A COMPARISON OF DOMESTIC WATER HEATING OPTIONS IN THE AUSTIN ELECTRIC SERVICE AREA

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ABSTRACT

This report examines the energy, demand, and economic effects of three alternative electric water heating systems from the perspective of both the City of Austin Electric Utility and its ratepayers. An hourly computer simulation was used to model the operation of (1) a conventional electric resistance water heater (ERWH), (2) a heat pump water heater (HPWH), and (3) a heat recovery water heater (HRWH). Data from a previously conducted field test of solar water heaters (SWH) in the Austin area was used to compare this fourth water heating option. In the base case, the SWH was found to save the most energy relative to a conventional ERWH followed by the HPWH and the HRWH, respectively. However, under most economic assumptions thought to be reasonable for the Austin area, the heat recovery water heater appeared to be the best choice for the Austin all-electric ratepayer. From the Utility's perspective, it was determined that: (1) widespread ratepayer use of heat recovery water heater systems would be beneficial to the Utility; (2) ratepayer use of solar water heater systems would be marginally beneficial to the Utility; and (3) ratepayer use of heat pump water heater systems would not be beneficial to the Utility.

INTRODUCTION

Like many other electric utility owners

an alternative to purchasing new capacity. As part of this effort, they offer cash rebates to the purchasers of three water heating systems for all-electric residences: the heat pump water heater (HPWH); the heat recovery water heater (HRWH); and the solar water heater (SWH). Additionally, the City has adopted an Energy Code which requires one of these alternative water heaters to be installed in new all-electric single family dwellings and multi-family units over 1000 square feet. In an effort to evaluate the impact of one of these alternatives, the City cooperated in a field test study of SWHs and conventional electric resistance water heaters (ERWH) in Austin (1,2). However, they have relied on studies conducted in other parts of the country and manufacturer's claims to estimate the energy savings and peak reducing capabilities of the other two alternatives. The purpose of this investigation is to evaluate the different methods of heating water by all-electric households in the Austin area. The options will be evaluated from both the viewpoint of the residential electric consumer and the Electric Utility.

The technologies used in these water heating alternatives are not new, but have been refined over the last few years in response to rising electricity costs. The HPWH uses the same vapor compression cycle as other refrigeration devices to deliver heat from the surrounding air to the water. The HRWH uses heat in the gases leaving the compressor of the household's air conditioning or heat pump system to heat water. And of course, SWHs use the direct energy of the sun to heat water. For nearly all cases, these systems use electricity, to power either pumps, compressors, or auxiliary resistance elements. Unlike the conventional ERWH, the performance of all three alternative systems depends on the geographical location of the system. The performance of the HPWH is a function of the surrounding air temperatures and the inlet water temperatures. Also, if this option is located in the conditioned space of a home, the removal of heat associated with its operation will affect the energy consumption of the home's heating and air conditioning system. Installed in the conditioned space, the HPWH reduces the energy consumption of the HVAC system during the cooling season, while increasing its energy consumption during the heating season. Likewise, the performance of the HRWH is greater in climates that require many hours of air conditioning. Finally, similarly sized SWHs are able to supply more hot water in locales which receive more solar energy.

performance and reliability under both controlled and actual operating situations. The large DOE/ORNL/EUS field test of HPWHs was probably the most comprehensive (3). The Florida Public Service Commission sponsored several field tests of all four water heating systems to evaluate the systems in Florida (4-6). NBS conducted a detailed laboratory test on the HRWH, measuring not only the heating capacity of two of these units, but also, measuring the effect of these units on the performance of the heat pump to which they were connected (7). Also, all of the methods have been mathematically modeled and their operation has been simulated (8-10).

Some of the studies have evaluated the economic merit of the options for the consumer (11). A few studies have attempted to evaluate the economic impact on utilities of replacing the ERWH with the various alternatives (12).

APPROACH OF STUDY

Since considerable testing and modeling of

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the various systems had already been conducted, it was felt that reasonably realistic models of the systems could be constructed. Additionally, computer simulations of the water heating systems allows control of both hot water demand variables and installation scenarios. Therefore, three of the water heater systems were modeled and their operations simulated: (1) a conventional electric resistance water heater, (2) a heat pump water heater, and (3) a heat recovery water heater. Data from the previously conducted field tests of solar water heaters in the Austin area was used to compare this fourth water heating option. Since a heat pump water heater will affect the energy consumption of a home's heating and air conditioning system if it is located in the conditioned space, this option was modeled in the conditioned space of a home using (1) a heat pump system and (2) an electrical resistance heater and an air conditioner. The heat pump water heater was also modeled in an attached garage. Since the amount of water heated by a heat recovery water heater is a function of the air conditioner or heat pump size and/or run time, this alternative was modeled for two house sizes (1455 square feet and 2196 square feet), and two HVAC systems (a heat pump system and an electrical resistance/air condtioner system). The household hot water demand, in terms of both gallons (average daily draws of 55, 40, and 70 gallons) and final delivery temperatures (137 F and 125 F), was also varied. The DOE-2 computer program was used to calculate heating and cooling loads and HVAC operation for the two homes modeled in this study. Output from these simulations was then used as input for the water heater simulation program of the present study.

RESULTS

The monthly electrical use of the water heating options for a household characterized by the base-case water draw (yearly average of 55 gallons per day) and house size (1455 square feet) are illustrated in Figure 1 and listed in Table 1. More than one installation scenario is depicted for the HPWH and the HRWH. The HPWH was assumed to be installed in (1) an unconditioned garage (HPWH-GAR), (2) a space conditioned by a heat pump (HPWH-HP), and (3) a space conditioned by electrical resistance heating and an air conditioner (HPWH-AC). The HRWH was assumed to be installed (1) in conjunction with a heat pump (HRWH-HP), and (2) in conjunction with an electrical resistance heating system and an air conditioner (HRWH-AC). Since Austin has a two-tiered rate structure, with the ratepayer paying more for their electricity in the "summer" months (May through October) than they do in the "winter" months (November through April), the energy savings (relative to the ERWH) for each of these rate "seasons" are also listed. The savings listed may differ slightly from those evident in the figure. The reason for this is that the savings for each alternative water heating method were calculated relative to an ERWH located in the same environment. The curve shown for ERWH energy use is one for an ERWH located in a garage. An ERWH located in the conditioned space would use slightly less energy annually, and is not shown in the figure.

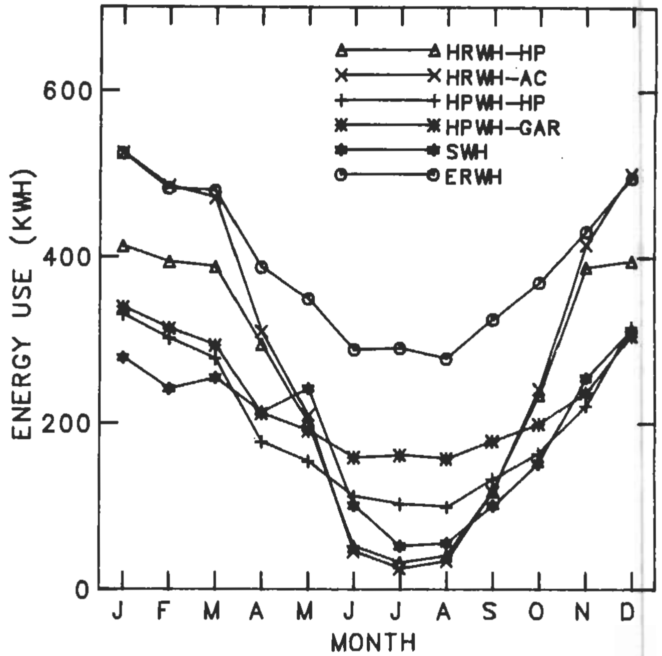

Fig. 1 Monthly energy use of water heating options

MONTH	ERWH (KWH)	HRWH-HP (KWH)	HRWH-AC (KWH)	HPWH-HP (KWH)	HPWH-GAR (KWH)	SWH (KWH)
JANUARY	526	413	526	331	340	279
FEBRUARY	484	395	486	303	315	242
MARCH	481	389	471	278	294	255
APRIL	389	296	311	178	212	214
MAY	351	202	210	155	191	242
JUNE	290	52	46	113	160	102
JULY	292	33	26	103	162	53
AUGUST	279	41	35	100	158	56
SEPTEMBER	327	119	118	133	179	101
OCTOBER	371	234	242	164	200	152
NOVEMBER	432	389	416	222	237	255
DECEMBER	497	397	501	317	306	313
ANNUAL	4719	2960	3387	2395	2752	2263
WINTER SAVINGS (KWH)		421	98	1071	1105	1251
SUMMER SAVINGS (KWH)		1241	1234	1156	862	1205
ANNUAL SAVINGS (KWH)		1662	1332	2227	1967	2456
(%)		36	28	48	42	52

Assumptions: (1) Annual average water draw of 55 gallons per day.
(2) Thermostat set point of 137 F.
(3) 1455 square foot house with 2.5 ton A/C or heat pump.

Table 1 Monthly, seasonal, and annual energy usage and savings of the water heating options

When the HRWH was used in the base case with either an air conditioner or a heat pump, most of the hot water demand could be met during the summer months using the waste heat of these units. In addition to this "free" heating of the water, the effect of the heat recovery unit on the air conditioner or heat pump is to improve its efficiency. The savings due to this effect are included in the energy use and energy savings shown for the HRWH scenarios. A HRWH will produce the most annual energy savings when the HVAC system used is a heat pump (about 36% in the base case). The HRWH system used with only an air conditioner essentially operates just as an ERWH does during the winter months and thus had an annual energy savings of only about 28% in the base case. Once the weather starts to dictate the need for cooling, the type of HVAC system employed has little effect on the energy savings obtained with a HRWH. The smallest savings achieved with a HRWH/heat pump combination will occur during mild transition periods when little air conditioning or heating is required.

For climates such as Austin's with long summers and mild winters, a HPWH located in a space conditioned with a heat pump is a viable installation location. During the winter months, a HPWH located in such an environment may perform just as well as one located in a garage. The temperature found in a garage will fall somewhere between that found in the adjoining conditioned space and that of the outside air. In the garage modeled in this simulation, the temperature dropped low enough (below 40 F) to cause power to be switched from the HPWH to the backup resistance elements several times. In addition to this inefficiency during the winter months, a HPWH located in a garage will operate slightly less efficiently than one located in the conditioned space (due to lower average surrounding temperature). In all cases modeled in this study, these disadvantages of the garage installation outweighed the disadvantage of increased heat pump run time attributable to a HPWH borrowing heat from the conditioned space to heat water. During the cooling season, cooling provided by a HPWH located in the conditioned space will reduce the run time of the home's cooling system. This benefit outweighs the slightly more efficient operation of a HPWH located in the warmer environs of a garage. The annual energy savings for the HPWH/heat pump option was about 48% for the base case assumptions, while the HPWH located in the garage saved approximately 42%.

Location of the HPWH in the conditioned space of a home heated by electric resistance and cooled by an air conditioner will save the least amount of energy annually (about 40% in the base case). However, as discussed above, the energy saved during the cooling season with such an installation will be greater than that saved with a garage installation. With a two-tiered electric rate structure such as Austin's, the larger and more valuable summer time savings possible with a HPWH located indoors are a benefit of this option that should be considered.

The energy consumption of a SWH, as illustrated in Figure 1, was derived from the field test data of the Austin study previously mentioned. This data was adjusted to reflect an annual hot water demand similar to that used in the simulations of the other systems. Although the annual solar fraction determined in the field test studies (about .52) is somewhat lower than generally thought to be optimal, the SWH still saved more energy than any of the other options for the base case assumptions. During the cooling season, a SWH can save about the same amount of energy as a HRWH. For a summer month during which much cloudiness is experienced (perhaps a month like May in Figure 1), the HRWH may outperform a SWH system. On the other hand, for a cooler and sunny month, the SWH should outperform a HRWH system (see September and October in Figure 1). During the hot months typical of Austin summers, both systems should use less than 20% of the electricity required by an ERWH.

For each alternative water heating method, the amount of energy saved will vary depending on the amount of hot water used and the delivery temperature of the water. The variation in energy savings with average daily water draw and delivery temperature are shown in Figure 2 and listed in Table 2 for the base case size home.

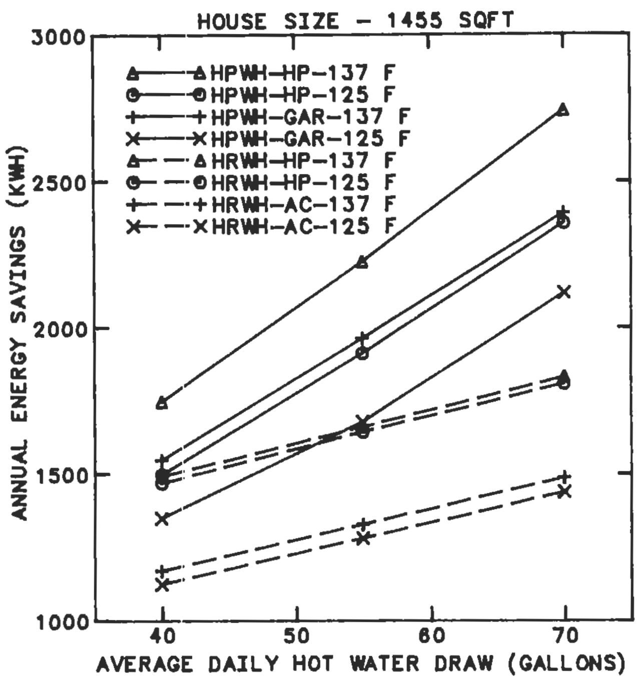

Fig. 2 Effects of hot water demand on energy savings of HPWH and HRWH

FINAL DELIVERY TEMPERATURE (F)	137			125		
AVERAGE DAILY HOT WATER DRAW (Gallons)	40	55	70	40	55	70
OPTION						
HPWH-HP	1750 (47%)	2227 (48%)	2743 (49%)	1501 (48%)	1915 (50%)	2359 (52%)
HPWH-GAR	1550 (41%)	1966 (42%)	2393 (42%)	1352 (42%)	1681 (43%)	2120 (45%)
HRWH-HP	1494 (40%)	1663 (36%)	1833 (33%)	1471 (47%)	1646 (43%)	1810 (40%)
HRWH-AC	1173 (31%)	1331 (28%)	1490 (26%)	1127 (36%)	1284 (33%)	1441 (31%)

Table 2 Effects of hot water demand on energy savings of HPWH and HRWH

For all of the alternative water heating systems, a household which uses less hot water than another has less to gain in energy savings by using one of the alternatives. However, the efficiency of the HPWH system increases at lower delivery temperatures and the efficiency of the HRWH system (relative to an ERWH) improves with both smaller draws and lower delivery temperatures, assuming that the HVAC operation is constant. Therefore, even though the user of less hot water (i.e. a family of two) can expect to save less energy using one of the alternatives than a larger hot water consumer (i.e. a family of four), the savings do not necessarily decrease at the same rate as the hot water consumption. Another point evident from Figure 2 is that the energy savings possible with a HRWH system are less sensitive to variations in the hot water demand than they are for the HPWH for a given HVAC operation. This is to be expected since the HRWH savings depend primarily on the cooling and heating loads of the home. For all three sizes of water draws simulated, water is heated when the HVAC compressor is operating, and the compressor operates identically in all three cases. More energy is saved with larger water draws because such draws keep the lower portions of the tank depleted of warm water and thus the water being passed through the heat recovery unit (HRU) is cooler and able to accept more heat from the refrigerant during a given air conditioner run period.

A SWH system is similar to the HRWH in that for a given system of collectors and storage, the heat available is not dependent on the hot water demand. A HRWH system has heat available when the HVAC system is running, while a SWH system has heat available when the sun is shining. However, unlike a HRWH system which uses a given size of HVAC system, the size and array of collectors for a SWH system can be optimized for the household's hot water demand.

Life-cycle costing methods were used to evaluate the consumer's economics for the water heating options. The net present value (NPV) of the water heating options are shown in Figure 3 as a function of the consumer's personal discount rate for the base case assumptions. The real escalation rate for the cost of electricity was assumed to be 1%. The internal rate of return (IRR) for each of the alternatives is also illustrated in Figure 3. The IRR for each option is equivalent to the discount rate at which the NPV for the option is zero. This is the consumer discount rate at which the discounted savings on electric bills just equal the discounted costs of purchasing and maintaining the option. If the consumer's discount rate is lower than this, then the option is a better alternative than the ERWH.

Even though the HRWH saves the least amount of energy of the options for the base case, it performs very well in the economic analysis. This is due to its lower initial cost and an expected life equal to the SWH and twice that of the HPWH. The HRWH used in conjunction with a heat pump would be the option of choice at all discount rates higher than zero under the base case assumptions. For households with the assumed characteristics but no heat pump, a SWH (with the federal tax credit) seems to be a good choice for discount rates of up to about 5%. If the consumer's discount rate is higher than this, the HRWH used in conjunction with an air conditioner

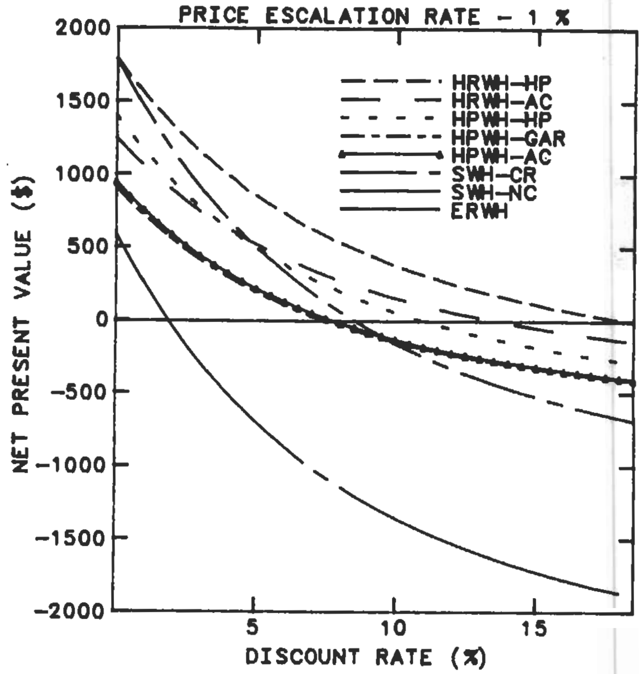

Fig. 3 Consumer economics for base case assumptions, 1% real price escalation

becomes a better choice.

In this analysis, the HPWH has the main disadvantage of a shorter life-expectancy than the two alternative options. All of the alternatives evaluated have a pump to circulate water to and from the storage tank. This has a life expectancy of about ten years. It was assumed that it was economical to replace this relatively inexpensive device for the HRWH and HPWH options. However, the HPWH also has a compressor with a life expectancy also of about ten years. Considering the expense of this component and the coincident expected failure of the water pump, it was assumed that it would be more economical to replace the entire appliance than to repair or replace these components. Nevertheless, in the base case, a HPWH located in a space conditioned by a heat pump is about as economical as a SWH with a federal tax credit at a discount rate of 5%. Due to the two-tiered Austin rate structure, a HPWH located in a space conditioned by an air conditioner and electric resistance heater has about the same NPV as one located in a garage. If the federal tax credit is discontinued for SWHs, and a HRWH is not a viable option, then the HPWH would be the option of choice at discount rates below about 8%.

If the cost of electricity should increase at a higher rate, then all of the options will become more attractive, with the options which save more energy benefitting the most. Figure 4 shows the results of calculations identical to those discussed above except the cost of electricity is escalated at 3% above the general inflation rate.

As discussed in the section on energy savings, the amount of hot water demanded can

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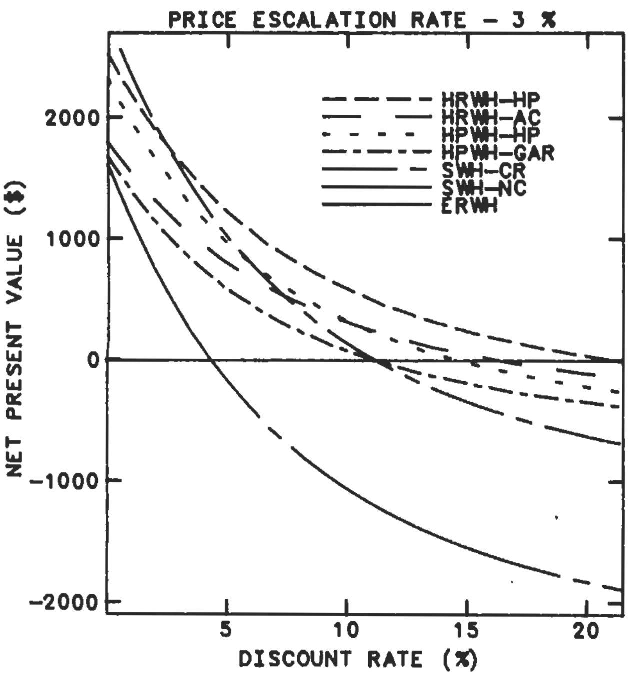

Fig. 4 Consumer economics for base case assumptions, 3% real price escalation

affect the amount of energy saved by the different options in different ways. This in turn will affect the alternatives' absolute and relative economic value. As expected, all of the options are less economical relative to the ERWH for households using smaller amounts of hot water. However, the HPWH options suffer the most since the amount of energy saved by this option is approximately proportional to the hot water demand, but the initial and maintenance costs remain constant. From this analysis, it appears that households with a hot water demand of 40 gallons per day or less (most households with 1 or 2 occupants), should only consider a HPWH if it is to be located in a space conditioned by a heat pump. A SWH will also save proportionately less energy with a smaller hot water draw but will be sized to meet the smaller demand, and will thus have lower initial costs. The household with a small hot water demand but a cooling load (and heating load with a heat pump) as large or larger than the one calculated for the base case home, should consider a HRWH. The energy saved by this option is more a function of the HVAC run time than the hot water demand. However, this being the case, it should be noted that as homes become more energy conserving, especially by incorporating measures which reduce the cooling load, the HRWH will become less attractive.

For a household which requires more hot water, the effects are just the opposite. Although all of the options are more economic at this larger hot water demand, the HPWH options benefit the most. However, the trend of increased savings with a HPWH with increasing hot water demand does have limits. Since HPWHs are available in essentially one size for residential use, the recovery rate of the HPWH could become a problem with very large hot water demands. This can occur not only in households which use large amounts of hot water daily (i.e. large families), but can also happen in households which use smaller amounts of hot water daily but use it within a relatively small period of time. This problem can be relieved somewhat by using a larger storage tank(s), or by activating the top electric element. These two actions, however, will incur higher initial costs and lower efficiencies, respectively.

There are factors to consider for each of the options which may preclude it as a consideration or tip the scale in favor of it. With a HPWH there is the possibility that an installation in the conditioned space will not be possible due to the location of the water heater, and even if it is possible, this location may be objectionable due to the noise it produces. All HRWH installations require fairly close proximity of the HVAC compressor and the water storage tank. This will exclude it as a possibility for some retrofit applications and will require early accomodation in the plans for new construction. Also, the installation of the HRWH is more difficult than that of the HPWH and there is less experience with the appliance than with SWHs. Finally, more efficient air conditioners and heat pumps and more energy efficient homes will result in lower energy savings for this option. With a SWH, the main non-economic drawback would bethe lack of a suitable installation site. Appearance is another factor to be considered when installing a SWH.

Although use of all of the alternative water heating systems will result in peak demand reductions for the City Utility, and will thus have the benefit of postponing future capacity additions, to estimate the total impact of these systems on the Utility, the effects of these systems on Utility operating costs and revenues is needed. The Utility needs to know the timing of demand and energy reductions achieved with the diversified use of the alternative water heating options, relative to the Utility System demand. This information is illustrated in Figure 5. The solid black curve in this figure shows the System load duration curve as a percentage of the System peak. This curve is derived as follows. For each hour of the year there is an average demand placed on the System. If these hourly average demands are plotted in descending order, the result is a load duration curve. Since the absolute value of the hourly average demands will vary from year to year, the load duration curve is normalized here by dividing all values by the System peak demand. This simulation, in addition to calculating an average System demand for each hour, calculates an hourly average demand reduction for diversified use of the HPWH and HRWH options. The demand reductions for these options are plotted below the load duration curve in Figure 5. They are arranged in the same manner that the hourly System demands are.

The HRWH reduces demand the most during

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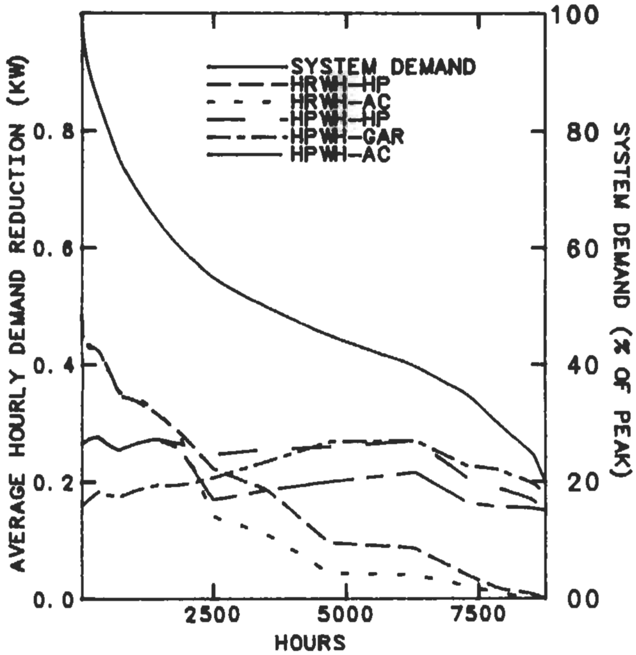

Fig. 5 Timing of HPWH and HRWH demand reductions relative to System demand

periods when System demand is near its peak. The average demand reduction for the HRWH when the System demand was 95%-100% of the peak was about .49 kW. Since this entire period was during the cooling season, the type of HVAC system used with a HRWH system makes no difference in the ability of the HRWH to displace capacity. It should be noted that this reduction in demand is greater than the actual ERWH demand. This is possible since the HRWH reduces the electricity consumption of the air conditioner during these periods by improving the air conditioner's efficiency. As expected, the HRWH systems result in substantial energy savings at higher System demands. This is because of the correlation between System demand and house cooling loads. For the HRWH/air conditioner combination, the energy savings drop off sharply below about 60% of the System peak, as there is little air conditioner operation at the corresponding temperatures. The HRWH/heat pump combination has practically identical energy savings as the HRWH/air conditioner combination until periods when the System demand is about 60% of the peak. For these hours and those for which the System demand is lower, a HRWH used in conjunction with a heat pump will reduce demand when the heat pump is meeting the heating load. During mild weather the System demand is generally the lowest and the energy savings possible with a HRWH are lowest since the house HVAC system will not be running.

For a HPWH, its location significantly influences its potential for demand reduction. If it is located in the conditioned space, it can reduce the System peak demand by about .27 kW. However, if it is located such that its cooling effect does not interact with the HVAC system, a System peak demand of only about .16 kW can be expected. For a HPWH located in the conditioned space, the type of HVAC system used will make little difference in the energy reductions until the heating season. During periods requiring heating, the cooling effect of the HPWH increases the electricity consumption of the heating system and the efficiency of this system dictates the demand reductions. This divergence is shown to occur in Figure 4 starting at a System demand of about 65% of the peak. During the coldest periods, roughly coinciding with a System demand of 50% to 60% of the peak, the use of backup resistance elements and lower HPWH efficiencies due to the colder temperatures prevent a HPWH installed in a garage from reducing demand as much as one located in a space conditioned by a heat pump. A HPWH located in a garage will reduce demand more than one located in the conditioned space during milder weather periods, when the System demand is at its lowest.

Since the SWH was not modeled in the simulation, a similar curve for a SWH is not included. However, by using the results of the Rodgers and Askey studies, an idea of how such a curve might look can be imagined. The demand reduction possible with a SWH during the System peak period would be somewhat less than that for a HRWH, since there is no reduction in air conditioner electricity consumption with a SWH. The SWH would essentially remove the demandthat would occur with an ERWH during the System peak, or about .4 kW. However, the SWH demand reduction curve would not drop off as rapidly as the one for the HRWH during periods representing light cooling conditions. For hours during which the System demand is below about 60% of the peak, the SWH would probably reduce demand just slightly more than the HPWH-HP combination.

Although the above discussion relates the timing of both the System demand curve and the demand reduction curves in terms of climatic conditions, it should be pointed out that all of the curves are a function of other variables such as time-of-day.

LCC methods were used to calculate the net present value of the alternative water heating methods to the Utility. Using a variety of assumptions, the calculated present value to the Utility of peak demand reductions achieved through conservation and load management programs is $743/kW. Therefore, the present value of displaced capacity benefits for the alternative water heating systems is simply the coincident demand reduction expected for the measure during the System peak, times the above present value per kW. In addition, the present value of twenty years of reduced variable operation and maintenance costs that would be achievable with each water heating option were summed. This benefit and the displaced capacity savings are the economic benefits that the Utility receives for customer use of each of the alternatives. The cost to the Utility is the revenues lost. The net present value of each alternative to the Utility is presented in Table 3, along with the quantities used to calculate it.

OPTION	COINCIDENT DEMAND REDUCTIONS (KW)	PV OF DISPLACED CAPACITY SAVINGS ($)	PV OF REDUCED O & M COSTS ($)	PV OF LOST REVENUES ($)	NET PRESENT VALUE ($)
HPWH-HP	.27	201	925	1197	-72
HPWH-AC	.27	201	787	1026	-39
HPWH-GAR	.16	119	816	1032	-97
HRWH-HP	.49	372	717	954	134
HRWH-AC	.49	372	584	803	152
SWH	.40	297	1010	1294	13

Table 3 Utility economics for ratepayer use of alternative water heaters

The most economically beneficial alternatives to the Utility are those with the greatest ability to reduce System peak demand and thus postpone future capacity additions, while at the same time not reduce revenues. None of the HPWH options proved to have a positive net present value for the Utility, and although the SWH saves the most energy of the alternatives, it is only marginally beneficial to the Utility. Of the HRWH options, the HRWH-AC combination is most beneficial to the Utility, closely followed by the HRWH-heat pump combination. These results can be explained by considering the load profile of water heaters and the Austin electric rate structure. The electric demand for heating water with conventional ERWHs is larger in the winter months than in the summer months, and larger in the morning hours than in the evening hours. The System electric demand is generally just the opposite. The demand is larger in the summer months than in the winter months, and the demand is generally larger in the afternoon-early evening hours than in the morning hours (the exception being very cold winter mornings). Therefore, much of the time for which it is possible to make large reductions in the electric demand to heat water, the generation plant tracking the System demand will be one of the more economical generators. This phenomenon, coupled with an Austin rate structure which captures a great deal of the cost differential between generating electricity in the cooling and heating seasons, favors the options which result in the highest deferred capacity savings and smallest lost revenues.

SUMMARY

This investigation shows that currently all three of the alternative water heating systems are good investments relative to buying a conventional electric resistance water heater. Once the federal tax credit is removed for the solar water heater (SWH), its competitiveness will decline substantially. The heat recovery water heater (HRWH) is a good choice for households whose cooling load is large relative to their hot water demand. The optimal HVAC system for use with a HRWH is a heat pump, because of the additional savings obtained during the heating season. For households with a small cooling load and/or a large hot water demand, the SWH or the heat pump water heater (HPWH) may be a better choice. The optimal location for a HPWH in hot climates is within the conditioned space of a home heated by a heat pump. Since none of the options are clearly more economical than the others in all cases, the consumer should evaluate each alternative considering such factors as type of HVAC system, amount of air conditioner use, hot water demand, installation possibilities, rate structure, and personal discount rate. Since such an analysis is too sophisticated for many consumers, it might be included as a service of organizations performing energy audits.

From the utility's viewpoint, conservation alternatives are beneficial only if the benefits associated with displaced future capacity and reduced costs outweigh lost revenues. For the City of Austin Electric Utility, with its two-tiered rate structure, it appears that only the HRWH is substantially beneficial, saving the City an average of $130-$150 for every HRWH installation. The SWH is only marginally beneficial, and the HPWH did not prove to be beneficial to the Utility. It should be noted that this analysis did not try to quantify the social "good" of saving energy or the benefits of encouraging local conservation industries versus spending tax dollars on generation plants and out-of-state fuel. Both of these factors were considered when Austin developed its current water heater policies.

ACKNOWLEDGEMENTS

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