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Market Assessment of Thermal Energy Storage

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ABSTRACT

The objective of this market assessment was to survey key participants of the three major industries (equipment manufacturers, electric utilities, and architects and engineers) involved in the implementation of thermal energy storage technology to determine the current state of the TES industry and predict future growth of thermal energy storage technology. The results of this assessment can be used to shape the future role of EPRI, TSARC, and other organizations and companies in this industry. The primary focus was cool thermal storage for commercial buildings.

The report includes the results of a national survey, information from other reports, information that has been gathered by the HVAC&R Center and TSARC, experiences of Center Staff and written input by nine selected experts in commercial cooling.

This report includes an overview of the current structure of Thermal Energy Storage for cooling and heating of buildings, process, and inlet turbine cooling. The report assesses the use of thermal storage for cooling commercial buildings.

The purpose of this report is to reflect the current consensus assessment of thermal energy storage, key benefits, barriers to market growth and development, and the near-term future of thermal energy storage.

ACKNOWLEDGMENTS

We extend our sincere appreciation to all of the participants in the development of this survey. We would like to thank Delores Niles and Nancy Davenport-Sis of the Wisconsin Survey Research Lab for their efforts in developing the survey. We appreciate the nine detailed opinions provided and wish we could provide the names of these experts; however, several requested confidentiality. We would also like to thank Ron Wendland in particular for his input during the development stage of this survey and his detailed review of the final results and report. Bruce Lindsay and Doug Reindl of the HVAC&R Center were essential in the review of the survey results and preparation of this report. We also appreciate the work the HVAC&R Center staff in assisting with the final report.

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1. EXECUTIVE SUMMARY

Thermal Energy Storage (TES) systems -- technologies designed to store heat or cold energy for later use -- are poised to become an ever more important part of the heating, ventilating and air-conditioning (HVAC) market. Modern TES systems are energy efficient, environmentally beneficial (i.e., "green"), mechanically reliable, and easily maintained. It is the consensus of many of the experts on TES that it is a technology whose time has come.

There are over 3,000 cool storage installations in the U.S. (mainly commercial and industrial) and over 35,000 heat storage systems (mainly residential installations using ceramic bricks). Approximately 450 additional cool storage systems will be installed in 1996.

This report is an overview of a study commissioned by the Electric Power Research Institute (EPRI) to collect information regarding the current perception of TES by designers, utilities, and manufacturers; the study was commissioned to assess the existing market and future market potential of TES systems. Eighty individuals from the three major industries involved in the implementation of TES technology participated in the survey. The survey participants came from:

- Utilities (54 firms representing utilities with generating capacities ranging from less than 100 MW to over 26,000 MW)
- Manufacturing (17 firms representing over 95% of the cool TES market)
- Architect and engineering (9 firms ranging from full design to specialty consulting).

Information related to both cool storage and heat storage was collected from sources with first-hand knowledge of TES systems and installations. A great majority of the representatives (and their organizations) had experience with various forms of TES; the majority of this experience was with cool storage, while some respondents had experience with heat storage.

Comments were solicited from known TES experts following the survey data collection. These experts, for the most part, agreed that cool TES is an HVAC technology that has matured over the last two decades and the market penetration of TES systems will continue to increase.

A conclusion reached after combining a consensus of experts with this study was that cool storage is applicable for approximately 60-80% of new commercial installations, and that 30-40% of these will have an appreciable first-cost benefit. However, it is anticipated that only 8-12% of planned installations will have cold storage installed during the next 5 years under current planning and design processes. The reason for this is the complex requirements for successful design, which is typically not fully funded by the building owner.

Cool TES may be the best societal answer to future cooling needs. Combining TES with direct cooling systems reduces emissions, increases generating efficiency, saves energy, and reduces refrigerant inventories. In addition, it has the benefits of shifting peak electric load, providing equipment redundancy, improving dehumidification, and lowering life cycle costs. It is a option which can enhance the productivity of cooling, heating, and refrigeration systems. For example, a study at TSARC for Texas Utilities and a study for the California Energy Commission have shown that cool storage reduces total source energy and reduces total environmental emissions. This, in addition to the economic benefits, is a strong justification for cool storage.

Recommendations for TSARC, EPRI, and the industry are:

- Numerous cool TES seminars and workshops have been held. However, it is evident by the data that more technology transfer is required in order to accelerate the acceptance of TES systems and stress the following:
    - ◊ End use benefits; for any product or service to be successful in the marketplace, it must provide benefits to both the vendor and the consumer.
    - ◊ Electric utility deregulation and its impact on rate structures; TES allows for flexibility in the use of electric power.
    - ◊ Environmental concerns, including lower emissions for night-time operation of power generation stations supplying cool TES systems and the reduced refrigerant requirement of smaller-capacity TES equipment .

    - ◊ Power generation, application with combined cycle turbine and inlet cooling, including the fact that many utilities use gas turbines for power but few use inlet cooling for improved generation capabilities.
    - ◊ Applications and benefits related to long term storage (weeks or more), industrial processes and advanced refrigeration in the U.S.
- Development of software tools to assess both thermal storage design and the improved economic benefits as rate structures evolve with utility deregulation.

Although this study only assessed the market for TES in the United States, it should be noted that some countries (including Taiwan, Korea, Thailand, and China) are taking a strongly positive position on cool storage for air conditioning. Other countries, such as Japan, have active electric utility programs.

2. INTRODUCTION

This report is divided into eight chapters:

Chapter 1 is the Executive Summary

Chapter 2 provides an introduction to thermal energy storage and gives an overview of this report

Chapter 3 describes the research methodology used

Chapter 4 contains the results of the survey

Chapter 5 describes the future of thermal energy storage

Chapter 6 presents conclusions and recommendations

Chapter 7 presents a suggested action plan for the HVAC&R Center

Chapter 8 describes follow-up opinions

2.1 Glossary of Terms

Cool thermal storage - Cooling capacity is generated during off peak periods or when excess cooling capacity is available and stored in the form of ice, chilled water, eutectic salts, or other media.

Full storage - A full storage system is one that is large enough to handle the entire cooling or heating load of the installation without operating chillers during electric peak periods. The system utilizes the stored energy to meet the load during the peak periods.

Heat storage - Heat energy is generated during off-peak periods by heating equipment and stored. This energy is then utilized during peak periods to reduce energy and/or demand charges.

Ice storage - Water is frozen, stored and melted as needed. Some methods include:

- Ice-on-coil (external melt) - ice forms on the outside of the coils and is melted from the coil by circulating water around the coil.
- Ice-on-coil (internal melt) - ice forms on the outside of the coils and is melted from the coil by circulating a warm liquid or refrigerant inside the coil.
- Encapsulated ice - ice forms inside capsules which are bathed in chilled water.
- ice harvester - ice forms on rods, tubes, or plates and is shed periodically; the accumulated ice is stored in a tank. When cooling water is required it is pumped through the ice, which lowers the temperature of the water, and this chilled water is then pumped through the air-conditioning piping system.

Partial storage - Partial storage systems are designed to assist an on-line cooling or heating unit through the cooling or heating period by providing stored thermal energy. The stored thermal energy is pumped through the cooling or heating unit to provide supplemental cooling or heating needed during the peak period. This supplemental energy reduces the required size of the chiller or boiler and therefore reduces peak demand, energy charges, and equipment cost.

Turbine inlet cooling - Turbine inlet cooling is cooling of intake air provided to a gas-fired turbine for power generation. The lower temperature of the inlet air increases generation capacity and efficiency of the turbine and provides the oxygen necessary for the fuel to burn. Thermal storage for inlet air provides a guaranteed generation capacity, regardless of ambient conditions.

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2.3 Objective

The objective of this market assessment was to survey key participants of the three major industries (manufacturers, electric utilities, and architects/engineers) involved in the implementation of TES technology to determine the current state and to predict the future growth of the TES industry. The results of this assessment can be used to guide the future role of EPRI, TSARC, and other organizations associated with this industry.

2.4 Issues

TES systems will have an increasingly important place in HVAC products and systems as the concern about environmental impacts of electric generation and refrigerant emissions become more widespread. CFC-related ozone depletion and the global warming issues surrounding HCFC and HFC refrigerants have become more and more pressing. TES systems take advantage of off-peak electricity generation (including generation by hydro-electric and nuclear stations), which consumes less fuel and can be more environmentally “friendly” (less pollution, etc.). Lower ambient temperature at night also helps to reduce electrical consumption by the TES system and therefore reduce electrical transmission and distribution losses. TES systems can be coupled with other environmentally-friendly technologies, such as geothermal or ground source heat pump systems.

Of the over 80,000 chillers currently installed in the United States, approximately 60,000 use CFC refrigerants. Manufacturing of new CFC refrigerants was halted on January 1, 1996. TES technology is a viable alternative in the replacement CFC chiller market and has additional benefits beyond cost savings. TES can be readily retrofitted into numerous existing HVAC systems. Partial storage TES systems use smaller compressors than a traditional chiller system, and therefore use less refrigerant.

TES systems can help to extend the life of the entire HVAC system by reducing cycling of the equipment. If one considers the amount of wear and tear on a HVAC system during peak periods - the middle of the day during the summer, for instance - the use of TES systems becomes even more attractive because the wear on a HVAC system is spread over a longer period with TES, thus reducing a spike or overload of the system. Furthermore, a HVAC system with TES can be designed with a smaller base capacity or chiller, since the TES system can provide the supplemental peak-period cooling.

State-of-the-art cool TES should be selected for many facilities because of its either lowest first- or life-cycle cost. Features of new TES systems include smaller chilled water distribution systems, cool storage with cold air distribution, and specialized combinations with other refrigeration plants (for example in supermarkets). It is frequently the lowest cost option for adding capacity or replacing an existing chiller plant, for developing turbine inlet cooling, for emergency stand-by cooling, and for industrial cooling needs.

Given the obvious advantages of TES systems over the major alternatives, the question arises: why doesn't TES have a larger portion of the HVAC market? Some specific issues - which this survey attempts to address - are:

- What is the knowledge level of TES within the three major TES industries?
- Is TES being favorably considered for HVAC projects?
- Why is TES not a larger factor in HVAC projects?
- What is the perceived future of TES?

The knowledge of TES which has been accumulated by the HVAC&R Center over its years of operation, in addition to the information gathered by this survey, indicates that professionals remain unaware of the wealth of information available on TES. This may be the result of a general negative bias against TES based on a few publicized reports or experiences.

The remainder of this document describes the survey and the detailed results in an attempt to answer these and other related questions.

2.5 Background on TES

Use of block ice from lakes, rivers, or desert ambient freezing cycles to cool buildings dates back over 1,000 years. The very first refrigerated cool storage systems were used in movie theaters during the 1920s; the storage system consisted of large blocks of ice. This is generally considered the first commercial building application of cool storage for air conditioning with refrigerated machines.

The modern development and growth of TES technologies has its roots in the "energy crisis" during the 1970s. The rising costs of energy, at the level of both the customer facility and the generation plant, provoked a great deal of interest in developing methods to reduce the expense of peak period electrical generation. In this context, TES was similar to other alternative energy technologies, such as solar energy and renewable energy in that only a few professionals had knowledge of or experience with the technology.

By the early 1980s TES had been installed at many sites nationwide; since that time, the number of installations has multiplied greatly. Robert Potter [1] estimates the total number of TES installations in the United States as of 1993 to be between 1,500 and 2,000. The technology has grown and developed over the past two decades and is now present in all segments of the marketplace, including the residential, commercial, industrial, and agricultural areas. There has been substantial international growth of the TES market in the past ten years. Interest in TES has decreased in some regions of the United States with the fall of oil prices and resultant stabilization of electrical prices during the last two years.

TES was originally developed as a demand-side management (DSM) tool designed to allow both the electric utility industry and the utility customer to limit and/or manage peak electrical demand. Although the current motivation for adopting TES continues to be demand shift and reduction, TES is also frequently selected for higher efficiency, more efficient load satisfaction, increased building comfort and indoor air quality, reduced maintenance, and refrigerant inventory reduction. TES systems take advantage of off-peak electric rates (when electricity is less expensive) or chiller plant excess capacity (capacity that exceeds concurrent cooling demands) for the production and storage of cool or heat energy. This stored energy is used during on-peak electrical rate periods or during peak cooling or refrigeration periods, thereby reducing (or shifting) electrical demand and usage. TES reduces the size of the cooling plant in many systems by utilizing the chillers throughout the full 24-hour day. Cold air distribution has been used for 10 years to reduce the first cost and operating costs of cool storage systems. However, many major manufacturers have not developed specific products for cold air distribution or even re-rated existing diffuser products for use with cold air applications.

The economic feasibility of TES relies on the following: planning and design for low first cost; control for electric savings achieved by shifting demand and usage to off-peak electricity rate periods; and down-sizing chiller plants heat-rejection equipment and distribution systems. In some projects, projected savings in energy, demand charges, and maintenance are used to offset project capital costs through a pay-back calculation. TES is most cost-beneficial to the customer when the utility either has a significant on-peak demand charge or offers a special time-of-day rate (which may be seasonal). TES is ideal for both the customer and utility when a high, narrow load profile occurs during the utility's on-peak period. Although this chiefly applies to cooling, similar strategies may be used for heat storage and low-temperature refrigeration.

There are three basic design strategies for TES systems:

- **Partial storage load leveling** reduces electrical demand during on-peak periods, reduces the size of the chiller plant needed, and operates the chiller equipment during most of the 24-hour day or the design storage cycle (e.g. weekly). When the capacity of the chiller equipment exceeds the load, the excess cooling is stored in TES system. When the load exceeds the chiller capacity, sufficient cooling is removed from storage to meet the load. This partial storage system 'levels' the load so that the equipment runs at or near capacity during the entire day and supplemental cooling is provided by storage. Figure 2-1 shows a diagram of the cooling load for a typical office building vs. the cooling provided by the chiller with excess cooling provided from storage.
- **Full storage** shifts the demand (load shifting) for cooling to off-peak electric rate periods. Load shifting runs the chiller equipment during the off-peak hours to store cooling and then turns the chiller off during the on-peak hours (times when the electric charges are highest). This full-storage system utilizes the chiller to capacity during off-peak periods and the storage to capacity during on-peak periods. Figure 2-2 shows the cooling load, the cooling provided, and the on-peak hours when the chiller equipment is not running.
- **Partial storage demand limiting,** a hybrid between leveling and full storage, utilizes TES to provide the additional cooling needed when building demand reaches a pre-established maximum level. In this design strategy, TES limits the building total electric demand to at or below a pre-established level.

In all properly designed storage systems, the area under the cooling load curve (the solid line on the following three figures) is equal to the area under the chiller operations line (dotted line.)

Figure 2-1 : Partial Storage - Load Leveling Profile

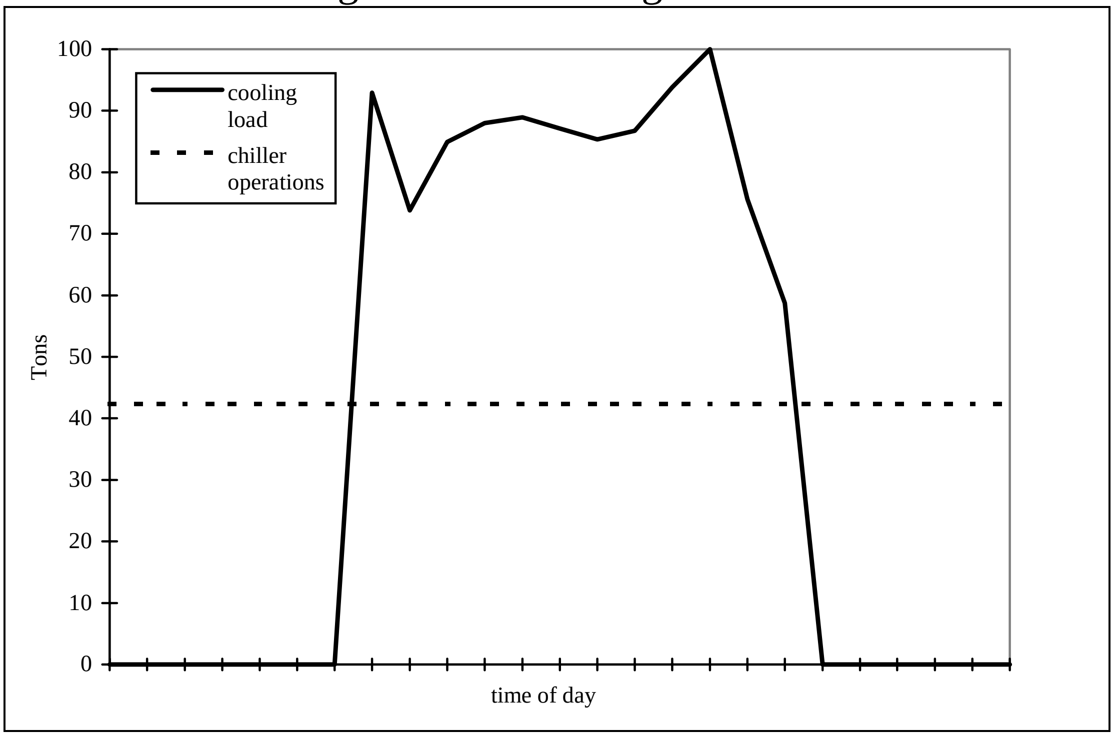


Figure 2-2 : Full Storage Profile

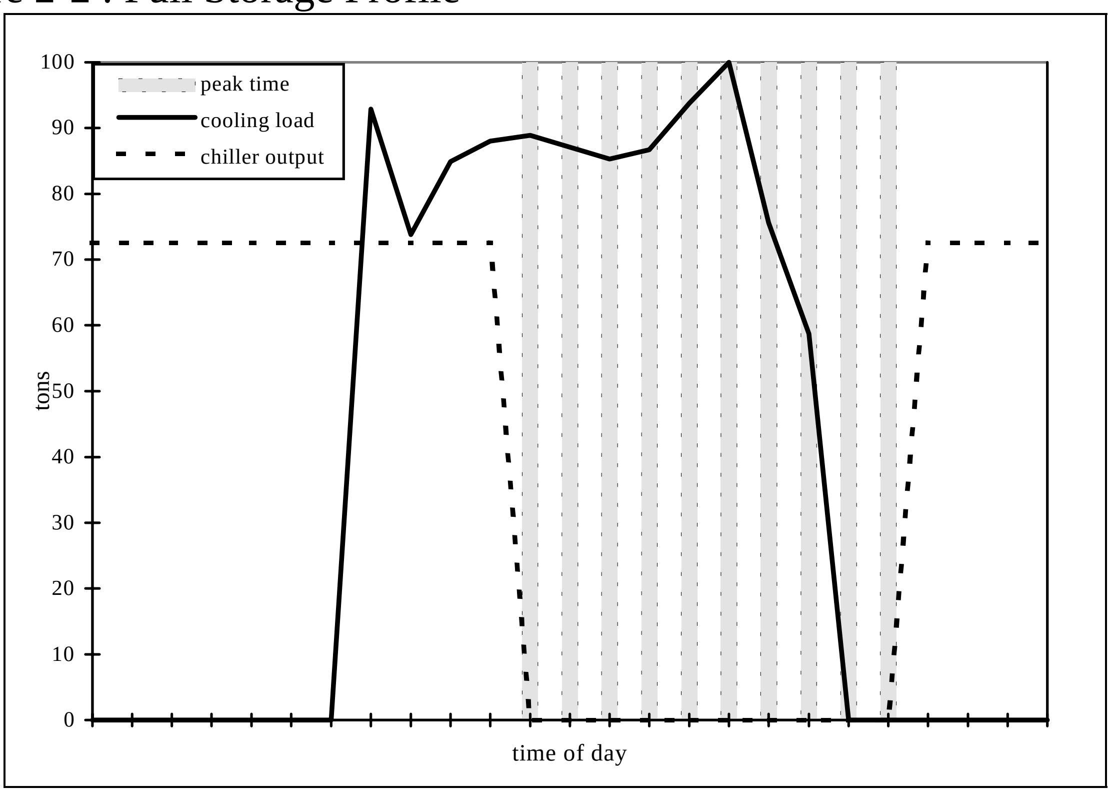
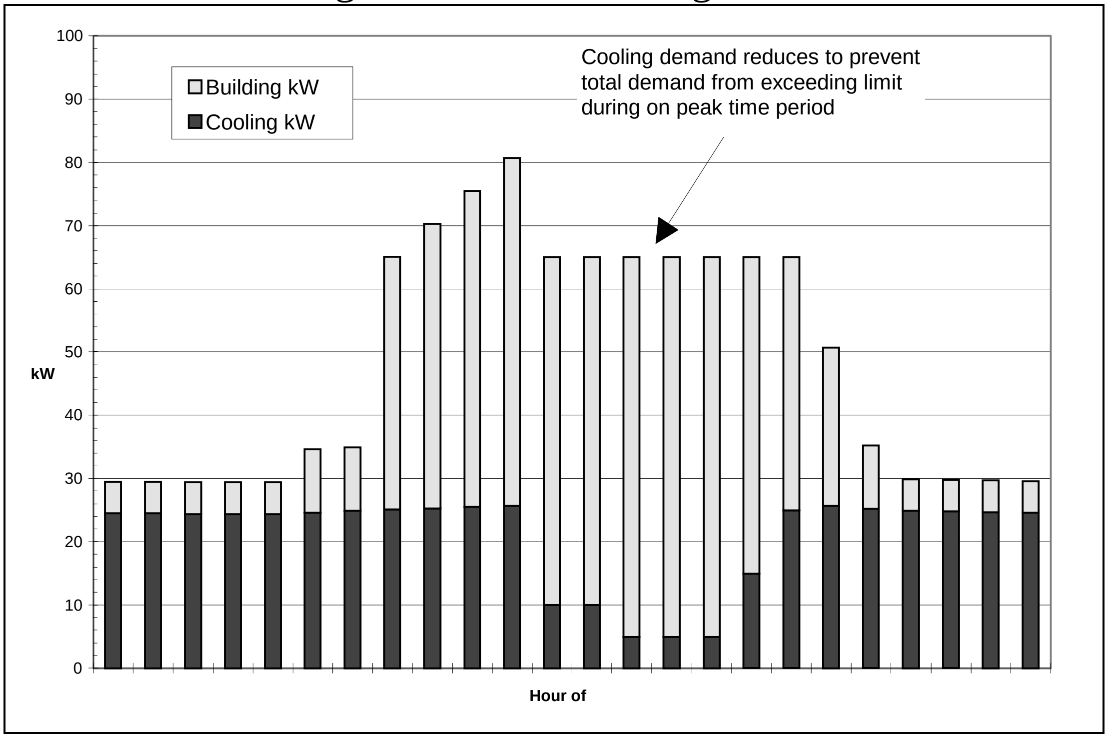


Figure 2-3 : Partial Storage - Demand Limiting Profile



2.6 *Emerging Technologies*

The majority of the survey answers and resultant conclusions in this TES market assessment are based on existing typically-applied TES approaches and applications. There are, however, some emerging applications and new technology that could alter the growth in the thermal storage market.

Up to the present, the majority of cool storage installations have been aimed at the medium to large building commercial cooling market. One potential new application for TES is the use of cool storage to condition the inlet air for gas turbine generators. There are currently two fully operational systems for turbine inlet cooling; both systems utilize ice storage exclusively. However, there is a large interest in this use and it could be a major TES application and provide market growth over the next 20 years, especially considering that several more projects are currently under development. Several variations of this technology are being developed; the most promising uses a mix of both ice and chilled water storage specially optimized to provide the greatest flexibility in providing air which is sufficiently chilled to create appropriate generator efficiencies.

Another newly developed application for cool storage is district and central plant cool storage systems. Some of the most successful cool storage installations to date have been large central plants. There are six district storage systems under development; these should provide a wealth of knowledge to assist in the design and installation of more district cooling systems. This experience could positively affect the growth of cool storage for the industrial market and retrofit of large chiller plants or replacement of CFC chillers.

Another growth market is TES applications for industrial refrigeration. There has been some use of TES for refrigeration during production and warehousing. There are also a few supermarket installations in the United States and Europe. Cool storage, moreover, has been used for short-term warehousing of agricultural products in Europe and on-site at-harvesting field storage of produce in California. Refrigeration for manufacturing, warehousing, and retail (e.g. supermarkets) could be a great opportunity for the TES market. Some companies have been very active in developing new refrigeration applications of cool storage, including a long-term involvement with the dairy industry.

Another development that can expand the market is new technologies. The small commercial and residential markets have not yet been presented with an economical TES product that meets their cooling needs. Some recent successes have been achieved with small heat storage units. Storage units for residential and small commercial buildings are under development; these units could change the market's size and character within 6 years. Other new products that may help the growth of the cool storage market include “slippery ice” and “slush ice”. Some units have or are being installed to gain initial experience with the technology. An additional new technology is dehumidification through TES, in the form of packaged storage units that provide dehumidification of outdoor air for schools and hotels as well as increased flow rates for office, industrial, supermarket, and other buildings that require a dehumidification unit instead of an air-conditioning process unit.

This survey highlights some major concerns and problems with cool storage applications. Some solutions are offered through printed materials and studies on TES effectiveness and efficiency; TSARC has published a report on the source energy benefits of cool storage, and a report will soon be available from the California Energy Commission on the significant source energy and emission benefits of cool storage. These publications could dramatically change owner and regulator opinions of cool storage. These publications could also improve any current projections of market growth for TES. Some other materials that promote TES or provide important information for owners and designers interested in TES are the following:

1. ARI:
   Guideline T, Rating of TES Systems
   Standard 900P, “Method of Testing For Rating Ice Harvester/ Chiller Thermal Storage Devices”
2. ASHRAE:
   GPC-1-1989R, “Commissioning Process Guideline”
   Standard 150P, “Method of Testing the Performance of Cool Storage Systems”
   “Guide for Cool Storage Design”
   Research Project: “Implementing Cool Storage”
   Design Guide for Cool Storage
3. EPRI:
   TR-101480 “Determination of the Operation Characteristics of Cold Air Diffusers”
   TR-104521 “Cool Storage Total Building Construction Cost Benefit”
   TR-104906 Cool Storage Open Hydronic Systems Design Guide

A final application - this of heat thermal storage - which is gaining in popularity is the integrated heat pump. Both water and brick storage systems are being used to replace the electric resistance heating elements in a conventional heat pump. The same principle of reducing on-peak electric use by storing heat generated during off-peak hours is employed; the storage capacity requirements of the integrated system, when compared to standard heat storage systems, are greatly reduced.

3. RESEARCH METHODOLOGY

This chapter describes the literature review, development of the survey questionnaire, and survey candidate selection. In addition, information related to survey performance, analysis, significance, and limitations is discussed.

3.1 Literature Review

The Center performed a literature review which included EPRI publications related to TES and demand-side management (DSM), as well as, relevant ASHRAE documents and major engineering publications. The review was used to formulate the background and define the problem for the market assessment. The literature search focused on publications and articles dated from the late 1980s to the present. The project's literature research identified a number of issues related to the present status and future growth potential of TES in the marketplace. These issues became the basis for the development of the survey. A list of relevant literature is provided in section 2.2.

3.2 Survey Development

The purpose of the survey was to collect information from utilities, manufacturers, architects, and engineers regarding their perceptions of the TES market at present and the market's future potential. Information related to both cool and heat storage was collected from individuals with first-hand knowledge of TES systems and installations. The survey was divided into two parts: the first, a common series of questions asked of all participants; and second, a series of questions for each of the three groups of respondents in order to obtain information specific to each group. Survey questions fell into four basic categories:

1. Respondent's perception of and experience with TES;
2. Applicability of TES technology;
3. Effects of incentives and competition on TES market penetration; and
4. The future of TES.

Specific TES topics explored:

- Knowledge of TES
- Experience with TES
- Knowledge of new technologies
- Comfort level of respondents in promoting new technologies
- Current HVAC project(s) status
- Suitability in various applications
- Benefits to application
- Barriers to application
- Incentives - effect on market penetration
- Competitive technology - effect on market penetration
- Future for TES technology from 1995 - 2010

The survey asked questions using three formats: yes/no, multiple choice, and open-ended text questions. Data from questions was collected and analyzed. Additionally, opinions were solicited from selected industry professionals about to the future of TES, based on historic and current information.

3.3 Survey Participants

A database of over 700 EPRI member utility contacts was used to randomly select 54 names. A list of 50 architect and engineering firms active in the design of TES installations was developed based on information gleaned from industry experts in manufacturing and utilities; nine (9) participants were randomly selected from this list. A list of manufacturers active in the manufacture or sale of TES equipment was obtained from ITSAC (International Thermal Storage Advisory Council) and the publication Heating, Piping, Air-Conditioning, and from this list 17 participants were selected. A total of eighty (80) respondents participated in the survey.

3.4 Survey Performance

The survey was conducted by the *Wisconsin Survey Research Laboratory*, a department of the University of Wisconsin-Extension. The Laboratory also assisted in the design of the survey to improve its presentation, and evaluate the 'flow' of questions to avoid querying respondents in areas that were not relevant. As a result, the number of responses to specific questions varies depending upon the number of respondents queried.

The survey was conducted via telephone during late November and early December 1994. During this three-week time period, the Laboratory called all eighty participants. Due to individual respondent schedules and availability, some interviews were completed during successive telephone conversations. The average interview was completed within 25 minutes. Survey respondents were very cooperative and responded favorably to survey content and format. Data was entered directly into the computer during each interview. The expert opinions were gathered from January 1995 through May 1995.

3.5 Survey Analysis

The Survey Lab provided initial compilation of the data in a 348 page report. This included the summaries of each question, as well as the transcribed responses to the open-ended questions and any additional comments made by the respondents. Raw data was also provided electronically.

Following initial compilation of data, basic statistical operations were performed and tables and charts were developed - where applicable - using Microsoft® Excel version 5.0. Additionally, verbal responses to open-ended questions were compiled following the survey with like answers weighted appropriately. A select number of TES industry professionals were asked to submit comments and opinions regarding the present and future state of TES. Opinions from these experts are contained in chapter 8.

The survey queried respondents from the three major industries involved in the implementation of TES technology; utilities (54 firms), manufacturers (17 firms), and architect and engineering (9 firms). The three respondent groups were asked a series of questions, 92% of which were common to all groups. In an effort to glean data from each group, questions were drafted which were specific to each group of respondents. The data was combined where the same question was asked of each group.

3.6 Survey Significance and Limitations

This market assessment attempts to forecast the future of TES over the next 15 years based on market survey data, perceptions of the 80 respondents, and opinions of the experts. When dealing with perceptions, researchers and readers must keep in mind the limitations of this type of research as it relates to participants' length of experience with TES, the informal (verbal/open-ended) nature of some survey questions, and the limited sample size of utilities and architect and engineers. Additionally, the ability to forecast TES market penetration relies on numerous unpredictable variables (electric rates, HVAC competition, system performance, and unknown factors affecting the HVAC industry).

The small sample size of architects and engineers makes it difficult to extrapolate for the entire profession; however, it is useful for understanding the concerns of this group and understanding trends and ideas.

Leaders and innovators frequently have as much impact on technology as does the consensus of the majority. However, surveys serve an important role in assessing the “conventional wisdom”. While this assessment may not always match EPRI’s or HVAC&R manufacturers' goals, it can be used to provide insight on how to adapt or adjust to better meet customer needs.

The survey participants were selected based on knowledge and experience with cool storage. The heat storage survey information is provisional, because the participants were not experts in heat storage (Table 4-2 vs. Table 4-19). We considered eliminating these questions from the report due to this knowledge bias; however, there are only a few questions and they do present limited feedback information on heat storage (they do not represent “heat storage” expert knowledge.)

4. SURVEY RESULTS

This chapter summarizes the detailed results of the survey in an attempt to answer the market assessment questions.

The small notations at the lower parts of the figures and tables are references to the full survey results. They are intended for the authors to refer back to the full results for comparison and ensuring that information is accurately transcribed. Table 4-1 shows the distribution of the survey participants.

Table 4-1 : Distribution of Survey Participants

Respondent type	Number	Percent %
Electric utility	54	68%
Manufacturer	17	21%
Architects and engineers	9	11%
Total Respondents	**80**	**100%**

4.1 TES Experience

Of the 80 respondents, 68 (85%) indicated that their company had first-hand TES experience, while 12 (15%) respondents indicated that their firm did not have first-hand TES experience (Table 4-2). Based on their lack of first-hand TES experience, the 12 organizations (1 manufacturer and 11 utilities) were only asked a limited number of questions. The bulk of questions were asked of 43 (63%) utilities, 16 (24%) manufactures, and 9 (13%) engineers.

Utilities with TES experience (43 of 54 or 80% of the utilities) were asked questions regarding their generating capacity and customer base. Results show a broad range of generating capacity (Table 4-3)and customer base size (Table 4-4). Based on these results, we should be able to extrapolate the electric utilities results to the entire population of electric utilities.

Table 4-2 : TES Experience

Industry Group	Yes	No	Total
Utility	43	11	54
Manufacturer	16	1	17
Architects and engineers	9	0	9
Total	**68 (85%)**	**12 (15%)**	**80 (100%)**

q19

Table 4-3 : Utility Size by Generating Capacity

Generation Capacity (megawatts)	Number of Utilities
less than 1,000	4
1,000 - 4,999	19
5,000 - 9,999	6
10,000 +	9
Don't know	5
TOTAL	**43**

q 20

Table 4-4 : Utility Size by Customer Base

Number of customers	Number of Utilities
less than 100,000	4
100,000 - 499,999	15
500,000 - 999,999	7
1,000,000 - 1,500,000	5
more than 1,500,000	9
Don't know	3
TOTAL	**43**

q 20a

4.2 TES Knowledge

To gain confidence in the survey results, it was important to establish the respondent's level of knowledge and experience with TES. Questions in this section were designed to determine the respondent's knowledge level (Figure 4-1). All participants were asked to rate their level of TES knowledge. All architects and engineers were knowledgeable of TES technology, indicating a knowledge level of either 'a lot of knowledge' or 'some knowledge'. Utility representatives also indicated a strong knowledge base with 40 (74%) having either 'a lot of knowledge' or 'some knowledge' of TES technology, 13 (24%) indicated 'a little knowledge' and only one (2%) indicated 'no knowledge' of TES technology. These results confirm the assumption that those chosen to participate in the survey were an informed group.

Interest in TES was also high among the survey group as shown in Figure 4-2. When asked how comfortable the respondent was in promoting new technologies, most indicated that they were either 'very comfortable' or 'somewhat comfortable' in promoting new technologies (Figure 4-3). Participants were asked this question to gauge if TES being a 'new technology' was a factor in its promotion and market penetration. They were also asked about different TES applications. This appears to be very positive for TES's future; although the exact numbers are not known, this is expected to be higher than competing DSM cooling technologies.

Figure 4-1 : Knowledge of TES

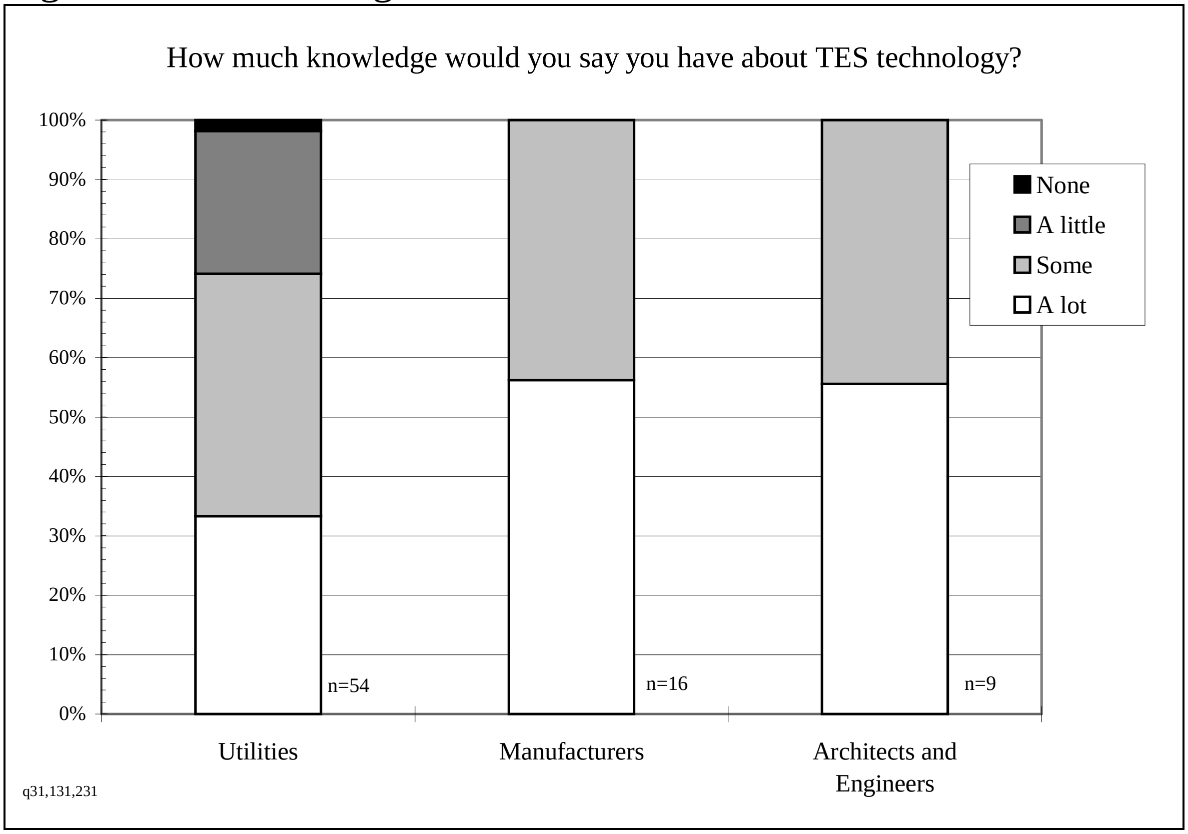


Figure 4-2 : Interest in TES

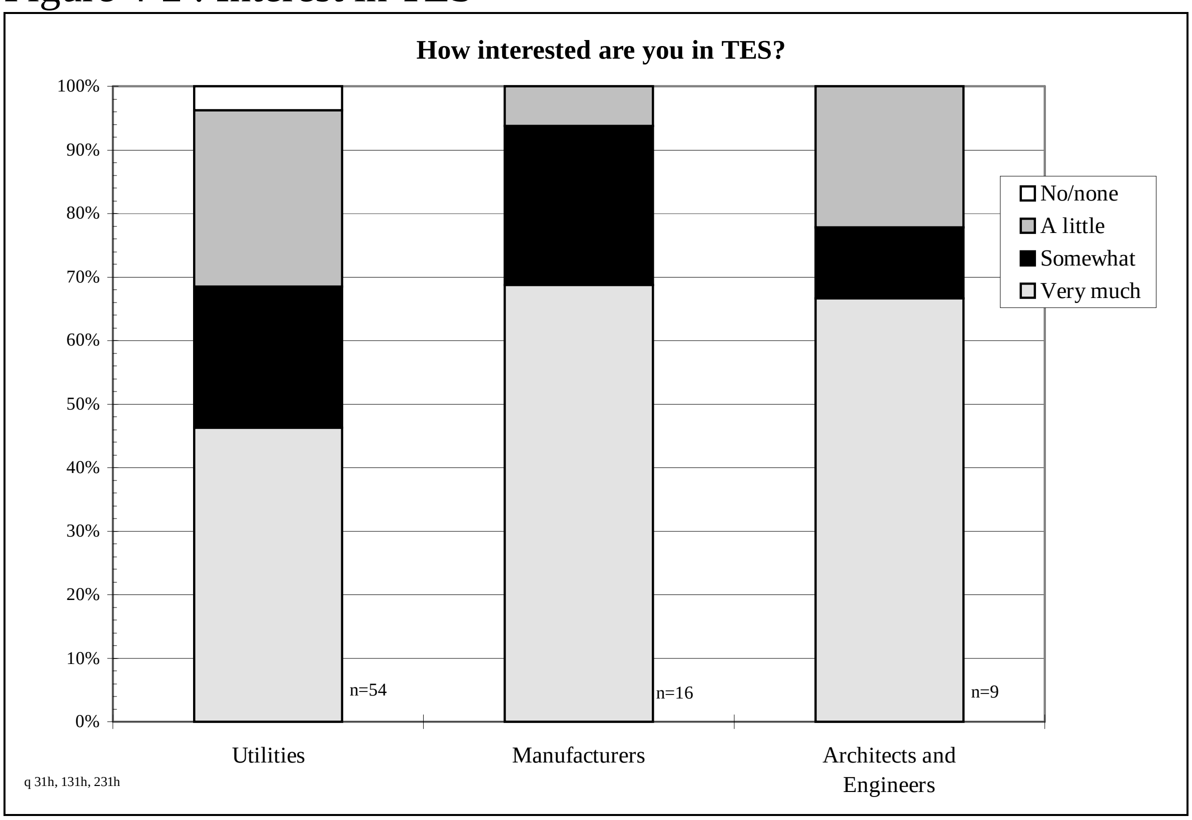
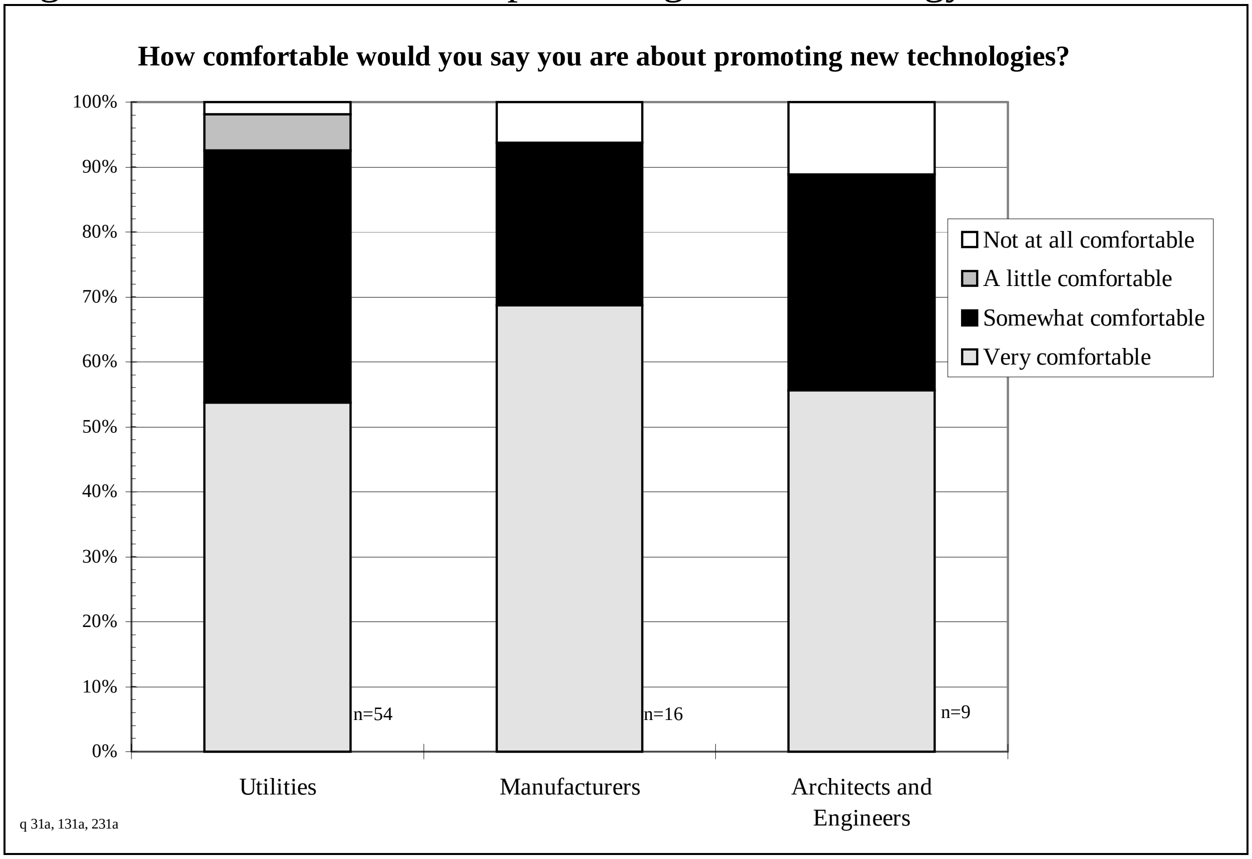


Figure 4-3 : Comfort level in promoting new technology



4.3 Perceptions of Cool TES

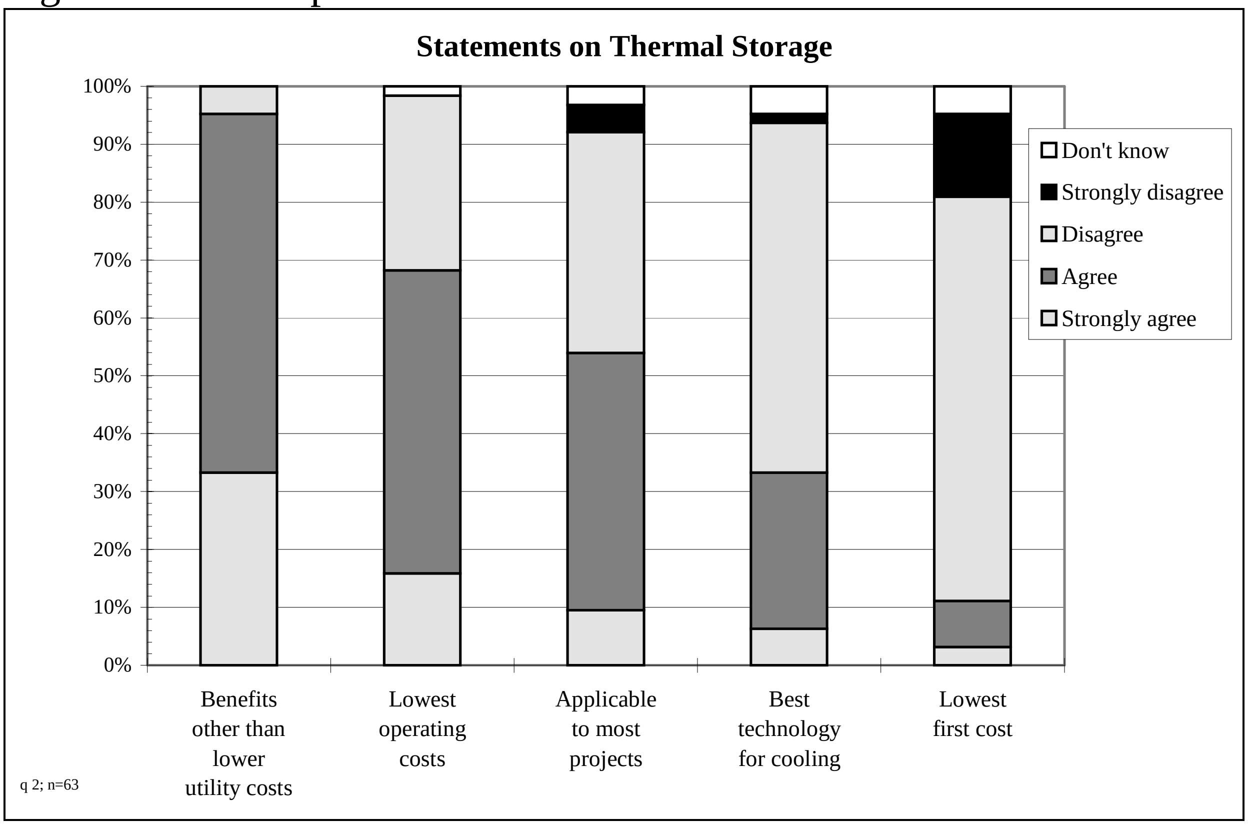
Participants were asked to respond to questions relating to their perceptions of TES in efficiency, economics, applications, and competition.

Those respondents whose firms had cool storage experience (63 of 68, or 93% of those with TES experience) were asked to respond to five questions regarding their perception of cool storage. More than half of the respondents 'agreed' or 'strongly agreed' that cool storage is applicable to most projects, has the lowest operating cost, and has benefits other than lower utility cost. It was, however, the consensus of this group that cool storage is not the best technology, in general, for cooling or that it is the cooling technology with the lowest first cost (Figure 4-4.)

Conclusions that can be drawn from these questions are that TES systems have benefits other than utility costs and lower operating costs. However, TES systems do not have the lowest initial construction cost, and therefore are difficult "sells." The focus of TES should be on the long-term benefits of TES systems showing that they have the advantages of better economics over the life of the system.

From this question, it appears that EPRI, electric utilities, and manufacturers need to document why and when TES is the best technology and lowest first cost.

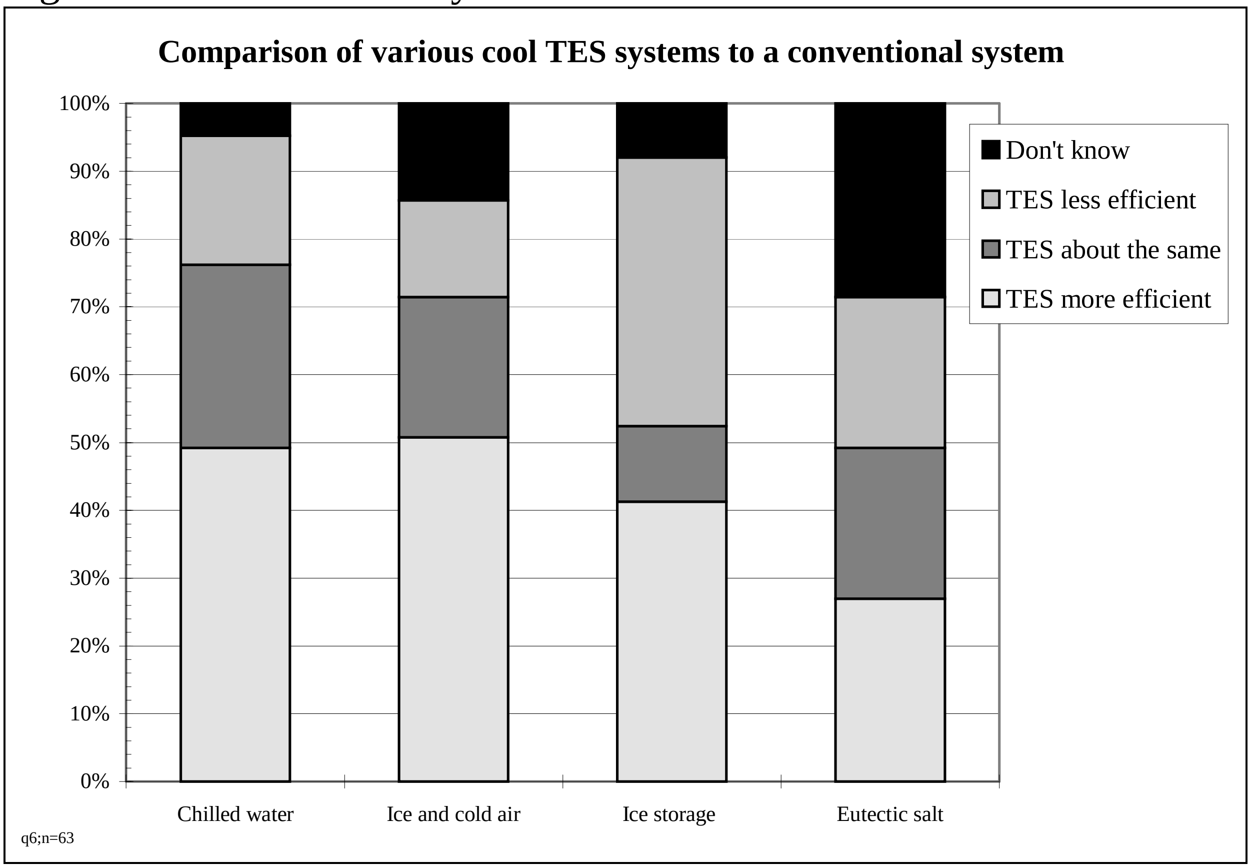
Figure 4-4 : Perceptions of Cool TES



4.4 Efficiency

The respondents were asked to rate the energy efficiency of cool thermal energy storage systems as compared to conventional air conditioning systems. Ice storage with cold air distribution (71%) and chilled water storage (76%) was thought to be 'as' or 'more' efficient than a conventional system. Ice storage was perceived as a less efficient technology. On the positive side, the general perception is that TES is more efficient than conventional AC systems. A small number (< 15%) still perceive TES as energy inefficient.[1]

Figure 4-5 : TES efficiency



[1] As on editorial note: many early TES systems were designed to shift load without regard to reducing energy use. Some utilities even took credit for more total energy use in their original rate and incentive proposals.

4.5 Applications

Participants were asked a series of questions relating to the applicability of TES in residential, commercial, industrial, and agricultural applications. Most of respondents indicated that TES is either ‘very applicable’ or ‘somewhat applicable’ in commercial and industrial projects (Figure 4-6). TES in agricultural projects was perceived as being less desirable, and residential projects were noted as being the least fitting application for TES.

Figure 4-6 : Applicability of TES to various applications

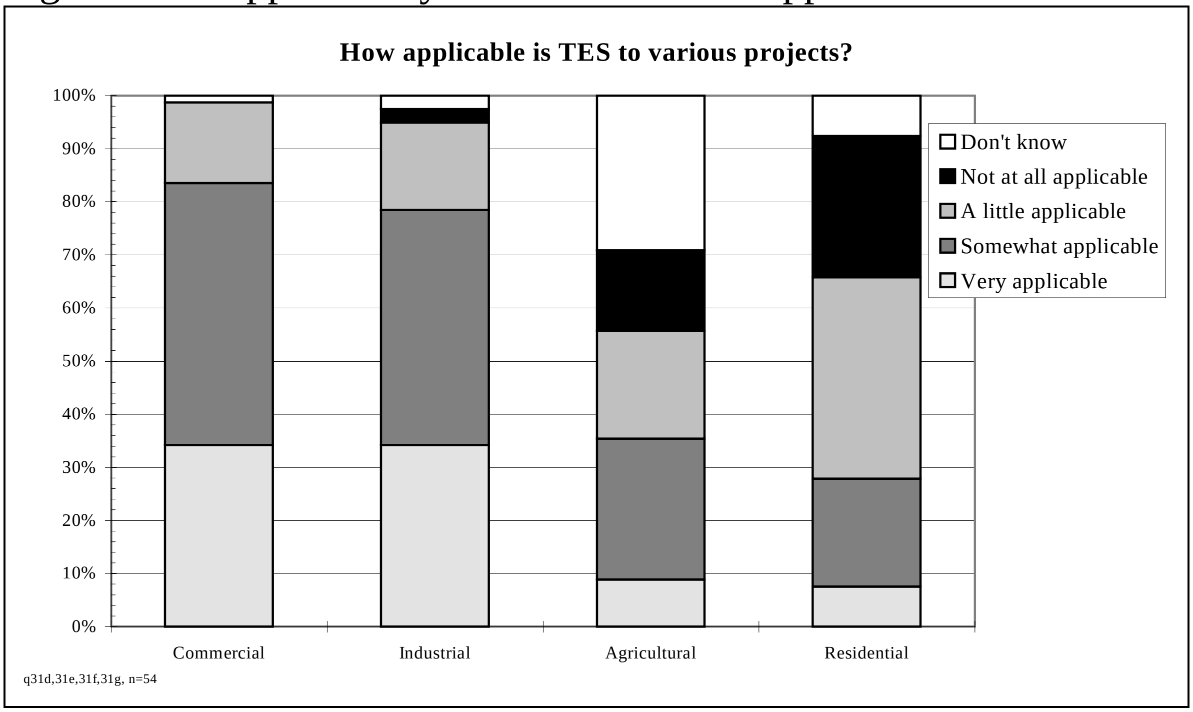
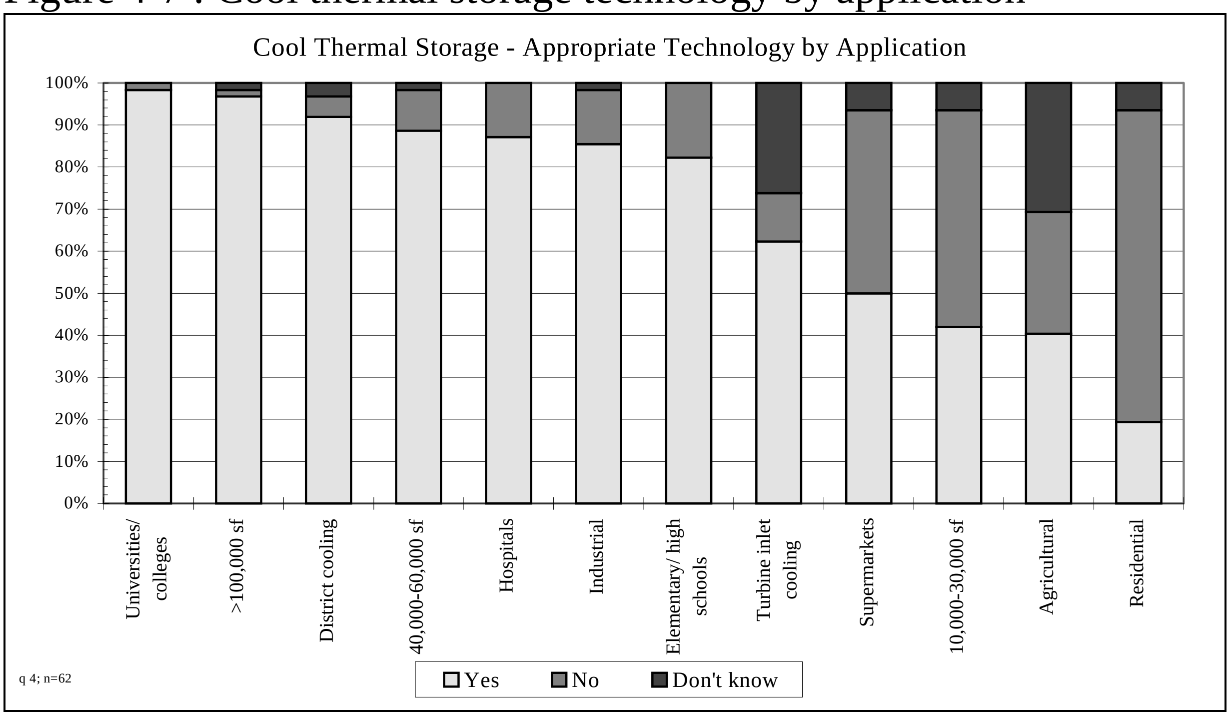


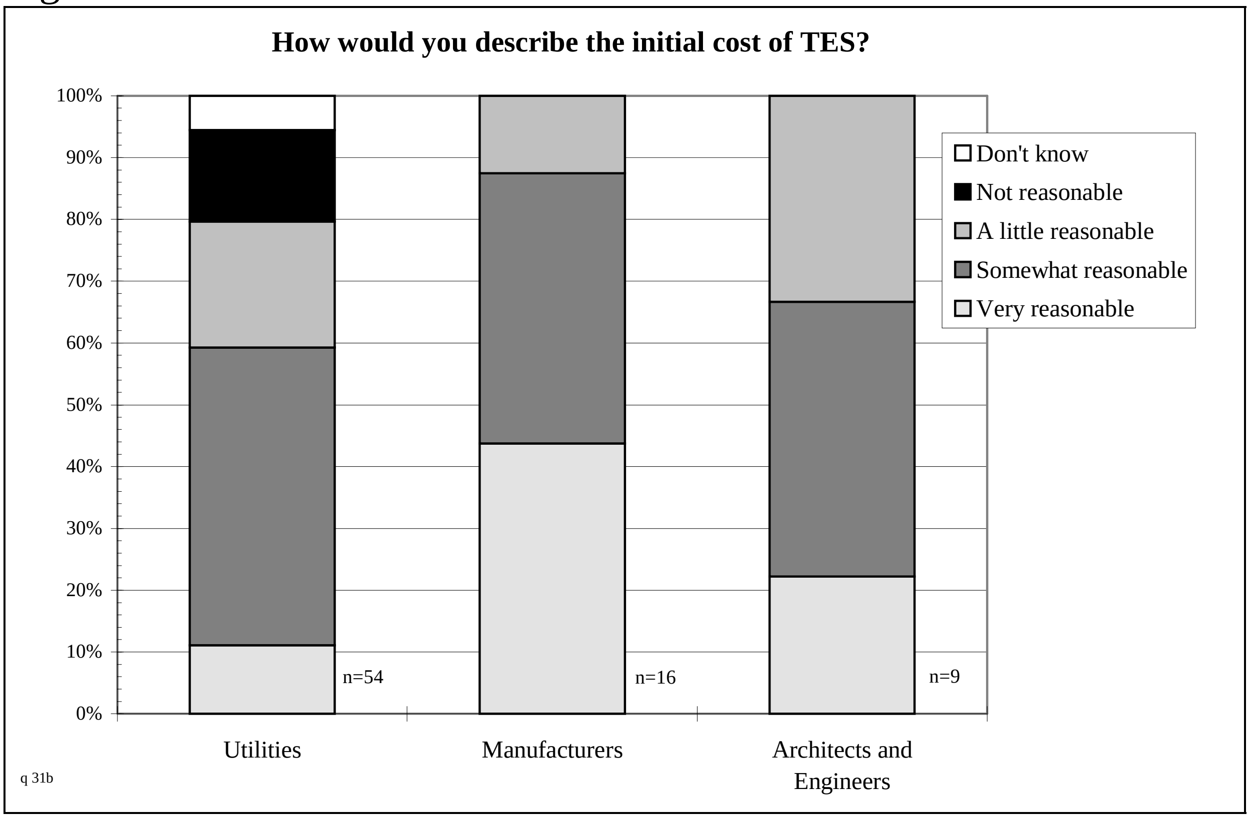
Figure 4-7 : Cool thermal storage technology by application



4.6 Initial Cost

All groups were asked to rate the initial cost of TES (Figure 4-8). Of the three groups, manufacturers were more likely to perceive the initial cost of TES as ‘very reasonable’ or ‘somewhat reasonable’. Nearly half of the utility representatives perceived the initial cost of TES as either ‘not reasonable’ or ‘a little reasonable’. It is to be expected that manufacturers never perceive their product pricing as “not reasonable”.

Figure 4-8 : Initial cost of TES



4.7 Competing Technologies

Respondents were asked about competing technologies. Specifically, if a thermal storage project was lost to a different technology (Figure 4-9) or if thermal storage was selected over another technology (Figure 4-10). Not surprisingly, conventional electric chilling was the number one competition. An interesting fact was that absorption chillers were second.

Figure 4-9 : Another HVAC technology over TES

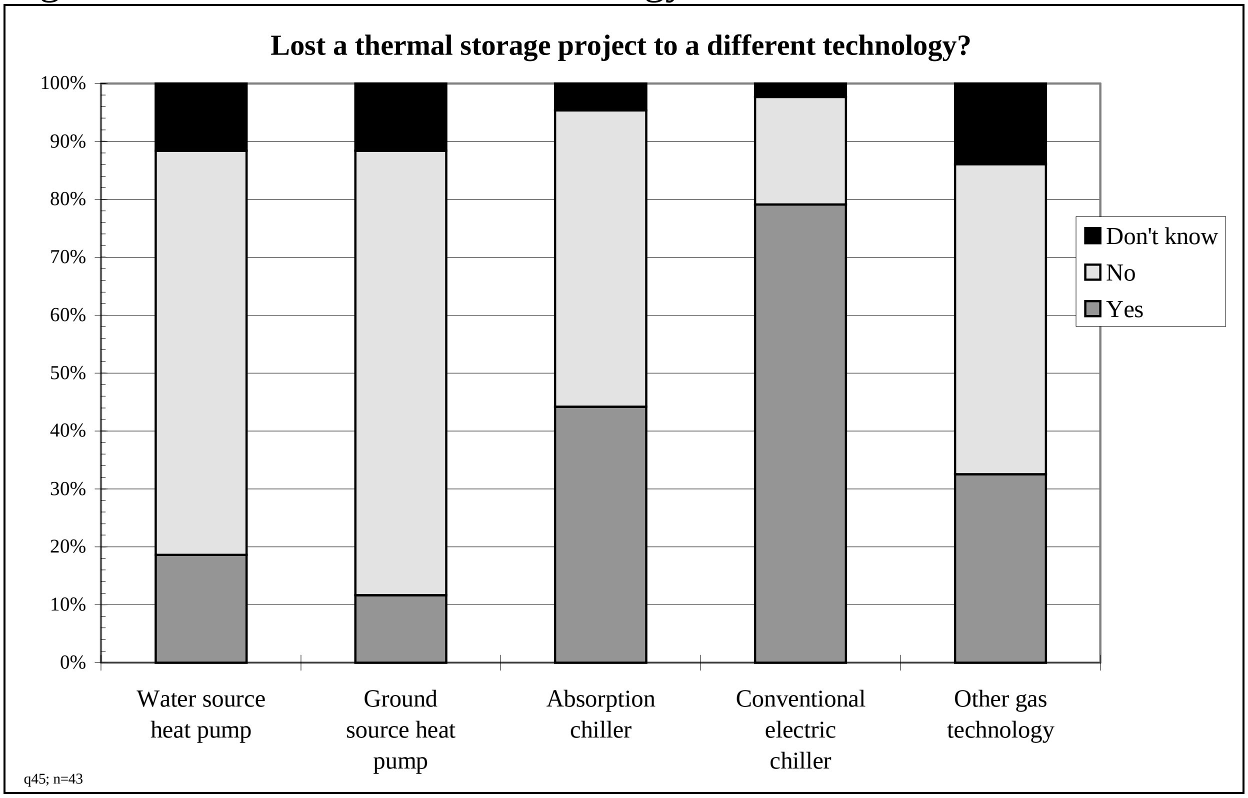
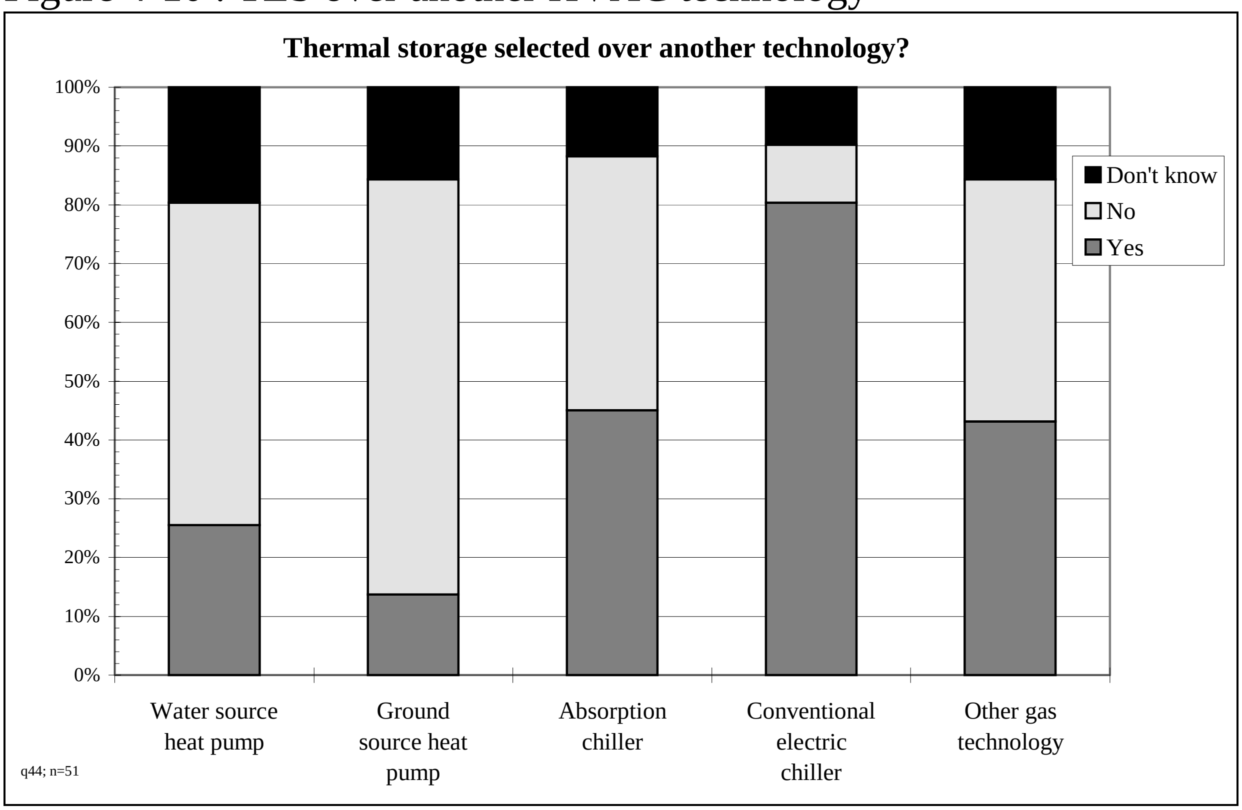


Figure 4-10 : TES over another HVAC technology



4.8 Barriers and Objections

The most frequently heard objection to TES from customers is ‘initial cost is too high’, followed by ‘pay-back too long’ and third the ‘inability to see an economic advantage’ to the installation of TES (Figure 4-11). Another barrier mentioned by survey respondents is ‘risks are too high’. Architects and Engineers were least likely to indicate that first cost was too high, but most likely to say the pay-back takes too long.

The results indicate that although initial cost is considered high, it is not excessive. Figure 4-11 shows that most indicate that the initial cost was very reasonable/somewhat reasonable. Clearly, this shows that although TES may not have the lowest first cost, it is considered a reasonable cost and indicates that price is not the sole issue when selecting TES systems

Participants were also asked to indicate whether specific reasons had been given for not selecting TES (Figure 4-12). The most (65%) commonly-heard reasons given to company representatives for not selecting TES was ‘inexperience with technology’. ‘Lack of knowledge of how TES works’ and ‘where it is applicable’ were also frequently heard reasons for not selecting TES.

In response to open-ended questions utilities indicated that economics do not favor the installation of TES systems. There is a strong feeling on their part that first cost coupled with low utility rates results in an unrealistic pay-back period. In addition, the lack of technology transfer, lack of knowledgeable contractors, building owners and operators, and technicians contributes to the non-selection of TES systems (Figure 4-13).

The most commonly heard reason for losing a TES project to a competitive technology was ‘lower first cost of competitive technology (Figure 4-12). Other reasons of significance were ‘thermal storage technology too new’, ‘savings could not be realized’, ‘decision makers changed’, and ‘ competitive edge of other technology’.

The survey found that most opposition to TES comes from architects, engineers and building owners (Figure 4-14). Utility personnel believed that most opposition to TES systems comes from architects, engineers and building owners; manufacturers believe that architects and engineers put up the greatest opposition. Overall, the perception is that architects, engineers and building owners have the greatest resistance to TES projects.

Respondents were asked an open ended question, “What are the three main barriers you see to applying Cool Thermal Storage technology?”. Utilities indicated that economics do not favor the installation of TES systems plus a strong feeling that first cost coupled with low utility rates results in a payback period which is not realistic. In addition, the lack of technology transfer, lack of knowledgeable contractors, building owners and operators, and technicians contributes to the non-selection of TES systems.

Manufacturers indicated that the primary barrier was technology transfer in areas such as getting accurate, useful information to potential customers and consultants.

Architects and engineers saw barriers as first cost, lack of operator training, and poor understanding of TES.

Figure 4-11 : Economic Barriers to TES

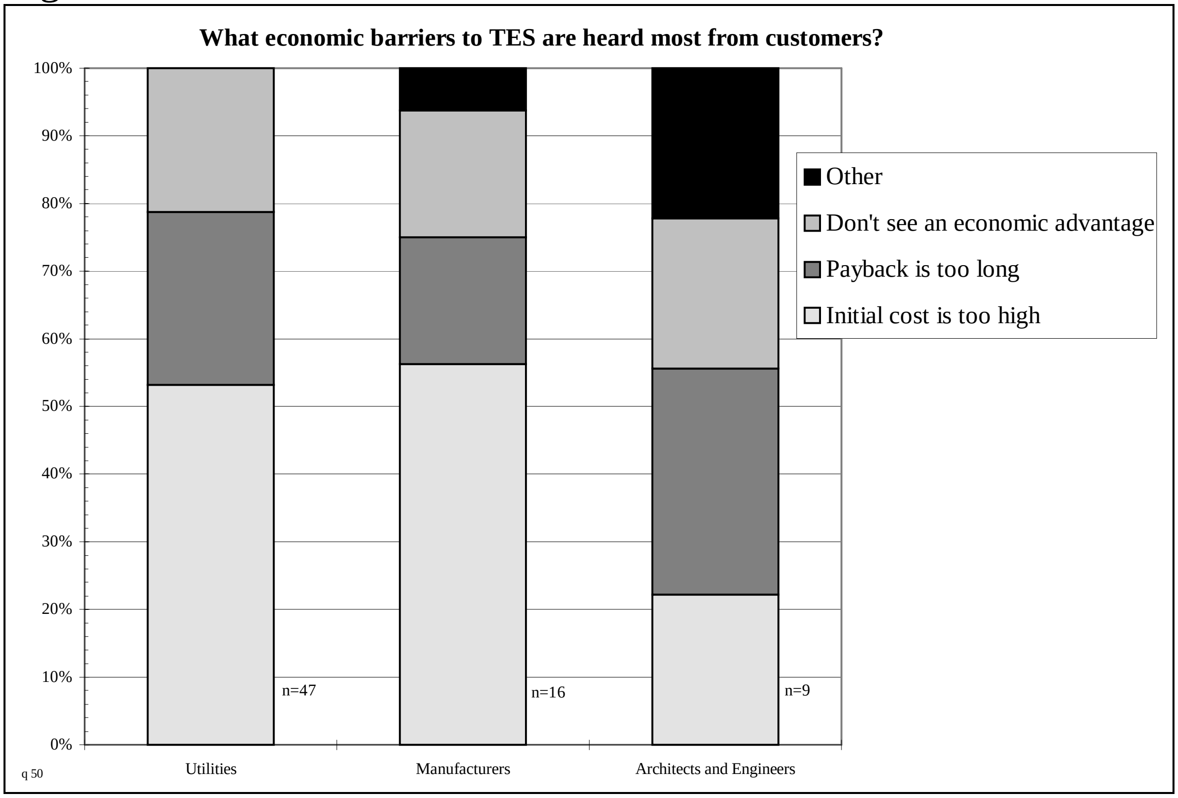
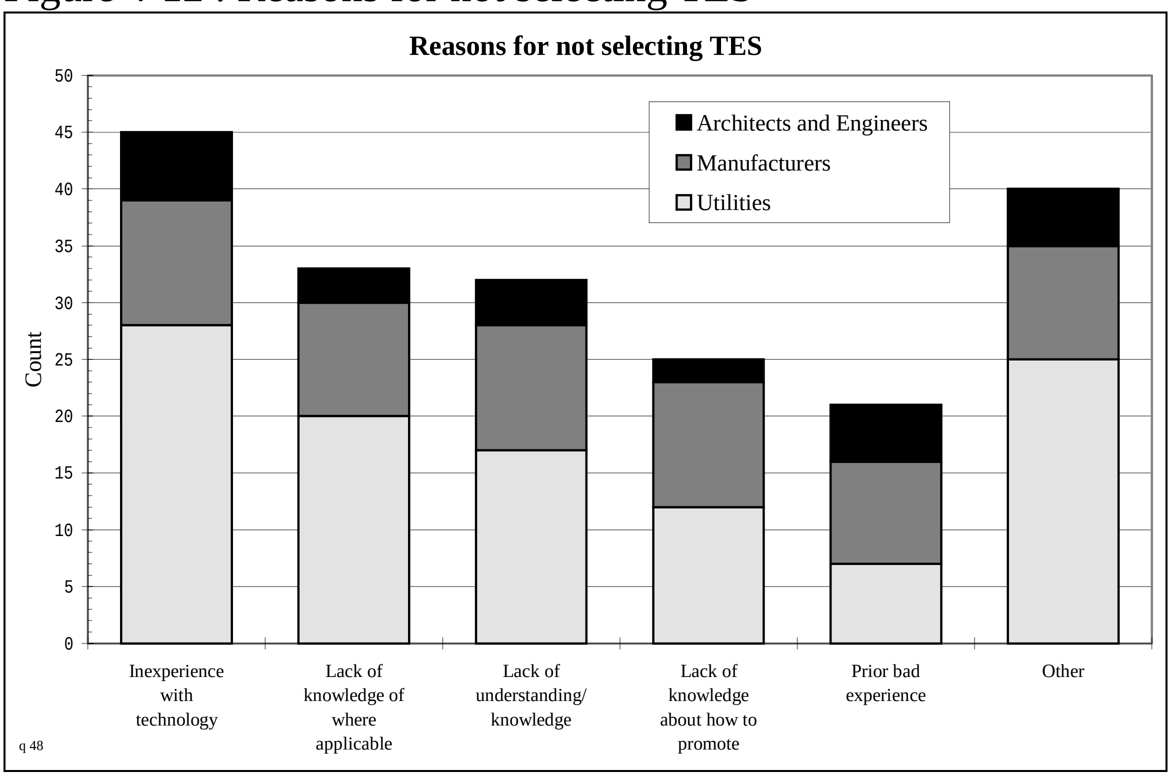
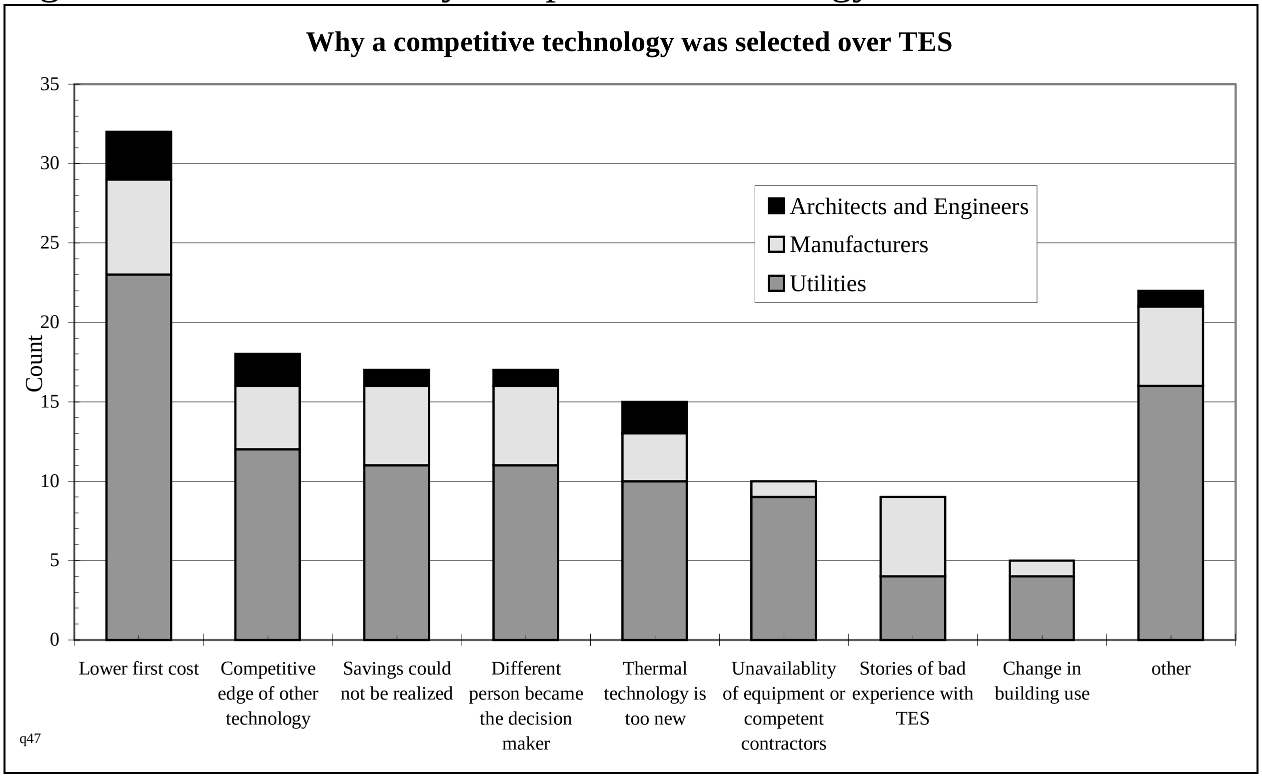


Figure 4-12 : Reasons for not selecting TES



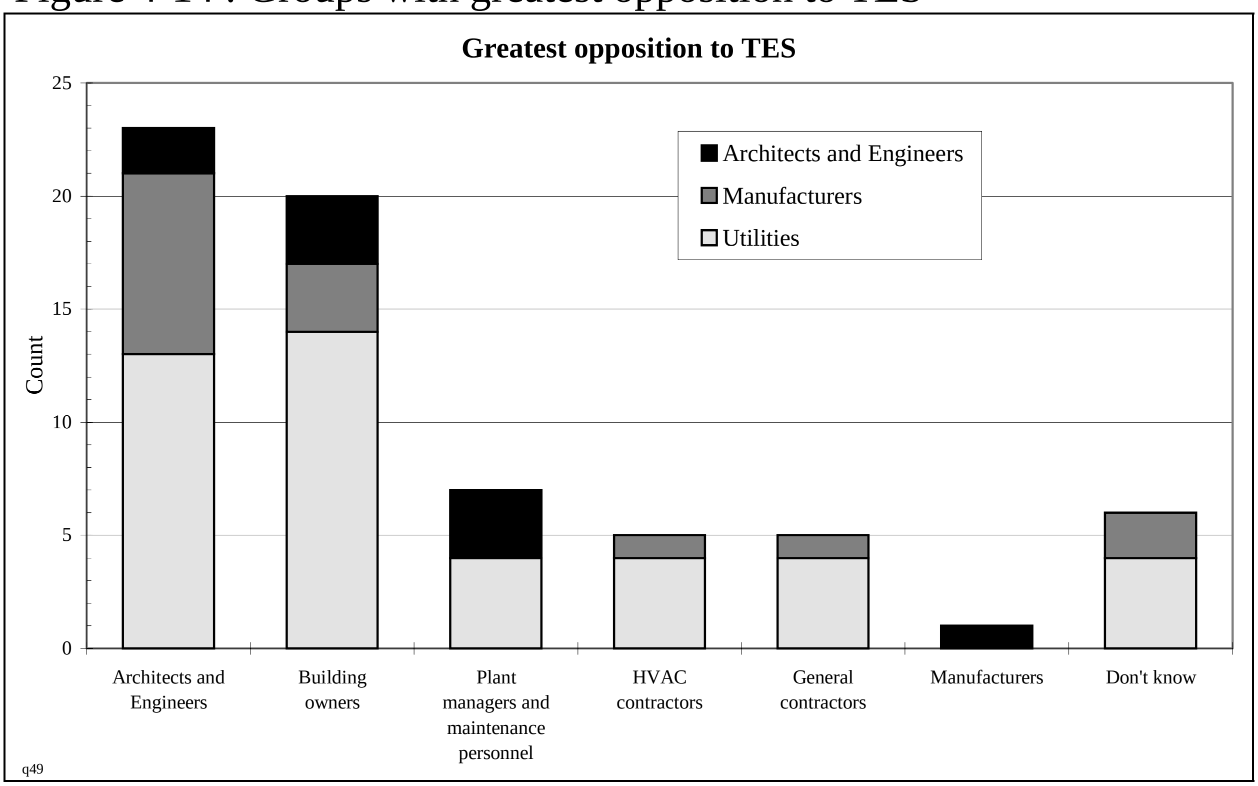
Respondents were allowed to select multiple reasons.

Figure 4-13 : Reasons why competitive technology selected over TES



Respondents were allowed to select multiple reasons.

Figure 4-14 : Groups with greatest opposition to TES



Respondents selected only one choice

4.9 Benefits

Respondents were asked an open ended question, "What are the three main benefits you see to applying cool thermal storage technology?" There is an overwhelming belief by all groups that cool TES has lower operating costs than alternative or conventional HVAC systems. The lower operating cost leads to lower life-cycle cost. The ability to shift load and obtain a flatter demand profile assists in load management for both the electric utility and building owner, as well as, the ability to take advantage of lower utility rates. TES may delay an utility's construction of additional generating capacity. It is further believed that electric generation during off-peak periods provides electricity more efficiently and produces fewer emissions. Benefits of TES systems, in addition to lower operating costs, include redundancy of equipment for cooling or heating, improved dehumidification and cooling or heating stand-by capacity.

4.10 Installations

Cool TES installation data from each of the 3 industry groups can be compared to determine trends in the application of the technology. However, due to overlapping 'territories', we are not able to combine data for cumulative results. In some cases we are able to compare the ratio of: 1) cool and heat storage installations; 2) cool storage technologies; and 3) new construction and retrofit applications. This analysis is limited by the data provided by participants. In some cases, the participant was unable to provide complete information regarding TES installations. Therefore, the analysis is limited to simple comparisons.

Respondents were asked how many known installations existed either in their service area or installed by their company (Table 4-5). The manufacturers' total should be the best national estimate of total installations. This data corroborates data found by Potter [1] which was a total installed number of 1,500 to 2,000 in 1993. From the manufacturers total estimates, it would appear that 2,500 existing installations would be reasonable, since not all current and previous manufacturers were included in the survey. All industry groups indicated TES activity in 1994 (Table 4-6) showing over 376 installations completed. The data for 1994 installations from both utilities and manufacturers is remarkably close. This data also corroborates the data found by Potter in 1994, who estimates the number of new installations annually to be between 350 - 400. Based on manufacturer totals and according to a few installations by other manufacturers, especially in chilled water storage, a projection of 400 additional cool storage installations in 1994 and 1995 should be an accurate estimate.

Respondents were asked about current or planned TES projects including new/retrofit and also of what type (Table 4-7, Table 4-8). Retrofit was the most frequent installation and ice the predominate system. It should be noted that designers indicate a high percentage of new installations. This is related to many existing installations that do not involve a design professional, but only the owner and a contractor.

Table 4-5 : Existing Cool Storage installations

Industry Group	**Cool Storage Installations**
Utilities	944
Manufacturers	2,200
Architects and engineers	137

q22,122,222

Table 4-6 : Number of TES installations completed in 1994

Industry Group	Number of installations
Utilities	376
Manufacturers	389
Architects and engineers	9

q21a, 121a, 221a

Table 4-7 : Cool storage projects - new/retrofit

	Utilities	Manufacturers	Architects and engineers
New	18%	43%	75%
Retrofit	82%	57%	25%

n34a, n35A, n35B

Table 4-8 : Cool storage projects - type

	Utilities	Manufacturers	Architects and engineers
Chilled water	15%	36%	10%
Ice	84%	61%	90%
Other	1%	3%	0%

n34c, n34j, n34k, n34l

4.11 Technology Transfer

TES seminars and workshops are offered by TSARC, utilities, ASHRAE, universities, and other resources. The survey found that manufacturers attended more EPRI- or utility-sponsored seminars and workshops than those presented by any other sponsor, while the number of EPRI- or utility-sponsored seminars and workshops attended by utilities and engineers was about the same as those sponsored by other groups (Figure 4-15).

Architects and Engineers attended the most seminars, while manufacturers either attended no seminars or more than two. Utilities were split fairly evenly on each category.

Participants were asked in what area was the greatest need of their company's representatives (Figure 4-16). Of those surveyed, the need for application information, competitive edge information, and technology transfer rated the highest.

Participants were also asked what services they provided (Figure 4-17).

Figure 4-15 : Training

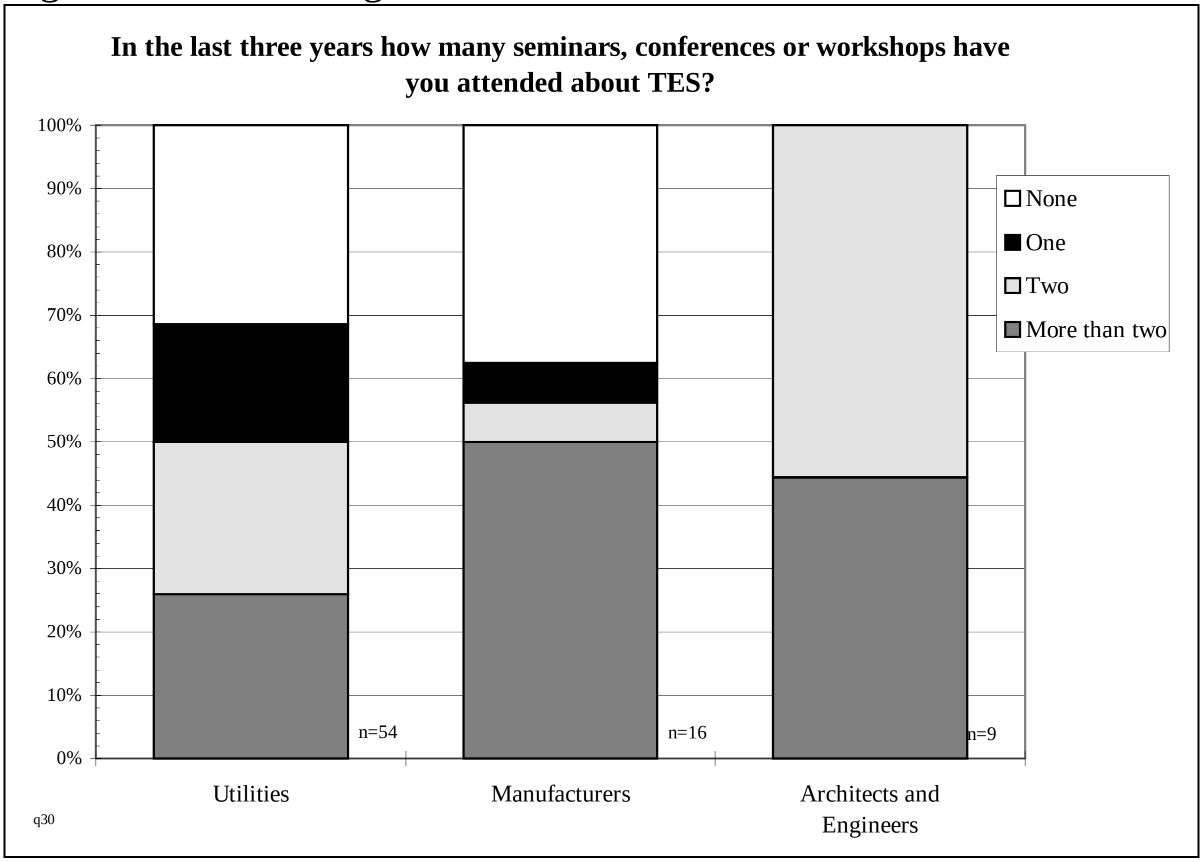


Figure 4-16 : Greatest informational needs

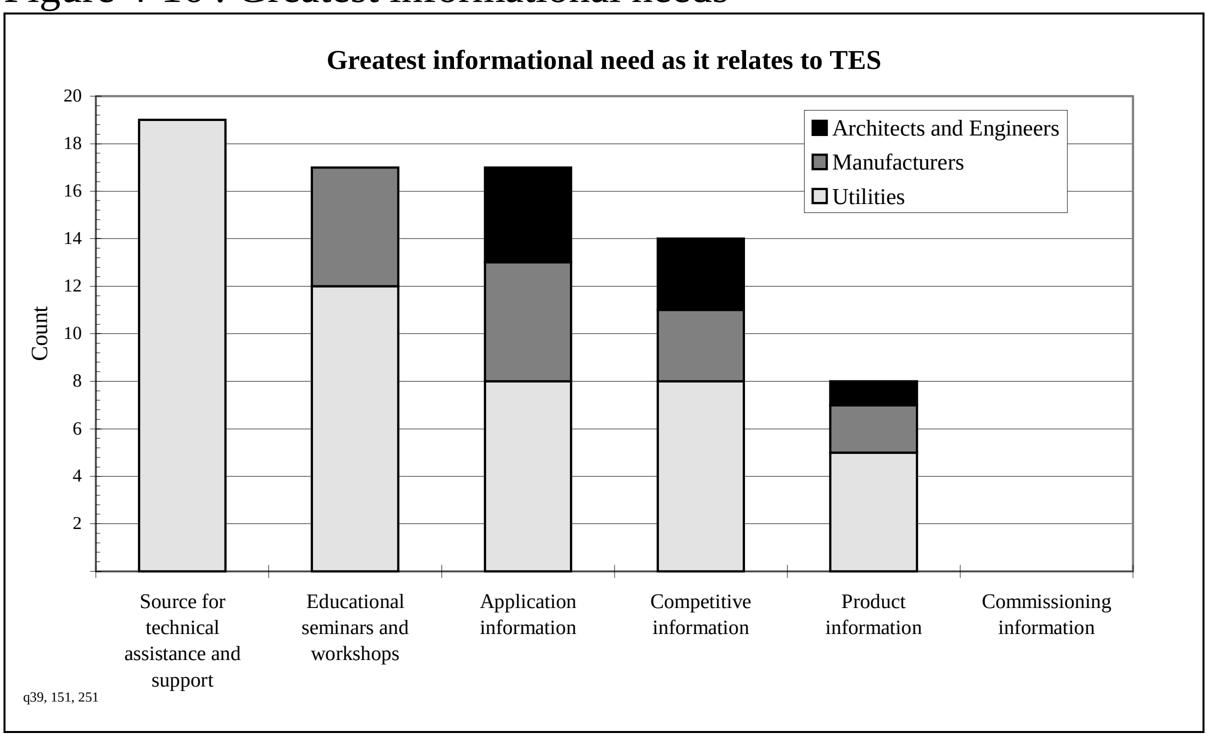
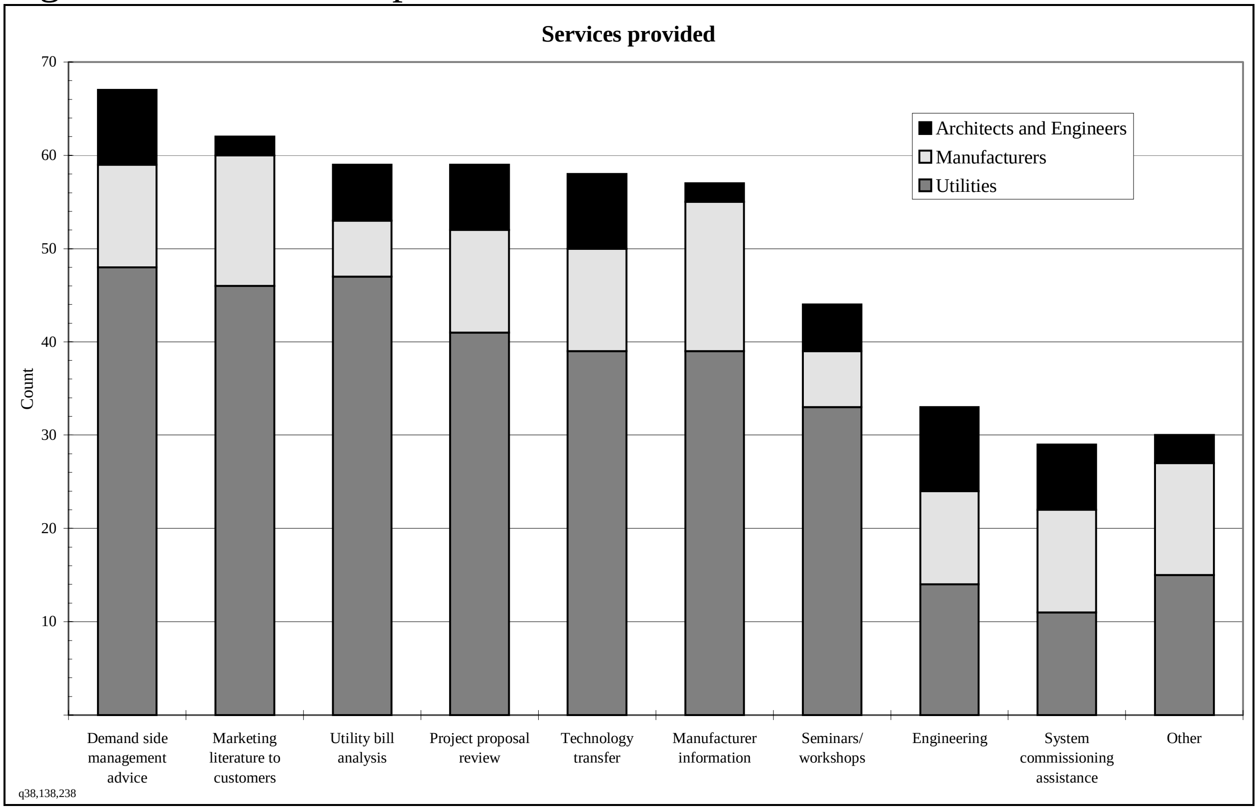


Figure 4-17 : Services provided



Respondents were allowed to select multiple services.

4.12 *Incentives*

This section deals with the perceived effects of incentives on the TES market. The survey found that 54% of the respondents felt that utility incentives were needed ‘very often’, 38% 'sometimes', and 14% 'occasionally' (Figure 4-18). Interestingly, none thought incentives were never needed. Most (57% or 31) of the utilities offer some sort of an incentive for TES.

Utilities that offered incentives were asked which type of incentive was available for TES installations (Figure 4-19). The 3 most commonly offered incentives were time-of-use, off-peak demand, and design or feasibility. Fewer utilities offered $/kWh for either electric demand reduced or shifted.

Utilities with an incentive program were asked whether their TES incentives had changed over the past 3 years. Most (39%) did not change, 16% were increased, and 29% decreased. There were 3 (10%) that started incentives where none existed before.

Table 4-9 : Does your utility offer incentives?

Does your utility offer incentives for thermal storage installations?		
Yes	31	57%
No	23	43%

q40

Figure 4-18 : How often are utility incentives needed for TES?

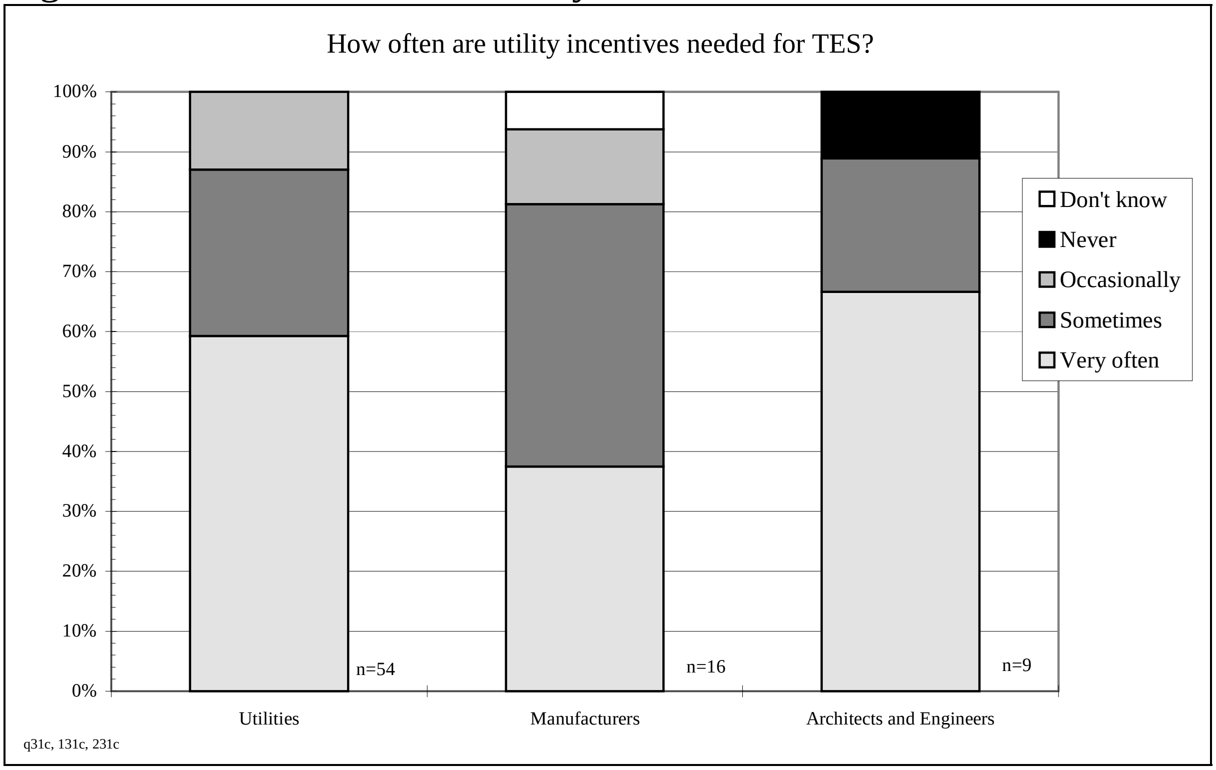
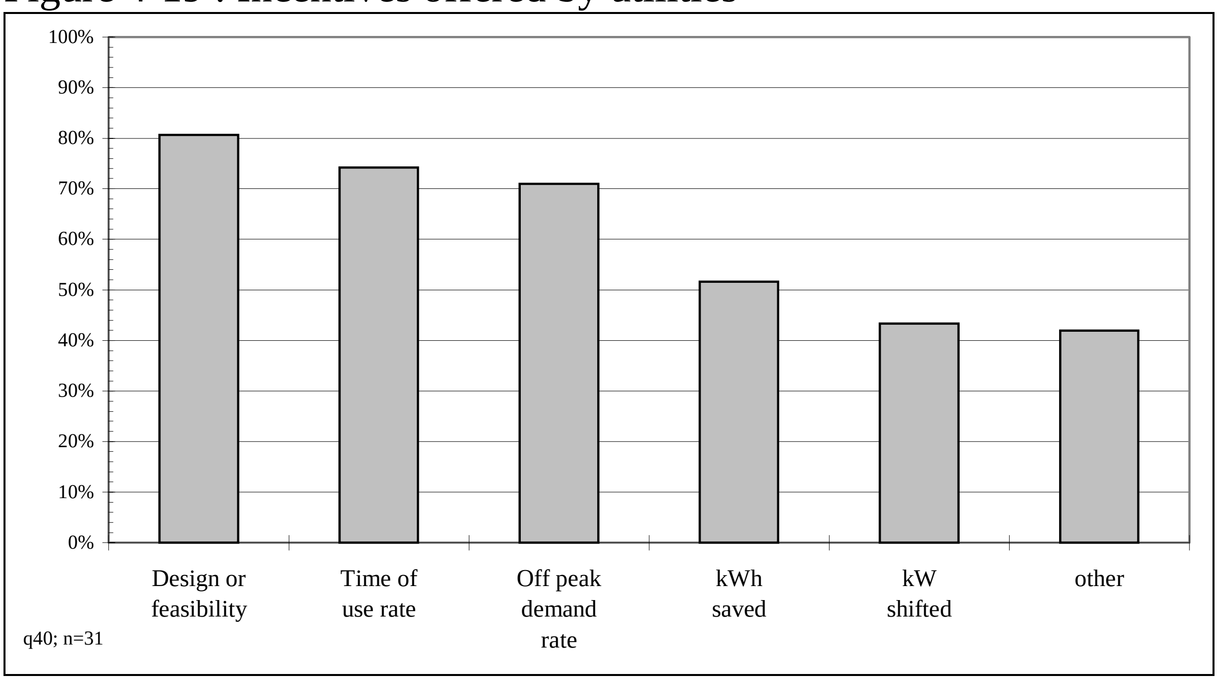


Figure 4-19 : Incentives offered by utilities



4.13 Deregulation

Utility representatives were asked to respond to questions regarding the effects of deregulation on electric rate structures and the TES market (Table 4-10). More than one-half (55%) indicated that deregulation would lower the electric rate structure. Only 25% indicated that it would increase the electric rate structure. Since deregulation is immanent, this could have a significant effect on the future of TES in those markets affected. It is the opinion of respondents that both incentives and deregulation have a significant effect on customer interest in TES. Changes in either arena will most certainly affect the future of TES.

Those who indicated that a lower rate structure would result were asked what effect this change would have on customer interest in TES (Table 4-11). Most (78%) felt that a lower electric rate structure would decrease customer interest in TES. Not surprisingly, utility respondents believe that lower rates would decrease interest in TES while higher rates would increase interest in TES.

Impact on rebates is even more striking (Table 4-12). Those that believe a lower rate structure will occur because of deregulation overwhelmingly believe that rebates will be reduced. Those that believe that a higher rate structure will occur are evenly divided on the change in rebates.

Demand-side management, one of the reasons for utilizing TES, would most certainly be affected by deregulation of the electric utility industry (Table 4-13). A majority, 66%, perceived that deregulation would affect DSM 'a lot'.

Table 4-10 : Effect of deregulation on electric rates

Effect of Deregulation on Electric Rates	Number	Percentage
Lower rate structure	32	55%
Higher rate structure	14	25%
No affect at all	2	9%
Don't know/refused	6	11%

q51, n=54

Table 4-11 : Impact of rate structure change on customer interest in TES

	Lower rate structure	Higher rate structure
Reduce customer interest	25	1
Increase customer interest	5	12
No affect	1	1
Don't know	1	0
Total	32	14

q51b&d

Table 4-12 : Impact of rate structure change on rebates

	Lower rate structure	Higher rate structure
Reduce rebates	24	5
Increase rebates	1	4
No affect	5	5
Don't know	2	0
Total	32	14

q51a&c

Table 4-13 : Effect of deregulation on DSM

	Number	Percentage
A lot	36	66%
Some	15	28%
A little	1	2%
Not at all	1	2%
Don't know	1	2%

q51h

4.14 Power Generation

Two aspects of TES that address the environmental advantages of producing either heat or cool energy at night are the perceptions by utilities that electric generation at night (Table 4-14) is more efficient and produces fewer emissions than electricity generated during peak hours (Table 4-15). Most respondents (65%) indicated that electric generation at night is 'more efficient'. Fewer respondents (56%) indicated that electric generation at night produces 'fewer emissions' than during peak generation times.

Utilities were asked about their use of gas turbines for electric generation on peak days (Table 4-16). It was found that more than 27% of the utilities have over 10% of their generation capacity with gas turbines during on peak days. Gas turbines must be derated when ambient air temperatures exceed 60ºF; capacity may decline by a significant percentage when ambient temperatures approach 95ºF. The use of turbine inlet cooling can increase the capacity of these turbines, thereby increasing power available on peak days. Utilities using gas turbines were asked whether they use utilize this technology for maximization of power generation (Table 4-17). Only 4% indicated the use of this technology. With so few utilizing turbine inlet cooling, there appears to be a large market for TES installations at these sites. For the utility this translates into the ability to possibly delay the construction of additional generating capacity.

Table 4-14 : Electric generation at night

Do you think that electric generation at night as compared to peak demand periods is more efficient, about the same efficiency or less efficient?		
Answer	**Number**	**%**
More efficient	35	65%
About the same efficiency	9	17%
Less efficient	5	9%
Don't know	5	9%
TOTALS	**54**	**100%**

q 29J

Table 4-15 : Emissions from electric generation at night

Do you think that electric generation at night as compared to peak demand periods produces more emissions, about the same amount of emissions, or less emissions?		
Answer	**Number**	**%**
Fewer emissions	30	56%
About the same emissions	14	26%
More emissions	6	11%
Don't know	4	7%
TOTALS	**54**	**100%**

q29k

Table 4-16 : Gas turbine generation use

On peak days, what percentage of your generation capacity comes from gas turbines?		
Answer	**Number**	**%**
None	16	30%
1-9%	15	28%
10-19%	11	20%
>20%	4	7%
Don't know	8	15%
TOTALS	**54**	**100%**

q 27

Table 4-17 : Gas turbine inlet cooling use

Is your utility currently using turbine inlet cooling as a means to maximize power generation?		
Answer	**Number**	**%**
Yes	2	4%
No	34	63%
Don't know	18	33%
TOTALS	**54**	**100%**

q 52

4.15 IAQ

Utility respondents were asked questions related to humidity, indoor air quality, and microbial growth control. Most (50%) indicated that TES provides 'better humidity control' but fewer respondents, 24%, indicated that TES 'provides better indoor air quality' (IAQ), or better control over microbial growth (28%). The following table shows that TES is perceived to provide better humidity control but not IAQ, with a split in opinion on the control of microbial growth.

Table 4-18 : TES and IAQ

	TES provides better humidity control	TES provides better indoor air quality	TES provides better microbial control
Yes	**50%**	24%	28%
No	31%	**54%**	**39%**
Depends	2%	3%	3%
Don't know	17%	19%	30%

n=54 q51i q51j q51k

4.16 Perceptions of Heat Storage

There were 29 respondents that had experience with heat storage. Twenty four companies, (15 utilities, 4 manufacturers and 5 engineering firms) had both cool and heat storage experience (Table 4-19). The response to this question clearly illustrates the greater market penetration of cool storage as compared to heat storage.

Of the 68 respondents indicating that their firms have had experience with TES, 43% (29) respondents indicated that their firm had had experience with heat storage. Based on their experience with heat storage this group of 29 was then asked questions relating specifically to heat storage.

It was found that 19 respondents (66%) agree or strongly agree that heat storage has benefits other than utility costs (Figure 4-20). Heat storage is not viewed currently as a key technology, nor is it perceived to be in the next 15 years, however the respondents believe that heat storage market penetration and acceptance will increase over the years (Figure 4-21).

Participants with heat storage experience were asked to indicate the appropriateness of this technology in various applications (Figure 4-22). Residential, industrial applications, campus settings such as universities and colleges, and public schools were perceived as being the most appropriate applications for this technology, while supermarkets and agricultural projects were viewed as the least appropriate application.

Table 4-19 : Experience

	Heat Storage Experience		Both Cool and Heat Storage Experience	
Industry Group	**Yes**	**No**	**Yes**	**No**
Utility	20	23	15	28
Manufacturer	4	12	4	12
Architects and engineers	5	4	5	4
Totals	**29 (43%)**	**39 (57%)**	**24 (35%)**	**44 (65%)**

q 1b

Figure 4-20 : Statements about heat thermal storage

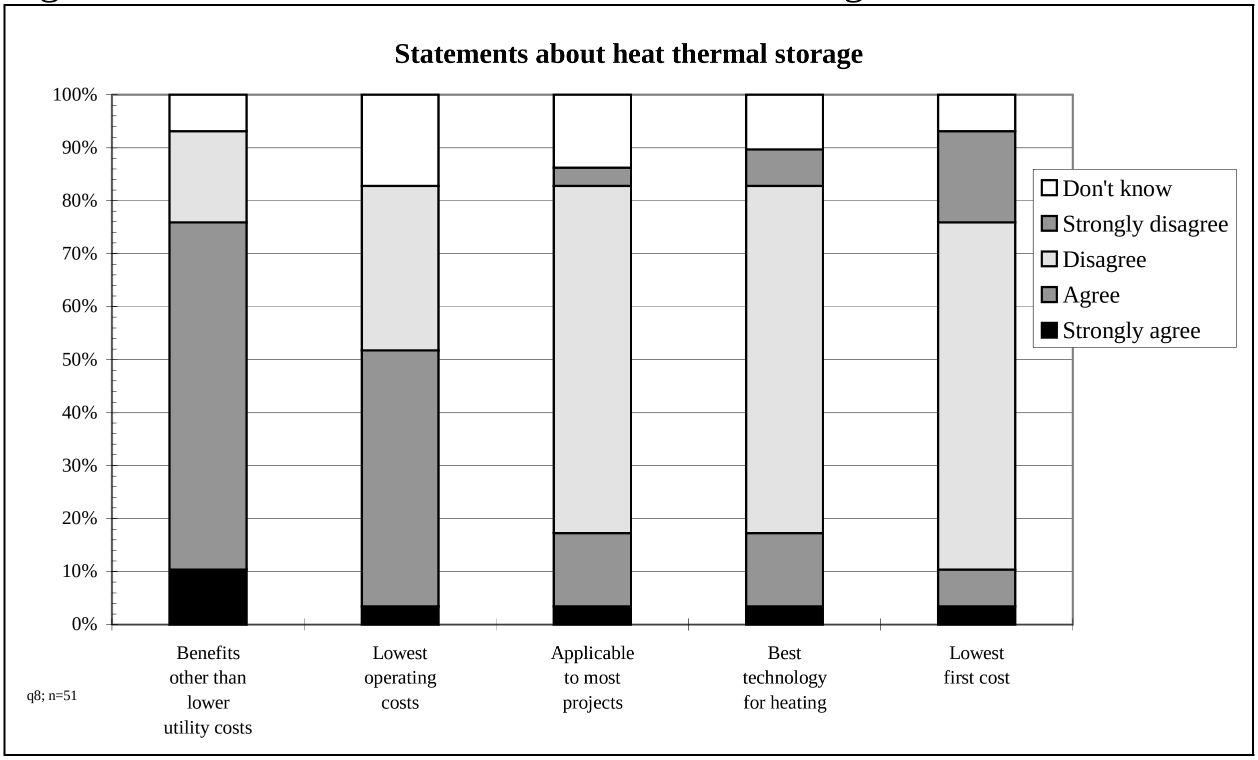


Figure 4-21 : Future of Heat Thermal Storage

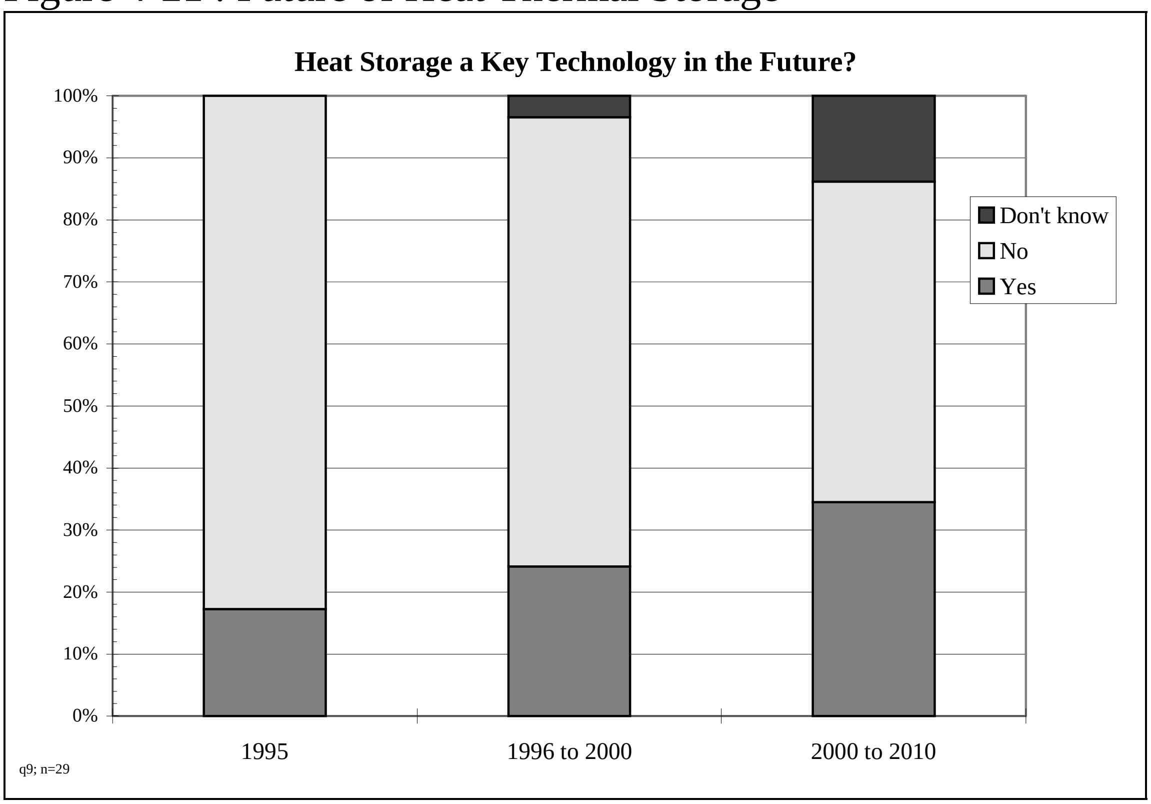
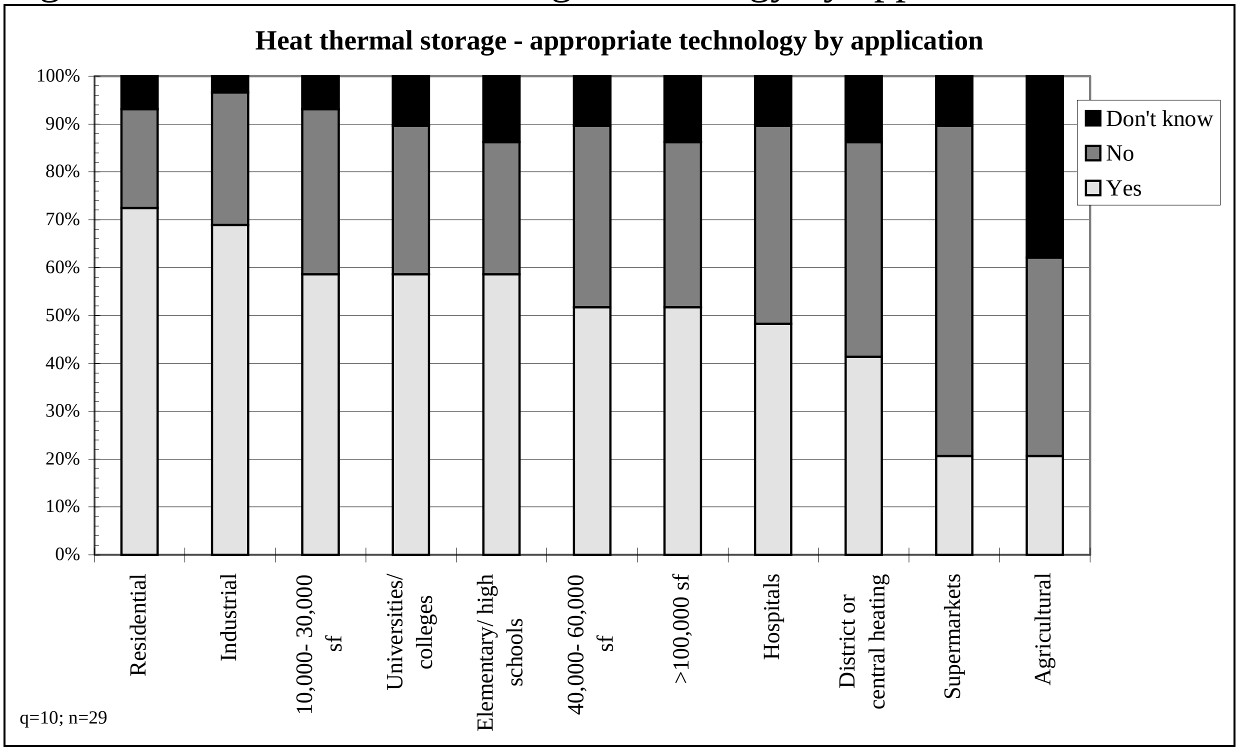


Figure 4-22 : Heat thermal storage technology by application



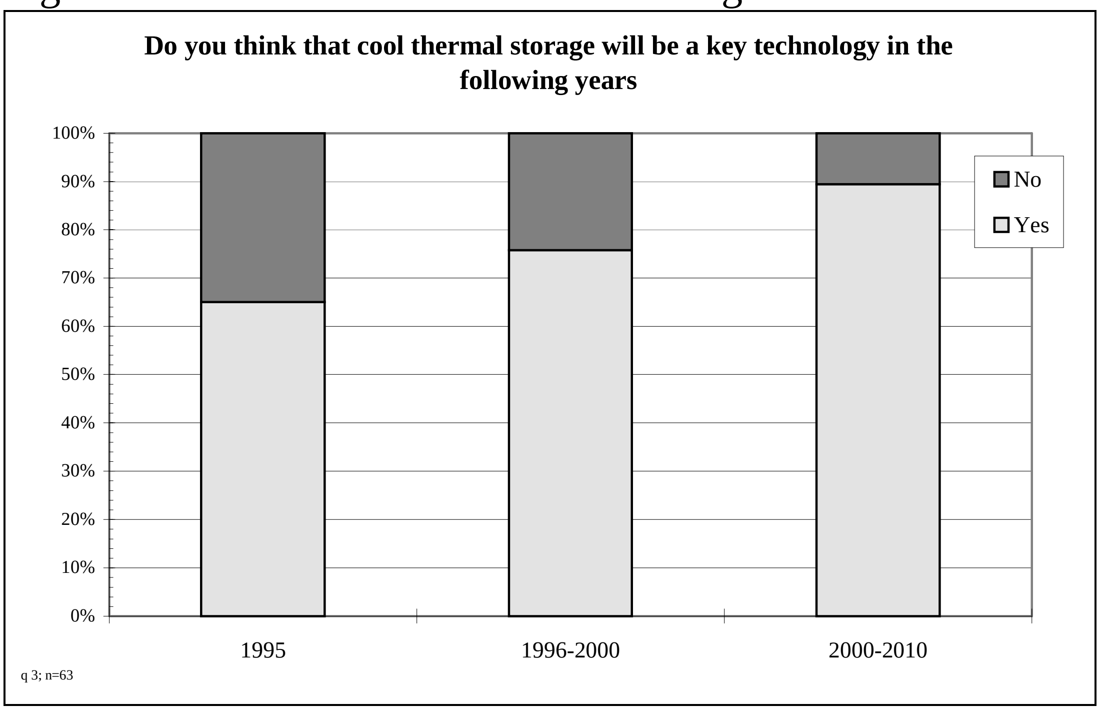
5. THE FUTURE OF COOL TES

Potter [1] estimated that between 300 - 400 new cool storage TES installations were commissioned in 1993. Potter estimates that between 25 - 40 TES systems are removed from service, abandoned, or replaced each year, but that there is an annual growth rate of the TES market of approximately 15 - 20%. Our survey of utilities and manufacturers indicate that this growth continues. Manufacturers indicated that 389 new TES installations were commissioned in 1994, while surveyed utilities indicated that 376 installations were commissioned in 1994 (Table 4-6). These estimates appear to be consistent indicating a continued growth in the TES market. Since not all manufacturers or utilities were surveyed, a reasonable annual estimate of new cool storage systems is 400 per year.

For both cool and heat storage projects, approximately 80% of applications are being designed for retrofit applications (Table 4-7). This is likely to be a reflection of the CFC and HCFC phaseout affecting customer HVAC systems as well as the general slowdown in new building construction. It may also be a lower cost option to chiller replacement in multi-chiller plants.

The respondents in this group indicated that cool storage will continue to gain acceptance and market penetration between the years 1996 to 2000 and 2000 to 2010. Based on this data, TES is expected to grow at a constant rate in the near future, unless significant measures are implemented to involve more owners, (including local and national government agencies, i.e. GSA, DOE, and EPA) manufacturers, and design teams.

Figure 5-1 : Future of Cool Thermal Storage



Questions concerning the future of TES received a variety of responses. The study attempted to forecast the growth of the TES market by obtaining recent project completion data and accessing the opinions of various professionals. The responses can be divided into two categories: those who saw no future potential in TES, and those who saw great potential.

In general, those who predicted a lack of growth in the TES market argued against it for economic reasons. Most cited the high initial capital cost and outlay as being a deterrent to initiating the construction of TES systems in new buildings. EPRI, utilities, and manufacturers must concentrate on overcoming this belief or, if this contention is true, develop more economical TES alternatives.

Furthermore, some electric utilities have cut back on TES marketing and awareness programs as a part of their more general program cutbacks. However, others have initiated new programs. It is not clear from this survey where the current direction of utility incentives is going. Some experts also thought it doubtful that enough of an engineering “infrastructure” or expertise base existed to support rapid growth in the market.

On the other hand, those who saw a "rosier" future for TES often presented arguments which answer in whole or in part the objections of those who saw little future for the technology. First of all, TES is a technology on the verge of wider acceptance, and as more people become aware of its benefits, the demand for TES systems will increase. The benefits of TES systems - flexibility, the ability to control the flow of cooling or heating with greater precision, and such benefits as electric demand and load shifting - will become more and more important in the future.

Some of the respondents also noted that energy costs are almost guaranteed to increase in the near future, which will re-emphasize the load shifting benefits of TES technology. The adoption of flexible and real-time rates should increase the desire for TES to meet peak cooling loads. On-peak energy costs will increase, and customers are becoming ever more energy-conscious. The technology has matured to the level where a certain degree of reliability and ease of installation and use has been achieved, and this will allow building managers to easily and flexibly take advantage of lower off-peak energy rates. It will also lessen the dependence on refrigerants which are now either in the process of or have been completely phased out.

The respondents also noted the various environmental benefits of TES technology which will make it more attractive in the future. As mentioned above, the CFC phase-out (a key environmental concern) means that refrigerants are in one way or another going to become very expensive - either due to prohibition in manufacture, the expense of sealing off an old CFC-driven unit, or through the use of non-CFC refrigerants. In this context, TES can be seen as a way to reduce the reliance on high refrigerant inventories (smaller equipment being used at off-peak times for the same HVAC volume.) Furthermore, the use of off-peak energy is more environmentally sound on the generation side; thus TES lends itself to alternative natural refrigerants, such as ammonia or propane.

Both groups - the ones who saw a future for TES technology and those who disputed it - stressed that the trends they saw would accelerate by 2010. Those who saw TES technology gaining greater acceptance, however, stressed that electric rates would increase as a key factor. Also, the development of 'fit in place' package TES units would be important, by taking the more complicated engineering and design aspects of TES technology out of the decision process.

The respondents also addressed some of the barriers to more general adoption of TES technology. Some of these problems which have been touched on before - the abandonment of utility rebate incentives and lack of common, easily available information and expertise about TES installation and design -- continue to hamper the growth of the market.

The lack of engineering support is perceived as a serious problem. Technology transfer and training efforts must increase to magnify awareness of the various benefits of TES technology. This effort must encompass not only the engineering fields, but also reach out to contractors, architects, technicians, and building owners and managers. EPRI technology needs to be transferred to ASHRAE and other trade publications. This should increase the market pull for TES systems by the engineering community.

The benefits of TES technology include many of those mentioned before, but the responses of the individuals polled include many others. TES results in more uniform building comfort and efficiency of the entire HVAC system. A steady load can be designed into the entire system, resulting in a smaller plant, piping, and pump system. The system is also available as an 'emergency' or redundant system for unexpected use. TES systems have lower wear and tear and a longer life cycle, which decreases the likelihood of expensive maintenance or replacement during the lifetime of the building. The respondents also noted the many environmental benefits of TES technology: lower use of fossil fuels, lower operating cost, stand-by capacity, reduction in the need for refrigerants, and lower emissions.

In summation, the benefits of TES technology can be seen to be long-term selection of a non-TES system may have lower initial cost, the potential future costs of such a system will be greater. Key benefits offered by TES include lower operating costs, lower electrical demand, and a less environmentally harmful system.

6. CONCLUSIONS

A brighter future for TES is immanent based on data collected from all industry groups as well as the general consensus of many experts. There are some barriers to the expansion of the TES market, however. The most notable barrier to TES installations continues to be its high first cost. Figure 4-8 shows that the initial cost is perceived to be reasonable; Figure 4-11, however, shows that the customer’s number one complaint is that the initial cost is too high. Utilities are the most likely to report that the initial construction cost of TES systems is not reasonable, which could be a significant reason behind building owner's reluctance to adopt TES. This apparent contradiction could be explained by the fact that that those closer to the industry may have a better understanding of the costs of TES systems while those with less experience with TES have much less knowledge of the costs and benefits. This can be addressed with technology transfer designed for the end use market segment (the economic buyers of TES systems) can dispel this misconception.

While the cost may produce “sticker shock” among those initially interested in the systems, more education and information dissemination is needed to educate customers on the long-term cost benefits of TES systems. Utilities and manufacturers must show that lifetime system costs outweigh higher initial cost outlay and, in fact, in many cases both first costs and operating costs are lower. Absorption chillers are, however, strong competitors to TES systems and show that costs are integral to various cooling technology calculations.

Participants were also asked to indicate whether specific reasons had been given for not selecting TES. The most commonly heard reasons (65%) given to company representatives for not selecting TES was ‘inexperience with technology’. ‘Lack of knowledge of how TES works’ and ‘where it is applicable’ were also frequently-heard reasons for not selecting TES. Again, this indicates that information is not being properly presented to the customer.

There is the perception that TES systems have good humidity control but bad Indoor Air Quality. This is probably related to the use of a lower volume of air in cold air systems; however, all HVAC designs require the same amount of outdoor air input. TES systems always have more available cooling capacity and thus provide better IAQ than a non-storage system. There has to be a more specific definition of what IAQ is and how TES can assist in the creation of a “healthy building”.

Fortunately, TES systems have compelling benefits over alternative systems. Cool storage is perceived to have benefits in addition to lower operating costs; these include redundancy of equipment for cooling or heating, improved dehumidification, cooling or heating stand-by capacity, and lower life-cycle costs. TES systems shift load and obtain a flatter demand profile, which assists in load and rate management for both the electric utility and electric utility customer. For the utility this may possibly delay the construction of additional generating capacity; it is further believed that electric generation during off-peak periods provides electricity more efficiently and produces fewer emissions. Marketing efforts should focus on the long-term benefits of TES showing that TES has the advantage of better economics over the life-cycle of the system.

Other factors promoting the growth of the TES market include; flexibility in applications, lower operating costs, standards and ARI Approved Guidelines, lower equipment cost, more competitive electric rates, the phase-out of CFCs and HCFCs, and increased technology transfer. CFC issues are most likely to become even more important to future construction or retrofit markets. Over the next 15 years, the cool storage market will continue to grow; this study, furthermore, found that both cool storage and heat storage will gain an increasing popularity in the years 1996-2000 and 2000-2010.

TES systems are competitive when compared to other HVAC technologies, including absorption chillers, engine-driven chillers, and peak shaving generation-sets. TES can reduce peak electric demand. Absorption chillers may claim refrigerant advantages due to the use of water as a refrigerant, but their poor efficiencies, high first cost, and heat rejection requirements limit their application. Absorption chillers, moreover, do not produce cold enough temperatures to provide adequate dehumidification. Engine-driven chillers have significant energy efficiency benefits over absorption chillers, but the increased maintenance costs for the engine and restrictions on nitrous oxide (NO_x) emissions will limit their adoption. Peak shaving generation sets run chillers during peak periods; interconnection requirements, power quality issues, and environmental emissions (including NO_x, noise, and vibration) have a serious effect on the selection of these sets.

Based on the survey, more seminars geared toward the architect and engineering communities as well as to building owners are needed to increase their awareness of cool thermal storage as a viable technology. Software for cool thermal storage does exist; marketing of this software needs to be improved so that it is better used and understood. A major section of any technology transfer effort should include the impact of deregulation; when combined, these efforts should reduce the TES “learning curve” and associated design and acceptance risks.

A final comment on the marketing of TES is comparison of TES to conventional cooling. Several problem installations of TES have been documented in published papers and presentations; however, non-storage cooling systems have major operating problems as well. This is not always noted or mentioned in published material. It is generally true that a new technology has “teething” problems. Designers and contractors often have more experience in avoiding problems and operating personnel have more knowledge in dealing with conventional systems. On the other hand, many TES systems have been designed and installed by highly skilled engineers and contractors and have substantially fewer operating problems when compared to non-storage cooling systems. Care has been taken in designing these systems and they work very efficiently and at low operating costs. It should be emphasized that a good TES installation will always be a superior system to a conventional cooling system.

7. SUGGESTED ACTION PLAN

Based on the survey, some suggested ideas for those interested in expanding the use of TES are provided below. It is anticipated that specific utilities, manufacturers, owners, and designers will see other opportunities. The opportunities for expanding the TES market include:

- **Continued interest in TES** (Figure 4-2). The interest is high and provides utilities and manufacturers an opportunity to be heard.
- **TES efficiency** (Figure 4-5). The existing perception is that TES is energy-efficient; this needs to be enhanced and documented.
- **Best technology for cooling** (Figure 4-4). The conclusion that TES is not the primary cooling technology choice should be a topic of future investigation and research. What technologies are considered better? Is a specific technology considered superior or are different technologies chosen for different applications (i.e. office, retail, central plants)?
- **Lower first cost** (Figure 4-4). Although it is known that TES may be the lowest first-cost choice for some applications, EPRI and manufacturers need to determine why it is not the predominate lowest first-cost system. Can this situation be remedied? Are there minor differences (1-5%, that on a life cycle basis can be saved in 1-2 years of operating and energy cost savings) or are there large differences in cost outlays when compared to conventional systems (10-20%)?
- **Competing Technologies** (Figure 4-9 and Figure 4-10). Further research needs to be completed to determine why gas cooling technologies were preferred over TES. The high percentage is threatening to electric utilities, considering that a great number of the survey respondents work for those utilities.
- **Barriers and objectives** (section 4.8). This section explores key technology transfer needs and to some extent identifies further research needs. The survey questions in this section indicate that more information and technology success stories are required to document applications where either; 1) first cost is the same or lower with TES systems than conventional systems; or 2) where life cycle cost through the first or second year are equal or less with TES (pay-back) than other cooling options. Figure 4-12 and Figure 4-13 provide information on both real and perceived barriers to the adoption of TES. These must be addressed in order for TES to achieve widespread use.
- **Technology transfer** (section 4.11). The survey indicates that architects and engineers need more information on applications and comparisons between different systems. Utilities are either not aware of existing information (EPRI has substantial resources available) or are not satisfied with what exists. There may be a need to analyze specific requirements for information. This observation was also discussed in Section 4.8.
- **Incentives** (section 4.12). It is anticipated that incentives (Table 4-12 and Table 4-13) for TES and other DSM measures will be reduced or eliminated by most electric utilities within the next several years. According to ITSAC, many utilities still offered incentives as of August 1995, and none of those utilities surveyed had deleted a program during the last three years; in fact, three (10%) had initiated incentive programs. The future of incentives is not obvious from the survey; however, this does not mean that changes in incentive policy will not be rapid as indicated by the deregulation questions in section 4.13. Since no respondents thought that incentives were <u>not</u> required, EPRI and electric utilities need to determine exactly what impact changes in incentive policy will have on thermal energy storage. The question arises; what can replace incentives to insure that this economically-viable cooling, heating, and refrigeration technology will continue to be utilized? Will time-of-use and special TES rates be devised to maintain the market for TES? Has the technology matured to the level that it is sufficiently known and understood to stand on its own merits?
- **Power generation**. A large number of respondents were not aware that electric generation was more efficient at night. It needs to be stressed that generating and storing TES energy at night is more efficient and produces less emissions than the use of conventional cooling systems, taking into account total source energy in power generation.

8. FOLLOW-UP OPINIONS

The following are brief statements from selected experts on TES installation and design presented in order to relate specific personal assessments of the thermal storage market which is independent of the statistical data gathered by this survey. These statements are brief and relate only a small portion of all the knowledge and viewpoints of those who contributed to this section. These viewpoints and expressions of the market should be referred to with caution; it is requested that these individuals not be quoted without the express permission of each contributor, to be obtained from the publishers of this market assessment. The purpose of these brief statements is to provide descriptions of their own perspectives on the market which can then be used by electric utilities and others to appraise the market and suggest action that can be taken in the future.

8.1 Building Owner #1

At the national level, stratified chilled-water storage systems continued to serve increasing numbers and new types of industrial cooling applications in 1994. In addition, several new concrete and steel tank manufacturers entered this segment of the thermal energy storage market and helped to improve pricing/competition. These factors evidence increasing maturity within this segment of the thermal energy storage market.

That said, the nucleus of leading-edge engineers skilled and experienced in planning, designing, and commissioning stratified chilled-water storage systems remains small and evidences infancy within this segment of the thermal energy storage market. The recent publication of ASHRAE's *Design Guide for Cool Thermal Storage* provides a comprehensive, up-to-date guideline for system planners and designers that will help to overcome this barrier. Upcoming ASHRAE guidelines for implementing thermal energy storage systems and standards for testing thermal energy storage systems will also help to overcome this barrier.

In Texas, sharp demand charge increases (resulting from two very expensive nuclear power plants), in conjunction with favorable incentive levels, well-designed time-of-day rate options, and aggressive DSM marketing programs by two large, investor-owned electric utilities continued to expand the market for thermal energy storage.

Notable among the new stratified chilled-water storage systems installed in Texas in 1994 were a multi-million gallon steel tank system at a large petroleum research facility in Houston and a multi-million gallon concrete tank system at a large semiconductor manufacturing facility in Dallas. Both were retrofit projects, with the former performing demand-shifting/operating cost reduction and the latter performing demand-shifting/operating cost reduction plus capacity expansion/capital cost reduction. These systems both provide a high after-tax rate-of-return and a competitive advantage in cooling energy costs. From this perspective, thermal energy storage is a fast-cycle, utility-leveraged, time-based competitive strategy. The market push provided by the compelling economics of these systems, in conjunction with the market pull provided by the electric utilities' DSM programs, will make stratified chilled-water storage the industrial cooling system of choice in Texas by 2000.

Obstacles in the path of even more widespread and rapid adoption of stratified chilled-water storage in Texas are: lack of information, lack of confidence, and/or lack of activation energy by many engineers and owners. Increasing energy costs, increasing global competition, and/or slowing economic growth as well as recognition of successful thermal energy storage projects beginning at the 1995 *Industrial Energy Technology Conference* in Houston, will help to overcome these obstacles and provide even greater market push.

What about deregulation of the electric power industry? Conventional wisdom postulates that competition is likely to cause electric utilities to reduce or eliminate their DSM programs, thus reducing market pull for thermal energy storage.

In Texas, industrial electricity prices are still relatively low, annual demand peaks are still increasing, and additional supply-side and demand-side resources are still being planned. At least one large, investor-owned electric utility is attempting to implement IRP in order to improve its competitive position in this environment. That electric utility's IRP plan was submitted to the Texas PUC in mid-October. The IRP plan seeks to add 1,241 MW of DSM resources (26.0% of total resource additions of 4,768 MW) from 1995 to 2004. DSM resource expenditures from 1995 to 2004 are estimated at $338 million (9.7% of total resource expenditures of $3,488 million).

In this case, the electric utility is seeking to add DSM resources in order to improve its competitive position 180 degrees opposite of conventional wisdom. A key question yet to be answered is: Will a means for cost recovery and a mark-up on DSM program expenditures be approved? If the answer is yes, market pull for thermal energy storage will increase greatly.

8.2 Building Owner #2

My opinion is that the lack of confidence by engineers and misunderstandings by the owners are major stumbling blocks to the advancement of thermal energy storage.

Engineers think that demand side management is a passing trend. Also, they don't understand the flexibility needed by the operators in the running the building mechanical system. Thermal energy storage provides the flexibility.

Owners perceive thermal energy storage as expensive, bulky, unsightly, and a new unproved technology. Until the perceptions are proven false, thermal energy storage will not expand rapidly.

8.3 Consulting Engineer #1

Over the last 15 years the thermal cool storage market has been largely driven by the electric utilities, which have been attempting to improve their load factor and to reduce summer peak demands for electricity. The technology has essentially remained static since 1980. Thermal energy storage (TES) consists at present of primarily ice storage, chilled water storage, and some eutectic salts. The major manufacturers have essentially remained the same, Calmac, Baltimore Aircoil Company, and CBI were major players with many years of experience in thermal storage since 1980, and remain the leading manufacturers in the market today. Others that have emerged as significant contributors include Natgun, Vogt/Turbo and Paul Mueller.

Although the technology appears to have remained essentially unchanged from 1980 to 1994, there have been several significant developments. The two developments I believe have had the most impact on improving the cost and energy effectiveness of thermal energy storage are: 1) stratified chilled water storage, and 2) cold air distribution. These developments have improved the energy efficiency of thermal cool storage to the level that cool storage uses less energy on an annual basis than non-storage cooling options. In addition, both technologies allow cool storage to meet functional cooling needs that cannot be effectively or efficiently achieved with non-storage systems. These include meeting standby needs, high short-term loads, periodic loads (i.e. those found in convention centers, museums, theaters, etc.), humidity control up to the 40-45% RH level, integration of space conditioning into existing refrigeration systems (supermarkets, warehousing, etc.), and space cooling options that meet a wide range of comfort requirements.

Even with these advances and a reasonably large number of installations throughout the world, thermal cool storage is still considered by many owners, architects, and engineers to be a "new" cooling technology, some even viewing it as experimental. This is one of the key image problems of thermal energy storage. The owner and design team that is not experienced with thermal energy storage must become trained and knowledgeable, or use experienced consultants to assist them in their first couple of projects. This is an essential requirement to achieving successful systems. This will require additional design and commissioning fees, however, the total project costs may not increase. A role government (those responsible for energy efficiency) and utilities can play in this process is to provide reimbursement for the costs for training, educating, and supporting experienced engineers. One of the functions of the EPRI-sponsored HVAC&R Center is to make a staff of experienced engineers available to assist owners, designers, and member utilities in achieving successful cool storage systems. In addition, there are a number of other experienced engineers that work with owners, design teams and utilities in achieving specific successful projects.

Although cool thermal storage is well understood, has a number of successful options, and can usually be the best low energy use cooling option, it still only accounts for a small proportion of the cooling market. If it is the best option, why doesn't it have a larger market? I cannot answer that question with certainty. It is my opinion, however, that there are at least three key factors. These are 1) perceived failure, 2) government/regulator non-involvement, and 3) the influence of major air-conditioning manufacturers.

To address the first concerns, it is true that we have had a number of systems that have failed. Additionally, it is perceived that a high percentage of cool storage projects have failed. The failures are due to improper design, and misunderstanding of the 24-hour cooling loads (both over- and under-sizing), and misguided application of unproved products and systems components (including storage tanks). Most of the marginal or unproved products are no longer being commercially marketed. However, the reputation of marginal and failed systems is well known. It is unfortunate that the many successes of TES systems are not as well known. Although successfully installed operating systems must consist of at least 98% of the total systems installed, the erroneous perception is that the failure rate of TES systems is around 50%. Perhaps it is the impact of a real or rumored failure that hinders belief in the successes. It is my opinion that almost all current projects are successful and that the key manufacturers (like Calmac, Baltimore Aircoil, Natgun and CBI) essentially have never had failures related to their product.

It should also be noted that a high percentage of the ASHRAE energy award projects have been thermal energy storage projects, including warm and hot energy storage. When we review these energy efficiency award-winners, it is clear that thermal energy storage has a true energy efficiency and cost advantage. The percentage of thermal storage winners in ASHRAE to the percentage of projects that are thermal storage indicates to me the true energy and cost effectiveness of thermal storage. There are a large number of successful projects that have a many successful years of operation. An example of four that have been well documented and presented in published sources are 1) the Alabama Power building, 2) the Henry C. Beck Middle School, 3) the Reedsburg Technical School, and 4) the Texas Instrument storage systems. These are all examples of successful installations that have been evaluated and illustrate four unique application of thermal storage.

The second restriction to the growth of thermal energy storage is that it has primarily been a technology that has been developed and promoted by electric utilities. Although it was initially a prime research topic for the Department of Energy in the 1970s, it was not given a high priority for additional research and development in the 1980s and 1990s. This may be changing, however, both the DOE and the EPA have emphasized efficient lighting and high-efficiency chiller technology over thermal storage. In addition, TES has not been a technology well understood or supported by many members of public service commissions. This has prevented thermal storage from being considered as an energy conservation technology. There has not been wide support for thermal storage from environmental groups. On the other hand, ASHRAE has had a major research and technology effort with programs at semi-annual meetings related to thermal energy storage during the 1980s. This has definitely contributed to the growth of thermal cool storage and the number of successful projects.

The third negative influence on the TES market comes from the major air-conditioning manufacturers. Essentially the major equipment manufacturers and control manufacturers are not directly involved in thermal cool storage products. Since thermal cool storage decreases the size of chiller equipment, controls, and air-handling equipment, there is no clear motivation for the air-conditioning companies to be involved in thermal storage, unless there is a clear and undisputed advantage. It is easy for most people to justify that efficient chillers, packaged units, gas cooling, and systems components can be designed into a system that is just as efficient as thermal storage. It is further easy to justify to owners that they should not use a system that they have not previously used. There are few positive economic motives for many players in the selection and application of cooling system compelling them to use thermal storage. In a previous survey I was involved with, it was determined that the mechanical design engineer selected the cooling approach on 90% of the proposed buildings. Further, a survey of mechanical engineers indicated that their primary source of information was from manufacturers and that they made only small changes in their design approach. Changes were usually influenced by manufacturers, marketing representatives, or owners directly.

My general assessment of the thermal storage market is that it has a lot to offer, but has several obstacles to overcome. It will require a major continuing effort by a dedicated group if it is to capture a significant proportion of the cooling market. This will have to be the electric utilities, government, ASHRAE, or an aggressive manufacturer. In addition, I believe that the market requires further integration of comfort heat storage and hot water recovery with or without storage to optimize its benefits and expand the air-conditioning market. There is a void in the market for small commercial and residential cool storage. This is a major problem since the majority of buildings are of those two categories. In order to fully penetrate the market, many more TES applications for these two categories must be designed.

8.4 Consulting Engineer #2

From our standpoint, we will continue to promote the concept using cold air distribution because we are convinced of the merits of the concept, based on the increased thermal comfort and improved indoor environment. We have never relied on incentives to justify a project. The market that we influence will remain stable.

There are still skeptics who do not accept the cold air concept and benefit of thermal storage. These are primarily the "good businessman" engineers who know it will cost them more money to design a thermal storage system and can not justify any marketing advantage. If the utilities want to promote the concept, they must give the engineer some incentive. The owner won't pay any more money for the design.

The efforts of EPRI and non-member utilities will be needed to keep the ball rolling, They must be convinced that the benefits are worth the promotional effort.

The major roadblock to increasing the thermal storage market is the lack of engineer incentive.

I feel that the thermal storage market is in elementary school stage. It's started, but there is a strong tendency to "drop out."

8.5 TES Consultant

I believe the cool thermal storage technology is now mature, but the marketing of it is still deficient! This deficiency is due to the industry's failure to develop convincing arguments in support of the premise that cool storage is an environmentally beneficial technology--in comparison to conventional air conditioning.

It can now be demonstrated that a large portion of cool storage installations save energy (kWhs) on an annual basis, as compared to conventional systems. Furthermore, all available indicators show that electricity generated during off-peak nighttime hours consumes less fossil fuels (result of lower heat rates) and produce less emissions than day-time generation, and that transmission and distribution losses are less at night as well. Since storage is charged using electricity at night, such "source energy" efficiencies are additive to on-site equipment energy savings.

Cool storage is uniformly and predominately perceived as a "load-shifting" technology. While this is certainly true, the fact that there are also conservation and environmental benefits of storage has not been generally acknowledged. Thus, the technology has not been accorded the deserved attention and support by DOE, EPA, Utility Commissions, and other regulatory agencies. This reflects the marketing failure by the industry to authoritatively substantiate source and on-site energy savings and reduced emissions.

A new "Thermal Storage Systems Collaborative" has recently been formed in California, under the auspices of the California Energy Commission, comprised of thirty or more industry "stake-holders" with the objective of developing a comprehensive Marketing Plan for Cool Storage. An essential element of this plan is research, now being financed by the Collaborative, to document and verify the source and on-site energy benefits discussed above. It is hoped that this effort will provide the industry with the tools to bring "marketing" up to the level of the technology itself!

8.6 Utility Representative

1) The annual market for TES will increase by 200-300% by 1998.
2) Widespread use of cold air and lower building construction costs will increase penetration. Penetration of the unitary market is required.
3) Utility deregulation will most likely have a negative effect on utility TES monetary incentives. However, this may also increase the differential between on & off-peak rates and speed the adoption of real-tine pricing.
4) The growing presence of Energy Service Companies (ESCOS) could have a positive effect.

5) Evolutionary technical advances in storage, air distribution, and controls will make TES more cost competitive and easier to apply.
6) A/E's are becoming more comfortable with TES.
7) The TES market is approaching maturity but more education is needed.

8.7 Manufacturer #1

Cool Thermal Energy Storage (CTES) is the "sleeping giant" in the HVAC industry. Although the use of CTES in large commercial and institutional applications has expanded in recent years, its use within the larger unitary sector of the industry has been negligible.

The use of CTES for all air conditioning **should** be encouraged, promoted and maybe even mandated because:

1. It significantly reduces the capital costs required by electric utilities by reducing on-peak demand.
2. In most applications it saves significant amounts of primary source energy because there is less use of low efficiency on-peak generating sources. Standby or off-peak "spinning reserve" losses of intermediate or base capacity sources are reduced. Transmission and distributions losses are reduced and the highest efficiency base capacity is used during off-peak periods. Reducing primary source energy use reduces emissions. Even when natural gas is used by on-peak combustion turbines, that same gas can be used more efficiently by base capacity combined cycle or conventional gas-fired steam generating units.

Hopefully, in 1995, the electric utilities will realize that CTES is practical and available and they will make mutually equitable time-of-use (TOU) or real time pricing rates available to their customers.

8.8 Manufacturer #2

Until very recently. no one in the TES industry has paid any serious attention to the small PTAC unit. Yet, installed tonnage in this market has been growing steadily while tonnage in field-erected chiller systems has been declining. In other words, we are pursuing the wrong market! The consulting engineer wants a system which can be designed as quickly as a non-storage system. We aren't there yet. The contractor wants a "box" which is simply set into place and connected. We aren't there yet. The National Accounts went a reliable, inexpensive and efficient unit. We aren't there yet. The Federal government is now on our doorstep insisting on increased PTAC unit efficiency. In some respects we have achieved it. But space comfort went out the window.

In order for TES to achieve significant penetration into the HVAC marketplace, it must meet at least these three goals

- it must be at least as reliable as a non-storage system
- It must be more energy efficient than the comparable non-storage system
- it must stand on its own merits without utility incentives.

If we can meet these goals *AND* produce increased **space** comfort with TES, significant market penetration *will* follow. Very significant. But **we** have to do our **homework** first.

I view TES in field erected systems as remaining static, with little to no appreciable growth (with the exception of turbine inlet cooling which will increase for about 5 years, then taper off). However, I see "packaged" TES as being in its infancy (Bob Tamblyn's sleeping giant is awakened!). We believe TES has the potential of reaching a 50% market share in the 10 to 15 ton rooftop size within 10 years, provided we can achieve a 2 year return-on-investment, or better. We see this as entirely possible.

The major roadblocks to achieving significant penetration are, in my opinion: excessive design complication, lack of adequate controls, excessive energy use ice-based systems, lack of a total unitary packaged unit and in far too many cases. excessive maintenance and lack of reliability. All of these points are addressable. Now let's Go to work!

8.9 Manufacturer #3

1) TES has been handicapped by many mistakes that caused poor performance and lack of confidence in several designs.
2) TES now has an ARI approved Guideline and coming Standard that assures good performance by ARI members. This has taken much more time to develop because of unique non-steady state performance.
3) There are only two basic systems: Chilled water is used in very large programs and areas and Ice Storage in small, medium, and medium large programs at one eighth size and equal cost per ton hour.
4) TES grew 44% between 1992 and 1993 (from 19 million to 34 million), and two new manufacturers joined ARI in 1994. Advanced equipment is well underway.
5) TES is growing fast in certain areas but not others, which is caused by utility rates, marketing, rebate insecurity, incomplete education, and a technical need of controls.

In conclusion, our opinion is that growth of TES will continue to grow at an enlarging rate with major effect on HVAC & R.

8.10 Technology Lecturer

- Engineers are not paid for additional design effort and risks. They will obstruct TES unless risks or design costs are reduced.
- Manufacturers promoting TES will reduce sales of existing product lines. They will obstruct TES. Additionally, they all promote products (e.g. absorption) with higher prices and margins. TES products need higher profit margins to justify promotion. May want to consider direct rebates to manufacturers [3:1 benefit] rather than to building owners.
- Utility rebates are targeted to owner, despite 90% of design by A/E. Feasibility studies are pre-determined - “won’t work” - due to <???> or design costs.. Utilities need to review marketing programs.
- Utility deregulation will transfer fixed costs of long term planning and peaking power to the customer. Future rates will have “take or pay” provisions encouraging customer to minimize contract service. TES will have strong economic incentive without DSM rebates.
- Technical support, software, and education programs to A/E and owners must be expanded. Utilities may want to “favor” TES experienced engineers and qualify firms to maximize penetration.
- Successful case studies and autopsies of failures (e.g. State of Illinois Center) must be developed. Engineers respond to threat of lawsuits, not marketing hype. [Knebel’s “33 things I’ll never do again”]
- We need to address design problems with TES. It is much easier to design for peak day (not week) and substitute absorption chiller rather than TES to achieve peak demand savings. Changes in occupancy are more critical for TES.
- More emphasis on “comprehensive CFC planning” and TES is needed. Cannibalization, schedule problems, and refrigerant minimization need to be promoted. It is the “easy solution”.
- IAQ and increased ventilation rates may also enhance TES. Added capacity can be met off peak
- Cold air distribution is the key technology. It reduces first cost, energy cost, relative humidity, and it improves IAQ. It eliminates absorption (43°F chilled water) as an option. It is new and high tech, and promotes an electric-only solution to all issues (CFC, IAQ, etc.)
- The biggest threat is regulator/standard efforts (e.g. ASHRAE Standard 90.1) that may not recognize cold air, TES, etc.