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ELECTRIC UTILITIES AND RESIDENTIAL SOLAR SYSTEMS

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ABSTRACT

The long-run incremental cost (LRIC) of providing electricity for solar heating and hot water systems is estimated for three utilities using a utility capacity expansion model and compared to the cost of providing electricity to electric-only systems. All investment, fuel and operating costs are accounted for. Hot water systems and combined heating and hot water systems are analyzed separately. It is found that the LRIC for solar backup is no more than the LRIC of electricity used for purely electric heating and hot water devices and also no more than the incremental cost of normal load growth. For the three utilities studied, there appears to be little basis for rate distinctions between solar devices using electric backup and electric-only heating and hot water devices. "Off-peak storage" heating and hot water devices have a much lower LRIC than the standard systems; again, there appears to be no basis for distinguishing between solar and electric off-peak devices. Compared to average cost pricing, incremental cost pricing offers considerable benefits to customers using solar and electric heat and hot water, especially if a separate lower rate is adopted for off-peak storage devices; these benefits can amount to several hundred dollars per year. Substantial savings in the use of oil and gas fuels can be achieved if residences using these fuels convert to solar systems, savings not necessarily achievable by a shift, instead, to electric systems.

ACKNOWLEDGEMENTS

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We also express our appreciation to LILCO, PNM, and WPL for providing utility system data and reviewing our results. In particular, thanks are due to John Weismantle and Frank Vitale of LILCO, Daniel Peck of PNM, and Paul Koeppe of WPL who went out of their way to be cooperative. Neither the utilities nor any of their staff, however, are responsible for the results and conclusions of this study.

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PREFACE

Since early 1978, National Center for Analysis of Energy Systems at Brookhaven National Laboratory has been studying regulatory and tax issues associated with solar energy for the Market Analysis and Evaluation Branch of the U.S. Department of Energy. These studies have examined on the economic, resource use, and environmental aspects of solar residential heating and hot water devices which are connected to electric utilities. This is one report in a series describing the results of these studies.

TABLE OF CONTENTS

TABLES

FIGURES

INTRODUCTION

About 22% of U.S. energy consumption is used to provide heating and hot water in residential and commercial buildings. Almost all of this energy comes from crude oil or natural gas. In much of the U.S., solar energy can be an ideal substitute for these increasingly scarce and expensive resources, especially as a source of energy for hot water. The most likely alternative to solar energy as a substitute for oil and gas in these applications is electricity. Compared to electricity, solar technologies do not require the use of additional nonrenewable resources, are environmentally more benign, and, especially in the case of hot water, will probably be cheaper in the long run.

To be cost effective, solar heating and hot water systems employ a backup energy supply which provides 20%-50% of the total energy required. Electricity is frequently preferred as the backup supply since hookups are readily available and the initial cost is low. Because electricity is an expensive form of energy, its cost is a major factor in the overall economics of solar* heating and hot water systems. Hence, the rate structure governing the price of electricity used for solar backup can play a crucial role in determining whether or not solar systems can compete with conventional systems.

The recently enacted Public Utility Regulatory Policies Act (PURPA) requires that, to the greatest possible extent, utility rate structures reflect the actual costs to a utility of providing electric service. This implies that rate classes should be appropriately delineated and that each class should pay its fair share of the total utility revenue requirements. In most utilities, residential customers using electric heating are either defined as a separate rate class or are effectively given lower rates through declining block rate structures. Customers using electric hot water also generally benefit from lower rates. The lower rates are justified by the argument that the cost of supplying the incremental electricity for these applications is lower than the average cost of delivered electricity.

Recently, some utilities have argued that customers using electricity to provide backup for solar heating and hot water systems should be defined as a separate rate class with a higher rate than that imposed on the average residential customer on the presumption that the more uneven use of electricity for this purpose requries extra capacity and imposes high costs on the utility. If these arguments are incorrect--i.e., if solar backup costs the utility no more than the average residential use of electricity--then the imposition of higher rates would be a contravention of the PURPA requirements. Since very little detailed, quantitative information has been available regarding the effect that solar backup loads actually have on utility costs, the validity of arguments calling for higher rates is questionable. The purpose of this study is to develop and apply a method for computing a utility's cost of providing backup for solar devices so that rate-making can take place in an informed environment.

This paper summarizes the results of three case studies in which the utility cost of providing electricity for solar backup is estimated and compared to the average cost of residential electric service and to the

*In this paper a "solar" system is one using electric backup. A solar system using oil or gas backup is denoted as a "solar-fuel" system.

cost of service for comparable electric systems. Using these results, a homeowner's total annual costs for heat and hot water are computed assuming two different rate design approaches for solar and electric systems. Finally, the net consumption of fuels to provide heat and hot water is compared for the various systems.

Methods and Assumptions

The methods employed in analyzing utility costs are extensively described in Ref. 1 and summarized below. The long-run incremental cost of service (LRIC) is used as the appropriate measure of utility costs and is simply defined as the total incremental cost of serving an incremental load. All investment, operating and fuel costs are included in this one measure; hence, the treatment of capacity related costs is integral to the basic study approach.

In computing the incremental load due to a heating or hot water device, the hourly loads due to a single such device are first estimated with a building thermal load simulation model using historical hourly weather data. The total incremental load on the utility is this stream of hourly loads, modified to account for smoothing of loads from many devices, and multiplied by an assumed market penetration of the device. The utility's revenue requirements are computed both with and without this incremental load, and the incremental cost is the difference in the revenue requirements. The revenue requirement estimates are calculated from optimal plant purchase schedules and fuel use patterns computed by a utility capacity expansion model, the Wien Automatic System Planning Model (WASP), which is run out to the year 2000. Using the same market penetration assumption, separate load and cost analyses are conducted for a variety of heating and hot water devices, with the utility expansion plan and fuel use reoptimized in each case, to provide the basis for a comparative analysis.

The LRIC's are estimated for each year from 1978 to 2000. The results reported are means for the ten years 1991-2000. Before this time, the penetration of solar devices is so small that incremental utility loads and incremental costs are negligible, which makes the LRIC computations unreliable. Although solar use before the 1990's may be limited, the resolution of rate issues cannot be delayed; some rate must be selected for the very first solar system hooked up to a utility (even if, by default, it is the common residential rate) and precedents have a remarkable tenacity. In addition, if there is any uncertainty as to the course of rates, consumer confidence, a crucial ingredient in the decision to proceed with the large investment in solar, will be adversely affected.

The three case studies completed to date examined the use of solar hot water (HW) and combined heating and hot water (HHW) devices in the service areas of the Long Island Lighting Company (LILCO), the Wisconsin Power and Light Company (WPL), and the Public Service Company of New Mexico (PNM). Electric resistance HW and HHW systems and off-peak* solar and electric systems were also analyzed for comparison.

The most recent (1980) forecasts of loads, fuel and plant costs, and capacity expansion options for each utility were used to the greatest extent possible. Real rates of increase of 4-5% per year for delivered

*Off-peak storage heating during 11PM and 7AM; no daytime use of electricity for heat or hot water.

petroleum products and 3-4% for coal and nuclear fuel were assumed starting from 1980 levels. Gas was assumed to increase in price sufficiently rapidly to equal the price of petroleum products by 1990. New nuclear capacity was assumed to cost about $990/kW and coal capacity about $900/kW (including scrubbers) in 1978$. All heating and hot water system costs were based on a survey of current costs for installed systems. For the results presented in this paper, solar system costs (exclusive of the costs of the conventional backup equipment) are assumed to decline in real terms at about 2% per year.† All cost results are presented in 1978$.

RESULTS

Utility Capacity Costs

The primary focus of concern regarding potentially adverse impacts that solar heating and hot water systems might have on utilities has been on capacity requirements. Does solar backup actually impose greater capacity related costs on utilities than do other electrical loads? We compared the ten-year mean (1991-2001) of the capacity related cost per kilwatt-hour of electricity delivered for solar backup to the capacity costs for other loads. In two out of the three utilities we studied, the incremental capacity required to meet the incremental load due to solar systems costs less, per kilowatt hour of delivered electricity, than it does for comparable electric systems, less than the capacity related portion of the cost of the average kilowatt-hour delivered, and less than the incremental cost of capacity for meeting increments in load growth (see Table 1). As would be expected, off-peak solar systems, like off-peak electric systems, impose very low capacity related costs on the three utilities; in most cases, these are much less than 1¢/kWh.

Our results, then, do not support the hypothesis that solar systems, in general, impose high capacity related costs on utilities.

Table 1
INCREMENTAL CAPACITY COSTS
10 year mean (1991-2000)
(¢/kWh)

	PNM		WPL		LILCO	
	HW	HHW	HW	HHW	HW	HHW
Average	3.5		2.1		5.8	
Incremental Growth	4.1		3.9		3.6	
Solar	2.2	1.8	5.3	3.1	2.4	0
Electric	5.0	3.2	3.6	2.4	3.2	2.7
Solar O.P.	0.1	1.0	0.1	0	0	0
Electric O.P.	0.2	1.5	0.4	0.9	0	0

†This 2% decline would result, for example, if a 95% learning effect were combined with a market penetration that led to 15% of all U.S. single family residences being out-fitted with solar hot water, and 5% with solar heating, by the year 2000; we do not consider it to be a particularly optimistic assumption.

Capacity related costs are only a portion of the total cost of delivery electricity. Production costs -- fuel and operating and maintenance costs -- comprise the bulk of the remainder. Consequently, capacity related costs are, by themselves, an incomplete measure of the total economic impact solar loads might have on utilities. In the next section, we compare the total costs of solar backup to the total costs of meeting other loads.

Long-Run Incremental Costs

The LRIC's estimated for the three utilities are shown in Figures 1a, 1b and 1c. For comparison, the average cost of electricity (total revenue requirements divided by total kilowatt-hours), with a residential service markup, is also shown. In addition, the incremental cost of incremental load growth (i.e., incremental growth with a load pattern consistent with the historic load shape rather than a load shape associated with an electric or a solar system) is shown. This latter measure is a more legitimate basis for comparison when judging whether solar loads cost more to serve than the average residential load.

The following observations can be made regarding the results in Figures 1a, 1b and 1c:

- The LRIC for backup to a solar system is, in general, about equal to the LRIC for the comparable electric system and less than or equal to the incremental cost of incremental growth.
- Off-peak systems have the lowest LRIC, substantially below the average cost of residential service in both utilities. All off-peak systems in each utility have about the same LRIC.

Sensitivity studies (not reported here) show that these observations are not affected by changes in fuel and plant cost assumptions and that the LRIC's are almost independent of the level of market penetration.

The implications of these results are that rates that discriminate against solar compared to electric systems are not justified for these three utilities. Furthermore, since the costs of solar do not exceed the incremental cost of incremental growth, it is questionable whether solar rates should exceed average rates even in those cases (see HW in WPL and PNM) when solar LRIC's are higher than the average cost. Based on their substantially lower LRIC's, all off-peak systems could be grouped into a single, separate class with a common rate for each utility (with the possible exception of PNM where there is a substantial difference in the LRIC between the HW and the HHW cases). This rate would be about 60% below the average residential rate for LILCO and about 50% below for WPL. Such lower rates do not imply a subsidy to customers using off-peak systems; in fact, if their rates were not lower than average, these customers would be subsidizing all other customers.

Homeowner Costs

The total annualized first year cost to a homeowner in each utility area estimated for the 1990's, is shown in Figures 2a, 2b and 2c. Solar HW and HHW systems are compared to electric systems, to "fuel" systems (oil or gas residential burners) and to "solar/fuel" systems (solar with oil or gas backup). These first year homeowner costs assume that the

Fig. 1a

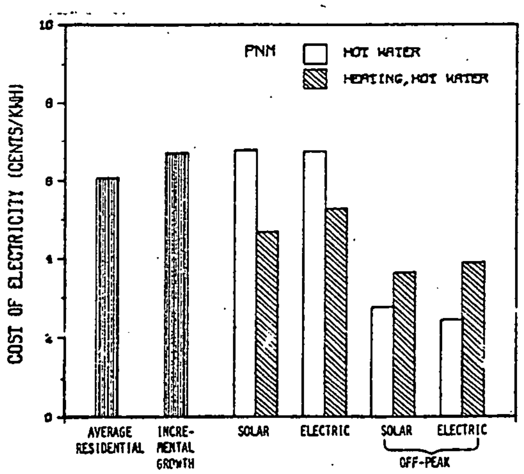


Fig. 1b

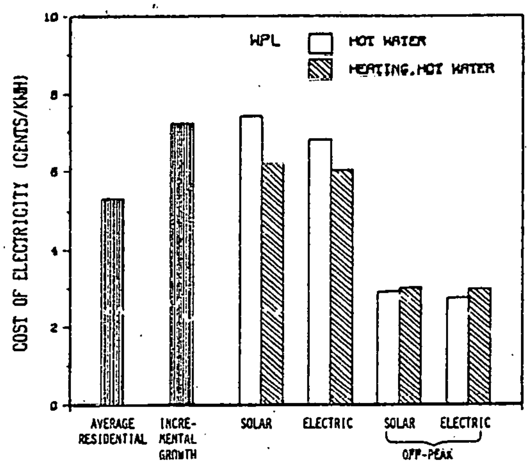
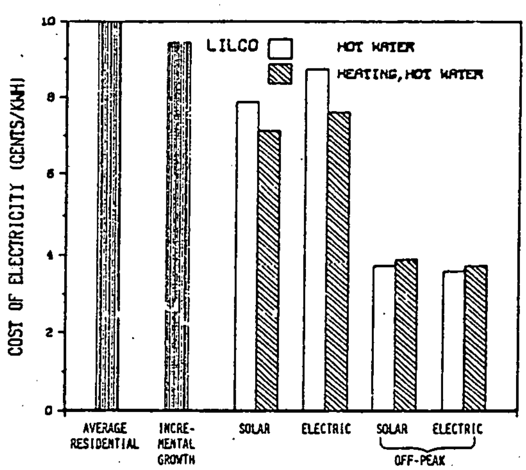


Fig. 1c



Figures 1a, b, c: The LRIC of electricty used to provide backup for solar heating and hot water systems estimated for the mid-1990's compared to the LRIC for comparible electric systems for the three utilities. Also shown for comparison are the average cost of electricity with a residential markup and the incremental cost of normal load growth.

Fig. 2a

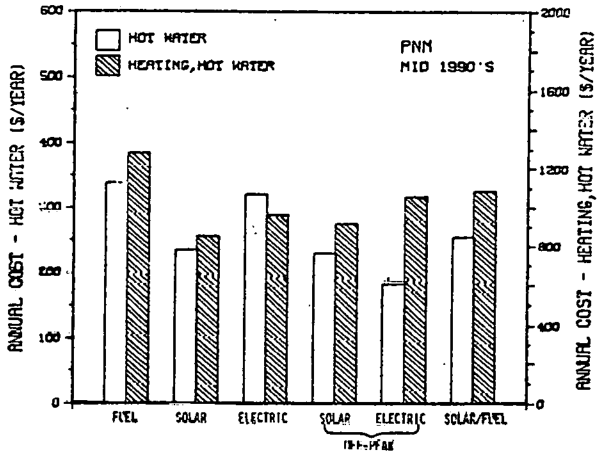


Fig. 2b

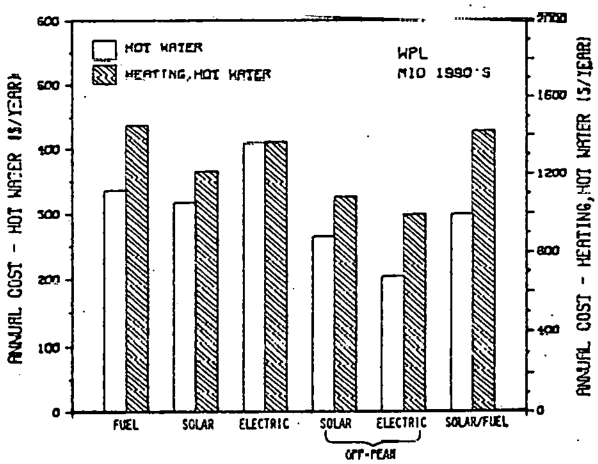
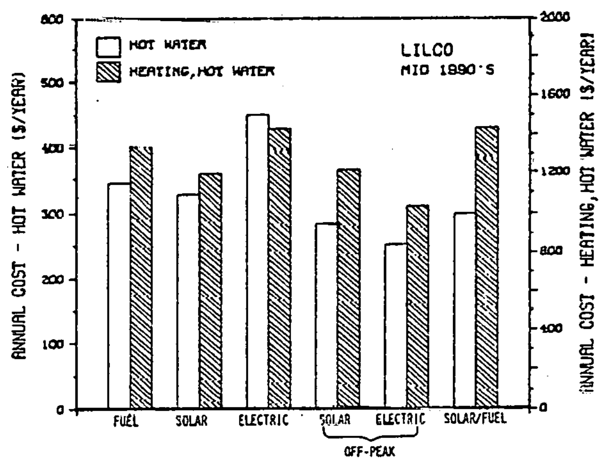


Fig. 2c



Figures 2a, b, c: Annualized homeowner costs for various heating and hot water systems estimated for the mid-1190's for the three utilities. Left bar of each pair is for hot water and should be read off the left vertical scale; right bar for combined heating and hot water systems and is read off the right vertical scale.

heating and hot water system is financed as part of a 20 year, 9.5% home mortgage, the homeowner is in a 33% combined federal and state tax bracket, no property tax is assessed on the solar portion of the investment, and that the federal solar tax credit has expired. Where electricity is required by the heating or hot water system, the electricity is assumed to be priced at the appropriate LRIC.

Given the assumptions underlying these homeowner cost computations, solar systems are competitive with electric and fuel alternatives by the 1990's. Off-peak solar systems are among the cheapest options available to a homeowner, being edged out only by off-peak electric systems. Solar systems with fuel backup offer no cost benefits to homeowners in these utility areas in this time period and, in some cases, are noticeably more expensive.

These homeowner cost computations were repeated with fuel and solar system costs and LRIC's appropriate for the early 1980's. The federal solar tax credit was included. The results (not shown in this paper) demonstrate that under incremental pricing "uncontrolled" (i.e., not off-peak) solar systems could compete with uncontrolled electric systems but not with fuel systems. In PNM and WPL, off-peak electric systems are comparable in cost with the fuel systems in the early 1980's and, hence, were cheaper than solar.

Although annualized homeowner costs are a reasonable measure to use in calculating the competitiveness of solar systems installed in new residences, they are probably a poor guide to consumer behavior in the retrofit market. Loans with the favorable financing terms characteristic of home mortgages are not generally available for financing solar system retrofits. For homeowners who purchase solar systems with no financing, a payback analysis provides a more realistic view of consumer behavior. The payback time for solar hot water systems, much more likely to be purchased as a retrofit than solar heating systems, are shown in Table 2 for both the mid-1980's and the mid-1990's. As in the annualized cost analysis above, electricity is assumed to be priced at the incremental cost appropriate for each application. Payback times for solar compared to electricity in the mid-1980's are a moderately favorable four to eight years, while payback compared to gas is substantially longer. By the mid-1990's, payback times are in the six to eight year range against both gas and electricity if the solar tax credit is assumed to have expired. A continuation of the credit would reduce the payback period by 1-2 years bringing them into a favorable four to six year range.

Effect of Rate Design

The approach to rate design is by no means an academic issue; it can have a major impact on homeowner costs. The homeowner costs shown in Figures 2a, 2b and 2c were recomputed using the average residential rates shown in Figures 1a, 1b and 1c instead of the LRIC's. In most cases, the homeowner suffers a penalty under average cost pricing compared to incremental cost pricing, especially with an off-peak system. The excess payments under average cost pricing, tabulated in Table 3 for solar systems, can be as much as several hundred dollars per year. The use of average cost pricing in such cases creates a significant and unjustified economic barrier to the purchase of solar systems.

Fuel Use

In all of these utilities, most of the homeowners currently rely on conventional oil- and gas-fueled heating and hot water systems. What are the impacts on total utility and residential fuel use, especially on the consumption of scarce oil and gas resources, if homeowners shift to an alternate system? To answer this, we plotted the ten-year mean (1991-2000) of the annual total fuel required per residence for each of the heating and hot water systems (see Figs. 3a, 3b and 3c). The utility fuel-use patterns were obtained by calculating the incremental fuel consumed to meet the incremental load associated with one of the systems. This data was part of the output from the WASP model runs that were used in computing the LRIC's.

Table 2
Payback Time for Solar Hot Water
(Years)

		Mid-1980's	Mid-1990's	
Tax Credit		Yes	Yes	No
PNM	Gas	9	4	6
	Electric	6.5	4	6
WPL	Gas	12	6	8
	Electric	8	4.5	6
LILCO	Gas	30	6	8
	Electric	4	4	5.5

Table 3

Effect of Rate Design on Homeowner's Energy Costs:

Excess Annual Payments Under

Average Cost Pricing Compared to Incremental Cost Pricing

($/Year)

System type	PNM	LILCO	WPL
Hot water			
Solar	13	37	-40*
Solar O.P.†	55	125	49
Heating and hot water			
Solar	33	333	-57*
Solar O.P.†	107	493	249

*Negative sign implies lower payments under average cost pricing.
†"O.P." = Off-peak.

Fig. 3a

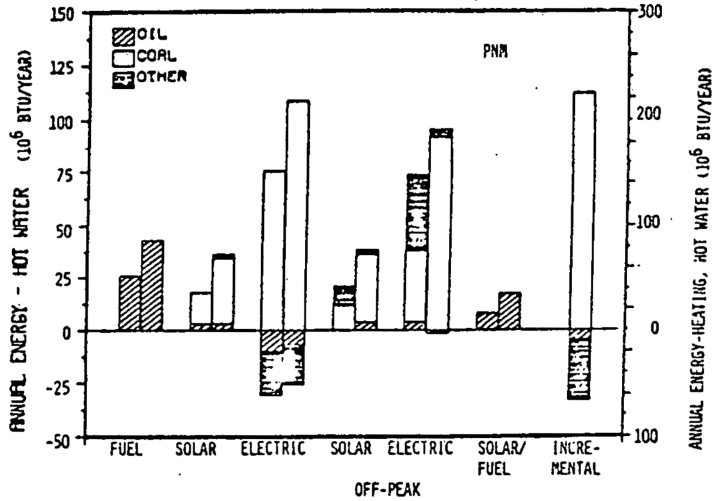


Fig. 3b

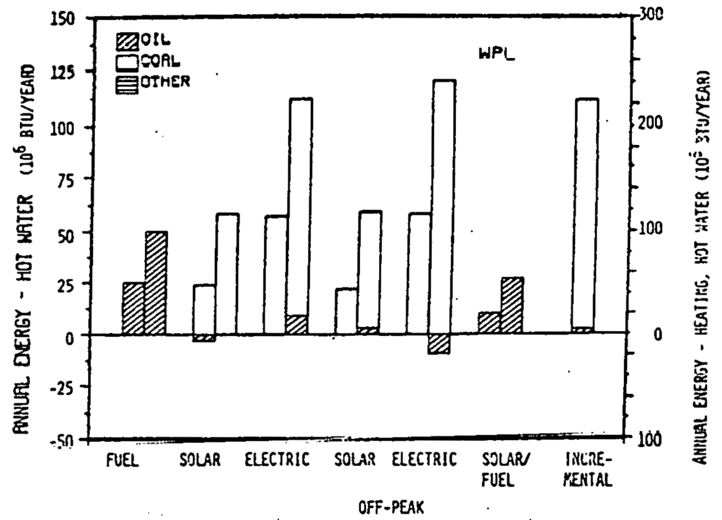
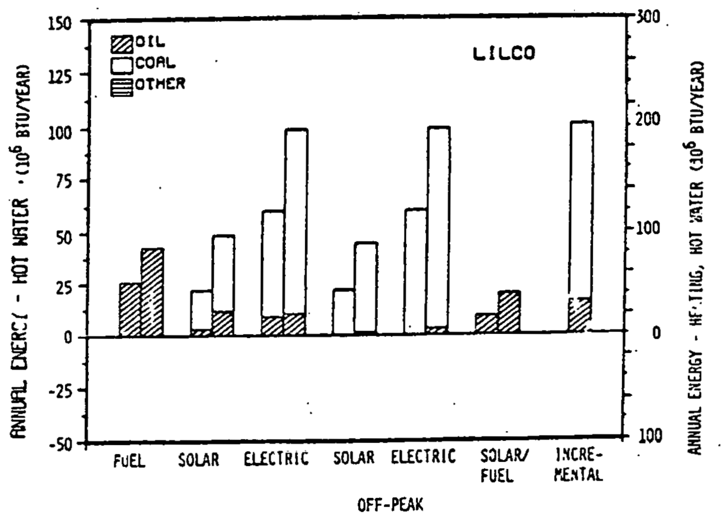


Fig. 3c



Figures 3a, b, c: Ten year mean (1991-2000) of total fuel consumption at the utility and the residence for various heating and hot water systems. Left bar of each pair is for hot water and should be read off the left vertical scale; right bar for combined heating and hot water systems and should be read off the right vertical scale.

The basic pattern of the results in Figures 3a, 3b and 3c is similar: All of the alternatives to the residential burners can greatly reduce the net consumption of oil and gas fuels. The solar/fuel systems, requiring that one-third of their energy be provided by oil or gas, are less effective in this regard than the other alternatives.* If homeowners shift from residential fuel burners to solar or electric heating and hot water systems, the primary shift in fuel use, ignoring the use of solar energy, is from the use of oil or gas at the residence to the consumption of coal at the utility. While the substitution of solar systems results in a approximately one-for-one shift of oil or gas for coal, the electric systems require at least twice as much coal to be burned at the utility as the fuel that would have been used at the residence.

The shifts in fuel use just described assume that current utility capacity purchase, modification, and retirement plans for these utilities, largely eliminating nuclear purchases and calling for oil-to-coal conversions, are actually carried out. These plans have been modified frequently in the recent past as load forecasts have been reduced and as federal coal conversion orders have been implemented. The fuel use results are very sensitive to these plans; if coal conversions are not carried out in LILCO, or if PNM's schedule of early retirements for its oil and gas capacity are delayed, then both utilities could find themselves using substantial amounts of oil or gas through the end of this century to deliver electricity to electric heating and hot water systems. In fact, when we examined alternate capacity purchase conversion and retirement options for these utilities, several of the electric heating and hot water cases in PNM and LILCO required the use of more oil or gas at the utility than would have been used by an oil or gas system at the residence. In contrast, solar systems always required the use of substantially less oil and gas than the residential burners.

Although it is frequently assumed that the substitution of electricity for residential oil and gas burners would add only to the consumption of coal and nuclear energy, these results demonstrate that this is not necessarily correct. In some utilities, such a shift could actually increase the net consumption of oil and gas during the next two decades, contrary to national energy goals.

CONCLUSION

For the three utilities studied, higher rates for solar than for comparable electric systems are not warranted; if electricity used for electric heating or hot water systems is allowed a special reduced rate, then so should electricity used to backup solar systems. Incremental pricing for solar backup can be an important factor in encouraging the use of solar systems because, compared to average cost pricing, it generally lowers the cost of electric backup to homeowners with solar systems. A special lower rate for off-peak systems, both solar and elec-

*The reason why oil and gas use goes "below zero" in a few instances is that the utility use of oil and gas in these cases is cut below the level in the fuel case in which no electricity was being used by the residence for heat or hot water. This can occur because the utility's entire capacity purchase schedule and pattern of fuel use are reoptimized for each case.

tric, is particularly desirable since the LRIC's for these systems are substantially lower than for uncontrolled systems, and much lower than the average cost. Without such lower rates, homeowners might end up paying several hundred dollars per year more for electricity than would be justified by the costs they impose on the utility. By the 1990's, given the cost and financing assumptions in this study, solar systems will be competitive with fuel and electric alternatives without the federal tax credit. The case studies also demonstrate that a shift from conventional oil and gas burners to solar systems would save substantial amounts of oil and gas, an important national energy policy goal, whereas these savings will not necessarily be achieved by a shift to electricity in these applications. Finally, electric heating and hot water systems will require the consumption of about twice as much fuel at the utility--probably coal--as the amount needed to provide electric backup for solar systems.

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1. R. Bright and H. Davitian, "The Marginal Cost of Electricity Used as Backup for Solar Hot Water Systems: A Case Study", Energy, 4, 1979.