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ENERGY CONSERVATION IN HOME APPLIANCES THROUGH COMPARISON SHOPPING: FACTS AND FACT SHEETS

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Work done partially under U. S. Department of Energy Contract No. W-7405-Eng-48

DISCLAIMER

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Abstract

Because of large variations in technical efficiency, energy use of major appliances (refrigerators, air conditioners, TV's) varies over a range of approximately 2 to 1. There is little correlation between energy use and first cost and, for refrigerators, almost no correlation between energy use and size. If Californians purchased the most efficient refrigerator and air conditioner in each size/feature range the savings in peak power after 10 years would be about 4000 MW. Energy labels are seldom present to help the consumer.

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INTRODUCTION

Home appliances are a major consumer of electric energy and peak power both in California and nationwide. About 20% of total electricity consumption in the state is demanded by appliances,[1] while over 30% of peak power is accounted for by only four major appliances,[2] mainly related to cooling.

There are important differences in energy consumption among different models of an appliance. These differences allow consumers to make a significant reduction in their energy use and utility costs as they replace existing appliances with new units or as new households are established. Thus, over the long run, if consumers are informed about the variations in energy use and life cycle costs between appliances, they have the ability to effect large reductions in appliance energy consumption.

Variations in energy use are a result of several differences. The most obvious are differences in size, or between features such as manual or automatic defrost refrigerators; however much of the variation in energy use can be explained by differences in technical efficiency (the ability of an appliance to deliver the same useful output as another model with less energy input). Technical efficiencies typically vary over a range of 2 to 1.

The technical efficiency of an appliance is not readily determined by its physical attributes; nor are high-efficiency appliances necessarily bigger, thicker, heavier, or of different appearance. Efficiency can only be measured by a standarized laboratory test procedure. For the consumer to make a decision about what appliance to buy he must have efficiency labels attached to appliances. Since most appliances are relatively long-lived, a decision made today will fix a demand for electricity or gas for the next 12 to 25 years. Thus, it is important to have labels on major energy-using appliances which provide the consumer enough information to allow him to make informed comparisons and choices between the different products available.

We recently surveyed appliance stores and found that most stores have fewer than one-fouth of their refrigerators and air conditioners labeled for energy utilization. Typically, the energy information, if present at all, is buried in small type amidst dozens of lines of other technical specifications. Also, predictably, the least efficient units are less likely to have energy labels than the higher efficiency models.

The Federal Government is currently in the process of designing mandatory energy labels, in coordination with the development of targets for appliance efficiency improvement. These labels will contain some measure of energy utilization efficiency of the product (similar to miles-per-gallon stickers on automobiles), and will also list the range of efficiencies to be found in models with similar features and capacity. Despite the improvement offered by the Federal labels, they still will not provide the consumer with sufficient information on which to make life-cycle cost decisions. For example, they do not provide data on appliance lifetimes and although the labels will list the extremes in efficiency with a given class, they will provide no data on intermediate units. Purchase prices of other units in the class are not given. No mention is made of whether the more efficient units are sold in the consumer's area.

In order to perform life cycle cost analyses on different appliances, the consumer needs all of the following information:

1. Purchase prices and annual energy utilization estimates for alternative appliances.

2. The projected lifetime of the unit.

3. Estimates of energy cost over that lifetime.

4. Suggestions about what other choices of size or feature may save energy and reduce life-cycle cost, albeit possibly at the expense of convenience or flexibility.

5. Some explicit calculations of life-cycle cost.[12]

We discuss below some examples of the information that might be contained in fact sheets on appliances, which would be used by consumers. We also discuss, on an appliance-by-appliance basis, some of the tradeoffs between life-cycle cost and first cost or between life-cycle cost and convenience or comfort.

REFRIGERATORS

There is a tremendous range in energy consumption between different models of new home refrigerators: from under 500 kWh/yr to over 3000 kWh/yr. While some of their variation is explained by differences in size, features (e.g., frost-free option), or style (e.g., side-by-side) there is still a range of about 2 to 1 in energy demand of units within a single class of size and features.

These differences are significant for several reasons. First, almost all households have a refrigerator while many have two or more (average is 1.15 per household).[1] Second, the lifetime of a refrigerator is quite long; 20 years on the average.[1] Finally, the actual magnitude of energy use is large. A typical new refrigerator accounts for 1/4 of the electrical energy used by the average California household for <u>all</u> purposes.[6]

Consider the most popular size and feature class: 15-18 ft^3 "top-freezer" automatic-defrost refrigerator. The lowest-energy-consumption frost-free unit rated by AHAM[4] uses 1062 kWh/yr while the highest consumption is 2016 kWh/yr. At the mid-1977 California electricity cost of 5¢/kWh, the difference (954 kWh/yr) costs $45 each year. Over 20 years the energy cost differential[5] is $900, more than twice the purchase price.

This $900 life-cycle cost reduction can be obtained for almost no increase in first cost. Figure 1a displays first cost and energy cost data for some 15-18 ft^3 automatic defrost refrigerators available in California in 1976. There is only a slight correlation between first cost and energy cost. It is, as expected, an inverse relationship. The most expensive units are apparently better designed to save energy. But note that Model U uses 44% less energy than model Q and has a slightly <u>lower</u> first cost. In this case, a consumer could save almost half the energy use by comparison shopping with no increase in first cost. The slanted lines on the figure give life cycle cost, with lowest life cycle cost at the bottom left corner of the figure. As these lines show, the consumer almost invariably saves money over the life of the refrigerator by choosing the lowest energy consumption. For example, Model Q has life cycle costs of about $2,100 while Model U costs only $1,350. The lowest life-cycle cost refrigerator is Model N, which has one of the highest first costs, but the lowest energy use.

Figures 1b and 1c display similar cost information for larger refrigerators. In both figures, we see large variations in energy use and operating cost and no correlation between efficiency and purchase price. Both figures illustrate the potential for consumers to save over $750 of life cycle cost with no increase in first cost, provided they are informed of the differences in energy use.

The reader should note that Fig. 1 illustrates differences only in technical efficiency. They do not involve energy conservation by sacrificing features or size.

Despite the large dollar savings available through comparison shopping for efficient refrigerators, consumers are generally unaware of their options in efficiency. To provide sufficient information on which they can make rational choices, a set of tables and graphs like those in Fig. 1 should be available to consumers. The values used for first cost and energy cost should be adjusted to reflect local experience and local untility rates, as well as local availability of different brands. If there are mandatory limits to energy use for new refrigerators (e.g., present and future California Energy Commission or Federal standards) these should also be displayed to show the consumer by how much the models exceed the minimum standards (or by what margin they fail to attain future years standards). For comparison with the data in Fig. 1, California maximum energy consumption standards for refrigerators are shown in Table 1. These standards are a function of size and features, and will be imposed in stages. Stage 1 began in 1977.

The 1979 standards will eliminate 100 of the 138 partial and automatic defrost refrigerator-freezers now sold in California.[3] However, one manufacturer's entire line already betters the 1979 standards by at least 8 kWh/month, and uses typically 10-20% less energy than the legal maximum. Another manufacturer has a line available which also tops the 1979 standards by at least 25 kWh/month.

We showed in Figs. 1a-1c that energy savings of up to 50% are possible by comparison shopping with a given class of refrigerator. We next discuss the potential energy savings in changing size or features.

The most important "lifestyle" determinant of energy use is the choice of features. As shown in Fig. 2, side-by-side refrigerator-freezers generally use more energy than top-freezer models. Further energy savings are possible by switching to a partial-automatic defrost model. "Partials" look like top-freezer automatics. They have frost-free refrigerator compartments but their freezers require manual defrosting a few times a year (less frequently than manual defrost refrigerators). As shown in Fig. 2b, the most efficient partial uses about 40% less energy than the most efficient automatic. However, the figure also shows that the least efficient partials use more energy than some automatics, illustrating the importance of comparison shopping. Manual defrost (typically one-door) refrigerators generally use the least energy, but again there is considerable overlap between the most efficient partials and the least efficient manuals.

Table 1.

California maximum energy consumption standards for new refrigerators and freezers (kWh/month; V = volume of appliance, including freezer, in ft^3.

	Date effective	
	1977[a]	1979[a]
Manual defrost refrigerators	40+2.5V	40+2.5V
Nonautomatic defrost refrigerator-freezers	40+5 V	40+2.5V
Automatic defrost refrigerator freezers	40+7 V	40+5 V
Freezers:		
Automatic defrost (upright)	40+7 V	40+6 V
Other	40+5 V	40+4 V

[a]Nov. 3 in both years.

Figure 2a also illustrates the large range of energy use within each feature class. This is mostly due to differences in efficiency. There is very little correlation between size and energy use within a class, as illustrated in Fig. 2b. As this figure shows, the lowest energy consumption in a class can occur in the largest size or in an intermediate or small size. Figure 3 is a scatterplot of all available top-freezer automatic and partial automatic defrost refrigerators available in California.[3] Although the automatics tend as a class to use more energy than the partials, it can be seen that within each class the energy use does not go up in the large models. The lowest-energy-use partial is the largest, at 16 ft^3, while the second lowest-energy-use model is the smallest at 10 ft^3. The most efficient large automatic (22 ft^3) uses less energy than the least efficient medium-small (13-15 ft^3) auto's.

Figure 3 again illustrates the overlap in energy use between classes. The most efficient 16 ft^3 automatic uses less energy than most of the partials, even though most of the partials are smaller.

The lack of correlation between size and energy use is corroborated by Fig. 4, which illustrates sales-weighted average energy use as a function of size. For manuals and top-freezer auto's it also shows no relationship between size and energy use. For side-by-sides, the only connection between size and power occurs in the very largest size range (25 ft^3 and larger). For partials, there is only a weak trend to more energy use in larger units.

Thus, it appears that detailed comparison shopping is a much more effective way to save energy than relying on rules of thumb such as "smaller units use less electricity" or "automatics use more energy than manuals." One can conclude that, for refrigerators, differences in technical efficiency are much more significant than differences in features in determining energy use, while size is the least important variable of all.

AIR CONDITIONERS

The general remarks concerning variations in efficiency among refrigerators also apply to air conditioners. However, in the case of air conditioners, there are additional complicating factors in the cost analysis. First of all, since central air conditioners are usually sold through contractors, it is hard to find a well-defined purchase price. Second, the annual cost of an air conditioner depends on whether some form of peak load pricing or time-of-day pricing applies. Third, the cost of energy (and perhaps, peak power) for an air conditioner depends on how many hours it is run; this in turn is a function of climate and usage patterns (e.g., whether a room air conditioner is used to cool the whole house when this is possible); such data are scanty.

Thus, the first need in preparing data sheets on air conditioners is for a set of field studies (for several regions) of consumption patterns. When this is accomplished, we would probably have to construct parametric fact sheets, with different sheets for different pricing methods (e.g., constant vs time-of-day pricing). Once the consumption data are collected, the consumer will see ranges of energy consumption and cost characteristics even wider than those seen in the refrigerator fact sheet. We discuss some of the causes of variations below.

Figure 5 shows that there is nearly a 2-to-1 variation in EER* for each size class. Figure 5a covers single package central air conditioners, while 5b lists split-system central units. Window air conditioners, both 110 and 220 volt models, are listed in Fig. 5c. Figure 5d plots through-the-wall room units. In each of these figures, large variations in EER are apparent from a low of about 5 Btu/watt-hr to highs of 8-12 Btu/watt-hr.

It should be noted that residential air conditioners are found only on the left side of these figures. Air conditioners larger than 3-5 tons (36,000-60,000 Btu/hr) are generally intended for commercial applications.

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*EER is a measure of air conditioner efficiency. It is defined as the ratio of Btu's of heat removed from a test room by an air conditioner, to the energy consumed by the unit (watt-hours). The test is performed under specified conditions of indoor and outdoor temperature and humidity. Higher EER's denote higher efficiency.

The first cost of air conditioners tends to increase with increasing efficiency. One analysis found that increased retail cost of a higher EER to be about 11¢ per watt saved, while another arrived at 18¢/watt for room-type air conditioners.[7] For central units, data supplied by a major manufacturer of air conditioning equipment suggest a cost of 18¢/watt saved.[7] These costs would result in 27-44% annual returns on investment if the unit is operated 1000 hours per year at 1977 electricity rates.

California has recently set minimum standards for the EER's of new air conditioners sold in the state. These standards are staged, with the first set taking effect in 1977 and the second to supercede them in 1979 (see Table 2). As in the case of refrigerators, it can be seen that most current models fail to attain the 1979 standard for EER, while a few units exceed the standard by a comfortable margin.

Table 2.

California minimum EER[a] standards for air conditioners.

	Date effective	
	1977[b]	1979[b]
Heat pumps, cooling cycle:		
Window or room type	7.1	8.3
Central type	6.7	7.5
Air conditioners:		
Window or room type:		
> 20,000 Btu/hr	7.0	8.7[c]
< 20,000 Btu/hr	7.5	
Central type	7.0	8.0

[a]EER (energy efficiency ratio) is defined as the ratio of an air conditioner output in Btu/hr to electrical input in Watts under specified conditions of temperature and humidity.

[b]Nov. 3 in both years.

[c]220-volt units (or other high voltage units) must exceed an EER of 8.2 instead of 8.7.

For climates with dry summer weather (most of the Western states), consumers should also be asked to compare evaporative coolers with air conditioners before making a choice. Evaporative coolers are less expensive than air conditioners, both in terms of first cost and operating cost. Their energy consumption is about 20% of that of an air conditioner. Their ability of such a unit to cool a house varies with climate. However, for a large segment of the Western population, the climatic conditions allow evaporative coolers to perform almost as comfortably as air conditioners.

Heat-exchange evaporative coolers, which do not increase the humidity of inside air, are currently under development for home use; these units are usable as the sole cooling source for a house in moderately warm weather, and can provide precooled air to a small air conditioners during the hottest periods of the year. Such units might find wide consumer acceptance if potential air conditioner customers were informed of their availability.

HEATING APPLIANCES: RANGES, CLOTHES DRYERS, WATER HEATERS, SPACE HEATERS

Despite gas curtailments in some areas, many consumers have a choice of fuels between gas and electricity (and, in some cases, oil) for heating appliances. Federal labeling procedures will attempt to compare the efficiency and cost of various types of appliances within the same category (e.g., gas water heaters), but ignore the question of fuel choice.

This is an unfortunate omission since, in almost all cases, substantial life cycle cost can be saved by the use of gas heating appliances rather than electric. In addition, this choice will save energy (and "scarce fuel", that is, gas or oil) for the U.S. as a whole. This is because in almost all regions of the U.S., an additional Btu of electricity demand from a resistance heating appliance will be met by the additional combustion of about 3 Btu of oil or gas at a power plant.[8] Since the efficiency of gas-fired home appliances is much greater than 1/3, the use of a gas appliance will result in lower energy consumption than the electric resistance version.[9] In addition, the long run costs of gas should be lower since the conversion, transmission and the distribution system is cheaper for gas than for electricity.

As an example, a representative gas price is \$2.00 per MBtu, while a typical electricity price is 4¢ per kWh. If gas heater efficiencies are about 60% relative to electricity heaters, then the costs per useful MBtu are \$3.30 for gas and \$11.70 for electricity, a ratio of 1 to 3.5. The price of natural gas or syngas will have to increase 350% before one could recommend electricity over gas on the basis of lower operating costs.

While there is some concern over the continued availability of natural gas, it seems unlikely that supplies will be unavailable to consumers if they are willing to pay a higher price. Gas prices have been regulated at levels of 30¢ to 50¢ per MBtu (1977 regulated price was \$1.46). At these prices, many have experienced a shortage. However, if one simply requires gas to be cheaper than electricity, the consumer can afford to pay approximately \$6.00 per MBtu.

For such prices, there are a number of potential new sources of supply (in addition to increased domestic gas extraction). They include:

1. Imported liquefied natural gas (LNG). A California gas utility estimates (in a filing with the F.P.C.) that the cost of Indonesian LNG will be about \$3.00 per MBtu, at the system boundary in Southern California.

2. Alaskan natural gas. California Public Utilities Commission staff estimates Alaska gas to cost \$3.00-\$6.00 per MBtu.

3. Synthetic gas (from coal). Price estimates for this source generally fall in the range of $2.50-$7.00 per MBtu.

Thus, sufficient gas supplies should be available to residential users who wish to fuel their heating appliances with gas, and the appliance labels should direct the consumer to make comparisons between fuels as well as between different models for water heaters, space heaters, ranges and clothes dryers. The labels will also point out expected life cycle cost advantages of electric ignition gas burners over pilot lights. Pilot lights typically consume 4 MBtu of gas per year at an annual cost of $8 and a life cycle energy cost exceeding $100.

TELEVISION SETS

We are unable to find any significant relationship between first cost and energy cost for solid state television sets in a small survey of local prices. (Price seems to depend only on features and cabinet decoration.) However, television energy consumption can be significant, and again, the consumers' choices can have a major effect in reducing energy demand.

The most important choice affecting television energy consumption is between vacuum tube and solid-state electronics. Although most sets are now solid-state, a significant number of vacuum tube and hybrid sets are available especially on the used market. The difference in power consumption between vacuum tube and solid-state sets is about 200 watts for color and about 180 watts for black-and-white sets (i.e., 350 vs 150 watts for color sets and 250 vs 70 watts for black-and-white sets). Television sets are operated about 1900 hours a year in California households, so the energy consumption differential for a household with a color solid-state set rather than a vacuum tube set would be 200 W x 1900 hr/yr = 390 kWh/yr. The annual cost savings at 5¢/kWh would be about $20, giving a life cycle saving of some $300, or about half the original purchase cost.[10]

There are also variations in power consumption between different brands and types of solid-state sets. However, they are less significant, since they are, at present, only about 10% of the previously mentioned differentials. Nevertheless, cost and energy information should be available to consumers not only to encourage energy-saving selection, but also to give an incentive for manufacturers toward further reductions in power.

IMPACT

The impact on electric peak power demand from consumers' comparison shopping is potentially very large. If consumers bought the most efficient appliance in the class they are now buying, savings after ten years would be about 4000 peak MW for California or about 15% of the total 1977 peak load.[11] This 4000 MW consists of about 3400 MW of peak-only power savings, due to raising the average new air conditioner EER to 9, and about 480 MW of year-around power savings from more efficient refrigerators. Savings from other appliances are smaller and harder to quantify. However, for winter-peaking utilities, the savings from using gas ranges instead of electric would be 500-1000 watts per appliance. For example, subtracting the low estimate of the load curve for electric ranges (see Ref. 1), from the San Diego Gas and Electric Company load curve for January 1975, produces a 6% reduction in the overall utility peak load (Fig. 6.).

IMPLEMENTATION

The major technical obstacle preventing the publication of detailed appliance fact sheets as we have outlined is the lack of data. This can be remedied fairly easily in many cases; however, the necessary actions have not yet been taken.

The basic data needs are as follows:

1) Price tabulations for each appliance, to go along with energy efficiency ratings, which are already being tabulated. 2) Projected utility prices for gas and electricity. This second task is fairly difficult. It will be required for each region of the state or nation, and the results may be controversial. However, price projections are necessary to life cycle costing; and if governmental policy makers are deciding things on the basis of a cost projection, there is no reason why the consumer should not be allowed to use the same projections himself. 3) Lifetime estimates. In preparing Ref. 1 we were unable to find any published study on the equipment lifetime for appliances. We developed a methodology based on the data collected to find out mean retention times for appliances. The agencies preparing fact sheets should either perform a new study on lifetime or use the results of the LBL model since most published lifetime estimates are actually retention time estimates; they underestimate the life of the unit by ignoring the time it operates as a used appliance. It would compromise much of the effectiveness of appliance efficiency labeling as a means to save money and protect poor people from energy cost escalation if appliances were chosen to be less efficient over their "new" lifetime and imposed extra costs on their eventual owners during their "used" lifetime(s). 4) Utilization patterns. Testing procedures generally provide a measure of efficiency, or energy need per unit time for a certain level of output. To perform life cycle cost analyses also requires information on patterns of use; for example, on how many hours a device is used per year. Published data on TV's, air conditioners, clothes washers and dryers, water heaters, and ranges are often incorrect or based on poorly performed surveys (see Ref. 1).

CONCLUSIONS

We have shown that there is usually a range of 2:1 between the technical efficiencies of otherwise identical appliances. This variation is not generally known by the consumer, thus people cannot make informed decisions about the tradeoff (if any) between higher purchase price and higher efficiency. Federally mandated labels will provide consumers with some of the information necessary to make decisions based on life cycle cost; it will be interesting to see how much difference the labels make in consumer buying habits.

Life cycle cost labels can be expected to be even more effective than labels which only list annual cost since the more efficient appliances now on the market almost invariably have a lower life cycle cost than the average-energy-use models.

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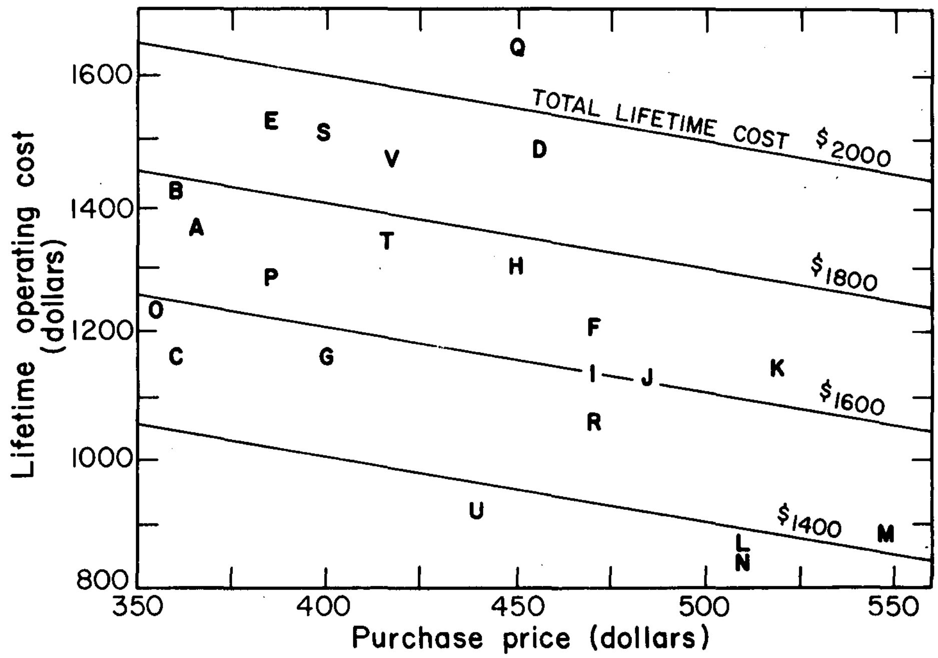
ACKNOWLEDGMENT

We wish to express our appreciation to Robert D. Clear for his help in compiling and analyzing the appliance data used in this report.



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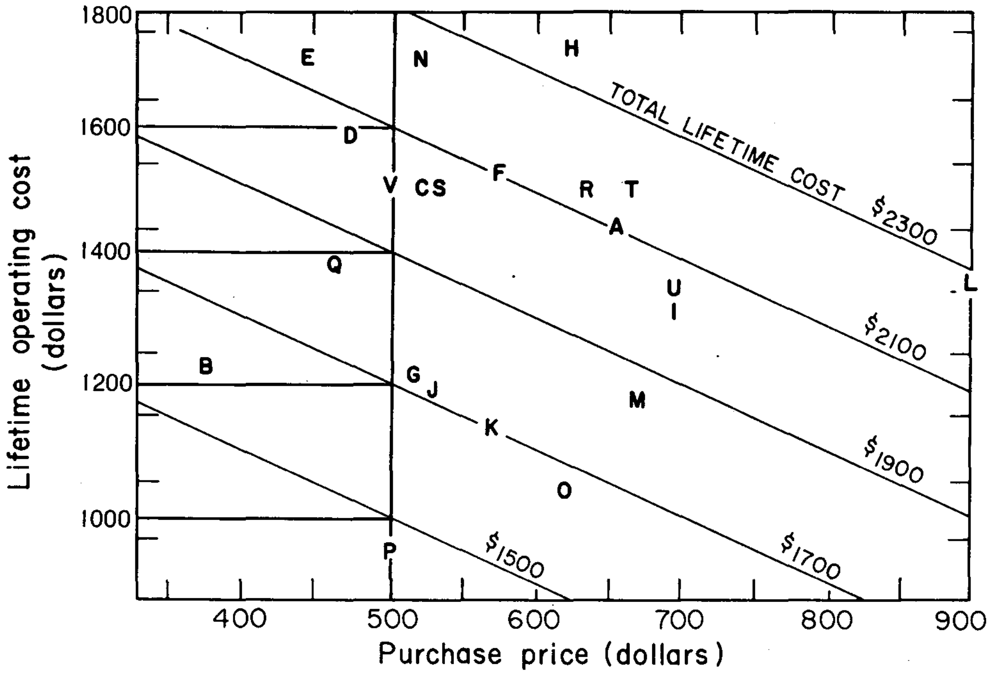
INITIAL PRICE VS. YEARLY OPERATING COST — REFRIGERATORS HAVING TOTAL VOLUME OF 15.0 to 18.0 CUBIC FEET

Symbol	Brand	Price	Ref. Vol.	FZ Vol.	Total volume	Energy use (kWh/month)	Annual oper. cost	Lifecycle cost[a]	Defrost[b]
A	Coldspot 7655110	$365	10.92	4.25	15.17	161	$68	$1717	A
B	Coldspot 7657110	360	12.30	4.77	17.07	169	71	1780	A
C	Coldspot 7657010	360	12.40	4.60	17.00	136	57	1502	A
D	Coldspot 7657411	455	12.31	4.75	17.06	175	74	1925	A
E	Coldspot 7657210	385	12.31	4.75	17.06	182	76	1914	A
F	Frigidaire FPS-170TA	470	12.26	4.75	17.01	144	60	1680	A
G	Gen. Electric TBF16VR	400	11.28	4.30	15.58	139	58	1568	A
H	Gen. Electric TBF18ER	450	12.92	4.65	17.57	155	65	1752	A
I	Gibson RT17F3	470	12.40	4.60	17.00	136	57	1612	A
J	Kelvinator TSK170KN	488	12.40	4.60	17.00	136	57	1630	A
K	Kelvinator TSK170KN	520	12.40	4.60	17.00	136	57	1662	A
L	Philco Cold Guard RD16G7	510	11.99	3.62	15.61	103	43	1375	A
M	Philco Cold Guard RD17G8	550	12.37	4.65	17.02	104	44	1424	A
N	Philco Cold Guard RD17G7	510	12.40	4.65	17.05	101	42	1358	A
O	Signature UFO-1525-00	355	10.44	4.74	15.18	146	61	1581	A
P	Signature UFO-1715-20	385	12.28	4.74	17.02	153	64	1670	A
Q	Signature UFO-1625-00	450	10.46	6.05	16.51	196	82	2096	A
R	Westinghouse RT170R	470	12.45	4.65	17.10	127	53	1537	A
S	Whirlpool EAT17NK	400	12.31	4.75	17.06	175	74	1870	A
T	Whirlpool EAT15PK	415	10.86	4.19	15.05	160	67	1759	A
U	Whirlpool EAT171HK	440	12.31	4.75	17.06	110	46	1364	A
V	Whirlpool EAT17PM	$418	12.46	4.75	17.21	175	$74	$1888	A

[a] Lifecycle cost assumes 20 year life. Electricity is assumed to cost 3.5¢/kWh, and fuel inflation rate (in true dollars) cancels interest rate.

[b] A = Automatic defrost, refrigerator and freezer.

Fig. 1a. Operating cost vs purchase price in 1976 for 21 automatic defrost refrigerator-freezers in the size range of 15 to 18 ft^3 for refrigerator plus freezer. Operation cost is calculated as kWh/month (from the 1974 AHAM Directory[4]) x 3.5¢/kWh (1976 electric cost) x 20 years.[5] Purchase price established by telephone survey; three stores in San Francisco Bay Area for each model.



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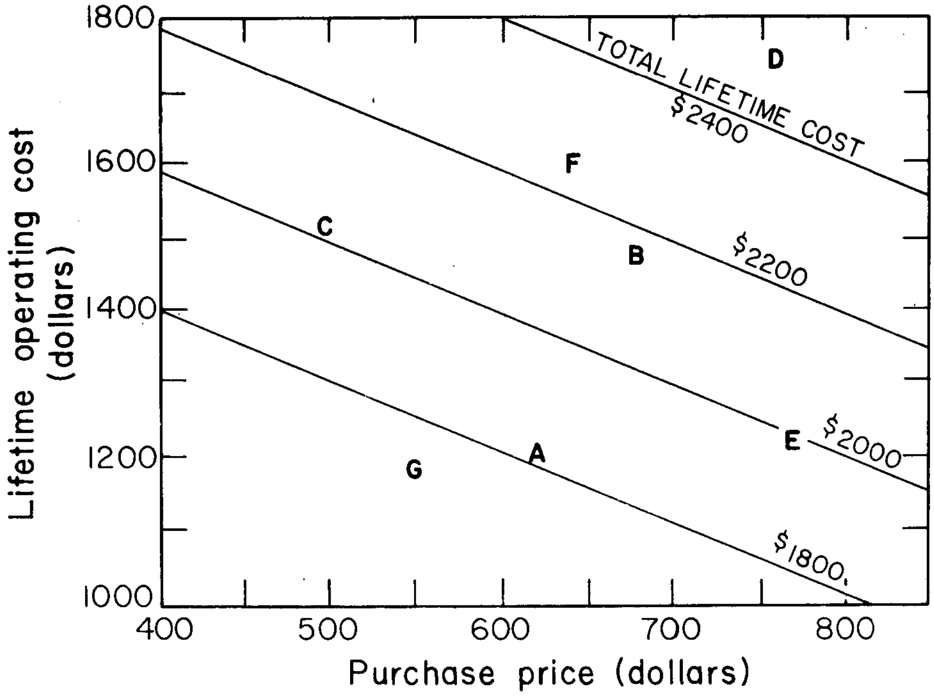
INITIAL PRICE VS. YEARLY OPERATING COST - REFRIGERATORS
HAVING TOTAL VOLUME OF 18.0 TO 22.0 CUBIC FEET

Symbol	Brand	Price	Ref. Vol.	FZ Vol.	Total Volume	Energy use (kWh/month)	Annual oper. cost	Lifecycle cost	Defrost
A	Admiral IND2059	$660	13.51	6.57	20.08	173	$73	$2113	A
B	Coldspot 7659010	380	13.65	5.35	19.00	146	61	1606	A
C	Coldspot 7659410	530	13.41	5.71	19.12	182	76	2059	A
D	Coldspot 7649110	480	13.56	5.75	19.31	189	79	2068	A
E	Coldspot 7630212	450	12.50	6.50	19.00	205	86	2172	A
F	Coldspot 7650510	580	12.66	6.34	19.00	183	77	2117	A
G	Frigidaire F-206T	520	14.66	5.94	20.60	146	61	1746	A
H	Frigidaire FPC-203V3-1	630	13.30	6.97	20.27	205	86	2352	A
I	Gen. Electric TBF21RR	700	13.81	6.82	20.63	158	66	2027	A
J	Gen. Electric TBF21KR	530	13.79	6.96	20.75	142	60	1723	A
K	Gen. Electric TFF19VS	580	12.29	6.46	18.75	136	57	1722	A
L	Gen. Electric TFF22RS	900	14.92	6.63	21.55	164	69	2278	A
M	Gen. Electric TFF22KS	680	14.98	6.80	21.78	140	59	1856	A
N	Gibson RS19F7	530	12.24	6.31	18.55	205	86	2252	A
O	Philco Cold Guard RD22F8	630	14.91	7.03	21.94	123	52	1663	A
P	Philco Cold Guard RT19B8	510	11.07	7.40	18.47	111	47	1442	A
Q	Signature HMG2135-00	465	14.80	6.60	21.40	165	69	1851	A
R	Signature HMG2285-20	640	15.18	6.56	21.74	180	76	2152	A
S	Signature HMG2275-00	540	15.18	6.66	21.84	180	76	2052	A
T	Westinghouse RS199R	675	10.88	8.20	19.08	178	75	2170	A
U	Westinghouse RS210R	700	12.84	8.24	21.08	162	68	2061	A
V	Whirlpool EAT 19 NK	510	13.58	5.70	19.28	182	76	2039	A

Fig. 1b. Same as Fig. 1a, except for larger frost-free refrigerator-freezers of size 18-22 ft^3.

0 0 0 0 4 7 0 5 6 1 9



XBL 768-3377

INITIAL PRICE VS. YEARLY OPERATING COST - REFRIGERATORS
HAVING TOTAL VOLUME OF 22.0 TO 25.0 CUBIC FEET

Symbol	Brand	Price	Ref. Vol.	FZ Vol.	Total volume	Energy use (kWh/month)	Annual oper. cost	Lifecycle cost	Defrost
A	Coldspot 7659612	$620	14.57	7.63	22.20	141	$59	$1804	A
B	Coldspot 7650610	680	14.67	7.45	22.12	175	74	2150	A
C	Coldspot 7660310	500	14.77	7.50	22.27	180	76	2012	A
D	Coldspot 7650710	760	14.66	9.34	24.00	206	87	2490	A
E	Gen. Electric TFF 24DS	770	14.98	8.77	23.75	145	61	1988	A
F	Signature HMG 2495-00	640	15.16	8.64	23.80	191	80	2244	A
G	Whirlpool EAT22PK	550	14.60	7.48	22.08	141	59	1734	A

Fig. 1c. Same as Fig. 1a, except for larger frost-free refrigerator-freezers size 22-25 ft^3.

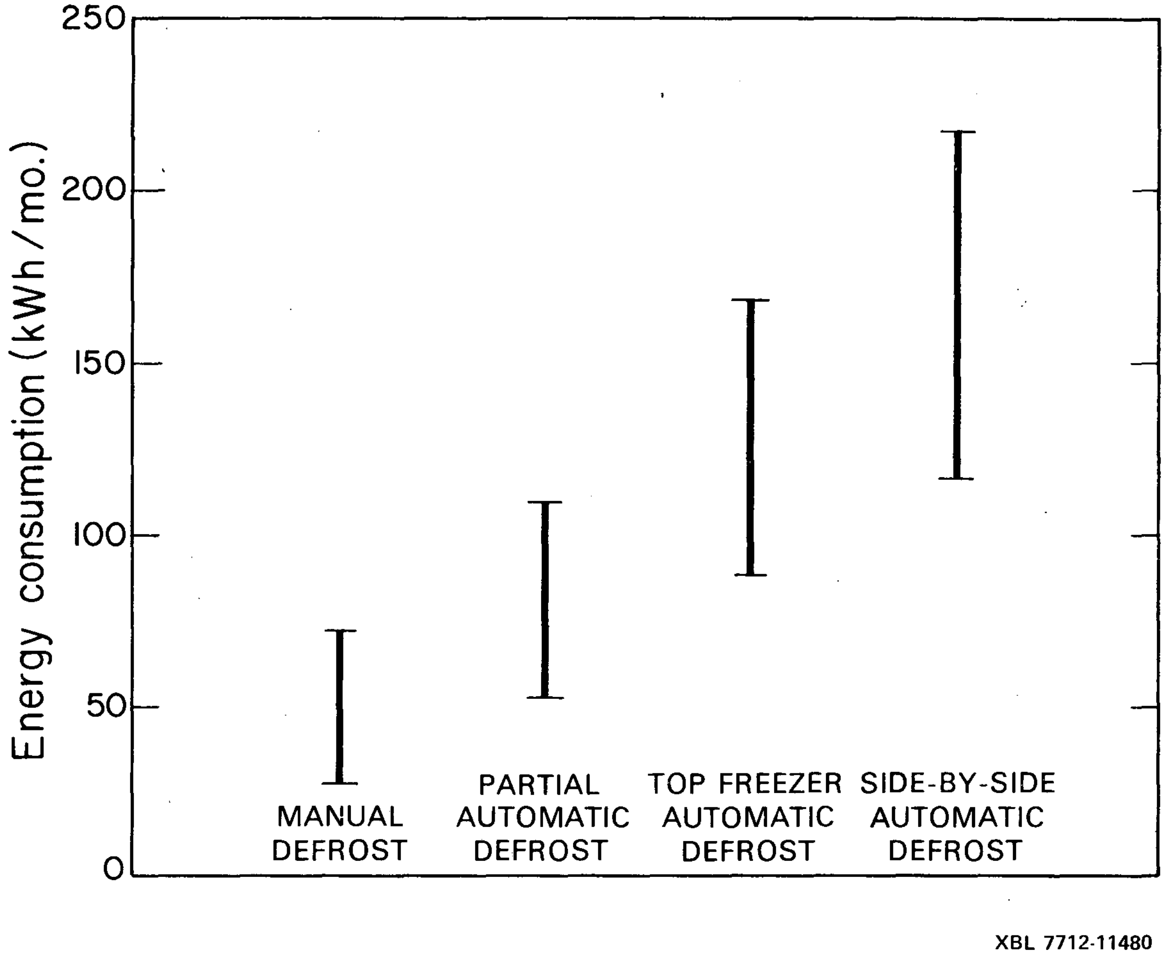


Fig. 2a. Refrigerator energy use vs features (manual defrost units smaller than 6 ft^3 excluded). Range of energy usage in 1977 refrigerator as a function of feature class. For units with a mullion heater switch the average of energy use with switch on and off is used (from Ref. 4).

0 0 0 0 4 7 0 5 6 2 0

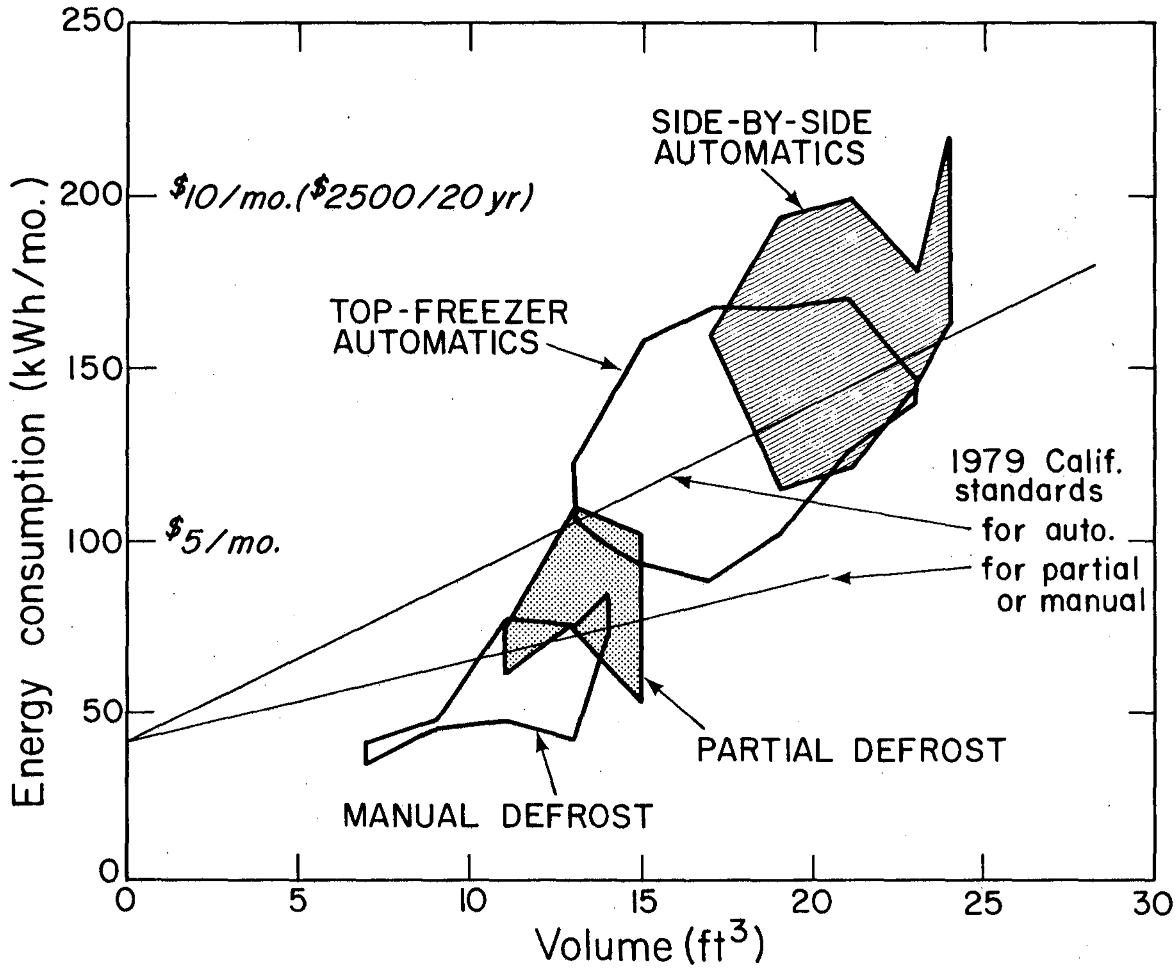


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Fig. 2b. Refrigerator-freezers, 1977. Range of energy usage as a function of size and feature class. Refrigerators are grouped in bins of 2 ft^3, thus the point at 11 ft^3 represents units with size between 10.0 and 11.9 ft^3 inclusive. For units with a mullion heater switch the average of energy use with switch on and off is used (from Ref. 4).

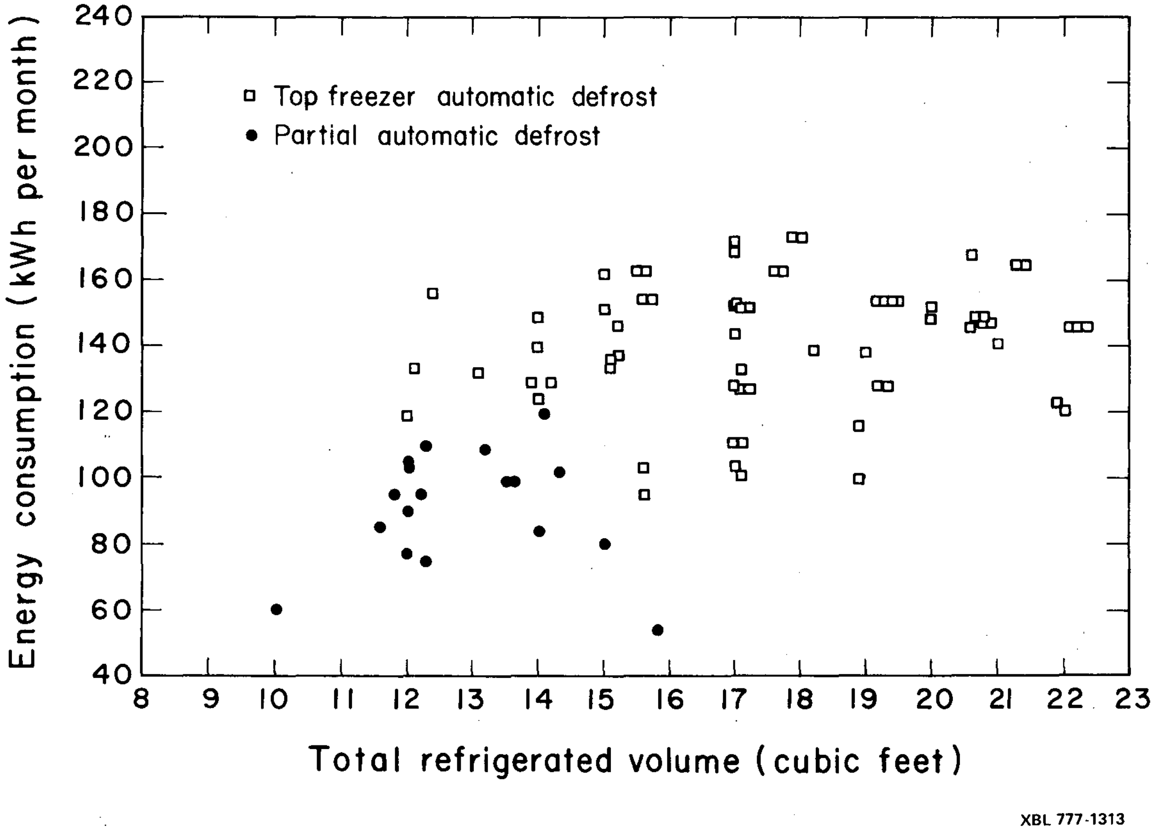

Fig. 3. Scatterplot of energy consumption vs size for all partial automatic and top-freezer automatic defrost refrigerators. For units with a mullion heater switch the higher energy consumption is used corresponding to heater on (from Ref. 3).

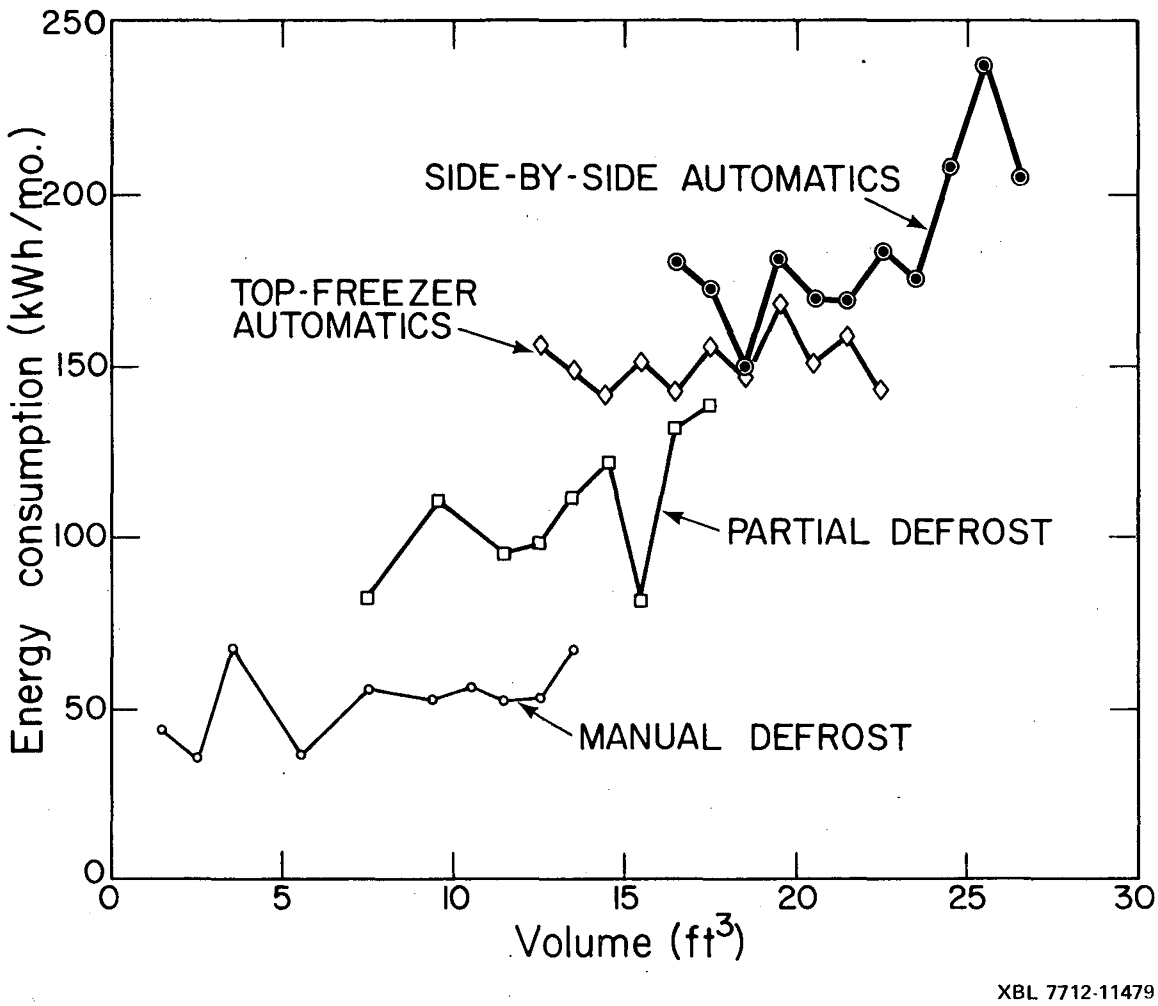

Fig. 4. Sales-weighted average energy use of refrigerators vs size and features, 1976 data (from Ref. 1, Table A7.3).

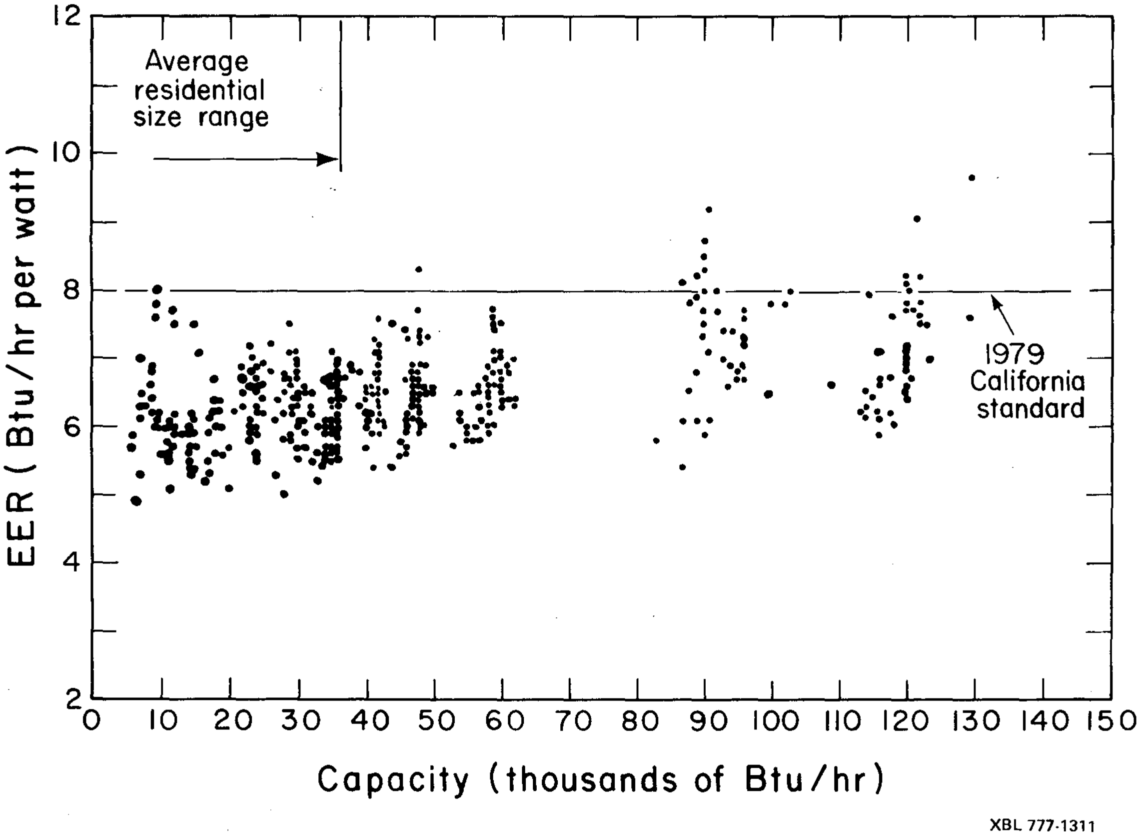

Fig. 5a. Single-package central air conditioners. Scatterplot of efficiency vs size. Residential size range for normal use is noted (from Ref. 3). See Table 2 for California efficiency standards.

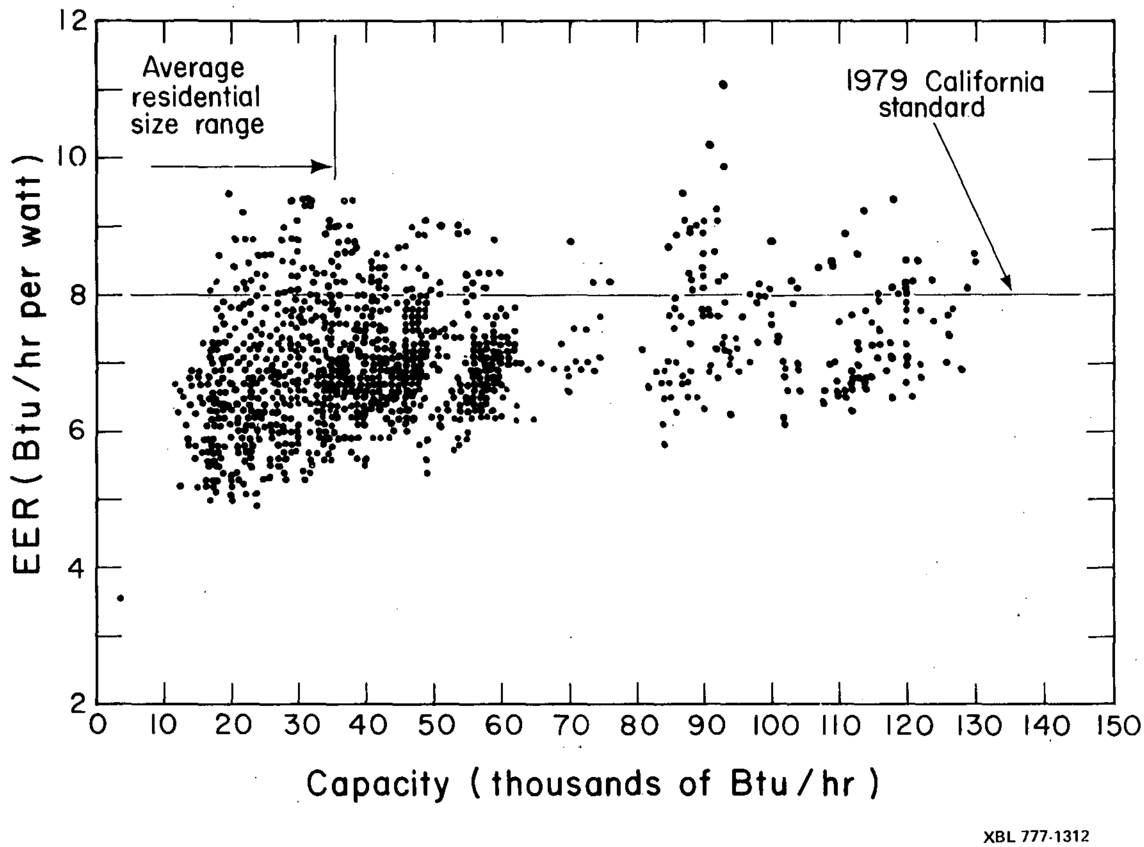

Fig. 5b. Split-system central air conditioners. Scatterplot of efficiency vs size (from Ref. 3). See Table 2 for California efficiency standards.

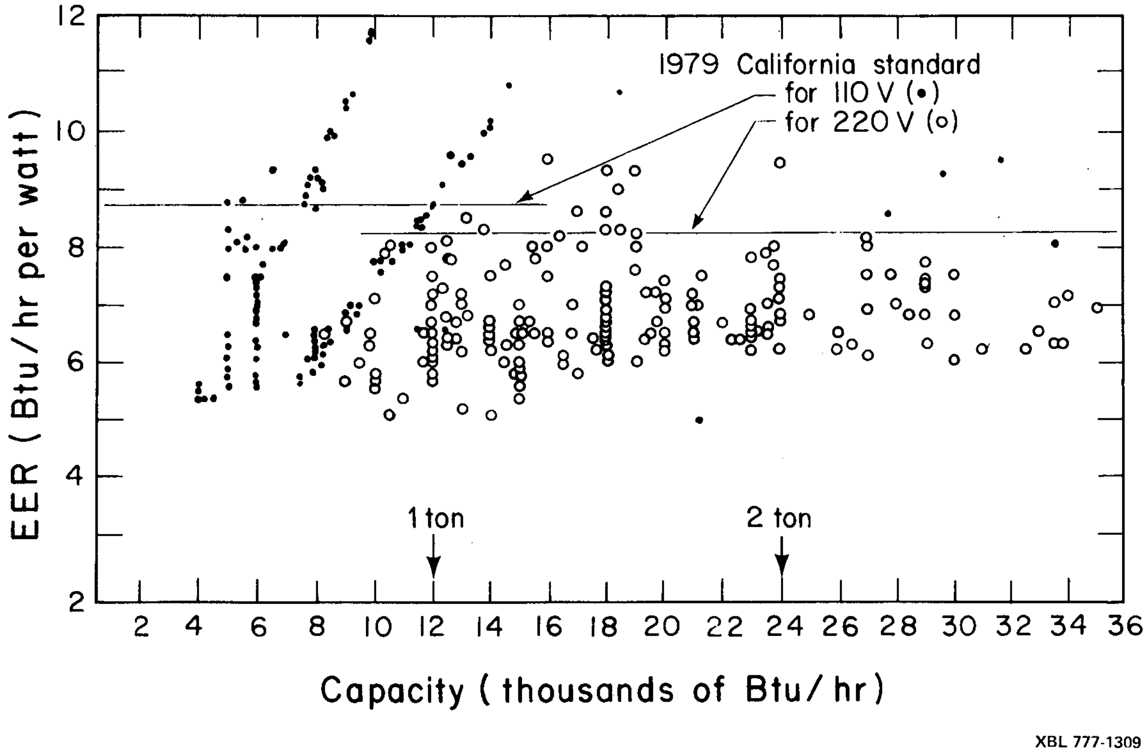

Fig. 5c. Window mounted air conditioners. Scatterplot of efficiency vs size (from Ref. 3). See Table 2 for California efficiency standards.

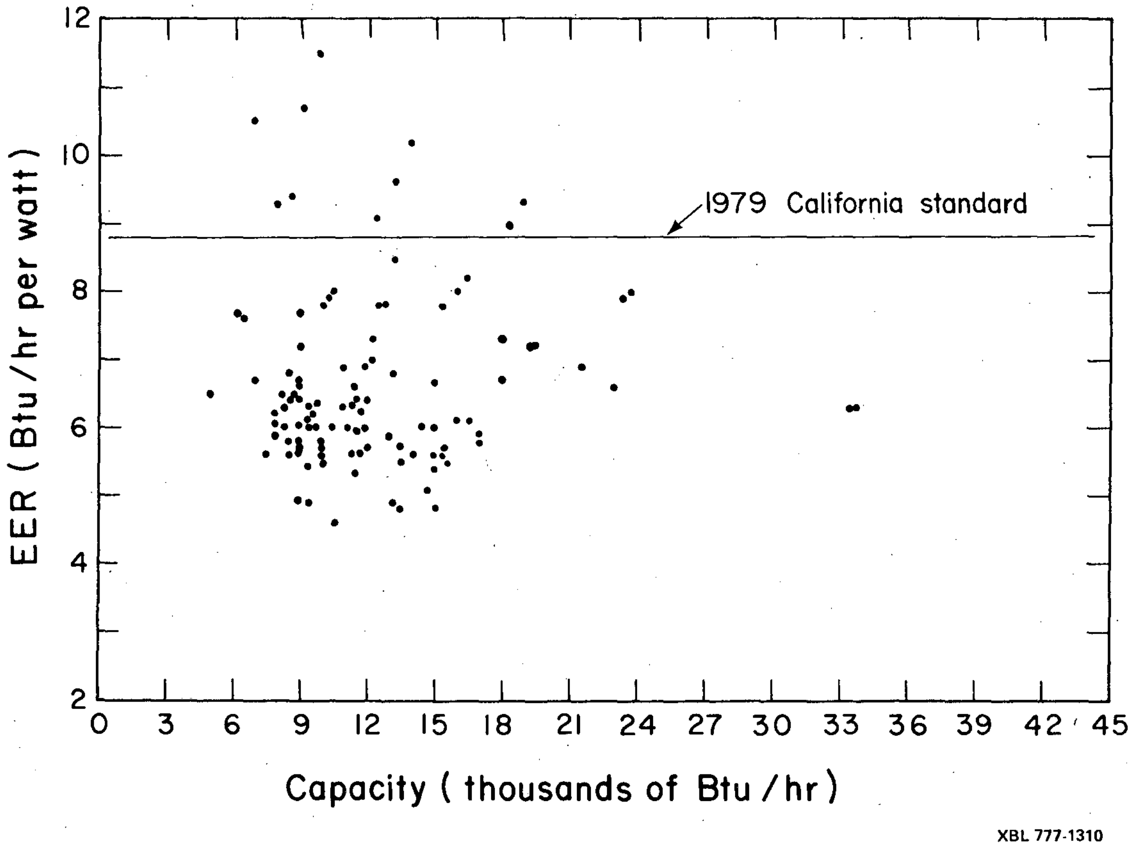

Fig. 5d. Through-the-wall air conditioners. Scatterplot of efficiency vs size (from Ref. 3). See Table 2 for California efficiency standards.

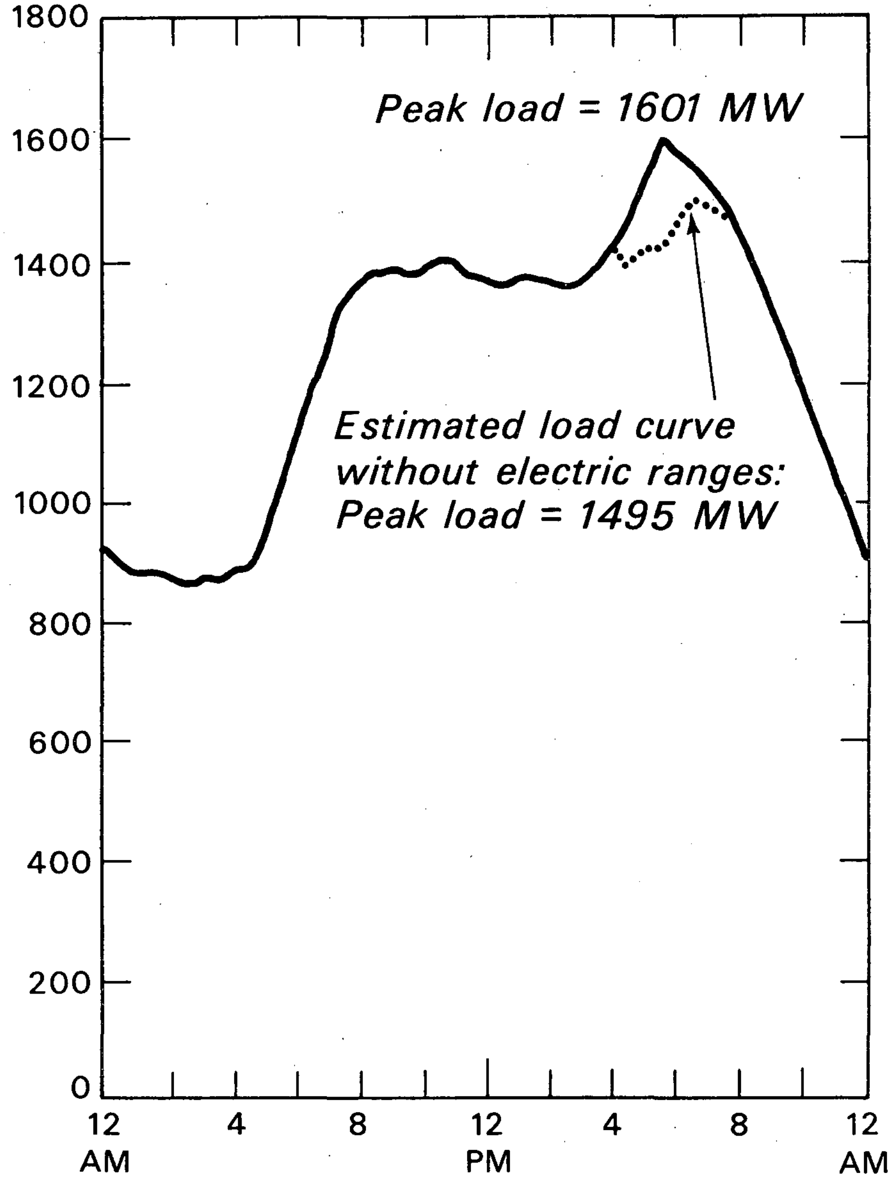

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Fig. 6. Load vs time of day for peak day in January 1975, San Diego Gas and Electric Company. The solid curve was observed; the dotted curve subtracts out the peak contribution of electric ranges.

FOOTNOTES AND REFERENCES

1. "Electrical Energy Consumption in California: Data Collection and Analysis," S. Berman, et al., Lawrence Berkeley Laboratory UCID 3847, (1976). Table 2 gives electricty consumption by end use; major appliance energy usages add to 29.65 x 10^9 kWh/yr. This is 19.92% of total electricity use statewide, as given in Table 1, (148.87 x 10^9 kWh/yr). All appliance data not attributed in the text to another source are taken from this Ref. 1.

2. As shown in the table below, central and room air conditioners each demand 3000 MW in California (D. Goldstein, Testimony before California State Energy Resources Conservation and Development Commission (CERCDC) on Proposed Regulations for Minimum Levels of Operating Efficiency for Refrigerator-Freezers, and Air Conditioners. Docket 75-CON-3. June 29, 1976.) Refrigerators used 155 watts each, (Ref. 1) so their total power demand is 1350 MW statewide. Freezers add another 250 MW, and electric water heaters (550 peak watts) provide a peak load of about 450 MW. Total demand from these four appliances exceeds 8000 MW before transmission losses, compared with a statewide coincident peak demand of about 28,500 MW (after transmission losses). If peak losses are 10%, these appliances represent 31% of peak load.

		Unit Watts	Statewide MW
A/C's	Central	3000	3000
	Room	1850	3000
Refrigerators		155	1350
Freezers		160	250
Electric Water Heaters		550	450
		TOTAL	8050

3. R. Michael Martin, Testimony before CERCDC on Proposed Regulations for Minimum Levels of Operating Efficiency for Refrigerator-Freezers and Air Conditioners, June 22, 1976. Mr. Martin's testimony has been revised by the authors of this paper to take into account a change in the final standards from the draft standards.

4. Association of Home Appliance Manufacturers. "AHAM Directory of Certified Refrigerator/Freezers 1974-1977," (20 North Wacker, Chicago, Ill 60606). The current directory is available for 50¢. However, 1978 directories omit the energy consumption ratings due to a change in testing regulations.

5. Life-cycle cost is what economists call "present discounted value":

$$\text{Life cycle cost} = \text{first cost} + \sum_{i=1}^{L} \frac{(\text{operating cost})_i}{(1+d)^i},$$

where L is the life time of the unit, and d is the discount rate.

The only operating cost considered here is the cost of energy. This will increase as the price of fuel increases. Fuel price increases are hard to predict, but will probably be in the range of 6 to 20% annually, in terms of current dollars. Recent experience in Northern California has been about 15%.

Discount rates are also difficult to specify, particularly for the consumer; typical rate ranges have been from 4% to 18%. Consumers frequently borrow at rates ranging from 9% for mortgages to 18% on credit cards. They typically receive 6% (after taxes) as a return on investment.

Thus expected fuel cost increases are likely to exceed the discount rate. For simplicity, we assume the two are equal. Eq. (1) then becomes:

Life cycle cost = First cost + L x (Operating Cost for first year).

6. By Ref. 1, an average new refrigerator uses 1600 kWh/yr, while average household electricity use for all purposes is 5900 kWh/yr.

7. Reference 2 discusses the cost/energy relationship among room and central air conditioners. Its results are summarized in the footnotes to Table 2d in P. P. Craig, et. al., "Energy Extension for California, Context and Potential Impact", UCID-3911 and LBL-5236, 1977.

8. The Edison Electric Institute Statistical Yearbook for 1976 (Tables 13-S and 14-S) lists the following percentage of "scarce" fuel (oil or gas) used for electricity generation by region.

REGION	PERCENTAGE OF ELECTRICITY GENERATED BY GAS OR OIL
New England	57%
Middle Atlantic	30
East North Central	6
West North Central	16
South Atlantic	26
East South Central	7
West South Central	90
Mountain	16
Pacific	34%

Note that in all regions except East North Central and East South Central, over 15% of the electricity used is produced from oil or gas. All regions use over 5% oil and gas.

Since oil and gas fired power plants have higher operating costs than coal, nuclear, or hydro plants, they will be turned on only when the cheaper-fuel plants are incapable of meeting the load. Any region with a substantial use of these plants is going to adjust to higher or lower electric demands by burning more or less oil or gas; this minimizes the cost of generating electricity. Thus, the addition of a heating appliance to the load of a utility will generally result in the combustion of oil or gas.

The efficiency of combustion can be estimated by looking at the heat rates in Electrical Worlds's "19th Annual Cost Survey" (Vol. 184 #10, Nov. 15, 1975). Average heat rate for a new fossil-fueled plant is 10,300 Btu/kWh. If transmission losses are only 5%, this gives an efficiency of 32%. Other data sources on heat rate generally use heat rates in the range of 10,000 to 11,000 Btu/kWh, not counting transmission losses.

Thus, for most regions of the country, the use of 1 Btu of electricity results in the additional consumption of about 3.3 Btu of "scarce" fuel. For a few utilities, however, the marginal fuel will be coal. But even if new coal plants were built in all regions to satisfy new electric demands, it would still not make economic sense to use electric heat. The reason is that the output of new coal-fired power plants will sell for 5-10¢/kWh delivered to the residential customer. This is equivalent to $15-$30/MBtu of heat delivered, and (after adjustment for efficiencies) compares with gas prices of $10-$20/MBtu. This price is much higher than all projected prices of gas produced from coal or other exotic production schemes; thus the direct use of gas would be more economical.

9. For example, the recovery efficiency of a gas-fired water heater is about 70%. (See "The California Appliance Efficiency Program, Revised Staff Report". California Energy Commission, Sept. 1977).

Space heater efficiency varies among different references from about 40-75%, with typical values ranging from 55-70% (see E. C. Hise "Heat Balance and Efficiency Measurements of Central Forced-Air Residential Gas Furnaces", Oak Ridge National Laboratory ORNL-NSF-EP-88, October 1975).

Gas ranges use about 6 MBtu for cooking (and another 4.5 MBtu for pilot lights, if present). Electric range energy use is about 1200 kWh (see Ref. 1), which converts to about 13 MBtu.

Gas clothes dryers (without pilots) use about 4 MBtu (see, for example, Stephen H. Dole "Energy Use and Conservation in the Residential Sector: A Regional Analysis." Rand Corporation R-1641-NSF, June 1975), while electric dryers use 1000 kWh (see Ref. 1), or 11 MBtu.

10. "Instant-on" tube sets draw about 30 watts when apparently turned off. The instant-on load of a solid-state receiver is 5 watts or less. This dissipation of energy can be corrected by installing a line-cord switch or simply pulling the plug when the set is not in use.

11. See Ref. 7., Table 3b.

12. The U. S. Congress has not authorized the use of life cycle cost labels on appliance, so mandatory labelling of this sort would be illegal at present. To provide the consumer with life cycle cost data would require either a change in federal law or programs for voluntary dissemination of fact sheets. A voluntary program could be handled through appliance dealers, utilities, or state Energy Extension services.

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