ESTIMATING THE MARKET PENETRATION OF RESIDENTIAL COOL STORAGE TECHNOLOGY USING ECONOMIC COST MODELING

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ABSTRACT

This study estimated the market penetration for residential cool storage technology using economic cost modeling. Residential cool storage units produce and store chill during off-peak periods of the day to be used during times of peak electric power needs. This paper provides projections of unit sales expected in 5-year intervals for the years 1995, 2000, 2005, and 2010. Such projections help to determine the maximum amount of energy that could be displaced by this technology in the future.

This study also found that price incentives offered to households must be varied dramatically by region for residential cool storage systems to be economically competitive relative to conventional systems. Under the most likely scenario, this analysis estimated that residential cool storage units will eventually capture about one-half of the central air conditioning (A/C) market.

INTRODUCTION

There are warnings about a serious electric power shortage by the mid-1990s (1, 2). This shortage is expected to occur during periods of peak electric power use, which occur on hot summer days for summer peaking utilities. Cool storage technology, developed for both commercial and residential applications, is one solution to meeting peak power needs. Demand for this technology is derived from utilities' hesitancy to pay the extremely high-capacity costs (per kW) required to generate electricity for use at peak periods.

This technology does not save energy--it merely shifts its use to a time when residential, commercial, and industrial demand for electricity is low. This technology produces and stores "chill" during off-peak periods of the day to be used during times of peak electric power needs. Thus, except for the electricity used to operate fans and recirculating pumps, all electric power use is shifted to late evening or early morning time periods.

The focus of this paper, based on a study conducted for the U.S. Department of Energy[b], is cool storage technology for the residential single-family market. Its objective is to estimate the market potential and expected market penetration of residential cool storage technology. This paper provides estimates of actual unit sales expected in the years 1995, 2000, 2005, and 2010. [See also QLA Inc. (3).]

The demand for residential cool storage units is a derived demand. There will be little or no interest in this product until utilities devise programs to encourage its use. Several factors have been identified that will influence the ultimate market penetration of residential cool storage. Some of these factors include the number of cooling-degree-days in an area, the time-of-day (TOD) electricity rates charged to households, price rebates offered by utilities to encourage purchase, and whether the cool storage unit is being installed in a new or an existing home. Several methods have been developed to generate market penetration estimates. This study will use a few of these methods (e.g., historical analogy and economic cost models) to develop an estimate of market penetration.

Projections are also made about the expected pattern of diffusion of this technology into the market place. This will be ascertained based on the market penetration pattern of a similar product in the market place. Of particular interest is the amount of time required to reach maximum market penetration. The diffusion pattern of residential central air conditioning systems will provide the historical analogy for residential cool storage units.

ESTIMATION OF MARKET POTENTIAL

Market potential is typically defined as the total number of consumers who can benefit from using a new product or technology. For this study, market potential is specified as the total number of households that might benefit from the use of residential cool storage technology. The first place to begin in attempting to estimate market potential is to identify the need satisfied by this technology. The market for residential cool storage technology, especially considering the expected shortfalls of electricity by regions in the U.S., is discussed below.

EXPECTED REGIONAL SHORTFALLS OF ELECTRICITY

The primary benefit of this technology is to shift demand for electricity off peak. Demand for this technology is derived from the extremely high-capacity costs (per kW) required by utilities to produce electricity at peak demand.

The first step in estimating market potential is to identify those geographic areas where there will be a problem in meeting peak summer electricity demand. The basis for making these estimates is

(a) Operated for the U.S. Department of Energy by Battelle Memorial Institute under contract no. DE-AC06-76RLO 1830.
(b) Weijo, R. O., and Brown, D. R., Estimating the Market Penetration of Residential Cool Storage Technology Using Economic Cost Modeling, Pacific Northwest Laboratory, Richland, Washington, (to be published).

an annual DOE study entitled Annual Outlook for U.S. Electric Power 1987 - Projections Through 2000 (4).

This study concludes that shortfalls in ability to provide peak electricity demands will become a serious problem in certain regions by the year 1995. By the year 2000, a serious power shortage will exist in almost all regions of the U.S.

Table 1 summarizes the findings from this study. This table describes the regions of the U.S. that are expected to have peak power shortages by the years 1995 and 2000. The first shortages of electricity will occur by 1995. The first areas to suffer from electricity shortages will be the Mid-Atlantic and Central regions. The Energy Information Administration (EIA) study concludes that virtually all of the U.S. will fall short of peak electric power by the year 2000. Only the North Central region is not expected to suffer from shortfalls.

Table 1, Anticipated Regional Power Shortages by the Years 1995 and 2000 (in Gigawatts) (4)

Region	Anticipated 1995 Power Shortage	Anticipated 2000 Power Shortage
New England	0.0	2.1
New York/New Jersey	0.0	1.0
Mid-Atlantic	4.2	11.3
South Atlantic	0.0	3.0
Midwest	0.0	16.3
Southwest	0.0	12.5
Central	3.1	7.5
North Central	0.0	0.0
West	0.0	5.7
Northwest	0.0	0.5

Given the pervasive character of power shortages by the year 2000, this study will not segment the potential market for residential cool storage technology by geographic area.

MARKET FOR RESIDENTIAL COOL STORAGE TECHNOLOGY

The market for cool storage technology is expected to be identical to the market that exists for central A/C. Central air conditioning includes both conventional central air conditioning systems as well as heat pump systems. There are two major submarkets for this technology: new homes and retrofits to the central A/C units in existing homes.

The first submarket is composed of new homes constructed in the U.S. Table 2 describes the proportion of new homes constructed in the U.S. that include central A/C. In recent years, approximately 70% of all new homes are constructed with central A/C. This percentage varies significantly from region to region. Table 3 describes the regional differences in installing central A/C in new homes. Of new homes constructed in the south, 92% include central A/C. The northeast region has the lowest proportion of new homes constructed with central A/C. Only about one-third of new homes constructed in that area include central A/C.

Table 2, New Single-Family Housing Completed with Central Air Conditioning or Heat Pump Units (5, 6)

Year	New Single-Family Housing(a)	With Central A/C or Heat Pumps(a)	Percent with Central A/C or Heat Pumps(a)
1971	1014	365	36
1972	1143	489	43
1973	1197	582	49
1974	940	451	48
1975	875	403	46
1976	1034	511	49
1977	1258	679	54
1978	1369	797	58
1979	1301	784	60
1980	957	598	63
1981	819	530	65
1982	632	416	66
1983	924	642	70
1984	1025	723	71

(a) All units listed are in thousands.

Table 3, New Single-Family Housing Completed with Central Air Conditioning or Heat Pump Units by Census Region (5, 6)

	Northeast		North Central		South		West	
Year	Units(b)	%	Units	%	Units	%	Units	%
1971	14	10	53	25	227	49	70	34
1972	17	11	68	29	299	56	105	43
1973	22	14	89	34	355	67	103	41
1974	21	16	78	35	284	72	64	34
1975	15	13	77	35	258	71	53	29
1976	16	13	107	40	320	78	68	29
1977	23	17	132	44	412	80	112	36
1978	28	20	141	47	480	84	149	42
1979	35	26	137	47	457	85	155	46
1980	29	29	77	45	384	84	109	47
1981	25	29	67	48	344	84	94	51
1982	21	27	40	43	290	85	64	53
1983	35	33	70	50	428	90	109	55
1984	44	34	86	55	466	92	127	55

(b) All units listed are in thousands.

The second submarket for residential cool storage are retrofits to the existing central A/C systems already included in homes. Brown and Spanner[c] found that modifying the existing central A/C equipment to incorporate cool storage was economically feasible for residential households. However, they concluded that removal of the existing system and complete replacement with a new residential cool storage system in an existing home was not economically feasible.

The expected life of central A/C equipment is approximately 15 years. Therefore, a typical household with central A/C must make major retrofits to this equipment every 15 years. Thus, one-fifteenth of the existing housing market with central A/C was considered the potential market for residential cool storage technology in any given year.

(c) Brown, D. R., and Spanner, G. E., Cost and Performance Goals for Residential Cool Storage Systems, Pacific Northwest Laboratory, Richland, Washington, (to be published).

Table 4 summarizes the saturation of air conditioning in existing residential housing by census region in the U.S.

A regression analysis was developed based on historical housing data to estimate the future size of the housing market. This model projected the total existing housing market to be as follows:

1995	111,459,000 units
2000	119,016,000 units
2005	126,572,000 units
2010	134,129,000 units.

Approximately 62% of these totals will be composed of single-family dwellings (7). Approximately 30% of single-family dwellings are projected to have central air conditioning. If one-fifteenth of this market composes the potential market in any given year, the potential annual market for residential cool storage systems in existing homes is approximately as follows:

1995	1,400,000 units
2000	1,500,000 units
2005	1,590,000 units
2010	1,680,000 units

A regression analysis model was also developed based on historical patterns of new housing starts. This model did not find a statistically significant relationship between annual new housing starts and time. Thus, the average value for housing starts over the last 5 to 10 years was used to estimate the expected annual new housing starts. On average, approximately 1,500,000 new housing units are constructed each year. Of this total, approximately 62% are single-family dwellings. Approximately 70% of these single-family houses will install central air conditioning. Thus, on average, approximately 650,000 new single-family homes are built annually with central air conditioning.

Including the totals estimated for both the new and existing housing market, the potential market for residential cool storage technology for the four target years is as follows:

1995	2,050,000 units
2000	2,150,000 units
2005	2,240,000 units
2010	2,330,000 units.

ESTIMATION OF MARKET PENETRATION

FACTORS INFLUENCING MARKET PENETRATION

Several factors have been identified that will influence the potential for residential cool storage. In a general sense, this will include the performance of residential cool storage units relative to their competitors. There are many dimensions to performance. Consumers generally make purchase decisions for expensive durable goods based on several product features: initial cost, operating cost, comfort, noise, warranties, familiarity of brand name, and maintenance requirements. This study did not attempt to study the influence of all of these features. Instead, it focused only on cost-related features. Cost competitiveness should be viewed as a necessary, but not sufficient, condition for the successful penetration of this technology into the market place.

There are several factors that influence the cost competitiveness of this technology. These include the TOD differential electric rate, price rebates offered by utilities, the first cost of the technology, operating and maintenance costs, and the cooling-degree-day requirements of an area. This study used an economic cost model to consider the importance of these factors in influencing the final market penetration.

ECONOMIC COST MODEL FOR ESTIMATING MARKET PENETRATION

Several methods have been developed to generate market penetration estimates (8, 9, 10). The economic cost model is appropriate for applications where the system cost is an important attribute in product selection. Cost and performance goals for residential cool storage technology were recently estimated in a study conducted by Brown and Spanner[(a)]. Other more accurate methods, based on consumer research also do exist to estimate market penetration. However, no consumer research has been conducted on this technology that might be incorporated in an estimate of market penetration.

Table 4, Saturation of Air Conditioning in Existing Residential Housing by Census Region and Division (11)

Census Region	Census Division	% of Housing with Central A/C Units	% of Housing with Room A/C Units	% of Housing without A/C
Northeast		10.9	39.9	49.2
	New England	4.7	37.2	58.1
	Middle Atlantic	12.5	41.1	46.4
North Central		27.3	32.4	40.3
	East North Central	21.1	32.2	46.7
	West North Central	40.6	34.4	25.0
South		47.3	29.9	22.8
	South Atlantic	44.9	27.2	27.9
	East South Central	43.1	39.7	17.2
	West South Central	54.5	28.4	17.1
West		22.9	15.9	61.2
	Mountain	35.5	15.6	48.9
	Pacific	18.4	16.0	65.6
Total U.S.		29.8	29.9	40.3

(a) Brown, D. R., and Spanner, G. E., Cost and Performance Goals for Residential Cool Storage Systems, Pacific Northwest Laboratory, Richland, Washington, (to be published).

The basic methodology employed in an economic cost model is simple. Raju and Teotia (8) provide a description of the steps in a typical economic cost model for estimating the market share of competing technologies:

> Economic cost models estimate market share as a function of only the cost-related aspects of the product. There are essentially four steps in the economic cost models. First, a set of competing technologies or products is identified. Second, for each product identified, the initial and after tax costs (e.g., capital, installation, and operation and maintenance costs) are estimated over the life of the product. Third, depending on the approach used, the costs are actually converted to a standard cost measure such as the 1) net present value or life-cycle cost ($), 2) internal rate of return (%), or 3) levelized energy cost ($/$10^6$ or cents/kWh). Finally, the market share of each product is estimated from the cost measure.

Economic cost models have had application in estimating the likely market penetration of solar technologies (12, 13). The S-shaped logistic curve has been used to develop these estimates. A comparison of payback periods and life-cycle costs provides the basis for comparing the relative attractiveness of competing technologies.

The S-shaped logistic curve will be used in this study to estimate the likely market share of competing technologies. Raju and Teotia (8) discussed the theoretical justification for using logistic curves in this analysis. They believe the logistic curve supports the theory that when technology is comparable only to conventional technology, only a small number of innovators will adopt it. As the technology becomes economically better, its market share increases rapidly. The growth rate for this technology slows when most of the market has been captured.

Important advantages and disadvantages have been presented for using logistic curves to estimate market penetration. The advantage of such a model is that cost factors can be developed early in the technology development process. In addition, sensitivity analysis can be performed using these cost estimates. A major criticism is that little empirical evidence is available to support the relationship between economic attractiveness and market share. Another disadvantage is that this model ignores most other customer attributes. Further, the equilibrium market share calculated from such a model will not be attained immediately. Diffusion of this technology will take several years despite its economic attractiveness.

SELECTION OF A BASE CASE HOME

One of the required tasks of this study was to select a building prototype that would be representative of the cooling load requirements of homes in the U.S. The estimation of a building's cooling load is a complex analytical calculation involving the following key building-specific factors, among many others:

1. Building floor area and layout
2. Type, quantity, and location of insulation
3. Internal heating loads
4. Ventilation practices
5. Indoor target temperature and humidity.

The housing characteristics selected for comparative economic analysis are based on the study conducted by Brown and Spanner. In that study, three different buildings were modelled to determine the impact of residential building size and type on the conventional cost of cooling. The housing characteristics analyzed in this study are a composite of characteristics common to these three house types. The energy-saving design practices, such as roof or wall insulating levels, were obtained from the ASHRAE Standard, which describes typical good building practices throughout the U.S. Table 5 provides a summary of the assumptions used to estimate conventional and residential cool storage system life-cycle costs.

Table 5, Assumptions Used to Estimate Conventional and Residential Cool Storage Life Cycle Costs

Model Assumptions	
Building style	Ranch
Cooling system capacity	3.5 tons
Conventional system capital costs	$2685
Conventional and thermal energy storage (TES) system COP (coefficient of performance)	1.75
On-peak period fraction of total daily load	0.73
Incremental capital costs for TES	$2000
Annual maintenance costs	$125
System life	15 yr
Property taxes	2% of initial capital/yr
General inflation rate	3.1%/yr
Electricity escalation rate	2.5%/yr
Maintenance escalation rate	3.1%/yr
Capital escalation rate	3.1%/yr
Discount rate	4.2%/yr

An important element of the estimate of life-cycle costs computed in this study is the cooling load in various locations and regions of the U.S. There is a wide range in the cooling-degree-day requirements at different locations in the U.S. Anchorage, Alaska, has less than 20 cooling-degree-days per year. At the other extreme, Miami, Florida, has over 4000 cooling-degree-days per year.

For this study, variations in cooling load requirements were modeled as a function of the cooling-degree-days (65-degree base) typical for locations in the U.S. Cooling load as a function of cooling-degree-days was calculated using the PEAR 2.0 program developed by Lawrence Berkeley Laboratory (14). This program estimates the heating and cooling energy use of buildings of various size and construction characteristics in different cities in the U.S. A regression analysis model was developed from data computed from a sample of cities in the U.S. to estimate cooling load as a function of cooling-degree-days. This relationship was then included in the economic cost model to estimate state-level market penetrations.

COMPARISON OF LIFE-CYCLE COSTS FOR CONVENTIONAL CENTRAL A/C AND TES SYSTEM

The methodology employed by Brown and Spanner[(a)] provided the basis for estimating the life-cycle costs for the conventional central air conditioning system and the residential cool storage system. This study used the same economic assumptions as in the Brown and Spanner study. Comparative life-cycle costs were developed, assuming various types of price incentives are offered by utilities. Figure 1 describes the findings of the influence of various TOD rates on the comparative life-cycle costs for a system. Figure 2 describes the influence of price rebates on the comparative life-cycle costs of the residential cool storage systems. The relevance of these findings is discussed below.

Figure 1 describes the effect of zero, $0.05, $0.10, and $0.15/kWh TOD rate differentials on the economic competitiveness of residential cool storage systems compared to conventional central air conditioning systems. The 45-degree line on this graph indicates the point where the TES system cost/MBtu equals the conventional system cost/MBtu. The portions of the graph on the right side of the 45-degree line indicate points where the TES system cost is lower than the comparable conventional A/C system cost. An example is presented below to help clarify the interpretation of this figure.

Another line on Figure 1 describes the comparative costs of the TES and conventional systems in climates with 1000 cooling-degree-days. This cost line crosses the 45-degree line at a TOD rate differential of approximately $0.14/kWh. This indicates that for TOD rate differentials greater than $0.14/kWh, the TES system has a lower cost per MBtu than conventional air conditioning systems.

Figure 2 describes the influence of price rebates on the economic competitiveness of residential cool storage systems compared to conventional A/C systems. This figure might also be interpreted as the influence of a cost reduction on the economic competitiveness of this new technology. The interpretation of this figure is similar to the explanation provided above for Figure 1. As an example, a $1000 rebate in climates with 500 cooling-degree-days has a dramatic effect on the cost competitiveness of TES systems. However, even with a $1000 rebate, a TOD rate differential of approximately $0.20/kWh would be required for the new TES system to be cost competitive with the conventional central air conditioning system.

From the findings described in Figures 1 and 2, this study concludes that pricing incentives must vary dramatically by region for residential cool storage units to be economically attractive relative to conventional central air conditioning systems. Assuming a $2000 differential price for residential cool storage units, a TOD rate differential of approximately $0.075/kWh would be required at 2000 cooling-degree-days (65-degree base) to allow residential cool storage technology to compete economically with central air conditioning. At 1000 cooling-degree-days, a TOD rate differential of approximately $0.15/kWh would be required to allow residential cool storage to compete economically with central air conditioning. Another

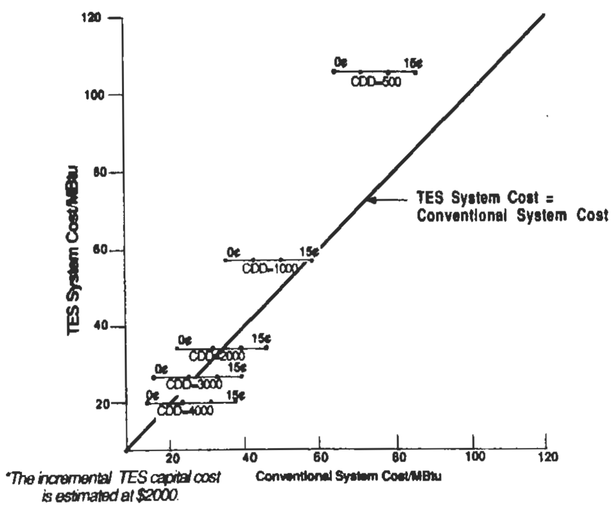

Fig. 1 A Comparison of Life Cycle Costs for Conventional and TES A/C Systems at Selected Cooling-Degree-Days for TOD Rate Differentials Between $0.00 and $0.15/kWh

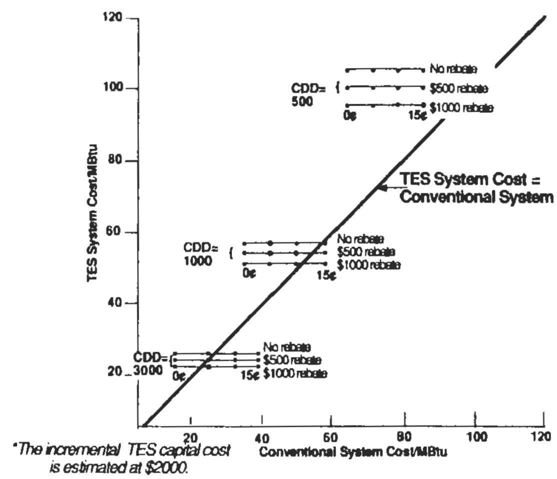

Fig. 2 A Comparison of Life Cycle Costs for Conventional and TES A/C Systems at Selected Cooling-Degree-Days for Price Rebates Between $0 and $1000

(a) Brown, D. R., and Spanner, G. E., Cost and Performance Goals for Residential Cool Storage Systems, Pacific Northwest Laboratory, Richland, Washington, (to be published).

option at 1000 cooling-degree-days is to offer a $0.10/kWh TOD rate differential with a $1000 rebate to make residential cool storage units economically competitive. Residential cool storage units are not economically competitive at 500 cooling-degree-days or less. Very extreme price incentives would have to be offered to make residential cool storage units economically competitive in these climates. This would require a $0.20/kWh TOD price differential and a $1000 price rebate.

EXPECTED MAXIMUM MARKET PENETRATIONS

The maximum national penetration of residential cool storage technology will be influenced by the average cooling requirements across the 50 states. States that have very low cooling requirements will have very low penetrations of residential cool storage technology. Two factors work against a high penetration of residential cool storage in states requiring little cooling. First, these states generally have a very low penetration of central air conditioning. In states such as Maine, window air conditioning is a much more economical way to cool than central air conditioning. Second, residential cool storage units, because of their high comparative life-cycle cost, are not competitive with central A/C that exists in these states. Both factors combine to minimize expected penetration in such states.

However, the reverse is true in other states. For example, in Florida, approximately 92% of newly constructed homes have central air conditioning. In such a climate, the high penetration of central air conditioning, along with the massive cooling required in such areas, can lead to very significant potential penetration for residential cool storage.

An economic cost model, developed using Lotus 123, estimated the maximum penetration of residential cool storage by state. This spreadsheet estimated the penetration for each state based on the average cooling-degree-days for that state. Each of the state estimates of market penetration was then weighted with the stock of existing housing and new construction occurring in each state.

These market penetration estimates were made over a variety of different scenarios. Different levels were set for TOD rate differentials and price rebates offered by utilities. The TOD rates considered included zero, $0.05, $0.10, and $0.15/kWh rate differentials above the off-peak rates. The price rebates that were considered include zero, $250, $500, $750, and $1000.

Table 6 presents the finding of estimated national market penetration of residential cool storage technology. Clearly, the penetration will vary significantly depending on the incentives offered by utilities. The worst case, when no incentives are offered, shows that residential cool storage would eventually replace only 2% of the central air conditioning market. In contrast, when a $0.15/kWh TOD rate differential is offered to consumers along with a $1000 rebate, over 80% of the central air conditioning market is expected to be eventually replaced by residential cool storage systems.

Table 6, Projected Maximum Market Penetration[(a)] of Residential Cool Storage Technology at Selected TOD Rate Differentials and Price Rebates

		Time-of-Day Rate Differential				
		None	$0.05	$0.10	$0.15	$0.20
Utility-Offered Price Rebates	None	1.9%	22.5%	47.8%	64.3%	75.2%
	$250	2.4%	25.2%	50.7%	66.9%	77.3%
	$500	3.1%	28.1%	53.7%	69.5%	79.3%
	$750	3.9%	31.3%	56.9%	72.1%	81.3%
	$1000	5.0%	34.8%	60.1%	74.7%	83.2%

(a) Based on the historical experience of residential control A/C systems, this maximum market penetration will probably be achieved about 40 years from product introduction.

Under the most likely scenario, a $0.10/kWh TOD rate differential was used to derive an estimate of final market penetration. This analysis estimated that residential cool storage units would eventually capture about one-half of the central air conditioning market.

ESTIMATION OF FUTURE UNIT SALES

PROJECTION OF SALES BY ANALOGY

The previous two sections have described the two important components of estimating unit sales, market potential, and eventual national market penetration. The only variable that remains to be estimated is the length of time required for residential cool storage systems to achieve their maximum market penetration into the U.S. building stock. To develop estimates of the expected unit sales between 1995 and 2010, this study compared the pattern of diffusion for a similar product. This pattern of diffusion was then used to project future unit sales for residential cool storage. Central air conditioning is very similar to residential cool storage systems. In many respects, the diffusion pattern of these two technologies should be very similar.

In each instance, a less expensive substitute was available for each product: with central air conditioning, it was the window air conditioning units; with the residential cool storage system, it was the central air conditioning system. It is anticipated that the initial consumer demand for residential cool storage units will be tempered by the cost of the system, as well as concerns about the durability and reliability of the newer unit.

It is hypothesized that the early adopters of both of these technologies are also similar. The early adopters of the residential cool storage unit are expected to be the more affluent and upscale homeowners who are replacing their first home with a more expensive, custom-designed home.

Later diffusion is expected to occur in medium-income new households and also as retrofits to central air conditioning systems in existing homes.

Raju and Teotia (8) discuss the merits and weaknesses of using the historical analogy method to estimate the diffusion pattern of a new technology:

> Historical analogy is a forecasting method based on the comparison of a new product or technology with an existing one that is analogous. The market penetration share over time is assumed to be essentially the same for both technologies. The method thus does not explicitly consider variables other than time and assumes that the new and the analogous products are similar and exist in identical competitive markets.
> Historical analogy is useful especially when historical data are not available, e.g., because the product or technology has been introduced very recently. It can also provide a useful first approximation before more sophisticated forecasting methods are used. Its success, however, depends on identification of an analogous product or technology and is therefore less likely to be useful for pioneering technologies.

ESTIMATED YEARLY AND ACCUMULATED SALES

Allowing for these limitations of the method, a logistic curve was fitted to the historical pattern of sales of conventional central air conditioning systems. Table 7 describes the diffusion pattern that fits the historical data. This diffusion pattern was used in Table 7 to estimate the expected unit sales by year for residential cool storage systems. This curve assumes that this technology is introduced to the market place in 1990. The first full year of sales is 1991. The estimated annual unit sales for this technology in 1995, 2000, 2005, and 2010 are approximately 60,000, 150,000, 300,000, and 500,000 units per year, respectively.

ESTIMATED SALES BY STATE

The economic cost model developed for this analysis estimated the unit sales for this technology by state. Table 8 describes the states that are expected to have the largest unit sales of this technology. The states that are anticipated to have the greatest unit sales are Texas, Florida, Georgia, Louisiana, North Carolina, Oklahoma, Arizona, Alabama, Tennessee, and North Carolina. It is apparent that the nearly all sales of this technology will be centered over the hot and humid southern tier states in the U.S.

CONCLUSIONS AND RECOMMENDATIONS

The objective of this study was to estimate the market potential and expected market penetration for residential cool storage technology. There will be little demand for residential cool storage until utilities offer sufficent incentives to

Table 7, Projected National Yearly Sales and Cumulative Sales for Single-Family Residential Cool Storage Units

Year	Projected Yearly Sales(a)	Projected Cumulative Sales(a)	Diffusion Pattern
1990	INTRODUCTION		
1991	30	30	0.03
1992	40	70	0.04
1993	45	115	0.05
1994	55	170	0.06
1995	65	235	0.07
1996	75	310	0.08
1997	90	400	0.09
1998	105	500	0.10
1999	120	625	0.12
2000	140	765	0.14
2001	165	930	0.16
2002	190	1120	0.18
2003	220	1340	0.21
2004	250	1595	0.24
2005	290	1880	0.27
2006	325	2210	0.30
2007	370	2580	0.34
2008	415	2995	0.38
2009	460	3455	0.42
2010	510	3970	0.46

(a) All units are in thousands

motivate homeowners to purchase these units. Several factors will influence the likely market penetration of residential cool storage: the cooling-degree-day requirements of a region, the time-of-day rate differential charged to households, price rebates offered to encourage purchase of these units, the first cost of the product, and whether the cool storage unit is being installed in a new or existing home.

MARKET POTENTIAL

Market potential is defined as the number of customers who might be able to benefit from the use of a product. For this study, market potential was defined as those households that would typically purchase either central air conditioning units or heat pump systems for their single-family dwellings. Market potential estimates for each of the four years used in projections included new housing construction per year as well as estimates of central air conditioning retrofits/modifications in existing housing. The estimates of market potential were as follows:

1995	2,050,000 units
2000	2,150,000 units
2005	2,240,000 units
2010	2,330,000 units

MARKET PENETRATION

This study found that incentives must vary dramatically by region for residential cool storage units to be economically competitive to central air conditioning units. Assuming a $2000 differential price for residential cool storage units, a TOD rate differential of only $0.075/kWh would be

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Table 8, Projected[a] Annual Single-Family Residential Cool Storage Sales by State Using a Mandatory Time-of-Day Rate Differential of $0.10/kWh

State	Average Cooling-Degree-Days	1995 Sales	2000 Sales	2005 Sales	2010 Sales	Eventual TES System Replacement of Central A/C Units
Texas	2682	15,000	38,000	79,000	135,000	84%
Florida	3348	11,000	27,000	57,000	95,000	90%
Georgia	1780	3,000	9,000	18,000	30,000	65%
Louisiana	2588	3,000	8,000	17,000	25,000	83%
North Carolina	1390	3,000	6,000	13,000	20,000	50%
Oklahoma	2010	2,000	6,000	13,000	20,000	72%
Arizona	2606	2,000	5,000	11,000	15,000	83%
Alabama	1921	2,000	5,000	10,000	15,000	70%
Tennessee	1392	2,000	5,000	9,000	15,000	50%
South Carolina	1830	2,000	5,000	9,000	15,000	67%
California	779	1,000	4,000	8,000	10,000	16%
Virginia	1093	1,000	4,000	8,000	10,000	53%
Missouri	1335	1,000	4,000	8,000	10,000	45%
Arkansas	1861	1,000	3,000	7,000	10,000	68%
Mississippi	2163	1,000	3,000	7,000	10,000	75%
All other states		10,000	18,000	26,000	65,000	
		60,000	150,000	300,000	500,000	48%

(a) This analysis assumed that residential cool storage units are introduced into the market place sometime during 1990. The first full year of sales are 1991.

required at 2000 cooling-degree-days (65-degree base) to make residential cool storage economically competitive to central air conditioning. At 1000 cooling-degree-days, a TOD rate differential of approximately $0.15/kWh would be required to make residential cool storage economically competitive to central air conditioning. Another option at 1000 cooling-degree-days is to offer a $0.10/kWh TOD rate differential with a $1000 rebate to make residential cool storage units economically competitive to central air conditioning. Residential cool storage units are not economically competitive at 500 cooling-degree-days. Very extreme price incentives would have to be offered to make residential cool storage units economically competitive with central air conditioning. This would require a $0.20/kWh TOD price differential and a $1000 price rebate.

An economic cost model was used to estimate the eventual market penetration of residential cool storage units. This model determined that the final market penetration will vary dramatically depending on the price incentives that are offered. Under the most likely scenario, a $0.10/kWh TOD rate differential was used to derive an estimate of final market penetration. This analysis estimated that residential cool storage units would eventually capture about one-half of the central air conditioning market.

ESTIMATED UNIT SALES

Under the assumption that the above conditions are met, this study estimated future unit sales for this technology. These estimates were based on an historical analogy to the diffusion time required for the penetration of central A/C units. The estimated unit sales for the four target years are approximately as follows:

1995	60,000 units
2000	150,000 units
2005	300,000 units
2010	500,000 units

The largest markets for this technology would include Texas and Florida.

RECOMMENDATIONS

Finally, the authors recommend that a more comprehensive consumer research study be conducted to estimate the likely market penetration of residential cool storage units. This study has focused on the economic factors that will be required to make this technology attractive to residential households. This assumes that households are only motivated by economic factors in the purchase of technology. In reality, this is not true. The purchase of a complex durable good is based on multiple product features. Issues of comfort, ease of use, and durability will likely have a significant impact on the final market share obtained by this technology. Tradeoff analysis methodologies used in consumer research should be used with this technology to develop more precise estimates of the probable final penetration of residential cool storage units.

The researchers also recommend that hourly electric power consumption patterns for residential central air conditioning be studied. The current lack of understanding regarding consumption by individual residences, the coincidence of demand by multiple residences, and the coincidence of demand for air conditioning with total utility demand are factors that make it difficult to specify the impact of residential chill storage on utility demand.

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