malfunction is therefore eliminated.</td>
</tr>
<tr>
<td>Less subject to clogging</td>
<td>The narrowest tubing used is typically 3/4” internal diameter, which makes the possibility of clogging over the long term by mineral/other deposits (in areas where water quality is poor) lower, compared to most other systems which use 1/2-inch piping.</td>
</tr>
<tr>
<td>Existing hot water tank used</td>
<td>Using an ICS unit requires no specialized tank, and is fully compatible with the existing hot water tank in a typical home.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall Disadvantages</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nighttime energy loss</td>
<td>The water in an ICS cools down during the night because the sun’s energy is no longer available to add heat to the system as it does during the day, and also because the glazing covering the ICS is a fairly poor insulator against radiative losses of heat energy from the tubes containing the hot water in the ICS.</td>
</tr>
<tr>
<td>Energy savings dependent upon user’s habits</td>
<td>The “loads” experienced by the overall hot water system (occupants’ use of hot water) is ill-timed with the available “supply” of hot water available through the ICS — this means that people must adjust their hot water usage habits in order to take full advantage of the potential energy provision of the ICS unit. Water in the ICS is at its coolest in the morning, since it has been cooling all night. Thus, when people take showers in the morning, they are causing the coolest water available from the ICS to be introduced into the home’s conventional water heater — this is likely warmer than groundwater, but not as warm as it would be towards the middle, or end, of the day. Hot water, of course, is still available due to the backup heat provided by the conventional hot water heater, but it is being made to do more work than it would if hot water were used during the middle and end of the day, instead of in the morning. Under the right circumstances, water from the ICS may even be cooler than the available groundwater. This is the worst scenario, as the conventional water heater would then have to provide more energy to heat water than it would normally do without the ICS unit — this would occur only if the ICS were emptied of its hot water in the evening, and if ambient outside air temperatures were colder than groundwater temperatures.</td>
</tr>
<tr>
<td>Weight of unit</td>
<td>These systems are heavy due their water storage capacity. Thus, they may require that the roof or attic (depending upon where the intermediate tank is installed) be structurally reinforced, thus adding time and effort to the installation process. (Thermal Conversion Technology, 1997)</td>
</tr>
<tr>
<td>Less fuel savings, compared to other systems</td>
<td>Because of nighttime energy losses and the fact that water passes through the collector only once (i.e. it only has one chance to collect the sun’s energy), the overall energy savings provided by these systems tends to be less than that provided by other SHW systems.</td>
</tr>
</tbody>
</table>
4.3.2.b Thermosiphon Systems

A thermosiphon system uses a special collector-tank component arrangement. With a collector area of about 40 square feet, a thermosiphon system could supply roughly 60% to 80% of the home's hot water energy needs (assuming a 3-4 person household). It is usually connected to a conventional 40 gallon hot water heating tank to ensure that hot water is always available at a constant temperature.

Thermosiphon systems can use either water or other heat transfer fluid as the agent which captures the sun's energy and delivers it to the household hot water supply. Either of these fluids can be used in the closed thermosiphon systems design. Only water may be used in an open system configuration.

The general plumbing configuration is shown in Figure 4.3-C, applicable to both types of system.

**Figure 4.3-C:**
Schematic of a Thermosiphon System

In both cases, the process by which the household's water is heated begins in the same way. Household water pressure delivers cold water to an intermediate hot water storage tank located on the roof. On its way to the intermediate tank, water passes through a shut-off valve, an isolation ball valve, and a drain valve. During the time the water spends in the collector-intermediate tank system, the open and closed system designs function differently.
In an Open Configuration ("direct" configuration)
The (cool) potable water introduced to the intermediate tank from the household supply sinks to its bottom (since cool water sinks relative to warmer water). It then exits the bottom of the tank and continues down a pipe to the bottom of the solar collector. As it enters the collector, the water begins to warm (due to the solar energy), causing it to rise. It rises up though the tubes in the collector, continuing to heat along the way. When that water reaches the top of the collector, it rises up through a pipe and is introduced into the middle of the intermediate hot water tank.

Meanwhile, comparatively cooler water at the bottom of the intermediate tank will sink to the bottom of the collector and the whole cycle will repeat itself.

In a Closed Configuration ("indirect" configuration)
The (cool) potable water introduced to the household hot water tank from the household supply remains in that tank until hot water is demanded from within the home. In the meantime, a heat transfer fluid such as distilled water or propylene glycol circulates between the collector and a heat exchange unit in the intermediate tank. (The heat exchange unit may be a fluid jacket surrounding, or a coil submerged in, or wrapped around, the intermediate tank.

The fluid moving around/through the heat exchanger is warm, and cools as it spends more time in it, since the fluid’s heat is transferred to the potable water inside of the tank. As cools, the fluid sinks to the bottom of the heat exchanger. Meanwhile, heat transfer fluid in the collector is warmed by the sun and rises (since warm fluid rise relative to cooler fluids) creating circulation around the collector-heat exchanger loop.

In this way, heat is constantly delivered to the water inside of the intermediate hot water tank.

In both the closed and open configurations, the circulation of fluid between the collector and the intermediate hot water tank is driven solely by the fact that the fluid in the collector is warm, and wants to rise relative to the cooler fluid inside of the intermediate tank. Since this tank-collector loop is completely filled with fluid, there is no hydrostatic pressure which needs to be overcome — the weight of the fluid sinking in the intermediate tank is enough to “pull” the rising fluid up from the collector and into the intermediate tank.

The potable water residing in the intermediate hot water tank will continue to be warmed (during the daytime) until hot water is demanded from within the household. At that time, hot water will be drawn from the conventional hot water tank for use in the home. This, in turn, will draw warm water from the top of the intermediate hot water tank on the roof down to the conventional hot water tank in the home, traveling through a drain valve, a check valve, and an isolation ball valve. And as this occurs, fresh cold water from the household cold groundwater supply will be drawn up and introduced into the bottom of the intermediate hot water tank on the roof.
The advantages and disadvantages of the thermosiphon system are summarized in Table 4.3-C below:

**Table 4.3-C: Key Characteristics of the Thermosiphon System**

<table>
<thead>
<tr>
<th>Freeze Protection Issues</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>If water circulates through collector:</td>
<td>Freeze protection is poor. Though the (warm) water in the intermediate hot water tank has a large thermal mass making it resistant to freezing, the possibility of water freezing in the thin tubes of the solar collector itself is quite high if nighttime temperatures are low.</td>
</tr>
<tr>
<td>If a heat transfer fluid circulates through collector:</td>
<td>High freeze protection. The heat transfer fluids (such as glycol solutions) used in SHW systems will remain fluids over a wide range of temperatures, subject to a change of state into a thick, sluggish liquid only at extremely cold temperatures.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall Advantages</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplicity</td>
<td>There are no mechanical or control devices which are needed to make this system work. Failure due to mechanical malfunction is therefore inherently low.</td>
</tr>
<tr>
<td>Existing hot water tank used.</td>
<td>This system does not require replacement of the existing hot water tank in a home.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall Disadvantages</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetics</td>
<td>The intermediate hot water tank is most frequently mounted on the roof above the collector; often homeowners do not like the look of a bulky tank on their roof.</td>
</tr>
<tr>
<td>Installation</td>
<td>These systems are heavy due to their incorporation of an intermediate hot water tank. Thus, they may require that the roof or attic (depending upon where the intermediate tank is installed) be structurally reinforced, adding to the time and effort of the installation process.</td>
</tr>
</tbody>
</table>
4.4 COMPETING HOT WATER SYSTEMS

4.4.1 CONVENTIONAL GAS OR ELECTRIC HOT WATER SYSTEMS

Conventional gas or electric water heaters are essentially large (typically 40- or 50-gallon) insulated, glass-lined tanks which heat potable water by either gas of electric means. In the case of electric water heating, two resistive electric heating elements (one each near the top and bottom of the inside of the tank) provide heat to the water. In the case of gas water heating, natural gas is burned near the bottom of the tank, and the hot gases which result from the combustion flow up through a heat exchanger on the inside of the tank, thus heating the water inside the tank.

Fresh water is typically introduced to the hot water tank near its bottom, where the coolest water in the tank resides (since cool water sinks relative to warmer water). The water at the top of the hot water tank is hottest, and it is from the top of the tank that hot water is always drawn for household usage. Two temperature sensors inside the tank (one near its bottom, and one near its top) sense the water temperature at both places, and send the temperature information to a controller housed within, or attached to the side of, the tank. This controller then regulates the amount electric or natural gas fuel provided to the hot water tank based on the information provided by the temperature sensors.

Both technologies are in use today. They perform, on the whole, to the standards promised by manufacturers, and are well-understood.

Table 4.4-A: Key Characteristics of Traditional Water Heating Technologies

<table>
<thead>
<tr>
<th>Overall Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of use</td>
</tr>
<tr>
<td>Simplicity</td>
</tr>
<tr>
<td>Familiarity</td>
</tr>
</tbody>
</table>
Overall Disadvantages

<table>
<thead>
<tr>
<th>Lifetime</th>
<th>The best of these systems last 15 years or so.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel use</td>
<td>These systems use fuel (gas or electricity) to heat water, and so incur household utility bills. Electricity is especially expensive.</td>
</tr>
</tbody>
</table>

4.4.2 TANKLESS HOT WATER SYSTEMS

These systems use a small electric-powered device (not larger than 2x1 feet, and usually smaller) through which water flows. Household water supply enters the device and is heated as it flows through it via a high-power resistive electric element. Depending upon the model and manufacturer, the water’s outlet hot water temperature is either variable — a function of flow rate, inlet water temperature and the power of the water heater — or can be set by the user to provide a fixed temperature increase to the water which flows through it, regardless of flow rate.

These tankless water heating units can be placed close to the point where the hot water is needed, so that heat loss through long piping distances is minimized. Alternatively, larger tankless water heating units can be placed in a centralized location to provide all of the house’s hot water needs. In either case, the standing heat losses associated with conventional hot water tanks are eliminated. Because of their large power requirements, they require hookup to the household’s 220V electrical supply, and cannot be merely plugged in to a 110V wall socket.

Tankless units cannot provide hot water at large flow rates however, such as that needed for a bathtub. For this reason, additional small booster tankless units may be needed at locations where large flow rates of hot water are needed.

Manufacturers of these systems include:

- AdTec Systems, Inc. / Emitron Companies, Inc.
- Advanced Tech Industries Miami, FL
- Niagara Industries Miami, FL
- Tankless Hot Water Systems, Inc. Germantown, TN
Table 4.4-B: Key Characteristics of Tankless Water Heaters

<table>
<thead>
<tr>
<th>Overall Advantages</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Instant hot water</td>
<td>This is probably the greatest, most noticeable advantage of tankless hot water heaters. If the units are placed near the point of use, there is absolutely no waiting necessary for the delivery of hot water.</td>
</tr>
<tr>
<td>Simplicity of use</td>
<td>These systems are simple to control, use, and understand by the user.</td>
</tr>
<tr>
<td>Fuel savings</td>
<td>These systems eliminate standing heat losses, as they heat water only at the moment it is needed. If the units are placed close to the point of use, heat loss through piping is eliminated, as well. For these reasons, manufacturers estimate that tankless water heating will save money over conventional technologies: 20-25% savings over the electric water heating, or 10% over the costs gas heating.</td>
</tr>
<tr>
<td>Mechanical simplicity</td>
<td>These systems function with no moving parts, and incorporate everything which is needed for their proper functioning into one unit. The possibility of mechanical failure is therefore eliminated.</td>
</tr>
<tr>
<td>Lifetime</td>
<td>These units are designed such that any sediment (formed from mineral deposits from water) deposited onto the heating elements will eventually cake off of them and fall to the bottom of the unit. They will subsequently be swept away with the flow of the water. Thus, no clogging or fouling of the unit ever occurs. Manufacturers offer warranties on their products of between 5 and 15 years.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall Disadvantages</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow rate of hot water</td>
<td>Hot water at high temperatures (e.g. 140°) cannot be guaranteed at all flow rates. May require additional supplementary units.</td>
</tr>
</tbody>
</table>

4.4.3 HEAT PUMP WATER HEATERS

Heat pump water heaters are potentially a real competitor to SHW systems. They function similar to other heat pump technologies — providing heat by essentially running air-conditioning technology backwards. This technology takes heat from the surrounding air to heat household water. These units are available in a variety of different forms, from all-in-one units which incorporate water storage and heat pump water heating into a single
appliance, to add-on appliances for retrofit purposes which attach onto conventional electric or gas hot water heating tanks.

The systems are basically stand-alone, and require only one more connection to the household than a conventional hot water tank would: heat pumps need access to a drain because moisture from the air condenses inside the unit during operation and must be drained off.

Heat pump water heaters can provide household hot water at conventional temperatures, while requiring only 50% - 60% of the energy normally used by conventional hot water heating tanks. Additionally, these systems can currently be installed for about $1,200 — personnel at A.D. Little believe that there is potential for the installed costs of these systems to come down to $700 - $900 (A.D. Little personal interviews, 1998).

**Table 4.4-C: Key Characteristics of Heat Pump Water Systems**

<table>
<thead>
<tr>
<th>Overall Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand-alone units</td>
</tr>
<tr>
<td>Fuel savings</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanically complex</td>
</tr>
<tr>
<td>Noise</td>
</tr>
<tr>
<td>Lack of experience</td>
</tr>
<tr>
<td>May require maintenance</td>
</tr>
<tr>
<td>Requires access to drainage</td>
</tr>
</tbody>
</table>
4.5 INSTALLATION OF HOT WATER SYSTEMS

The installation of a SHW system is by no means a quick and simple process — especially when compared to installing a conventional hot water tank. It is therefore perhaps not surprising that stories of improperly installed SHW systems abound throughout the industry, and came up in almost every interview conducted. Because of the time and materials involved in the process, the cost of installing a SHW system also lies far beyond the cost of just the solar collector itself, which alone costs as much or more than installing a new conventional hot water tank.

4.5.1 SHW PRE-INSTALLATION CONSIDERATIONS

The SHW installation process often begins on the day before the installation job is to be done. Interviews with contractors revealed that some contractors spend several hours verifying that equipment is defect free and/or pre-assembling as many of the components together as possible without being on-site. Because the price of installation is usually pre-negotiated with the customer and therefore fixed, it is in the interest of the contractor to complete the installation in the shortest amount of time possible. Nevertheless, installations take a fair amount of time to complete (Table 4.5-A), and contractors must therefore often pay their workers a full day's work to install one SHW system.

Table 4.5-A: Summary of Time Spent During Installation

<table>
<thead>
<tr>
<th>Phase of Installation</th>
<th>Contractor</th>
<th>Number of People Working</th>
<th>Hours Spent Installing Active Systems</th>
<th>Hours Spent Installing ICS Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attaching</td>
<td>A</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Collector to Roof</td>
<td>B</td>
<td>2</td>
<td>1-2</td>
<td>---</td>
</tr>
<tr>
<td>Roof</td>
<td>C</td>
<td>3</td>
<td>---</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>2</td>
<td>---</td>
<td>1-3</td>
</tr>
<tr>
<td>Plumbing</td>
<td>A</td>
<td>(same)</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Between Roof and Hot Water</td>
<td>B</td>
<td></td>
<td>&lt;1</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td></td>
<td>---</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td></td>
<td>---</td>
<td>3-5</td>
</tr>
<tr>
<td>Valves/Plumbing</td>
<td>A</td>
<td>(same)</td>
<td>3-4</td>
<td>3-4</td>
</tr>
<tr>
<td>Connections to Tank</td>
<td>B</td>
<td></td>
<td>3+</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td></td>
<td>---</td>
<td>1+</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td></td>
<td>---</td>
<td>2-3</td>
</tr>
<tr>
<td>Travel and Set-Up Time</td>
<td>(all)</td>
<td></td>
<td>1-2</td>
<td>1-2</td>
</tr>
</tbody>
</table>

Source: personal interviews, 1998
It is not certain why installation times for contractor D are longer than for other contractors. However, the data suggest that the most significant amount of time spent during installation is used in making the final plumbing connections near and to the hot water tank.

4.5.1.a Considerations Regarding Strength of Roof Structure

Solar hot water systems in the United States today are installed with the assumption that the solar collector sits on top of the roof of the house. Any SHW systems which mount only a solar collector on the roof do not need to worry about roof deformation, and can be bolted into the roof rafters without worry. However, systems which incorporate water storage on the roof (such as ICS and most thermosiphon designs) should pay close attention to the structural strength of the rafters versus the weight of the system being installed.

Because they store large volumes of water on the roof, ICS designs have weights which range from 19 to 24 lb. per square foot of their roof-projected area; the tanks used in thermosiphon systems can have weights up to 32 lb. per square foot of their projected area upon the roof. Manufacturers suggest that these components be mounted over a supporting wall, near the apex of a slanted roof (typically, the top edge of the component should be within 12" - 18" of the apex), or that the weight of the unit be spread out by using stringers which span several rafters (Thermal Conversion Technology, 1997). If this is not possible, and any heavy components must be mounted over an open span of roof, the roof structure may require structural reinforcement.

Weight ranges for all types of systems are given below (Table 4.5-B).

<table>
<thead>
<tr>
<th>Collector Type</th>
<th>Weight Range (lbs/ft²)</th>
<th>Potential for Roof Deformation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Collectors</td>
<td>4-6</td>
<td>No</td>
</tr>
<tr>
<td>(all designs)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermosiphon</td>
<td>4-5 (for collector)</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>30+ (for roof tank)</td>
<td></td>
</tr>
<tr>
<td>ICS</td>
<td>19-24</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Source:
(Thermal Conversion Technology, 1997)
(American Energy Technologies, 1994)
4.5.2 SHW INSTALLATION I: MOUNTING A SOLAR COLLECTOR

Many different methods have been developed to bolt the solar equipment onto the roof surface. Only the principal concepts of attachment will be described in this section, as many variations exist within the industry as to the specifics of bolting mounting hardware to the roof. Importantly, solar collector units are not light, and two people are needed to mount the collector to the roof.

The first step in any installation process is to mount the collector and other rooftop components to the roof of the house. All mounting methods discovered during the course of this study involve first bolting a clip, mounting block or other mounting hardware over the roof's roofing materials, and then attaching the collector and any other equipment to that hardware such that the equipment is suspended an inch or two above the surface of the roof.

To bolt the mounting hardware onto the roof, a bore hole made in the roof rafters. To prevent outside elements from entering the house through the holes drilled into the roof, some installers simply put a good deal of caulking under the mounting hardware before it is bolted into the pre-drilled hole. A more tidy way to do this is to first ensure that the pre-drilled bore hole is the same diameter as the top of the bolt which will be used, and then to apply a liquid sealer (or around the hole before attaching the mounting hardware and bolting it in. The tight fit of the bolt in the hole, plus the sealant at the top, ensures a weather-proof fit and seal. Caulking is often used over the head of the bolt to seal it from exposure to the elements. For both caulking and bore hole sealing purposes, butyl rubber or synthetic butyl products offer good, durable seals. Silicon sealant are prone to drying and crystallizing.

Once the mounting hardware is securely bolted to the top of the roof, the collector (and tank, in the case of thermosiphon systems) can be mounted. This is often done simply by clipping or otherwise attaching the corners of these components to the mounting hardware in an appropriate fashion. Alternatively, some manufacturers have designed mounting rails that attach to the mounting hardware bolted into the roof; the solar equipment then attaches to the mounting rails.

4.5.3 SHW INSTALLATION II: PLUMBING BETWEEN THE COLLECTOR AND THE HOT WATER TANK

Once the equipment has been installed on the roof, two pipes must be run from the collector into the household: one pipe to bring water to the collector, and another one to take water back into the household. This requires two more roof penetrations, each of which needs to
be located vertically below the inlet or outlet ports of the collector which they serve (water needs to flow up to, and down from, the collector). To ensure a good seal around these penetrations, flashing is typically used (Figure 4.4-A).

Figure 4.4-A: Schematic of Roof Penetration

Source: (Thermal Conversion Technology, 1997b)

Flashing is placed around the area of the roof through which a roof penetration for the pipe must be made. How the flashing is placed (under/over roofing materials, for example) varies from contractor to contractor. Caulking is often used under the flashing to provide a water-tight seal. A pipe runs through the flashing, and is often soldered to it, making the flashing and piping one unit. This pipe also runs through the roof penetration, and into the household environment. Caulking is often used under the flashing and around the bore hole through which the piping runs to provide a good seal. This pipe then provides a tubular path through the house roofing for a pipe serving as the water inlet or outlet for the collector. A “cooler cap” is soldered to the middle of a section of this pipe, which then acts as a skirt that covers the top of the larger tube providing the roof path through the roof, thus keeping outside elements out of the pipe providing the path through the roofing.

Piping from the collector is run to the area of the house where the conventional (or 80-gallon solar) hot water tank is located, which may have to be replaced depending upon the
type of system being installed. The types of connections between the collector’s piping and the hot water tank which are necessary at this point is a function of what type of system is being installed.

4.5.4 SHW INSTALLATION III: CONNECTIONS TO THE HOT WATER TANK

4.5.4.a For active systems
An 80-gallon hot water tank will need to be installed, and the old tank removed. An appliance may be available from the manufacturer which incorporates all or many of the heat exchanger (if applicable), pipe, pump, and valve connections which must be made between the piping lines to the collector and the hot water tank. If such an appliance is included, one has relatively few plumbing connections to make (Figure 4.4-B). Otherwise, all connections will have to be custom-done on-site (Figure 4.3-A).

Figure 4.4-B: Schematic of Active System with Appliance

As with a conventional hot water tank, household water supply feeds into the bottom of the hot water tank; household hot water is taken from the top of the tank. Another line runs from the bottom of the tank to the SHW appliance (if applicable), or else first to the pump and then the appropriate series of valves; another line runs from the appliance (or else from the top of the solar collector) to the middle of the tank. And between the appliance and the collector there are also two sets of lines (if an appliance is used). Thus, an overall circulation loop is formed between the hot water tank and the collector, with the appliance in the middle containing all of the necessary valves, pipe bypasses, etc. (if used).
Once all piping is connected, temperature sensors must be installed at both the collector outlet and the water outlet which runs from the hot water tank to the appliance. Wires run from those sensors to the controller (which may be located in the appliance), which must then be hooked up to the household electricity.

4.5.4.b For passive systems
The existing hot water tank in the household can be used. Fewer plumbing connections are necessary with passive systems than with active systems, since there are no pumps, heat exchangers, temperature controllers or drain back tanks involved in the system. However, the connections are still numerous and time consuming (see plumbing schematics in Figure 4.3-B)

4.5.5 INSTALLING A CONVENTIONAL WATER HEATER
Conventional water heaters are very easy to install. As one unit, they incorporate everything needed for the complete system to function properly. There are only three connection points to the household: two water ports (inlet and outlet) and one fuel supply line (to either the household gas or electric supply).

Before installing a hot water tank, the household water supply and household hot water feed lines must be shut off. Additionally, the electric supply or gas line to the old water heater must be shut off. After that, it is a simple matter of disconnecting the old hot water heater at its three points of attachment to the home, taking it out, putting the new tank in its place, and reconnecting up the three points of attachment. Finally, the water and fuel lines must be reopened.

4.5.6 INSTALLING A TANKLESS WATER HEATER
Installing tankless water heaters is also fairly simple. The old hot water tank can be removed and done away with. The installation is easiest if one wishes to install just one centralized heater which is capable of providing all of the hot water to the household.

Each tankless water heater has four points of attachment to the home. The first three are the same as for conventional water heaters: two water lines (one in, one out), plus one fuel line (in the case of tankless heaters, the fuel is electricity — necessarily so in order to use an energy supply which can quickly adapt to changes in the amount of energy it must provide). The fourth point of contact is a physical mounting to a part of the house (on a wall, or other fixed surface), as they will malfunction if oriented incorrectly — they cannot, for example, be left dangling off of plumbing lines. The hookup to electricity must be to the house 220V supply, as tankless heaters require more energy than a wall socket would be able to supply.
Tankless water heaters, however, cannot provide large flow rates of hot water (such as that needed when filling a bathtub, for example) — this would require electricity beyond what a normal house would be able to supply. Most manufacturers make models that provide water at a constant temperature chosen by the user via a dial setting on the tankless unit. Other options include buying one large tankless unit which can be installed at a central location in the house to provide all of the home’s hot water, or buying several smaller units which can be installed near each point where hot water will be needed (one in the kitchen, one in each bathroom, etc.).

4.5.7 INSTALLING A HEAT PUMP WATER HEATER

There are several designs of heat pump water heaters available. The most convenient design to install is a unit which contains everything needed for the system: the tank, a pump, temperature sensors, a controller, a condenser, and a fan. In a sense, because this type of system is self-contained, it is not much more difficult to install than a conventional tank is. The only difference, in terms of its hook-ups to the household, is that it requires a drain (condensing water in the system needs to be drained away).

The other type of system is a retrofit module which can be attached to a conventional hot water tank. Here, the plumbing connections are more complicated, as the cold water-in and hot water-out ports on the conventional tank must be used as dual-purpose: they must carry water to/from the household, as well as allow water to circulate between the tank and the heat pump unit. Research did not allow a thorough analysis of this configuration.

4.6 SHW SYSTEMS COMPARED

There are a bewildering number of issues and variables associated with solar hot water technologies. The fact that four fundamentally different solar hot water technologies exist (active flat plate — open and closed loop designs, active evacuated tube, thermosiphon, and ICS technologies), all of which have their own strengths and weaknesses, makes the evaluation of these technologies all the more difficult.

To offer a way in which one may compare the various SHW technologies against each other in a structured format, the technologies introduced thus far in this report will be listed in this chapter in tabular format with comments offered for each technology under different categories which are relevant to their evaluation.
4.6.1 CATEGORIES FOR COMPARISON

Before making the actual comparing of the technologies against one another, however, the different categories under which they will be compared will be briefly explained.

4.6.1.a Installation considerations

New hot water tank required Some systems require a new hot water tank in order to function properly. This adds to the expense of the system being installed.

4.6.1.b Mechanical failure modes

Freezing of Collector Freezing is a danger for SHW collectors, because they are mounted to the roof and exposed to outside temperatures. Damage occurs when water inside the collector tubes freezes and bursts the tube walls. All systems can use freeze dribble valves on or near the collector to automatically allow water to drain out when temperatures become cold. (This is typically seen with active open loop, thermosiphon and ICS systems.)

Freezing of Roof Pipes Short sections of pipe run between the collector’s inlet or outlet ports to the point in the roof where the pipes enter the household. These sections of pipe must be heavily insulated in some climates to protect them from freezing. Nevertheless, freezing can still occur if temperatures fall to severe lows, or if the insulation deteriorates over time and is not repaired.

Clogging via scaling Mineral and other deposits from the local water supply may deposit themselves on walls of piping or valves — typically, in areas of the system where temperatures are highest — which hinders system efficiency and may cause system malfunction.

Other If a system is dependent upon mechanical devices such as a pump, failure of that device will stop the system from providing any benefit to the homeowner, and will cost money to repair.

4.6.1.c Indirect failure modes

Household tank made to do extra work Due to household water use habits, passive systems with single glazing can actually introduce water to the household water tank which is cooler than the household supply normally would be, thereby requiring that the tank expend more energy to heat the water than it otherwise would have to do. Alternatively, some systems can remove heat from the household water tank by allowing hot water within the tank to rise up to the collector (via natural convection) during cool periods, thereby “venting” the water’s heat energy needlessly to the atmosphere.

Roof deformation If a system’s rooftop components are heavy enough and not installed correctly, the roof structure may deform over time, requiring extensive repairs to the roof structure. (See: Considerations Regarding Strength of Roof Structure, this chapter.)
Roof leaks  All systems today require roof penetrations to mount rooftop components and to allow water to flow between the roof top collector and the household environment. These penetrations can potentially cause roof leaks if done improperly.

4.6.1.d Human factor categories for comparison

Requires regular maintenance  Homeowners are notoriously poor maintainers of household equipment with which they do not interact frequently (personal interviews, 1998). They may easily forget to perform maintenance on SHW system components, leading to lower system performance or complete malfunction.

System operation is self-evident  Simpler is easier to understand, and people tend to trust things which they comprehend more than those which they do not. Also, an understanding of how a systems works is helpful when trying to determine whether or not it is functioning properly.

Malfunction of collector is apparent  If a collector is malfunctioning and this malfunction goes undetected, the consumer will gain very little (or no) energy savings from the SHW system. Because all U.S. SHW systems are connected to backup hot water tanks which can heat water independently of the SHW collector (to ensure that hot water is always available), a collector malfunction may go undetected, since the homeowner will continue to receive hot water from the backup system anyway.

4.6.1.e Energy factors for comparison

% Energy Saved (vs. conventional technology)  Not all SHW systems provide the same amount of energy savings to a hot water system, as compared to conventional electric or gas hot water tank heaters. Typical values are given here.

Unavoidable energy loss/consumption  Some SHW systems require energy from the household in order to work, or naturally lose a significant amount of energy as part of their routine operation. Both scenarios detract from the net hot water energy savings which those systems provide.

4.6.2 COMPARISON OF ACTIVE FLAT PLATE SYSTEM CONFIGURATIONS

With active solar hot water technologies, there are several different ways in which the technology may be configured as a system. This is true for all active systems, but the discussion here relates to active flat plate systems only. The variables in configuring a system are many: one may use a closed design using a drain back tank (or not), and either water or another fluid as the medium which brings heat energy from the collector to the hot water tank; one may use an open system design.

To see how some of these different configurations compare against one another, they are compared in Table 4.6-A below. First, however, a quick explanation should be given on the
motivations and constraints which govern the decisions made in designing a system configuration.

Open (or "direct") systems typically yield better energy efficiencies than closed systems. This is because, in an open system, potable water is heated directly in the collector, and there are no other heat transfer steps in which energy can be lost. The chief advantage to having a better energy efficiency is that water will be heated more quickly — the temperatures ultimately reached in the hot water tank will not necessarily be greater than those obtained in a closed system. Water, however, is subject to freezing. Open systems must therefore either utilize a freeze dribble valve, manual draining, or else must be able to turn on the pump to circulate hot water up to the collector occasionally.

Closed (or "indirect") systems are useful for either of two reasons: (1) a glycol solution can be used as the circulating fluid, which will not freeze in the collector except in very severe conditions, or (2) if distilled water is used as the circulating fluid, most problems of clogging within collector tubes, valves and piping are avoided via the fact that a fixed volume of circulating water has a fixed amount of mineral deposits which can be deposited on the walls of piping and valves to cause clogging. (Use of water, however, will require use of a drain back tank.)
Table 4.6-A: Comparison Between Different Active Flat Plate SHW System Configurations

<table>
<thead>
<tr>
<th>System Configuration:</th>
<th>Open, with manual drainage or dribble valves</th>
<th>Closed, with Drain back</th>
<th>Closed, no Drain back</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circulating Fluid:</td>
<td>Water</td>
<td>Water</td>
<td>Glycol</td>
</tr>
<tr>
<td>Installation considerations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New hot water tank required</td>
<td>yes, with full system</td>
<td>yes, with full system</td>
<td>yes, with full system</td>
</tr>
<tr>
<td></td>
<td>no, with retrofit system</td>
<td>no, with retrofit system</td>
<td>no, with retrofit system</td>
</tr>
<tr>
<td>Mechanical failure modes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freezing</td>
<td>- possible - any of the freeze protection measures may fail</td>
<td>- not a problem - danger avoided by having water always drain down into the collector</td>
<td>- not a problem - danger avoided through use of glycol mixture, which will not freeze</td>
</tr>
<tr>
<td>Freezing of Roof Pipes</td>
<td>- possible -</td>
<td>- possible -</td>
<td>- possible -</td>
</tr>
<tr>
<td>Clogging via scaling</td>
<td>possible</td>
<td>less of a problem</td>
<td>less of a problem</td>
</tr>
<tr>
<td>System Configuration:</td>
<td>Open, with manual drainage or dribble valves</td>
<td>Closed, with Drain back</td>
<td>Closed, no Drain back</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------------------------</td>
<td>-------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Other</td>
<td>pump may burn out</td>
<td>pump may burn out</td>
<td>• pump may burn out</td>
</tr>
<tr>
<td></td>
<td>• temperature sensors may fail, causing improper circulation</td>
<td>• temperature sensors may fail, causing improper circulation</td>
<td>• glycol can become acidic and ruin pipes and tank lining</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• temperature sensors may fail, causing improper circulation</td>
</tr>
</tbody>
</table>

**Indirect failure modes**

<table>
<thead>
<tr>
<th>Household tank made to do extra work</th>
<th>possible - check valves can clog, allowing hot water from tank to thermosiphon up to collector at night, where water loses heat</th>
<th>no</th>
<th>yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof deformation</td>
<td>not a problem</td>
<td>not a problem</td>
<td>not a problem</td>
</tr>
<tr>
<td>Roof leaks</td>
<td>unlikely</td>
<td>unlikely</td>
<td>unlikely</td>
</tr>
</tbody>
</table>

**Human factors**

<table>
<thead>
<tr>
<th>Requires regular maintenance?</th>
<th>yes - users encourage to manually drain their system in any type of cold weather, in case other freeze protection measures mail.</th>
<th>maybe - circulating water may evaporate or leak from drain back tank, but should not. Must be replenished, or pump may burn out.</th>
<th>yes - expansion tank may need repair; glycol solution must be replaced every 7-10 years; check glycol for acidity every year</th>
</tr>
</thead>
</table>
(Table 4.6-A: Comparisons of Active Flat Plate System Configurations, Continued ...)

<table>
<thead>
<tr>
<th>System Configuration:</th>
<th>Open, with manual drainage or dribble valves</th>
<th>Closed, with Drain back</th>
<th>Closed, no Drain back</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System operation is self-evident?</strong></td>
<td>- no - components are simple, but details of how they interact is not</td>
<td>- no - components are simple, but details of how they interact is not</td>
<td>- no - components are simple, but details of how they interact is not</td>
</tr>
<tr>
<td><strong>Malfunction of collector is apparent? (If hot water tank is on)</strong></td>
<td>- no - household hot water tank continues to provide hot water; end-user must check system temperatures or indicator lights</td>
<td>- no - household hot water tank continues to provide hot water; end-user must check system temperatures or indicator lights</td>
<td>- no - household hot water tank continues to provide hot water; end-user must check system temperatures or indicator lights</td>
</tr>
</tbody>
</table>

**Energy Factors**

<table>
<thead>
<tr>
<th>% Energy Saved (vs. conventional technology)</th>
<th>70% - 90%</th>
<th>70% - 90%</th>
<th>70% - 90%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unavoidable energy loss/consumption</strong></td>
<td>small amount of power needed for pump, if not PV-powered</td>
<td>power needed for pump to circulate and raise water up to collector</td>
<td>power needed for pump</td>
</tr>
</tbody>
</table>

Source: interviews with manufacturers, distributors, installers, SEIA, FSEC

Active flat plate systems are the highest performing in the SHW industry, as far as thermal performance is considered. As is clear from the table above however, there is no single “best solution” configuration for these systems. They all, more or less, provide the same amount of hot water energy savings, and cost roughly the same to install.

It is worth noting however, that a tradeoff seems to exists between lessening the risks of clogging and freezing (seen with open systems), versus increasing the mechanical complexity of the system (seen with closed systems). Closed systems involve larger pumps (required to not only circulate water, as in an open system, but also to lift the water up from the drain back tank to the collector on the roof) and heat exchangers, thus adding to the list of components which might potentially need replacement during the system’s lifetime. However, the lessening of the chances of scaling and freezing are significant advantages,
and if the closed water drain back system could be made to be truly maintenance-free, this might yield it the competitive advantage needed to become the standard configuration within the flat plate solar hot water industry.

### 4.6.3 COMPARISON OF OTHER SHW TECHNOLOGIES

The three other SHW technologies aside from active flat plate technologies (ICS, thermosiphon, and evacuated tube) are listed below in Table 4.6-B, evaluated under the same categories as were flat plate system configurations.

**Table 4.6-B: Comparison Between Different SHW System Configurations**

<table>
<thead>
<tr>
<th>shaded entries</th>
<th>indicate undesirable quality or characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Configuration:</td>
<td>ICS</td>
</tr>
<tr>
<td>Circulating Fluid:</td>
<td>Water</td>
</tr>
<tr>
<td>Installation considerations</td>
<td></td>
</tr>
<tr>
<td>New hot water tank required</td>
<td>no</td>
</tr>
<tr>
<td>Mechanical failure modes</td>
<td></td>
</tr>
<tr>
<td>Freezing</td>
<td>not a problem in climates without severe cold</td>
</tr>
<tr>
<td>Freezing of Roof Pipes</td>
<td>- possible -</td>
</tr>
<tr>
<td>Clogging via scaling</td>
<td>- unlikely - use of wide tubes and valves ensure good flow. After several years, clogging may occur.</td>
</tr>
</tbody>
</table>
(Table 4.6-B: Comparison of Other SHW System Configurations, Continued....)

<table>
<thead>
<tr>
<th>System Configuration:</th>
<th>ICS</th>
<th>Thermosiphon (Open)</th>
<th>Thermosiphon (Closed)</th>
<th>Active (Closed) Evacuated Tube</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other</td>
<td>(no mechanics)</td>
<td>(no mechanics)</td>
<td>(no mechanics)</td>
<td>pump may burn out</td>
</tr>
</tbody>
</table>

Indirect failure modes

- **Household tank made to do extra work**: - possible - if ICS is emptied of hot water in the evening, the water it is refilled with will cool during the night, thereby introducing water cooler than groundwater into hot water tank the following morning (applied mainly to single-glazed units)

- **Roof deformation**: problem if mounted incorrectly

- **Roof leaks**: unlikely

**Human factors**

- **Requires regular maintenance**: no

- **System operation is self-evident?**: yes - simple concept of pre-heat tank

- **System operation is self-evident?**: no
(Table 4.6-B: Comparison of Other SHW System Configurations, Continued....)

<table>
<thead>
<tr>
<th>System Configuration:</th>
<th>ICS</th>
<th>Thermosiphon (Open)</th>
<th>Thermosiphon (Closed)</th>
<th>Active (Closed) Evacuated Tube</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malfunction of collector is apparent</td>
<td>- no - household hot water tank continues to provide hot water</td>
<td>- no - household hot water tank continues to provide hot water</td>
<td>- no - household hot water tank continues to provide hot water</td>
<td>- no - household hot water tank continues to provide hot water</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy Factors</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>% Energy Saved (vs. conventional technology)</td>
<td>50% - 60% likely (60% - 80% possible)</td>
<td>70% - 80%</td>
<td>60% - 70%</td>
</tr>
<tr>
<td>Unavoidable energy loss/consumption</td>
<td>Water in ICS loses 10-20°F during night (may lose more, if unit is single-glazed)</td>
<td>- none -</td>
<td>- none -</td>
</tr>
</tbody>
</table>

Source: interviews with manufacturers, distributors, installers, SEIA, FSEC

Here again, as seen when comparing the flat plate system configurations, there exists no clear “winning” technology. The high cost of evacuated tube collectors, given the typical energy savings they offer and the availability of alternatives, make purchase of this technology today somewhat difficult to justify on economic grounds. Thermosiphon collectors using water are probably not a good option for most locations in the United States, given the possibility of freezing.

Of the remaining two technology options, glycol thermosiphon and ICS systems, ICS systems seem to have a net competitive advantage. While the glycol thermosiphon system may provide more energy savings than an ICS system, it is more expensive to install, will require maintenance to replace the glycol solution every 5-7 years, and requires use of a tank on the roof that may not be aesthetically pleasing to consumers. The ICS system meanwhile, may provide less energy savings, but is both simpler and cheaper to install, and requires no maintenance. This may explain why so many more ICS systems are seen in use than thermosiphon systems. However, both systems are limited to climates where very cold weather is infrequent.
5. ECONOMICS OF HOT WATER SYSTEMS

In Short: Use of SHW is economical under several sets of assumptions, ensuring their economic competitiveness in the real world in more than just niche markets. The reasons for the slow diffusion of SHW cannot be blamed on economics alone. The SHW industry therefore has to look to other places for the source of their problems, such as identifying and targeting appropriate and specific markets, ensuring that the needs of all stakeholders involved along the industry's value-added chain are being met, and/or addressing further technical issues.

5.1.1 INTRODUCTION
Solar hot water systems save their users significant amounts of fuel costs, compared to conventional hot water systems, because SHW systems gain a large portion of the energy required for water heating from the sun, for which there is no usage charge. But SHW systems require a much higher initial investment from end-users upon their installation. Can these high initial investments be justified by the energy savings that the systems provide? This is a question to which there is not a single clear answer.

There are a variety of factors which influence the total costs which users incur over the lifetime of the hot water systems they use. Such factors include water quality (which affects how often components must be replaced), energy prices, and the energy needs of the specific hot water system. A full picture of the economics of a hot water system is therefore not provided, for example, by saying simply that one system is $25 or so cheaper to operate per month (once installed) and end the analysis there — all hot water systems require maintenance and parts replacements over their lifetimes, and these costs must be counted.

5.1.2 BASIS FOR ANALYSIS: LIFE CYCLE COSTS
An economic analysis in which all of the costs relating to a system are included over its useful lifetime (installation, fuel, repairs, maintenance, etc.) is called a life cycle analysis. Once life cycle costs for a variety of systems have been calculated over equivalent lifetimes, a fair basis for comparing different systems against each other is provided. Once these data have been generated, however, there remain different ways of viewing and analyzing them. The two analyses presented here are the simple payback analyses and the discounted life cycle cost analysis.

All hot water systems in this report are compared on the basis of a 30-year life cycle, assuming that the solar collectors installed last for the entire 30-year period (this is the
minimum design life for many of the solar collectors used in the industry) (personal interviews, 1998).

A sensitivity analysis will be performed to gauge how sensitive conclusions are to the length of the system lifetimes, which this study assumes ends when the solar collector is permanently broken.

5.2 VARIABLES AND ASSUMPTIONS

Before a life cycle cost analysis can be performed, a description of what the relevant components involved are, their ranges in cost, and the variables which influence them must be obtained. A description of such factors is given here.

5.2.1 TECHNOLOGIES EXAMINED

The technologies considered in this economic analysis are all compared against conventional electric or gas water heating tank technology as a baseline. The technologies examined are:

- Active flat plate solar systems — full, not retrofit (Evacuated tube systems are very similar in cost structure to active flat plate systems, as the components which may need to be replaced over the life span of the systems are essentially the same.)
- Integral Collector-Storage (ICS) solar systems
- Thermosiphon solar systems
- Tankless water heating systems
- Heat pump water heaters
5.2.2 INSTALLATION COSTS

Usually, installation prices with SHW contractors are pre-negotiated. The contractor must naturally cover his/her costs. These are summarized below (Table 5.1-A).

Table 5.1-A: Contractors’ Costs (per installation)

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Flat Plate Systems ($)</th>
<th>ICS Systems ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHW Equipment / Components</td>
<td>1500 - 1750</td>
<td>900 - 1000</td>
</tr>
<tr>
<td>Tax on Equipment (@ 7%)</td>
<td>105 - 122</td>
<td>63 - 70</td>
</tr>
<tr>
<td>Misc. Parts</td>
<td>150 - 250</td>
<td>100 - 200</td>
</tr>
<tr>
<td>Labor: 2 people, 1 day</td>
<td>300 - 500</td>
<td>300 - 500</td>
</tr>
<tr>
<td>Installation Permit</td>
<td>0 - 125</td>
<td>0 - 125</td>
</tr>
<tr>
<td>Contracting Company Overhead</td>
<td>150 - 200</td>
<td>150 - 200</td>
</tr>
<tr>
<td><strong>Sub Total</strong> (not including any profits)</td>
<td><strong>$ 2205 - 2947</strong></td>
<td><strong>$ 1513 - 2095</strong></td>
</tr>
</tbody>
</table>

Possible Additional Costs

- Sales Commission: up to 500
- Contracting Company Profit: up to 500

Source: personal interviews, 1998

The sub total costs in Table 5.1-A are taken as absolute minimum installation prices in the economic analyses. However, these do not include any sales commissions paid to other people for recruiting a sale, nor do they include any profits for the contracting company. The maximum installation prices assumed for each technology were taken as the highest quoted installation prices revealed through contractor interviews. Summaries of installation price ranges are given on Table 5.1-B.
Table 5.1-B: Hot Water System Installation Costs

<table>
<thead>
<tr>
<th>Technology</th>
<th>Installation Cost</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Flat Plate</td>
<td>high: $3,500</td>
<td>manufacturer interviews, 1998</td>
</tr>
<tr>
<td></td>
<td>low: $2,200</td>
<td>Table 5.1-A</td>
</tr>
<tr>
<td>ICS</td>
<td>high: $3,200</td>
<td>personal interviews, 1998</td>
</tr>
<tr>
<td></td>
<td>low: $1,500</td>
<td>Table 5.1-A</td>
</tr>
<tr>
<td>Thermosiphon</td>
<td>high: $3,500</td>
<td>personal interviews, 1998</td>
</tr>
<tr>
<td></td>
<td>low: $2,000</td>
<td>(assumed - no data available)</td>
</tr>
<tr>
<td>Conventional Gas</td>
<td>$700</td>
<td>(NAHB Research Center, 1998)</td>
</tr>
<tr>
<td>Conventional Electric</td>
<td>$350</td>
<td>personal interviews, 1998</td>
</tr>
<tr>
<td>Tankless</td>
<td>$750 - $1,000</td>
<td>(doubled equipment cost, as this is often the practice with conventional water heaters)</td>
</tr>
<tr>
<td>Heat Pump</td>
<td>$1,000 - $1,200</td>
<td>(A.D. Little personal interviews, 1998)</td>
</tr>
</tbody>
</table>

5.2.3 HOT WATER SYSTEM COMPONENTS AND REPLACEMENT

The various systems analyzed incorporate a variety of different components, some of which must be replaced during the lifetime of the system. A listing of all components which this analysis takes into account is given here (Table 5.1-C). On complicated systems (such as an active flat plate system), a full analysis of all applicable parts and components was not possible. However, these neglected components — such as an expansion tank and/or gallons of propylene glycol, whose costs lie within $100 each, (personal interviews, 1998) — contribute little to the overall life cycle cost of the system, and should therefore not distort the conclusions of the analysis to any great extent. (The intention here is to provide broad economic insight, not dollars-and-cents detail.)
<table>
<thead>
<tr>
<th>System</th>
<th>Components Included in Analysis</th>
<th>Needs periodic replacement?</th>
</tr>
</thead>
</table>
| Active Flat Plate Solar| - flat plate collector  
                        | - pump  
                        | - controller  
                        | - 80-gallon hot water tank | Y                           |
| ICS Solar              | - ICS unit  
                        | - household 40-gallon hot water tank | Y                           |
| Thermosiphon Solar     | - thermosiphon collector  
                        | - thermosiphon tank  
                        | - household 40-gallon hot water tank | Y                           |
| Conventional Electric Tank | - household 40-gallon hot water tank | Y                           |
| Conventional Natural Gas Tank | - household 40-gallon hot water tank | Y                           |
| Tankless System        | - tankless unit  | Y                           |
| Heat Pump System       | - heat pump appliance  | Y                           |
5.2.3.a  Operational or Maintenance Costs
Occasionally, components of a SHW system will wear out and will need replacement. This is often a function of water quality. The costs are given below (Table 5.1-D).

Table 5.1-D: Operational or Maintenance Costs

<table>
<thead>
<tr>
<th>Component</th>
<th>Assumed Cost (Installed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 gallon hot water tank (solar-compatible)</td>
<td>$900</td>
</tr>
<tr>
<td>Thermosiphon tank</td>
<td>$1,500</td>
</tr>
<tr>
<td>Circulation Pump</td>
<td>$250</td>
</tr>
<tr>
<td>Temperature Sensors and Controller</td>
<td>$250 (Installed)</td>
</tr>
</tbody>
</table>

Source: personal interviews, 1998

5.2.3.b  Component Lifetimes: Water Quality
SHW collectors are assumed to last the entire 30-year lifetime of analysis (manufacturer interviews, 1998). However, not all of the components which form the balance of the hot water system will last this entire time.

This analysis assumes that users do no regular maintenance on their hot water system.

Water quality is a crucial factor which bears upon the lifetime of system components, and thus, on the economics of solar hot water. In areas where water quality is quite poor, many of the components through which the potable water flows (such as the household hot water tank, pumps, piping, etc.) may not last longer than 5-6 years, either because they become caked with sediment and minerals which come out of solution from the water at high temperatures, or else because the water is acidic enough to ruin system components. On the other hand, in areas where water quality is high, components may not need to be replaced for 15 years or more (personal interviews, 1998). The more equipment which
must be replaced, the more expensive any hot water system becomes over its lifetime. Analyses in this study define water quality according to its effects on component lifetimes (Table 5.1-D1):

**Table 5.1-D1: Water Quality and Component Lifetime**

<table>
<thead>
<tr>
<th>Water Quality</th>
<th>Lifetime of Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>6 yrs</td>
</tr>
<tr>
<td>Medium</td>
<td>10 yrs</td>
</tr>
<tr>
<td>High</td>
<td>15 yrs</td>
</tr>
</tbody>
</table>

At these times, it is assumed that all types of tanks (excepting thermosiphon tanks) and pumps will need to be replaced.

**5.2.3.c Component Lifetimes: Other**

Some system components may wear out independently of water quality. Such components include:

**Table 5.1-D2: Components with Fixed Lifetimes**

<table>
<thead>
<tr>
<th>Component</th>
<th>Replaced Every:</th>
<th>Justification:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Active SHW controllers</td>
<td>15 yrs</td>
<td>- electronics may fail; breakage possible</td>
</tr>
<tr>
<td>• Tankless water heaters</td>
<td>15 yrs</td>
<td>- designed for long life: avoids sediment buildup due to design of water flow.</td>
</tr>
<tr>
<td>• Thermosiphon tank</td>
<td>15 yrs</td>
<td>- Solahart offers 12 yr warranty on tank</td>
</tr>
<tr>
<td>• Solar Collector Units</td>
<td>30 yrs</td>
<td>- manufacturer design life</td>
</tr>
</tbody>
</table>

**5.2.4 SYSTEM ENERGY SAVINGS**

It is important to consider how much fuel a new hot water system will require in order to operate, since fuel costs have a direct economic impact on the life cycle cost of a system. This report often makes reference to percentages of energy which new hot water systems are able to save the user (compared to conventional technology). These savings may result from obtaining a significant amount of energy from the sun (as with a solar water heater), by reducing or eliminating the standby losses of heat from a conventional hot water tank (as with a tankless water heater), or by obtaining a significant amount of energy from the surrounding atmosphere (as with a heat pump water heater). The amounts of energy saved
by vary according to the type of technology adopted. The energy savings may vary for a given technology, as well, since this is an empirical value influenced by such factors as individual consumer behavior and quality of installation. To take all of this into account, wide ranges of possible energy savings have been assumed as inputs to the economic analyses (Table 5.1-E), in order that the sensitivity of the analysis to energy prices may be tested. The minimum and maximum ranges given are not based on any engineering or scientific assessments, and are based on values which were obtained through personal interviews.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Energy Saved (Assumed Range)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Flat Plate</td>
<td>70% - 90%</td>
<td>manufacturer interviews, 1998</td>
</tr>
<tr>
<td>ICS</td>
<td>50% - 80%</td>
<td>manufacturer interviews, 1998</td>
</tr>
<tr>
<td>Thermosiphon</td>
<td>60% - 80%</td>
<td>manufacturer interviews, 1998</td>
</tr>
<tr>
<td>Tankless</td>
<td>15% - 25%</td>
<td>(A.D. Little personal interviews, 1998)</td>
</tr>
<tr>
<td>Heat Pump</td>
<td>40% - 50%</td>
<td>(A.D. Little personal interviews, 1998)</td>
</tr>
</tbody>
</table>

### 5.2.5 FUEL COSTS

#### 5.2.5.a Electricity

Electricity rates vary from state to state. In California, rates such as 11 cents/kWh are common, while in Texas and Florida rates such as 8 cents/kWh are common. Arizona has rates of 9 cents/kWh (Energy Information Administration, 1997). To account for differences in the electricity usage and utility rates applicable across different households, as well as for different usage habits in individual households, U.S. average values for electricity consumption attributable to water heating were varied up and down in size by 20%, as shown in Table 5.1-F.

<table>
<thead>
<tr>
<th>Electricity Consumed in hot water heating (per person)</th>
<th>kWh/ year</th>
<th>avg. - 20%</th>
<th>US average * (4 person household)</th>
<th>avg. + 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>836</td>
<td>1045 kWh</td>
<td>1254</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Expenditures for hot water heating (per household)</th>
<th>$/ year (@ 8 c/kWh)</th>
<th>$ 267</th>
<th>$ 334</th>
<th>$ 401</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$ 367</td>
<td>$ 459</td>
<td>$ 551</td>
<td></td>
</tr>
</tbody>
</table>

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5.3 METHODS OF ANALYSIS

Life cycle costs of the different hot water systems will be calculated over 30-year life cycles. This data will then provide the basis for two types of economic analysis: the simple payback analysis and the discounted life cycle cost analysis. First, however, a description must be given as to how the different systems are compared against one another.

5.3.1 METHOD OF COMPARISON

The available “new” hot water technologies (solar, tankless, heat pump) must be able to be compared against the incumbent conventional electric and gas hot water tank heater technologies such that the resulting data are clear and easy to understand. To do this, the comparison between new technologies and incumbent ones will be made by subtracting the costs of one from the other, so that only one number — the difference in costs of operating the two types of systems — need be used in the analysis. Specifically, the costs in each year which result from the operation of a new technology will be subtracted from the costs resulting from the operation of a conventional technology.

To do this, the yearly operation and maintenance costs of a new water heating technology (such as solar) are plotted along those which would apply to a conventional water heating system (Figure 5.2-A).

Figure 5.2-A: Yearly Operation and Maintenance Costs of Water Heating Systems (conventional and solar)

Next, the operation and maintenance costs of the solar system are subtracted from those of the conventional system, yielding the “Solar Savings/yr” bars (Figure 5.2-B) — the amount of money which users save each year due to their use of a solar hot water system. Different maintenance costs are associated with conventional and SHW systems, thus producing
“bumps” from year to year in the savings provided by the solar system — occasionally even yielding negative savings, if expensive repairs or component replacements must be made.

Figure 5.2-B: Yearly Solar Savings  
(Conventional Costs - Solar Costs)

5.3.2 DEFINITION OF SCENARIOS

All of the scenarios in the economic analyses involve the use of several standard sets of variable values (Tables 5.2-A and 5.2-B). This ensures that the data will be easy to compare against each other. The variables which collectively define a specific scenario are split up into two categories:

Scenario variables define a given scenario. These describe the environment in which a technology is being used, such as the cost of fuel and the quality of local water. Scenario variables include:

- Annual cost of gas which would be incurred by using a conventional gas water heater;
- Annual cost of electricity which would be incurred by using a conventional electric water heater;
- The frequency with which system components (hot water tanks and pumps) must be replaced (dependent upon local water quality).

Technology variables define the technology being used. One of these variables may be varied across its appropriate range within a scenario to view the sensitivity of its effect on the economics conclusions.
Scenarios are referred to in this analysis according to the following terminology:

- **"Optimistic:"** assumes all scenario variables to have values which favor the economics of solar hot water as much as possible.
- **"Average:"** assumes mid-level values for all scenario variables, which may be representative of situations typically encountered in real life.
- **"Pessimistic:"** assumes all scenario variables to have values which detract from the economics of solar hot water as much as possible.

**Table 5.2-A: Values for Scenario Variables**

<table>
<thead>
<tr>
<th>Scenario Name</th>
<th>Optimistic</th>
<th>&quot;average&quot;</th>
<th>Pessimistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of Electricity</td>
<td>$550</td>
<td>$400</td>
<td>$250</td>
</tr>
<tr>
<td>(conventional heating)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of Gas</td>
<td>$250</td>
<td>$200</td>
<td>$150</td>
</tr>
<tr>
<td>(conventional heating)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Replace Components Every</td>
<td>15 yrs</td>
<td>10 yrs</td>
<td>6 yrs</td>
</tr>
<tr>
<td>(due to water quality)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Although the scenario variables remain constant within a given scenario, the technology variables (Table 5.2-B, below) may be varied across appropriate ranges within a scenario, depending upon the analysis being done.

**Table 5.2-B: Ranges of Values for Technology Variables**

<table>
<thead>
<tr>
<th>Technology Variables</th>
<th>Optimistic End of Range</th>
<th>Pessimistic End of Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active Flat Plate Solar</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Savings</td>
<td>90%</td>
<td>70%</td>
</tr>
<tr>
<td>Installation Cost</td>
<td>$2,200</td>
<td>$3,500</td>
</tr>
<tr>
<td><strong>ICS Solar</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Savings</td>
<td>80%</td>
<td>50%</td>
</tr>
<tr>
<td>Installation Cost</td>
<td>$1,500</td>
<td>$3,200</td>
</tr>
</tbody>
</table>
(Table 5.2-B, continued...)

<table>
<thead>
<tr>
<th>Technology Variables</th>
<th>Optimistic End of Range</th>
<th>Pessimistic End of Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thermosiphon Solar</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Savings</td>
<td>80%</td>
<td>60%</td>
</tr>
<tr>
<td>Installation Cost</td>
<td>$2,000</td>
<td>$3,500</td>
</tr>
<tr>
<td><strong>Tankless</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Savings</td>
<td>25%</td>
<td>15%</td>
</tr>
<tr>
<td>Installation Cost</td>
<td>$750</td>
<td>$1,000</td>
</tr>
<tr>
<td><strong>Heat Pump</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Savings</td>
<td>50%</td>
<td>40%</td>
</tr>
<tr>
<td>Installation Cost</td>
<td>$1,000</td>
<td>$1,200</td>
</tr>
</tbody>
</table>

Source: Table 5.1-E and Table 5.1-B

5.4 SIMPLE PAYBACK PERIOD ANALYSIS

The cost of installing a more efficient water heating technology is usually greater than the cost of installing a conventional technology. At some point in time however, if the energy savings offered by the new efficient technology are great enough, the lower costs of its operation will eventually offset the initial cost needed to install it. At that moment in time, the system is said to have “paid” for itself (as an example: year 12, in Figure 5.2-B, where the Cumulative line crosses the x-axis). The period of time beginning with installation, and ending when the system has “paid” for itself, is the payback period.

5.4.1 PAYBACK: COMPARISONS AGAINST CONVENTIONAL ELECTRIC

The following graphs (Figure 5.3-A - 5.3-D) demonstrate ranges of payback times required for various SHW systems, as compared against conventional electric water heaters.
Figure 5.3-A

Payback Year for Active Flat Plate SHW (compared with conventional electric)

- Pessimistic Scenario
- "average", Install= $3,500
- "average", Install= $2,200
- Optimistic Scenario

Figure 5.3-B

Payback Year for ICS SHW (compared with conventional electric)

- Pessimistic Assumptions
- "average," Install= $3,200
- "average", Install= $1,500
- Optimistic Assumptions

Figure 5.3-C

Payback Year for Thermosiphon SHW (compared with conventional electric)

- Pessimistic Assumptions
- "average", Install= $3,500
- "average", Install= $2,000
- Optimistic Assumptions
Under all "optimistic" and "average" scenarios, the solar systems analyzed had payback periods ranging from 5-17 years. The data suggest that SHW compete fairly well, economically, with conventional electric technologies, but that, if very unfavorable conditions exist, their competitive edge is drastically reduced.

5.4.2 PAYBACK: COMPARISONS AGAINST CONVENTIONAL GAS
The following graphs (Figure 5.3-E - 5.3-H) demonstrate ranges of payback times required for various SHW systems, as compared against conventional gas water heaters.
Clearly, solar hot water technologies have a more difficult time competing with conventional gas technologies than they do with conventional electric ones. The data curves presented bound a range of payback periods, within which all “average” and most “optimistic” assumptions fall. Within this range, thermosiphon systems had the longest payback periods (12 - 17 years), while ICS systems had the lowest (5 - 10 years).

The fact that very optimistic assumptions must be made in order to have payback periods on the order of 10 years suggests that it will be very difficult for SHW to compete with gas on economic grounds. The industry will likely have to promote other advantages which their technology offers when competing against gas.

5.4.3 EXTENDING PAYBACK: EQUIVALENT COMPOUND INTEREST

Payback periods may be extended to imply what equivalent rates of return on an investment is. A payback period of, say, 5 years implies that 20% (i.e. 1 / 5 yrs.) of the original solar hot water investment is recaptured every year through the fuel cost savings offered solar hot water system. Other rates are given in Table 5.3-A.

<table>
<thead>
<tr>
<th>Payback Period (years)</th>
<th>% of Solar Investment Recaptured (per year) via avoided fuel costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(non-compounding)</td>
</tr>
<tr>
<td>3</td>
<td>33%</td>
</tr>
<tr>
<td>5</td>
<td>20%</td>
</tr>
<tr>
<td>10</td>
<td>10%</td>
</tr>
<tr>
<td>15</td>
<td>6.7</td>
</tr>
</tbody>
</table>

One may also wish to view the savings which solar provides in terms of equivalent compounding interest rates, which could be earned through investments in stocks, savings or money market account, etc. (Table 5.3-B). Two such rates of return are given. The simple rate of return is the compounding growth rate at which an investment (in a bond, for example) would have to grow, such that its face value (before taxes) after 30 years would be equal to the size of the cumulative SHW savings in year 30 (i.e. the height of the right triangle in Figure 5.2-B). The equivalent rate of return is the compounding growth rate which a tax-deferred investment (such as an IRA, taxed at 30% at the end of 30 years) would require, such that its after-tax face value would be equal the size of the 30-year cumulative savings realized through the SHW system in year 30 (i.e. the height of the right triangle in Figure 5.2-B).
Table 5.3-B: Payback Periods and Equivalent Compounding Rates of Return

<table>
<thead>
<tr>
<th>Payback Period</th>
<th>Payback Period's Simple Growth Equivalent Rate of Return* (Compounding Interest)</th>
<th>Payback Period's Equivalent Rate of Return* for Tax-Deferred Investment (Compounding Interest)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>7.6%</td>
<td>8.9%</td>
</tr>
<tr>
<td>5</td>
<td>5.5%</td>
<td>6.8%</td>
</tr>
<tr>
<td>7</td>
<td>4.0%</td>
<td>5.3%</td>
</tr>
<tr>
<td>10</td>
<td>2.3%</td>
<td>3.4%</td>
</tr>
</tbody>
</table>

* Assuming 30-yr. life span of system (see Chapter 1 for calculations)

Looking at the data, then, one may take away two pieces of information (assuming a comparison of SHW with conventional electric technology):

- the ability of SHW systems to pay for themselves is substantial (Table 5.3-A); and
- short payback periods are required in order for SHW to have strong equivalent compounding rates of return over a 30-year period (Table 5.3-B).

5.5 DISCOUNTED LIFE CYCLE COST ANALYSIS

The value of money is not constant over time. For example, $90 invested today can become $100 tomorrow — the value of the original $90 increases over time. It is therefore important that the economic analysis of a project be considered with this in mind — especially when the life of a project may span a significant length of time. The discounted life cycle cost analysis takes this into account.

5.5.1 CONCEPT: PRESENT VALUE

A discounted life cycle cost calculates the amount of money which would need to be invested today (at an assumed interest rate), such that it would grow to become some specific amount in the future. In this way, one can think (today) of future amounts of money as being worth actually less than their face values would imply, because smaller amounts of money today could be invested to become those face values in the future — in this way, these face values are “discounted.” (As an example, an amount of $100 in the future may be discounted to a value of $70 of today’s dollars, since $70 could grow into $100, given an appropriate interest rate.) The formulas which perform this discounting are summarized in Chapter 1.
5.5.2 UNDERSTANDING PRESENT VALUE OF LIFE CYCLE SAVINGS

Because the data in this chapter are subtracted from each other (costs of conventional technology - costs of solar technology, etc.), one may refer to the subtracting of two discounted life cycle costs as the present value of life cycle savings. Specifically:

\[
[\text{Present Value of life cycle Savings}] = \\
[\text{Present value of operating a conventional technology}] \\
- [\text{Present value of operating a new, efficient technology}]
\]

Negative values for the present value of life cycle savings, then, indicate that choosing the conventional technology, and using the balance of the money (which would have gone towards purchasing the new technology) to invest or pay down debt (at the given discount rate) is the better economic decision for the user. On the other hand, if the resulting savings are positive, the non-conventional (solar, tankless, etc.) system is more attractive, because the savings which result from it leave more money in the hands of the user than they would be able to get by investing it (or paying off debt) at the given discount rate. In any case, the bottom line strategy is:

- **negative** present values of life cycle savings: user should use conventional technology;
- **positive** present values of life cycle savings: user should use non-conventional technology.

5.5.3 ECONOMICS OF SHW VS. CONVENTIONAL ELECTRIC

The data for solar systems presented here have been organized to show sets of bounds that mark the limits of ranges of present value life cycle savings which could result from using a new technology under certain assumptions. The heavy lines on the charts (Figures 5.4-A - 5.4-C) represent absolute bounds — taking into account extreme “optimistic” and “pessimistic” scenarios for SHW technologies; the dashed lines represent a narrower range of possible present value life cycle savings which may be more likely under “average” assumptions.

**Figure 5.4-A**

![Graph showing present value of lifetime savings over conventional electric.](image)
From these data, two observations may be made:

- First, if the most optimistic assumptions are applicable, then the SHW system is more economically attractive (i.e. the “Optimistic” curve lies above the x-axis) than conventional electric hot water tank technology, regardless of the discount rate (up to 18%).
- Second, and more importantly, even if the most optimistic assumptions are not applicable, SHW systems are nearly always more economically attractive than conventional electric systems under “average” assumptions. If high installation prices are assumed, then discount rates up to 7% or 8% will still yield favorable economics for the SHW systems. If low installation prices are assumed, then favorable economics are seen with discount rates of 15%. 
5.5.4 ECONOMICS OF OTHER TECHNOLOGIES VS. CONVENTIONAL ELECTRIC

The data here bound ranges of present values of life cycle savings which may result under "average" assumptions for electricity costs and component replacement frequency (see Table 5.2-A). The ranges are bounded by dark lines for heat pump water heaters, and by dashed lines for tankless water heaters.

![Figure 5.4-D](image)

Present Value of Lifecycle Savings (over conventional electric)

It is clear that, of the two innovating technologies presented here, heat pump water heaters offer greater economic advantage. This statement should be fairly accurate, even if the exact dollar figures are not, because a harsh assumption was made about heat pumps: since the only data available on this technology was its installation costs and typical ranges of energy savings over conventional technology, it was assumed that entirely new units would have to be replaced (at full installation cost) at times when components from other systems (such as conventional hot water tanks) also have to be replaced (a function of water quality — see "Component Lifetime: Water Quality" in this Chapter). Despite this assumption, present values of life cycle savings were still more attractive for heat pump water heaters than for tankless or conventional electric water heating technologies, over a wide range of discount rates (up to rates of about 15%).

It is interesting to note however, that while heat pump water heaters are economically preferable (versus conventional electric heating) over a wider range of discount rates to SHW technologies, the net present values of life cycle savings which heat pumps offer are significantly smaller (less than $2,000) than those for SHW heaters (which range from $2,500 - $5,000). This may be expected, however: heat pump water heaters provide energy savings of approximately 40% - 50%, while SHW systems sometimes provide energy savings close to twice that amount, up to 90%.
5.5.5 ECONOMICS OF SHW VS. CONVENTIONAL GAS

Present values of life cycle saving for solar water heating technologies over conventional gas technology were conducted using discount rates of 2%, 10% and 18%. Each of the three solar technologies was examined under “optimistic” assumptions, as well as under “average” assumptions using high installation prices.

Figure 5.4-E

Present Value of Life Cycle Savings (Active SHW vs. conventional gas)

<table>
<thead>
<tr>
<th>Discount Rate</th>
<th>0%</th>
<th>5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimistic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;average,&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Install=$3500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5.4-F

Present Value of Life Cycle Savings (ICS vs. conventional gas)

<table>
<thead>
<tr>
<th>Discount Rate</th>
<th>0%</th>
<th>5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimistic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;average,&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Install=$3200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The data here confirm the results obtained from the payback analysis: it will be quite difficult for SHW technologies to compete with conventional gas technologies, unless the most optimistic situations exist. Only at low discount rates, and only along the “optimistic” curve, are SHW technologies competitive with conventional gas under this framework.

5.5.6 SENSITIVITY OF DISCOUNTED ANALYSES TO LENGTH OF LIFE CYCLE

Having drawn conclusions from the discounted life cycle data presented in this chapter, one needs to check and see if the results would change much, given a shorter life cycle. Hence, a representative SHW system was chosen, and its accruing life cycle savings was observed over the assumed 30-year life cycle using different discount rates. Hence, one may view the present value of life cycle savings at any time before 30 years.

The choice of the particular type of SHW system chosen is not important here. Since discounting involves manipulations of percentages (not fixed values), the characteristic shapes of the curves below will not change from system to system (i.e. a steeply rising curve in early years, and flattening out of the curve in the later years).

From Figure 5.4-H, one can see that, when using discount rates of 10% or 18%, the values of life cycle savings do not change substantially after 15-20 years — they essentially level off and become flat after that point. Hence, one can be confident that any discounted life cycle savings data presented in this report (resultant from using discount rates of 10% or 18%, over 30 years) should be good approximations to cases where the life of a solar collector turns out to be only 15-20 years.

Using a discount rate of 2% yields much more sensitive data. Within the assumed 30-year period, the accruing life cycle savings curve shows little sign of leveling off. Hence,
conclusions regarding data calculated using a 2% discount rate over 30 years will fluctuate much more with varying life times than do data using 10% or 18% discount rates. However, present values of life cycle savings, discounted at 2%, will always be larger than those discounted at higher rates — so much higher, in fact, that the basic conclusions resulting from these values (that SHW systems are worthwhile investments when discounting at 2%) would not change, even given a life time of 15-20 years, instead of a life time of 30 years.

Figure 5.4-H

![Sensitivity of Life Cycle Savings to Length of Life Cycle]

Cumulative Life Cycle Savings Curves of a representative SHW system at different discount rates

$r =$ discount rate
6. STAKEHOLDER ANALYSIS / DISTRIBUTION OF BENEFITS

6.1.1 INTRODUCTION
When considering a technology such as solar hot water, whose successful diffusion and implementation requires the involvement of many different parties — or "stakeholders," such as manufacturers, installers, users, etc. — it is useful to understand the points of view with which each of the stakeholders views the issues surrounding the technology (Chapter 2). If discrepancies in viewpoints or assumptions exist among the stakeholders, the diffusion of the technology may be slowed, since assumptions by one party about what the role of another should or ought to be may lead to disjointed efforts and inefficient cooperation.

Therefore, this chapter will summarize and analyze the viewpoints of the stakeholders involved within the SHW community. How these parties fit together within the structure of the industry is presented in Chapter 4. The stakeholders analyzed in this chapter are:

- SHW manufacturers
- SHW distributors and wholesalers
- Specialty SHW contractors
- Home builders
- General trade contractors
- Consumers
- the U.S. Department of Energy

At the end of the chapter, some parallels are drawn across the viewpoints of the different stakeholders, thus identifying areas of clear consensus among them and indicating subjects within the SHW industry which may need to be improved upon.
6.2 SHW MANUFACTURERS

**source of data:** *all views expressed here are the author’s interpretations of how SHW manufacturers view themselves and their industry, as revealed through personal interviews conducted during the course of this study (1998).*

The solar hot water manufacturers who are in business today have been so for some time — many have been in the business since the 1970’s. They are all “believers” in solar hot water, so to speak, in terms of the technology’s quality, its potentials as an energy source for the United States, and as a means to reduce usage of fossil fuels. As staunch advocates of solar hot water and the clear environmental benefits it provides, these manufacturers have no intention of quitting the business, though other professions may offer a higher wage. These manufacturers have invested a tremendous amount of personal energy and vision into their respective companies, and plan on staying with SHW no matter what. “It really is a labor of love,” said one manufacturer, “you don’t get into this business unless you really want to do solar hot water” (personal interviews, 1998).

6.2.1 MANUFACTURING

SHW production facilities are not currently operating at capacity. If they were, manufacturers say they would be able to lower their prices of solar collectors by between 7% and 20%, depending upon the manufacturer. Government technical assistance has been of help to several manufacturers where their manufacturing technologies are concerned, and manufacturers speak positively about these cooperative efforts. As demand in the industry is currently low, manufacturers do not complain about not being able to keep up with production schedules, but say that some of the equipment which they use is fairly old and inefficient, and could use replacement. However, due to capital constraints, they are not able to make these replacements.

6.2.2 SHW, AS A SIMPLE TECHNOLOGY

On the whole, manufacturers have a deep appreciation for the importance of “keeping it simple,” and are aware of the overall trend that has seen SHW systems simplified over the years. Nevertheless, current SHW technologies require a fair amount of skill to install and, according to home builder and consumer interview data, are still confusing and complicated to the non-expert. This “SHW-is-simple-yet-complicated” paradox was revealed in manufacturer interviews, as well. Comments by manufacturers included:

> “Solar hot water is easy — it’s so simple... You just have to know what you’re doing;”
> “We think it’s obvious what to do [when installing a SHW system] — still, we get reports about systems being hooked up backwards.”

Many active system manufacturers have developed so-called “appliances.” These units combine many of the components needed by an active system into one unit which is typically
installed directly next to, or on top of, the hot water tank inside the home. Some manufacturers are individually working on simplifying various aspects of their own systems, such as simplifying their plumbing, selling systems as kits including all needed parts, and designing hot water tank units with lifetimes longer than those of conventional hot water tanks.

6.2.3 QUALITY CONTROL, OUTSIDE OF COMPANY

When asked what was in their power to ensure the quality of installations of SHW systems in which their collectors were used, there was no consensus among manufacturers. Typical comments included:

- “nothing”
- “pre-package the system”; “we do all the installations in the area”
- “choosing experienced companies to represent our products”

Clearly, manufacturers are using a variety of business models to sell their products. No determination was possible, however, as to which model is best.

6.2.4 BARRIERS TO SHW

Lack of Public Awareness and Government Support  This was most often cited as the chief barrier to the industry. Manufacturers are confident that they offer good products, but feel that nobody knows that they exist, and that support from the government is very weak.

Economics  Solar hot water manufacturers are keenly aware that the economics of SHW are of great importance, and that people are not prone towards making large, up-front capital investments for something as unfamiliar as SHW which, in the end, only provides hot water — something that people have. “People have hot water already — we’re not providing them with anything new” said one interviewee. Manufacturers also do not expect the average person to simply switch over to SHW simply because it is the “right” environmental thing to do. Other comments from manufacturers included:

- “Our problem is 99% economic.”
- “People have money — they could buy solar hot water if they wanted to.”

Fossil Fuel Subsidies  Another barrier frequently mentioned by SHW manufacturers, are (apparent) large subsidies from the federal government which fossil fuels enjoy, thus distorting the energy markets and prohibiting energy technologies from competing on a “level playing field.” The Gulf War is an example of these subsidies.

Disjointed Industry  Many manufacturers feel that the industry does not work well together. Some manufacturers complain that industry members are not creative, or that they are “not good business people — waiting for the government to bail them out.” When asked if the industry should pool its money together for purposes of doing generic “SHW is a
good thing” advertising, some respondents said that it was a good idea, while others said that doing targeted marketing in specific geographic regions is better.

**Photovoltaics** Finally, photovoltaics manufacturers are seen by manufacturers as a sort of indirect barrier for SHW, in that photovoltaics get significantly more attention in the press and from government officials. In this way, photovoltaics are a distraction to SHW. Manufacturers see this as ironic, since solar thermal technologies are much more efficient in making use of the sun’s energy, not to mention more economical.

**Low Quality Reputation** The SHW industry’s reputation for quality is also cited as a barrier for the industry. Poor equipment and bad installations were frequently seen during the tax credit years in the late 1970’s — this reputation still plagues the industry today, despite its high-quality products. The quality of installers’ work is therefore also of concern to many manufacturers — they feel that too many installers like “doing things their own way,” and do not perform quality installations, thereby prolonging a lingering reputation of poor quality.

### 6.2.5 FEDERAL INVOLVEMENT IN SHW

On the whole, manufacturers are enthusiastic about the federal government providing vocal support for SHW, financing mechanisms for its customers, and technical R&D support to manufacturers. They believe that the federal government could act as a stamp of approval for SHW, and legitimize the image of the industry with the American public — this is needed especially in light of the lingering reputation for poor quality which manufacturers feel surrounds their industry.

While stories abound about past failed joint industry-government laboratory development efforts, opinions today about these types of efforts are much more positive, emphasizing that the government laboratories have become much more sensitive to the needs and constraints of manufacturers, and that the results from these relationships have therefore been much more productive — especially in efforts to improve manufacturing capability and quality.

### 6.2.6 WISH LIST

SHW manufacturers would like to see:
- Greater public awareness of SHW (cited as #1 need, by many manufacturers interviewed);
- Increased federal vocal support to lend credibility to solar hot water industry;
- Access to low-interest loans for capital replacement;
- Availability of low-interest loans for purchases of SHW systems;
- More access for themselves to the talents and resources of government R&D laboratories: specialty glass coatings are desired, for example, to increase the efficiency of solar collectors.
6.3 SHW DISTRIBUTORS AND WHOLESALERS

**source of data:** all views expressed here are the author’s interpretations of how SHW distributors and wholesalers view themselves and their industry, as revealed through personal interviews conducted during the course of this study (1998).

SHW distributors and wholesalers specialize in the selling of solar technologies and the components necessary for their installations. Like manufacturers, the distributors and wholesalers feel strongly that solar technologies have much to offer the world, in terms of the energy savings they can provide and the environmental benefits which are derived from those savings.

They pride themselves on distributing products which they feel are of good quality, and of always being able to have those products on-hand for fast and efficient sales — hence, they take pride in the size of their inventories. As may be expected from large volume distributors, profits are made by being able to buy large quantities of products from manufacturers at low prices, and then by selling them at higher prices to subsequent people. Money is also made by adding value to products, such as by pre-packaging components into kits, or by pre-assembling and pre-plumbing some components.

6.3.1 WISHES FOR SHW INDUSTRY

They indicated that low interest financing for consumers wishing to purchase SHW systems would be a big help to the industry, citing that high up-front costs are a big deterrent to consumers.

6.4 SPECIALTY SHW CONTRACTORS

**source of data:** some views expressed here are the author’s interpretations of how five specialty SHW contractors view themselves and their industry, as revealed through personal interviews conducted during the course of this study; views from other contractors have been interpreted from a report which summarizes the results from a focus group session which included nine specialty contractors, conducted independently of this study (NAHB Research Center, 1998).

SHW contractors typically act as independent companies, although some of them work exclusively with particular manufacturers. Those contractors that function as independent companies often install both solar pool heaters, as well as SHW systems for domestic hot water supply. They are more or less neutral towards installing solar pool heaters or domestic hot water systems, though one installer did mention that he preferred to install
SHW for domestic use over solar pool installations, due to a faster installation time. Specialty contractors seemed split over which types of SHW (domestic use) systems they prefer — some preferred active over passive, others vice versa, and others would be happy to install either type (personal interviews, 1998).

6.4.1 CONTRACTOR ECONOMICS

*(See detailed economic schedule of SHW installation costs in the Chapter 6.)*

Contractors often operate under tight economic profit margins. A single call-back or complaint can cause the net value of doing a job to become negative. The two main causes for the high costs incurred by the contractor are (1) high cost of equipment, and (2) high labor costs (usually, two or three people are required to install a SHW system) (personal interviews, 1998).

High labor costs could be reduced if more than one job could be done per day. This is difficult, however, due to the amount of time spent driving between two locations and the time needed to set up and clean up in each location. As such, contractors were enthusiastic about any measures that could reduce their installation times to the point where two jobs (in two separate locations) would be possible in one day. On property development sites, the installation crew could work simultaneously on two jobs, overlapping work hours and eliminating the transportation and extra set up time which would be required for jobs in different locations. Most contractors said that such increases in productivity would be enough to allow them to reduce their prices, and that they would be willing to do so (personal interviews, 1998).

6.4.2 INSTALLATION

*(See detailed time schedules for SHW installations in the Installations section of Chapter 5.)* Contractors suggested that they receive diagrams or cut-sheets during pre-installation meetings, and felt that manufacturers purposely did not give detailed installation instructions to limit their own liability should problems develop. Contractors would like to have more guidance from manufacturer field-trained representatives. Some contractors suggested not installing collectors on the roof at all, but did not suggest where else to put them (NAHB Research Center, 1998).

6.4.3 WISH LIST

Specialty SHW contractors would like:

- A further simplified and speedier installation process (NAHB Research Center, 1998) (personal interviews, 1998);
- Ability to do multiple installations in one day (requiring installations to be geographically close) (personal interviews, 1998);
- A clear way to calculate and represent the savings which solar provides to customers (NAHB Research Center, 1998).
6.5 HOME BUILDERS

Source of data: The opinions of home builders expressed here have been condensed from a report summarizing comments from a total of 38 builders (consisting of a mixture of move-up, custom, starter builders) who were interviewed in a total of five focus group sessions held in Orlando, FL; Phoenix, AZ; and Sacramento, CA (NAHB Research Center, 1998).

6.5.1 BUILDERS AND THEIR CUSTOMERS

Home builders have a number-one priority to please their home-buying customers. As such, home builders are willing to install just about anything on a home that home buyers are willing to pay for — builders are, in fact, constantly looking for features and products which would differentiate their homes from those of their competitors. For these same reasons, notions of value are very important, including:

- Low cost
- Efficiency
- Lack of problems/maintenance
- Recovery time
- Reliability

Builders said that consumers (especially women) were the key decision makers in influencing which type of hot water system is installed in a home. However, builders said they thought that customers did not pay much attention to what type of hot water system was installed. However, builders find that customers are very sensitive to aesthetics.

6.5.2 GENERAL KNOWLEDGE OF SHW

All home builders interviewed had some familiarity with SHW, although on varying levels. Importantly, they believe that SHW manufacturers who managed to survive the end of the tax credits are “reliable and reputable.” However, they said that manufacturers need to “stand behind” their products more.

On the whole, builders showed a good ability to talk about SHW in terms of relevant issues and terms. However, they were misinformed about the realities of current day SHW systems. Builders in Orlando offered the following top-of-mind reactions to the term “solar water heating:”

- “Inefficient”
- “Low consumer awareness”
- “Not reliable”
- “Questionable because of liability”
- “Roof damage”
(Wishes, continued...)  
• “Roof leaks”  
• “Too expensive”  
• “Ugly” When shown pictures of more modern solar collectors which look similar to an roof skylight, the reaction from builders became positive, saying: “You’re moving up — that looks better; I can live with that; It looks pretty much like a skylight; It’s integral with the roof.”

6.5.3 BUILDERS’ WISHES FOR SHW

Service and Warrantee: SHW manufacturers should provide information on their systems, and warranties of 10-30 years — perhaps to match the warranty of the roof. Reliable service, and a dependable supply of parts is needed.

Economics: The payback time of a SHW system should be 1-5 years, and installation process should be between $1,000 and $1,500. However, builders stated that there was no way to prove how much money SHW would save consumers each month. “Your grandkids would almost have to live in the house forever for it to pay off without the tax break... it might save you $10 per month,” said one interviewee. Empirical data, indicating how systems perform in different geographic regions, would be something “the consumer can actually see and believe in. That is really an advantage.”

System and Installation: SHW should use simplified technology, with as few controls as possible. Builders were unanimous in indicating that SHW was too difficult to install. Installation should be simplified and “idiot-resistant, if not idiot-proof.” They would like to see solar installed on the ground, to improve the ease of installation and to avoid roof penetrations.

Partnerships: Builders would be more confident in SHW technologies if manufacturers were teamed up with the federal government and/or large manufactures such as Rheem, Carriers and Trane.

Relationships with SHW industry: Builders would like more opportunities to meet with, and talk to, SHW manufacturers and their representatives.
6.6 GENERAL TRADE CONTRACTORS

source of data: the opinions of trade contractors expressed here have been condensed from a report summarizing comments from a total of 9 contractors (consisting of people specializing in roofing, siding, windows, plumbing, and/or general home improvement) who were interviewed in a focus group session held in Sacramento, CA (NAHB Research Center, 1998).

6.6.1 GENERAL ATTITUDES

Responses from trade contractors were very pragmatic in general, and focused on the nuts and bolts difficulties involved with SHW. Contractors showed a good deal of skepticism about SHW, especially regarding how long SHW units would properly function, and that system lifetimes were often limited to about seven years. They were misinformed about the appearances of SHW, and thought that all systems were ugly. When shown pictures of modern collectors which look similar to a roof skylight, reactions were positive, giving a score of “8,” on a “10 = best” scale.

Those hot water system attributes deemed most important by the trade contractors interviewed were:

- up-front cost
- appearance
- visible cost-savings
- warranty length and conditions

For these reasons, they viewed conventional gas water heating technology as highly valued — they work reliably, are easy to install, and come with solid warranties.

Trade contractors normally pre-negotiate prices with their customers for payment of the services they render (author’s note). It is therefore not surprising that the trade contractors who participated in the focus group session said that they do not want to have to come back to a job to adjust or fix it after the initial installation, as this would not be in their economic interest. Because of this fear of mechanical failure, the contractors indicated that brand names and warranties are very important to them — trusted brand names and warranties signal to contractors that products can be trusted, and will not cause problems.

6.6.2 CONTRACTORS’ WISHES FOR SHW

Economics  Contractors want a way to calculate and demonstrate payback times to customers clearly and easily. At $1,500 however, one contractor thought consumers would “grab up” SHW systems; at $2,000, he said consumers would consider it. Furthermore, they thought SHW should have a payback time of 2-7 years.

System and Installation  Contractors thought that SHW systems were too complex: “They’re a headache; A lot of people can’t work on them; You’ve got to be a rocket
scientist to figure it out.” For this reason, they would like better labeling and manuals to reduce the uncertainty in their work. Contractors were also concerned that mountings and flashings deteriorated too quickly; freezing was also a worry. They would like to see systems designed for installation on roof eaves, so that they would not need to walk on the roof.

Partnerships Contractors worry that manufacturers may not be in business long enough to honor their warranties. For this reason, they would like to see manufacturers partnered in some way with larger companies or organizations as the federal government.

Service Contractors think manufacturers should provide more technical support.

6.7 HOME OWNERS

source of data: (1) the viewpoints of consumers expressed here have been condensed from a report summarizing comments from a total of 28 individuals (who have never owned a solar water heater, are planning to buy a home in the next two years, represent a mix of household sizes, and who are “not completely opposed” to using solar energy) interviewed in a total of three focus group session held in Orlando, FL, Phoenix, AZ, and Sacramento CA. (FOCUS Marketing Services, 1998).

(2) viewpoints of current users of SHW have also been condensed from the same report. These people are characterized as being: users of a solar water heater for at least two years (mix of new versus retrofit users), representative across a range of household sizes, and “not completely dissatisfied” with their solar water heater (FOCUS Marketing Services, 1998).

6.7.1 GENERAL ATTITUDES, AND FAMILIARITY WITH SOLAR HOT WATER

The non-users interviewed were totally unfamiliar with the concept of using SHW for household hot water purposes. They have little idea as to what is involved in SHW installation and operation, had little knowledge of existing solar energy incentives, and were under the impression that all SHW collectors were big and ugly. When shown pictures of modern collectors that look similar to roof skylights when installed, their opinions on the aesthetics of SHW changed considerably and were much more positive, although some respondents seemed mistrustful that such small attractive panels would be very effective at heating water.

The users of SHW from the focus groups showed an ability to speak about the topic of SHW in terms of relevant issues.
The interview data clearly show that, for all consumers, aesthetics and saving money are chief motivations in purchasing a solar hot water system. Additionally, consumers indicated that it is crucially important that hot water systems be hassle free. The fact that SHW is environmentally beneficial is a “nice” secondary characteristic of SHW, but not important towards making the choice to purchase a solar system.

6.7.2 PERCEPTIONS OF SOLAR HOT WATER

• Users of SHW tend to be very satisfied with the systems they own — indicating that they enjoy the lower utility bills, and have found maintenance to be of little concern (although the report did not indicate which types of system designs they had installed).
• Non-users of SHW however, are confused about what a full SHW system is comprised of, and what is involved in using it. Typical questions include:
  “Aren’t the systems very involved — with circulators and pumps?”
  “There’s not a lot of information out there. You’d have to seek it out.”
  “Do I need a separate storage tank?”
  “How do you control the level of heat?”
Non-users were also under the impression that SHW systems involved a good deal of expensive repairs and maintenance, and were concerned that builders and service people would not be around to repair a SHW system if something went wrong a few years later:
“I always think of these fly-by-night companies,” said one respondent.

6.7.3 ECONOMIC CRITERIA

• Users of SHW seem to feel that the energy savings which SHW is providing is good, even if they cannot specify the amount of those savings.
• Non-users are skeptical about SHW paying for itself: “Why would I do all of this to save just five dollars a month?” asked one person. Those non-users who currently heat water with gas, feel that the savings with SHW would be too minimal to justify purchasing a SHW system. Non-users who currently heat water with electricity seemed slightly more open to SHW.

Breaking even financially is not acceptable. Many consumers said they would be more likely to pay for a SHW system up-front, as opposed to financing it, since they were worried that interest on loans would eat away at the savings solar would provide.

(Reference for this paragraph: Alliance to Save Energy interview, 1998) Consumers do have positive attitudes regarding “efficiency.” This suggests that they favor the concept of maintaining current standards of living by using products or technologies which cost them less to operate.
6.7.4 SHW ON NEW HOMES

The non-users of SHW interviewed all wanted the backing of a strong warranty, in order to guarantee against expensive repair costs, should they consider buying a SHW system. Interestingly, they indicated that, given the attractive skylight look of modern SHW collectors, they would not steer away from buying a home equipped with such collectors pre-installed, especially if all the homes in the local community had such units as well, or if SHW were offered as part of a general “efficiency” upgrade option (including efficient lighting, appliances, etc.) to a new home. However, they might be mistrustful of SHW being offered as an option on a new home, as they are suspicious that builders might do this simply to make more money, rather than to offer a better product to the customer.

6.7.5 WISH LIST

Overall, consumers would like to see the following, where SHW is concerned:

- a nice, clean look for the solar collector, which should look integrated into home/roof;
- substantial savings on energy bills;
- strong warranties or guarantees on SHW systems;
- low maintenance;

6.7.6 HOMEOWNERS ASSOCIATIONS (source of data for this subsection: personal interviews, 1998)

This is a different group of consumers. As opposed to looking at individual consumers and their willingness to purchase SHW systems, homeowners associations are collections of local homeowners who are concerned with the look, safety, and overall quality of life within their individual communities.

Personal interviews with industry personnel and their trade association (SEIA), reveal that homeowners associations often present barriers to the SHW industry, by opposing the installations of SHW systems on homes within their communities (in the state of Florida however, it is illegal to prohibit a homeowner from installing solar equipment on their home, unless prohibited by local building codes).

Some industry members suggested that the general opposition to SHW by homeowners associations may stem from assumptions that SHW systems for domestic hot water purposes look like SHW systems for swimming pool heating, which include large arrays of thin black plastic tubes (much larger in square feet than a SHW collector for domestic hot water would be) which are often installed on roofs and considered by the associations to be ugly.
6.8 FEDERAL GOVERNMENT

**source of data:** all views expressed here are the author’s interpretations of how the U.S. Department of Energy (personnel within the Office of Energy Efficiency and Renewable Energy) view themselves and their role where the SHW industry is concerned, as revealed through personal interviews conducted during the course of this study (1998).

The federal government has a loud voice and, as such, is in a position to get their opinions out to large numbers of people. They are also in a position to introduce legislation which offers financial incentives to consumers or specific industry sectors. Because of the influences they might potentially have, they are in a position to alter the working of the SHW industry.

Additionally, it is reasonable to assume that the Department of Energy undoubtedly has its own agendas to influence and improve the energy markets within the United States. As such, it must be counted as a stakeholder within the SHW industry.

6.8.1 KNOWLEDGE ABOUT SOLAR THERMAL TECHNOLOGIES

The Department of Energy is enthusiastic about the potential solar energies could play in the U.S. energy economy. At a Million Solar Roofs Initiative ("MSRI" — see description of program in Chapter 4) meeting held in the Fleet Center in Boston, Massachusetts in February, 1998), DOE personnel commented that they were aware that solar thermal technologies (such as SHW) currently offer greater advantages than photovoltaic technologies do in utilizing the sun’s energy (as far as percentages of sunlight used as useful energy is concerned), and that the economics for solar thermal technologies are currently more favorable, as well. They furthermore indicated that they would like to know what the solar industries would like to see incorporated into the MSRI program.

However, personal interviews with solar industry people reported a lack of interest by the federal government level at the politician level.

6.8.2 GOVERNMENT CAUTION

However, the DOE is cautious about making bold actions to “choose” one type of technology. They are very sensitive to the fact that the large federal tax credit efforts of the late 1970’s and early 1980’s created a distorted market for solar technologies, and that those credits catalyzed the formation of companies who offered poor solar technologies which eventually earned the solar hot water industry a very poor reputation. (See comments under: Help from the Government, Chapter 2).
6.8.3 GOVERNMENT EXAMPLE-SETTING
The fact that the federal government is taking an active interest in solar technologies may generate a substantial amount of public interest. At the very least, the MSRI commitment to install solar technologies on 20,000 federal buildings could be a substantial advertisement for solar industries, thus increasing the public’s awareness about solar industry technologies.

6.8.4 INCENTIVES
Unrelated to the MSRI, a proposed 15% personal income tax credit based on consumers purchases of solar technologies, is currently under review in Congress. It is unlikely that the passing/failure of this legislation will be known before November of 1998.

6.9 SUMMARY OF STAKEHOLDER VIEWPOINTS ON SHW

Having summarized the viewpoints of the various stakeholders who have roles to play in the U.S. SHW industry, some time is worth spent summarizing how those views fit together. On which issues are people thinking alike, and on which issues are people thinking differently? These are the two central questions to be answered in this summary.

6.9.1 COMMUNICATION OF ECONOMICS
All of the stakeholders who have direct contact with the end-users of SHW (i.e. home builders and all types of contractors) express that they need to be able to clearly represent to consumers what kind of economic savings may be realized through use of SHW technologies. Thus, one may suppose that this is also something which homeowners have expressed a desire to see. This is clearly a major concern on the minds of many stakeholders and therefore identifies a clear area of effort which the SHW industry would be appropriate in addressing.

6.9.2 WILLINGNESS TO ADOPT SHW
Perhaps surprisingly, both builders and consumers seemed quite optimistic about the notion of giving SHW a try, once they saw pictures of modern-day SHW collectors that look like skylights on a home’s roof. Nevertheless, these parties maintain a risk-averse stance, as they perceive a fair amount of inconvenience and complexity involved in installing SHW systems, and worry about problems occurring with their systems after installation; they would like to see any number of things from manufacturers which would provide a signal
that SHW is a safe bet, and that any risks involved with installation or with problems several years afterwards are minimized well in advance of installing systems. Along these lines, they would like to see:

- faster installation times and a simpler process;
- partnerships of SHW with larger manufacturers or the government;
- stronger warranties;
- better information on what the technology is;
- clearer information as to the savings SHW provides

### 6.9.3 INSTALLATION TAKES TOO LONG

The stakeholder analysis revealed that the installation process is a real stumbling block to the industry. All contractors and home builders complained that installation process for SHW systems either took too long, was too inconvenient, or included too many opportunities for errors to be made. These complaints arise from either the economics of a the installation (long installation times lower the profitability of the job for contractor s hired at fixed fees), a dislike for the inconvenience of working on the roof, or fears that maintenance problems may result due to mistakes made on a complicated job, thus causing displeasure from customers, not to mention an economic drawback, as someone would need to pay for the needed repairs. Clearly, those people who are responsible for the implementation of SHW have issues with the installation process, thus identifying another topical area which may deserve attention by the SHW industry.

### 6.9.4 WISHES FROM WITHIN SHW COMMUNITY

The people involved in selling SHW (manufacturers, SHW contractors, distributors, wholesalers) seem confident in their technologies, and thus indicate that their products require little or no artificial financial support from external sources. Rather, the SHW industry would like to see low-interest financing made available to their would-be customers, so that those customers would no longer face the large up-front costs of installing SHW systems. Issues of misinformation throughout the public however, are cited as the largest barrier facing the industry today.

Thus, it is not surprising that their first and foremost wish of the federal government is that the government use its loud voice to get consumers interested or otherwise informed about the usefulness of SHW.

Concerns about the public's misinformation regarding SHW seem justified, in light of comments from home builders and consumers, all of whom initially expressed negative views on SHW, only to express much more positive inclinations once they were acquainted with some of the facts (especially as regards the physical attractiveness of the systems).
7. CONCLUSIONS

The solar hot water industry in the United States is one whose entire success and credibility hinges upon the proper functioning of the systems into which its technologies are incorporated (Implementation of Innovations, Chapter 2). However, few people are providing leadership towards ensuring that quality systems are physically delivered into the household environments of consumers. It is no wonder, then, that the industry sometimes feels that its efforts are disjointed: although the Solar Rating & Certification Corporation provides guidelines as to how quality systems should be configured, it is left largely up to installers to carry this task out — all of whom do it in their own particular way.

When faced with problems, there are at least five lenses through which industries may view those difficulties and look for solutions. Those areas are:

- the industry’s economics;
- the industry’s technology;
- the industry’s market;
- the organization and operation of the industry;
- the context in which the industry operates: external influences, political climate, etc.

The economics will be presented first, in the “Basic Findings” section of this chapter. The other four topical areas, as well as strategies relating to them, will be covered in separate subsections of this chapter.
7.1 BASIC FINDINGS

Summarized below are the basic findings of this thesis.

7.1.1 SHW OFTEN HAS FAVORABLE ECONOMICS

Solar hot water often shows favorable economics, especially when compared to conventional electric hot water heating (Chapter 5). Home builders and contractors of all types, however, wish for ways to clearly represent these economic benefits to the consumers and home owners who hire them (Chapter 6). Access to low-interest loans for purchasers of SHW is cited as the #2 overall wish by members of the SHW industry (Chapter 6).

Solar hot water can be viewed as a long-term investment (Figure 7.1-A). Total installed costs of solar hot water technology lie between $1,500 and $3,500 for the consumer purchasing a system, depending upon both the specific technology installed and the profits which contractors (who install the systems) add to their bills. SHW is more expensive to install than conventional technologies, but the consumer's energy bills are comparatively lower in every year after the solar hot water system has been installed. While it takes several years for those savings to "pay for" the initial investment needed to install the system (for example: years 1 - 6 in Figure 7.1-A), the consumer is making money on his/her investment every year after that point. The total amount of money saved by the consumer (compared to what s/he would pay if using a conventional electric water heater) is represented by the vertical height of the right-most triangle in Figure 7.1-A.

Figure 7.1-A

![Diagram of the Solar Investment]
7.1.1.a  **SHW vs. Conventional Electric Water Heating**

SHW is very competitive economically with conventional electric water heating technology. Only under the most pessimistic assumptions is this not true. "Pessimistic" assumes that use of SHW saves low percentages of energy over conventional electric technology — as far as SHW’s ranges of potential energy savings is concerned, SHW systems cost over $3,000 to install, household electricity expenditures for water heating are low at $250 - $300/yr, and local water quality is such that system components need replacement every 6 years.

The first analysis performed was the payback period analysis. Results of this type of analysis are highly dependent upon installation prices (higher prices make SHW economics look worse) and assumes that shorter payback periods are better than longer ones.

Under all assumptions (except the most pessimistic ones), SHW systems have payback periods of: 3 - 15 years, with the bulk of those lying below 10 years.

This implies that (under most assumptions) a fixed percentage of 10% to 33% of the required initial investment to install a SHW system (equal to the costs above those which would be needed to install a conventional electric system) will be paid back to the consumer each year through the fuel cost savings which SHW systems provide. Payback periods, when compared to putting money in a financial growth account for 30 years, imply equivalent compounding rates of return on investment summarized in Table 7.1-A.

<table>
<thead>
<tr>
<th>Table 7.1-A: Summary of Payback Periods and Equivalent Rates of Return</th>
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<tbody>
<tr>
<td>Payback Period :</td>
</tr>
<tr>
<td>Fixed Percentage of Investment Recaptured per Year</td>
</tr>
<tr>
<td>(through fuel savings) (non-compounding)</td>
</tr>
<tr>
<td>Equivalent Compounding Rate of Return on Investment</td>
</tr>
<tr>
<td>(30-year simple growth)</td>
</tr>
<tr>
<td>Equivalent Compounding Rate of Return on Tax-Deferred Investment</td>
</tr>
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<td>(taxed at 30% after 30 years)</td>
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Source: Table 5.3-B
The cash flow savings realized through use of SHW offers consumers opportunities to do other things with their money. It is in light of this fact that discounted economic analyses are valuable (see Chapter 5), as this compares whether a consumer is better off installing a solar system, or using that money to investment or pay down debt at given interest rates, referred to in this analysis as “discount” rates.

In all but the most pessimistic cases, the savings of SHW proved worthwhile to the consumer over a variety of discount rates. At low discount rates (i.e. applying to people who do not have investment opportunities or debt to which higher interest rates apply), the value of SHW is more valuable to the consumer than at higher discount rates. (See Figure 7.1-B as an illustrative example: lower discount rates make SHW more valuable as an investment.)

![Figure 7.1-B](image)

Under a set of assumptions which may be considered “average” (i.e. components replaced every 10 years, energy savings over conventional technologies of 80% for active flat plate systems, 65% for ICS systems, and 70% for thermosiphon systems), SHW systems proved worthwhile over their entire ranges of installation costs for people whose investment opportunities or debt responsibilities involve interest rates lower than 8%.

The more favorable an environment is to SHW (i.e. higher household energy bills for water heating, better water quality allowing longer component lifetimes, lower installation prices), the wider range of discount rates under which SHW is a worthwhile investment. In the example above, SHW can be a worthwhile investment (if conditions are favorable enough) even for those people whose investment opportunities or debt responsibilities involve interest rates of 18%!
7.1.1.b SHW vs. Conventional Gas Water Heating

When compared to conventional gas water heating technologies, the economics for SHW were favorable only when the most optimistic sets of assumptions (regarding energy savings by SHW, component life time, and installation cost) were made. This implies that it may be very difficult for SHW to compete economically with conventional gas technologies.

7.1.2 LEADERSHIP IS NEEDED

The individual technologies offered by the SHW industry are sound and of high quality. The technical problems which remain in the industry are erratic and depend largely upon the particular contractor who installs the SHW system. This results from the fact that full SHW systems are the ultimate products delivered by the industry to the consumer. These systems are comprised of many individual components (the inventory list for one distributor’s SHW kit seen during interviews contained over 70 parts and pieces, including installation hardware), and are installed by individual contractors who work using a variety of practices and choices of components. Thus, if SHW collector manufacturers do not provide leadership by somehow controlling quality in the systems that incorporate their technologies (by standardizing system components and/or the people or practices used to install systems), there is no guarantee that anyone else will take on this responsibility, and these variations in system quality will continue.

If they are not already doing so, the SHW industry needs to make a serious marketing effort (see The Data in Support of Marketing, Chapter 2) to ascertain who the most appropriate customers for the industry may be (this report suggests that home builders could be very attractive customers), and to understand and address the specific needs of those customers. The customer is always right!

7.1.3 HEAT PUMP TECHNOLOGY: A THREAT TO SHW?

Importantly, heat pump water heaters may be a threat to SHW systems in the future. Though they offer less energy savings over conventional technologies than SHW systems do, they are much simpler and easier to install, because of their ability to be “stand alone” units: no complicated roof installations are necessary! This simplicity appears to be very important to consumers, home builders and contractors of all types (Chapter 6), which could make heat pump water heaters the energy efficient technology of choice.

7.1.4 SHW TECHNOLOGY IS ATTRACTIVE

SHW technology deserves a better reputation with the general public where aesthetics are concerned. Consumers unfamiliar with solar hot water technology indicated that they believed it to involve use of large, ugly roof-mounted equipment, using materials such as cheap black plastic tubing. However, when they were shown pictures of current-day solar collectors (which have glass covers, and look much like a skylight), their opinions about the
look of the collectors improved dramatically, saying: "This looks nice and clean" "I like the way it blends in with the roof" (FOCUS Marketing Services, 1998).

7.1.5 SHW MANUFACTURERS DESERVE A BETTER REPUTATION

Most of the current manufacturers have been in the business of solar hot water for some time, dating back often to the 1970's. Their production facilities make use of modern equipment and have collaborated with U.S. government laboratories in the past to make improvements to their factory floors. Every indication exists to indicate that the SHW industry is comprised of quality, dedicated people who are committed to the companies they represent.

7.1.6 SHW OFFERS SIGNIFICANT ENVIRONMENTAL BENEFITS

When solar hot water systems replace conventional hot water heating technologies, the energy efficiency of the hot water heating process is greatly improved. As less fuel is needed from other sources (electricity from utilities, burning of natural gas), overall emissions of carbon dioxide (CO₂) are decreased. But only by looking at the entire fuel chain (from raw materials to end-use) can one obtain an adequate picture of the energy and CO₂ savings provided by solar hot water (calculations in Appendix 1).

Energy savings and CO₂ displacements provided by SHW systems are presented in Figure 7.1-C. As a basis for comparison, data is also presented for the hypothetical case of energy savings which would result from doubling a car's fuel efficiency from 30 mpg to 60 mpg, assuming that the car drives 15,000 miles/yr, as is common for new cars (American Automobile Manufacturers Association, 1995).

![Figure 7.1-C](image)

Source: Appendix 1
7.2 SHW TECHNOLOGY STRATEGY

7.2.1 SHW IS A RADICAL TECHNOLOGY

SHW technology is clearly one that “shakes things up.” The concepts behind it are simple, yes, but by the definitions presented in the literature review in Chapter 2, and the descriptions presented in Chapter 4, show SHW to be a “radical” innovation, overturning entire concepts of water heating which people have become accustomed to, and altering both the linkages which tie the hot water system together as well as those which connect it to the household. And because it is a technology which currently comes to the home by way of contractors, who often pick and choose the components which make up the systems themselves, SHW must also be considered a configurational technology, requiring a good deal of on-site customization and adaptation. All other water heating technologies are, by comparison, simpler to implement.

This means that the SHW industry may have to do a good bit of hand-holding. SHW is more complicated than any other hot water technology on the market by virtue of the fact that it involves more pieces of equipment to install, and brings with it needs for education (of end users, as well as of installers), and for quality control of all aspects involved in delivering it to the consumer. To reiterate Fleck’s quote from Chapter 2: “All components are potentially of importance; not just the purely technological ones” (Fleck, 1994). “Components,” as used by Fleck, takes on a broad meaning, including such concepts as customer support, management processes and back-up planning for unexpected or emergency situations.

The people in the SHW industry have been in the business for a long time, and are so used to the concepts and subtleties involved with SHW, that they likely take them granted and see them as painfully obvious. Because of this, they may not fully appreciate the extent to which SHW alters everything that people have come to accept as “normal” where water heating is concerned. The reader is asked to consider the sheer size of Chapter 4 as a reflection on how “simple” SHW appears to the non-expert.

7.2.2 SYSTEMS DELIVERY IS THE PURPOSE OF THE INDUSTRY

The Solar Rating and Certification Corporation (SRCC) has been a tremendous help to the SHW industry, in terms of setting standards for solar collector quality and for designs of appropriate system configurations. There is, however, little that the SRCC can do towards
physically installing quality systems into individual households. And as far as evidence is concerned, suggesting a need for improvements in installations, the data are in:

- "[SHW is] a headache; A lot of people can’t work on them; You’ve got to be a rocket scientist to figure it out" (Trade Contractors, Chapter 6);
- The greatest amount of time spent during the installation process is on making the connections to/near the household water tank (System Installations, Chapter 4);
- Builders were unanimous in indicating that SHW was too difficult to install. Installation should be simplified and “idiot-resistant, if not idiot-proof” (Home builders, Chapter 6).

7.2.2.a Actions

What can be done about SHW, as far as systems go? A number of possibilities exist. As a first order of business, simple things can be done:

- Better labeling can be made on the SHW collectors such as “COLD IN HERE ➔” or “THIS END UP” etc. This might do much to avoid stories of collectors being hooked up backwards (SHW Manufacturers, Chapter 6).
- The Inclusion of small and simple key components with collectors when sold, regardless of whether or not contractors ask for them, could help some system quality problems. The anti-siphon check valves would be a key candidate for such inclusion: the industry abounds with stories of poor quality valves which quickly malfunction, causing warm water to thermosiphon up to the roof at night where it loses all of its heat.

7.2.2.a.i Use Better Parts

It appears that certain contractors are using inferior components in the systems they install:

- Insulation protection: some SHW systems are installed using UV-resistant paint to protect piping insulation from the sun. This paint will wear off in a few years. However, other contractors report that using metallic tapes to protect insulation will last significantly longer.
- Anti-thermosiphon valves: stories about these valves malfunctioning abound. Yet some manufacturers and distributors swear that particular designs never malfunction — there seem to be valve technologies which are clearly superior to others. Why does everyone not use them?
- Drain-back tanks: some installers reported that regular maintenance is required on drain back active SHW systems (see Chapter 4), because water from the drain-back tanks eventually evaporates and must be refilled. However, other manufacturers report technical solutions around this problem, which completely eliminate it.

7.2.2.a.ii Develop System Kits

As a second, and much more substantial measure, manufacturers of solar collectors may wish to consider selling and shipping their collectors in complete kits, and thus take responsibility for the quality of all of the components of the system. This might, however,
require that manufacturers design parts of the kits around the needs of the most difficult (or costly) potential installation scenarios, such as using 3/4” piping, instead of 1/2”, if they believe some installations might require the wider piping.

Clear labeling, and the pre-assembly of as many of the little parts as possible makes everyone’s lives easier down the road, thus eliminating one more stumbling block. Some distributors have stepped into this role already: they pre-assemble and color-code some of the smaller components, for instance, to prevent valves from being installed backwards. This is likely the type of “idiot-proofing” which home builders are hinting at: such measures remove the possibility of certain problems occurring altogether (Home Builders, Chapter 6).

7.2.2.b Technical Innovations Needed

- “Idiot-proof” and faster, more efficient installations is something that everyone seems to want (Summary, Chapter 6). One innovation for passive systems could serve to further both purposes. A simple “box” which incorporates all of the required plumbing and valve connections, in accordance with standards set by the SRCC, would both eliminate errors on the connecting of valves, and would reduce time from the lengthiest phase of the installation process: that of making the plumbing connections to, and near, the household hot water tank.
- Aesthetics play a crucial role in peoples’ decisions to adopt or reject SHW (Consumers, Chapter 6). Thermosiphon manufacturers likely feel the effects of this constraint considerably more sharply than ICS or active flat plate manufacturers, since thermosiphon systems typically use an obstructive tank on the roof. Perhaps there are ways to camouflage these tanks, to make them look as if they are actually a structural part of the home, disguising them as a chimney, for example, or as a small dormer window.
- A hot water energy meter would be helpful to the industry, as it could accurately measure the energy savings which solar systems are providing, thus lending solid evidence of the benefits of SHW. However, this would require use of a flow meter, and interviews revealed that these are prohibitively expensive.

7.2.3 EMERGING INNOVATIONS TO WATCH FOR

Two complementary technologies that are currently emerging from their R&D phases, plus a third technology which currently exists, may offer significant opportunities for the SHW industry. A fourth technology — heat pump water heaters: new, but commercially available — could become a serious competitor to the SHW industry.

- The first of these technologies is a hot water tank that incorporates all necessary pumps, controls, etc. needed for an active systems, designed by Sun Trapper Solar Systems, Inc. This tank has a design life of 30 years or greater, and is immune to mineral deposits and clogging (personal interviews, 1998).
• The second of these technologies is “smart glass.” This technology can change glass from being transparent to infrared-opaque by passing a small electric current across the glass panels. This could be an obvious benefit to solar collectors that need to retain heat energy at night, such as with an ICS system. A variety of manufacturers are designing smart glass technologies, all of which vary in design. For instance, some smart glass systems sandwich a specialty liquid — capable of changing its transparency — between two panes of glass, while other technologies make use of solid state coatings on glass to perform the transparency changes (Slaughter, 1998).

One smart glass developer is Sustainable Technologies Australia Ltd. Their technology sounds particularly promising, as all components are solid state, and the fail-safe mode of its operation leaves the glass clear (in absence of electricity), thus allowing solar heating to continue, should the technology break. Other smart glass technologies use liquids that are opaque if left alone — only in the presence of electricity do they become clear (STA interview, 1998).

• The third of these technologies are the tankless water heaters, already described in Chapter 4.

7.2.3.a New SHW Systems

"You know your product is ready, when it is an order of magnitude better than anything else out there."

- Keynote speech by Guy Kawasaki, one of the founding programmers for Apple Computers, now CEO of garage.com, Inc., delivered February 4, 1998, at the kick-off event for the annual $50,000 entrepreneurship contest hosted at the Massachusetts Institute of Technology

The three innovations listed in the previous section could produce “order of magnitude” improvements for the SHW industry, placing it in its own separate technological category — distinct from, and clearly better than that which is considered standard technology today.

SHW systems today all rely on hot water tanks based on conventional technology. Hence, one might say that SHW is merely an (impressive) efficiency improvement over traditional water heating technologies.

But the benefits of having a tank for active systems which incorporates all necessary components (thus avoiding the need to install them separately) and which will last two or three times longer than any other hot water tank in the industry, would truly give the SHW industry something to brag about, justifying pride not only in the energy efficiency of the systems, but also in the fact that the system uses a tank that is clearly superior to conventional technologies.
Passive SHW technologies also have a significant opportunity. The benefits of smart glass to ICS systems are obvious: heat can be retained by the units better at night. But the incorporation of tankless water heaters in passive systems might make them “an order of magnitude” better than anything else on the market. One or two tankless units, connected in series, could eliminate the need for a hot water tank completely. Passive systems then would gain several new advantages worth boasting about. With the full removal of the hot water tank from the system, more space is created in the home. Moreover, standby heat (energy) losses would be completely eliminated, thus further increasing the energy savings of the system overall. Third, there would be no need to worry about hot water tanks wearing out. Lastly, and depending upon where the tankless units were installed, hot water could be provided more quickly to the household from the moment the tap is turned on — a significant convenience for homeowners and perhaps an interesting feature for home builders, who are always looking for ways to differentiate their homes from those of their competitors.

7.2.3.2 Competing Technology

Heat pump water heaters (see description in Chapter 4) offer roughly 40% - 50% energy savings over conventional technologies. This is less than the energy savings that SHW systems provide, but is substantial, nonetheless. More importantly, however, they are a modular innovation (Classification of Innovations, Chapter 2), which means that they can easily be swapped with conventional technologies. Like conventional technologies, they require only water in/out lines and an electrical hook up; their only technical difficulty is that they must have access to drainage. Nevertheless, they offer a simple and easily implementable option where energy efficiency is concerned: everything required for their operation as a system can be contained within one unit.

7.3 SHW MARKET STRATEGY

Finding good markets for SHW will require a significant amount of effort by the industry and should, by no means, be considered a “side” activity. The conclusions presented here are founded, in part, on interview data summarized in reports containing results of focus group studies conducted with builders, contractors and private consumers. (See individual headings under each section of Chapter 6 to see the details of data sources.) As such, the conclusions of this section are meant to inspire new thoughts, ideas, and individual marketing efforts by members of the SHW industry, who will then have to ascertain for themselves what the specific needs of those customers are whom they target.
7.3.1 SHW IS DIFFICULT TO SELL

The U.S. market for SHW has not proven easy to tap into. The views presented in Chapter 6 would indicate that current American non-users of SHW — home builders, home owners, and trade contractors alike — all perceive SHW as a system that detracts from the convenience of their lives: they see SHW as an unfamiliar and "ugly" technology, requiring much more effort to implement and use than conventional technologies do. Since these people are already busy with their own lives and have hot water anyway, they are left with few incentives to take the time and effort to learn more about even the basics of SHW systems. This may be different from markets in developing countries, which may today be more like the markets seen with the first two U.S. SHW industries (see Chapter 3). Those early U.S. markets had strong incentives to invest in SHW: either hot water from a tap did not exist (as in California around 1900), or else electricity and/or natural gas were either too expensive, unavailable or inconvenient to obtain.

7.3.2 A POTENTIALLY "HUGE" MARKET

The present U.S. market for SHW is potentially huge. There are millions of existing homes in the U.S., and hundreds of thousands of new homes are built every year. However, the entrepreneurial community frowns upon the assumption that small percentages of huge markets can somehow be captured by a business by sole virtue of the products it sells, without doing substantial market targeting.

A general partner in the Venture Capital Fund of New England, in a presentation at the Massachusetts Institute of Technology on April 15, 1998 said:

"We really don’t like to see companies that say: 'There is a huge market for this product — all we need is 1% of it to have a successful business.' These companies rely on the consumer being self-motivated to buy their products, and generally don’t understand the specifics of how their market operates... The growth of the markets for missionary products are always slower than the entrepreneur thinks."

According to the entrepreneurial community, the better approach to developing a customer base, is to seek customers out, one at a time, making sure that their needs are met, and to build up trusting relationships with them which will endure over time.

7.3.3 TARGET: UTILITIES

Despite these difficulties that the SHW industry is up against, there are some rays of hope. Although time did not permit a thorough analysis of utilities as a market for SHW, such a market would have significant advantages.
If utilities led the efforts to install SHW systems, they would probably remove several of the barriers which currently keep consumers at a distance from the SHW industry: namely, taking the time to find out the basics of SHW, searching out systems which are suitable for use in a particular region, and finding reputable contractors to do the installations. Utilities could additionally assume the risk of actually owning the SHW systems that are installed in homes by renting them to customers, thus removing one more barrier to consumers’ adoption of the technology.

Utilities may be looking for just such new markets in the years to come as the utility industry is deregulated across the United States. The 1998 Electric Industry Outlook reports that, for the third year in a row, the number one concern within the electric industry is the loss of customers; “the average utility should expect to lose 20% to 50% of its customers if choice [in choosing a utility to supply power] is voluntary,” states the report. As such, utilities are worried about their futures and are investing hundreds of millions of dollars to search out new ways to make money — they may offer different services, different products, or may even quit the industry altogether. The publisher of the report also states that they believe there is an “inevitable technological trend that ... is a key driver: the long-term shift away from large, centralized technologies.” (Washington International Energy Group, 1998) This might mean that utilities in the future will pay more attention to SHW.

Chip Bercher with Wisconsin Public Service has done some research on understanding utilities’ attitudes towards SHW. Additionally, Lakeland Power (Lakeland, FL) is considering implementing a SHW program (FlaSEIA personal interviews, 1998).

7.3.4 TARGET: HOME BUILDERS
Perhaps the most promising market for SHW is that of the new homes market. Already, there is interest being shown by home builders: Ditz-Crane Homes of Phoenix is planning to offer an ICS SHW system as an option for $2,400 - $2,800 on new homes it is constructing in its Cove Valley Ranch development (personal interviews, 1998). Additionally, there are sympathetic employees of U.S. Homes in Florida who have given free booth space to representatives of the SHW industry at trade shows, and are installing SHW technology on model houses that are shown to prospective customers in their Parade of Homes (FlaSEIA personal interviews, 1998). These people are likely allies of the SHW industry whose influences within their industry could perhaps be well-leveraged (Champions of Innovations in Large Firms, Chapter 2).

Installing SHW systems into new homes has significant advantages. From a technical standpoint, it offers the opportunity to install the collectors into the roof framing, so that the collectors are flush with the roof’s surface. This would eliminate the possibility of water freezing in the pipes that run from the collectors into the home (a danger now for all SHW systems — see SHW Systems Compared: Mechanical Failure Modes, Chapter 4), and would make solar collectors look even more like skylights, an aesthetic advantage.
Additionally, this might enable the separation of labor during the installation process. If the home builders and their general contractors could install units flush with roof, the special skills needed to run piping in through the roofs would be eliminated, thus reducing the configurational nature of the system (Configurational Technology, Chapter 2): if the needed connections to the rest of the plumbing environment inside the home were simple enough (i.e., using pre-assembled components or tanks which include all needed pumps and valves), plumbers could perform the rest of the installation, thus freeing the SHW industry of the required specialty skills that currently limit the geographic regions in which it is able to do business.

But even if the simplifying steps mentioned above could not be implemented, selling SHW to home builders offers installers the opportunity to do multiple installations within one day (if working on a multi-home development site), thus potentially increasing their profit margins (Specialty SHW Contractors, Chapter 6). In this way, the interests of one more group along the value-added chain are satisfied, likely resulting in smoother cooperation along that chain (Stakeholders Along the Value-Added Chain, Chapter 2).

Lastly, large home building companies selling SHW homes equipped with SHW carry three additional benefits for the SHW industry: (1) their participation would lend credibility to SHW; (2) targeting them makes marketing simpler for the SHW industry — there are fewer of them to pursue as customers (as compared to the general U.S. population), and potentially may buy many systems on a repeat basis (in contrast to individual homeowners, who would buy only one system every 20 years, or so) (Adopters of Technology, Chapter 2); and finally (3) they are a source of SHW marketing and advertising — should they adopt SHW, they would naturally have an incentive to promote it as a specialty product which they offer over their competition (Home Builders, Chapter 6).

But getting home builders on board will take some effort. They need to be catered to — their concerns must be addressed. Specifically, they:

- want more marketing from SHW representatives: educational literature, personal conversations with manufacturers at trade shows, etc.;
- would like to see installation times reduced and simplified;
- want empirical data showing just how much energy savings consumers can likely expect from SHW systems in specific regions;
- would like to see their own risks of adopting SHW reduced: either through strong warrantees, or to see SHW manufacturers partnered with big names in the industry (Trane, Rheem, etc.) or with the federal government.

All of this data suggest that home builders would like to avoid doing all of the research themselves, and that personal contact with manufacturers or their representatives allows them an opportunity to “do their homework” on SHW (Adopters of Technology, Chapter 2).
7.3.5 TARGET: SPECIFIC NEIGHBORHOODS

Talking directly to homeowners’ associations would provide insight into concerns of private homeowners. Rather than letting these associations come to the industry with complaints, it might be a show of good faith to approach them instead and to give them the facts: SHW (for domestic hot water) will not destroy the look and attractiveness of their neighborhoods — and can save them money as well. Talking to homeowners’ associations, in any case, would provide an opportunity to talk to more people at one time than door-to-door selling allows. And, in the off-hand chance that an association reacted warmly to SHW, their opinions and judgment (on SHW) might carry (influential) weight with the rest of the people in the community.

7.3.6 RAISE THE IMAGE OF THE INDUSTRY

The SHW industry clearly faces (unjust) negative images by many of the people to whom they would like to sell their products. Images of ugly black tubing on the roof, of “fly by night” solar companies who cannot be depended upon, or of solar companies who will not be around long enough to support their products are all views which come from potential users or installers of the technology (Chapter 6).

Clearly, there needs to be an effort to change the image of the SHW industry. A new image might stress such images or concepts as:

- there is a “new” solar industry: compare clean, corporate images of attractive skylight-like panels installed on homes to images which poke fun at the “old” industry;
- “skylight pre-heaters”: this would immediately connote the image of an attractive skylight, not ugly black panels. The notion that panels are pre-heaters might put to rest suspicions that manufacturers are promising something which they cannot deliver (Consumers, Chapter 6), emphasizing instead that solar (“skylight”) panels are only part of a larger system;
- “efficiency”: consumers are generally interested in efficiency — getting more for less (Aliance to Save Energy interview, 1998) — while their views on “solar” are misinformed and muddled (Chapter 6);
- pictures of actual (attractive) panels mounted on homes — aesthetics is a key concern among users and builders (Chapter 6);
- the high quality of the technology, as guided by the SRCC — an independent “regulatory” body which ensures quality within the industry (Chapter 3);
- the dependability of SHW manufacturers, most of whom have been in business for a long time, thus confronting the notion that SHW companies are “fly by night” or otherwise not dependable;
- the interest which the Department of Energy has in SHW technologies, and the fact that it will (or has already) installed SHW technologies on its own buildings;
- the fact that solar is now a serious interest of the President of the United States (for example, MSRI is a Presidential initiative);
7.4 ORGANIZATIONAL STRATEGY

The previous section highlights marketing ideas which may be useful to the SHW industry. However, it is up to the industry to ascertain for itself what the specific needs and constraints are of the customers which they target.

Advice from the entrepreneurial community — as introduced in Chapter 2 — would suggest that the SHW industry make significant changes in how it spends its time and money. Specifically, much more of it should be spent on marketing — not on advertising, but rather in talking to and educating prospective customers, building up customer bases, identifying customer needs, and designing compatible business models to meet those needs. Consequently, less time should be spent on engineering or other technical tweaking activities, as these should be performed at a later date, directed by the results of the market research conducted.

7.4.1 DIVISION OF LABOR

The SHW industry is cost-constrained, so there may need to be a significant amount of cost spreading in the industry initially, in order to implement many of the efforts which this study suggests.

7.4.1.a Manufacturers Have to do the Marketing

Nevertheless, there are some activities which manufacturers simply have to do themselves and which cannot be effectively spread across the industry. For one, if builders or utilities are to be targeted as customers, they will likely want to know the specifics of the technologies involved, and will want to hear it from the people who make the technology. As builders suggest (Home Builders, Chapter 6), this could be done at trade shows, by making private presentations or through other means. Such activities could also be learning opportunities for manufacturers, enabling a better assessment of what the bottom line is for the people to whom they wish to sell. There is also every indication that people would like to see manufacturers shoulder some of the risks which people perceive themselves as incurring when installing SHW systems into homes: stronger warranties have been suggested (Chapter 6). Perhaps guaranteeing customer satisfaction or some type of refund may be in order — at least on the first several installations which builders or utilities do.

7.4.1.b Share the Costs Where Possible

While much of the direct contact with potential customers will have to be done by the manufacturers, there is much work that can be spread across the industry — this could very well be done by the Solar Energy Industries Association (SEIA).
Such efforts might include:

- General advertising: communicating something as simple as the facts that domestic SHW technologies are attractive and of high quality.
- Educational video tapes: perhaps educating builders or utilities about SHW basics.
- Holding architectural design contests, with constraints on where collectors can or cannot be mounted, thus coming up with innovative design solutions from professionals (or students) to problems which face the industry (NAHB Research Center, 1998). For example, trade contractors and home builders do not like mounting collectors on the roof, due to feelings of inconvenience during mounting and of concern for the roof integrity, respectively (Chapter 6).

7.4.1.c Coordinate SEIA, FSEC and the Million Solar Roofs Initiative (MSRI)

Perhaps most importantly, the opportunities which the MSRI presents should be leveraged to the best extent possible. To this end, SEIA would be wise in spending considerable time with the people running MSRI (if, indeed, they are not doing so already), to ensure that the two entities constructively coordinate efforts and ensure that effort or work is not duplicated or otherwise wasted.

Two issues present themselves as immediately important.

The first issue is a need, expressed both by SHW contractors and home builders alike, to have clear and unambiguous ways of presenting to consumers how much energy savings may reasonably be expected from a SHW system (Specialty SHW Contractors, Home Builders, Chapter 6). Some of this empirical data may already exist at the Florida Solar Energy Center. Additionally, their TRNSYS software may be capable of generating such data with reasonable accuracy through computer simulation (Solar Rating and Certification Corporation, Chapter 3). In any case, much more data seems to be needed through a centralized, accessible source that people know about.

An unofficial publication by the DOE titled: “Million Solar Roofs Initiative - Top Ten Questions” (Revised December 18, 1997) lists, as a type of activity to be undertaken through the MSRI:

"Committing government efforts to overcome barriers to solar energy and energy efficiency in buildings."

The lack of definitive information regarding the savings which solar thermal systems provide certainly seems to be a barrier to solar energy, in light of evidence presented in this report. As such, it deserves attention from the MSRI.

The second issue is that of information flow. The MSRI is described by people with the Department of Energy as a “top-down” and “bottom-up” initiative (Chapter 3). If they have not done it already, the MSRI and SEIA would be wise to coordinate how the program is going to be promoted, which of the two parties interested consumers are likely
to contact first, who will be responsible for providing what information — and in what order. The fact that interested consumers may wind up calling either SEIA or MSRI — since both seem to be “umbrella” solar organizations — leads one to suspect that there may be many opportunities for information (and interested, but frustrated consumers) to get lost somewhere between these two entities.

7.4.2 QUALITY SYSTEMS MUST BE DELIVERED

However the marketing work is split up among the different players in the industry, the ultimate goal of delivering systems into the homes of consumers — the ultimate function of the SHW industry — must still be addressed.

Whereas manufacturers in the industry seem to currently operate under a centralized method of diffusing their technology throughout their markets — that is, they stand at the center of everything, sending their technology out into the world — the processes by which full SHW systems are delivered into households is a more evolutionary and configurational process (Models of Diffusion, Chapter 2), by which contractors try different components, tricks of the trade and methods of assembling the necessary components, until they find methods of installing systems which are suitable to their working styles. In this way, no two SHW installers work in exactly the same way. Manufacturers often have little or no input to this process — some have nothing to do with their technology once it leaves the factory floor.

For this reason, manufacturers often blame SHW contractors as the weak link in the industry (personal interviews). While this may often be the case, this is not something that must always be so.

7.4.2.a Manufacturers are the Leaders

If manufacturers do not take responsibility for the quality of the systems in which their products are used, there is no guarantee that anyone else in the industry will. It is their technology which defines the industry and keeps it alive. They therefore are the only ones with any control over where that technology winds up, and so must also be the ones to take some initiative — to the greatest extent possible — which will ensure the quality of the industry’s ultimate product: full installed hot water systems. If they do not, any system quality problems which exist today will only multiply as the SHW market grows.

As was seen with flexible factory automation technology (Acceptance of Technology, Chapter 2), designing a business model which takes responsibility for the quality of a system up through its delivery and implementation into the home may require a completely different business model or style of skills and management. There are at least three different business models which manufacturers could adopt in taking such an initiative.
7.4.2.a.i Sellers of Kits

First (as mentioned in the "SHW Technology and Economics" section of this chapter), manufacturers might decide to remain in their central position in the industry, sending their products out into the world. The difference is that their product could be changed to full SHW system kits, with as many of the components pre-assembled as possible, without their becoming too inflexible to SHW installers. This would allow all component quality decisions to rest with the manufacturer.

However, this would require that manufacturers become knowledgeable of all of the necessary system components. For manufacturers whose systems require little in the way of needed extra components, this may not be problem. For other manufacturers, this could be a significant obstacle.

7.4.2.a.ii Manufacturer-Distributor/Wholesaler Partnerships

Second, manufacturers might decide to sell only through distributors (or through only one distributor) who take on the task of assembling the collectors into kits with their components — the choice and quality of which would be subject to negotiation between the manufacturer and distributor. The distributors, if exclusive and only few in number, might also have an incentive to promote the manufacturer’s products to a greater extent, as their exclusivity would ensure that no one else would benefit from their promotional efforts (Appropriability and Complementary Assets: Chapter 2). However, the more professional relationships that exist (as with a network of partners), the greater the time and expense required to maintain them.

7.4.2.a.iii Manufacturer-Installer Partnerships

Third, as some companies currently do, manufacturers could take on the job of installing the systems themselves. But then, of course, they are limited to one geographic region. The extension of this model would be to have a network of exclusive contractors over several geographic areas, whose choices of materials and methods of installation are subject to manufacturer approval. As with the manufacturer-distributor model (above), use of the manufacturer-installer network model could entail a great deal of managerial time and effort.

7.4.2.b Reliance on Specialty Contractors is a Hindrance

Whichever business models companies choose, the use of specialty contractors could become a limiting factor to the industry, should sales volumes ever begin to climb rapidly: there will not be enough of these contractors in other parts of the country to meet demand. The two solutions to this dilemma are to either train more specialty contractors, or else to design systems so that specialty SHW contractors are no longer necessary. The choice is not an easy one to make. If the industry takes the route of training more specialty contractors, issues of an educational infrastructure and of uneven skill distribution must be
considered. On the other hand, should the industry go the route of designing systems such that specialty skills are not needed, much more technical innovation is needed.

It would seem, that the greater the extent to which room for human error is removed, the better. The removal of the need to train contractors would allow the industry to focus more time on its marketing and technical innovation activities, as well. However, it is not clear that specialty skill will ever be able to be completely removed from the SHW installation process. If collectors are mounted into the roof framing flush with the roof surface, special skills similar to those needed for skylight installations are needed. If the collectors are mounted either onto the roof surface (as is common practice), or if mounted anywhere away from the home, a penetration of the household envelope is still required, also requiring some special skills. At the very least, it may be possible to remove most of the errors involved with the plumbing connections inside of the house. Appropriately bundling or suitably pre-assembling system components could allow the average plumber to perform the work.

7.5 POLITICAL CONTEXT OF THE SOLAR HOT WATER (SHW) INDUSTRY

"I would rather see and hear speeches made by Al Gore about the benefits of solar hot water, than see new tax credits"

— Solar hot water industry representative (personal interviews, 1998)

The political climate within which the current U.S. solar hot water industry operates is a mixed one, which seems to display either enthusiasm or complete silence. While the Department of Energy is enthusiastic about SHW and acknowledges that the technology offers benefits (both environmental and economic) which are currently superior to those of photovoltaic technologies (which generate electricity from sunlight), the concept of heating water with solar energy seems to be met with silence and apathy by the rest of the government (personal interviews, 1998). Almost unanimously, the interviews conducted during this study revealed that members of the SHW industry feel ignored by the federal government, with the exception of the Department of Energy.

This is puzzling to the SHW industry, because their technology clearly addresses issues which, they assume, are of concern to the federal government. Specifically, such issues include:

- the economic welfare of Americans;
- investing in the future (money, technology, resources);
- improving the environment and air quality;
• improving the energy efficiency of the economy;
• being a world-leader in technology.

President Bill Clinton, at least, seems to be concerned with the issue of energy efficiency. During his State of the Union Address in January, 1998, he said: “We have it in our power to act right here, right now. I propose $6 billion in tax cuts ... to encourage innovation, cleaner factories, fuel-efficient cars, and energy-efficient homes” [emphasis added].

7.5.1 WIN-WIN SITUATIONS

SHW manufacturers, as well as the data in this report, find that solar hot water presents win-win situations to all parties involved: it saves consumers money, improves the energy efficiency of the national economy, and reduces pollution. Certainly, lending a friendly voice to the cause of the industry can cost the government nothing; industry representatives therefore wonder why the federal government as a whole seems so apathetic about solar hot water.

7.5.2 WHAT THE SHW INDUSTRY WANTS

The “Number One” wish of the SHW industry — with nearly unanimous consent of all parties interviewed — is for the federal government to show more vocal enthusiasm for solar hot water technologies. Their “Number Two” wish is that financing mechanisms be made available, so that the high up-front cost of installing SHW is removed as deterrent towards their purchase by would-be customers.

While the second of these requests is currently being addressed by the Million Solar Roofs Initiative — a Presidential initiative being led by the DOE to install solar technologies on one million roofs in the United States by 2010 — the industry’s first and foremost plea for vocal support seems to go unheeded.

7.5.3 WHAT SOLAR HOT WATER OFFERS

The technology of the U.S. solar hot water industry is used to heat water for household tap water purposes by using the sun’s energy. In doing so, solar hot water systems do two things:

• Save money for consumers. Typically, consumers save 60%-80% on the portions of their yearly utility bills which account for water heating. With average expenditures of $400/yr to heat water with electricity, these savings can be substantial. (See Chapter 5, or “Economics,” in the first section of this chapter.)
• Save energy and reduce CO₂ emissions by amounts comparable to those which would be realized if automobiles driving 15,000 miles per year doubled their fuel efficiency from 30 mpg to 60 mpg. (See “Energy and Environmental Benefits” in the first section of this chapter.)
7.5.4 ADDITIONAL BENEFITS

The use of solar water heating technologies could provide a new type of financial benefit to the government. This possibility stems from the growing international concern about global warming (caused in part by emissions of carbon dioxide — CO₂). Choosing SHW heaters over conventional technology saves significant amounts of energy and thus avoids significant amounts of CO₂ production (Figure 7.1-C). It is possible that an international system of tradable CO₂ permits could be implemented in the future as a measure to reduce global CO₂ emissions. This is suggested by Article 6 of the Kyoto Protocol (UN, 1997), which states:

"any Party ... may transfer to, or acquire form, any other such Party emission reduction units resulting from projects aimed at reducing anthropogenic emissions ..."

Because the United States is a large consumer of fossil fuels, it is also a large generator of CO₂ emissions. It is therefore foreseeable that the U.S. might need to purchase CO₂ emission permits from other countries in the future, should such a system ever be adopted. Thus, by reducing its CO₂ emissions by as much as possible at home, the nation could potentially save money in the future. As solar hot water is a technology which clearly offers an economic opportunity to do this, the government may wish to pay it more notice.

7.5.5 CONCLUSIONS: A FEDERAL VOICE IS APPROPRIATE

Positive, public comment by the federal government, educating the public as to the facts of solar hot water, and lending credibility to the industry, is the first and foremost want of the U.S. solar hot water industry, and would further the interests of the federal government.

Consumers are misinformed about solar hot water technologies, and the open market is therefore not choosing a worthwhile technology via its own mechanisms.

The data from this report find that the general public likely shares the following views concerning the solar hot water industry (Chapter 6).

Common misconceptions include:

- SHW offers low economic benefits, if any;
- SHW collectors are low quality and aesthetically displeasing;
- SHW technology comes from manufacturers whose reputations are suspect.

Additionally, home builders show a moderate interest in using solar hot water products (Home Builders, Chapter 6), but are hesitant to do so. They would feel more comfortable about it if the industry were partnered with larger companies or the federal government. Thus, showing a little vocal support for the industry could go a long way towards improving the interest of all parties involved. Specifically:
- the federal government would be aiding energy efficiency measures and environmental improvement;
- home builders, seeing federal support, may feel more comfortable and confident in SHW, and thus might adopt SHW as a new distinguishing feature in their homes;
- the SHW industry would receive due recognition as a credible industry;
- people deciding to adopt the technology (given appropriate conditions) would save money.
8. APPENDIX 1

8.1 ENERGY / ENVIRONMENTAL CALCULATIONS

The calculations below are the input for Figure 7.1-C. The calculate the energy saved (in BTUs/year) and CO₂ displaced (in lbs/year) under the following scenarios:

- A SHW system (which saves 75% energy over conventional technology) replaces a conventional gas water heater;
- A SHW system (which saves 75% energy over conventional technology) replaces a conventional electric water heater;
- An automobile that drives 15,000 miles/year, and that has a fuel economy of 30 mpg, has its fuel economy doubled to 60 mpg.

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<tr>
<th>key results</th>
<th>data / calculations</th>
<th>reference</th>
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**Doubling fuel economy of auto (30→60 mpg)**
- avg. density of gasoline = 0.75 g/ml
- 1 gallon = 3.714 liters
- 1 kg gasoline contains 0.85 kg carbon
  \[0.75 \times 3.714 \times 0.85 = 2.413 \text{ kg carbon per gallon gasoline}\]
- 2.413 kg C/gallon gas (above)
- mol. wt. CO₂ / mot. wt. C = 44/12
  \[2.413 \times (44/12) = 8.85 \text{ kg CO₂/gal gasoline}\]
- doubling fuel efficiency avoids 5900 lb CO₂/yr
  - 30 mpg, 15,000 mile/yr \[\Rightarrow 500 \text{ gal gasoline/yr}\]
  - 60 mpg, 15,000 mile/yr \[\Rightarrow 250 \text{ gal gasoline/yr}\]
  - 18% original crude oil lost to refining and distribution
    \[\Rightarrow (250) \times 8.85 \text{ kg CO₂/gallon} / (1-18\%) \times (2.2 \text{ lb/kg})\]
    \[= 5900 \text{ kg CO₂ displaced}\]
- doubling fuel efficiency saves 38 million BTU/yr
  - 250 gallons gasoline saved /yr (above)
  - 125,000 BTU/ gallon gasoline
  - 18% original energy content of crude oil lost in refining and distribution (above)
    \[\Rightarrow 250 \times (125,000) / (1-18\%) = 38 \text{ million BTU}\]

- Downstream Alternatives, 1995
- Marland, 1989
- Downstream Alternatives, 1995
- United States, DOE, 1992
<table>
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<tr>
<th>key results</th>
<th>data / calculation</th>
<th>reference</th>
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<tr>
<td>• 1391 (2.2) = 3000 lb CO₂/yr displaced w/ SHW, when replacing natural gas water heating</td>
<td>• 31800 cu.ft. gas/yr consumed by water heating (4-person household average)</td>
<td>- Energy Information Administration, 1994</td>
</tr>
<tr>
<td></td>
<td>• 1.26 mol CO₂ / cu.ft natural gas</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 44 g/mol CO₂</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 5% fuel lost in production/distribution</td>
<td>- United States, DOE, 1992</td>
</tr>
<tr>
<td></td>
<td>• assume 75% energy savings by SHW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>➔ 31800(1.26)44 / (1-5%)(0.75)= 1391 kg CO₂/yr</td>
<td></td>
</tr>
<tr>
<td>• 26 million BTU saved per yr w/ SHW, when replacing gas water heater</td>
<td>• 32.7 million BTU from natural gas per year used in water heating</td>
<td>- Energy Information Administration, 1994</td>
</tr>
<tr>
<td></td>
<td>• 5% energy/fuel lost in distribution (above)</td>
<td></td>
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<tr>
<td></td>
<td>• assume 75% energy efficiency of SHW</td>
<td></td>
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<tr>
<td></td>
<td>➔ 32.7 (0.75) / (1-5%) = 26 million BTU saved /yr</td>
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</tbody>
</table>

**SHW versus conventional electricity**

<table>
<thead>
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<th>key results</th>
<th>data / calculation</th>
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<tbody>
<tr>
<td>• 5700 lb CO₂ /yr avoided, when replacing electric heating w/ SHW</td>
<td>• 3864 kWh used /yr to heat water</td>
<td>- EIA, 1994</td>
</tr>
<tr>
<td></td>
<td>• 0.9 kg CO₂/kWh (over whole fuel chain)</td>
<td>- United States, DOE, 1992</td>
</tr>
<tr>
<td></td>
<td>• assume 75% energy efficiency of SHW</td>
<td></td>
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<tr>
<td></td>
<td>➔ 3864 (0.75) (0.9) 2.2 lb/kg = 5700 lb CO₂ /yr</td>
<td></td>
</tr>
<tr>
<td>• 25 million BTU saved per yr w/ SHW, when replacing electric water heater</td>
<td>• 3864 kWh used / yr to heat water</td>
<td>- EIA, 1994</td>
</tr>
<tr>
<td></td>
<td>• 60% of original fuel energy lost in generation and transmission</td>
<td>- United States, DOE, 1992</td>
</tr>
<tr>
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<td>• assume 75% energy efficiency of SHW</td>
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<td>➔ 3864 (0.75) / (1-60%) = 7250 kWh saved /yr</td>
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