NORWEGIAN ELECTRICAL APPLIANCE OWNERSHIP, FAMILY TYPES AND POTENTIAL ENERGY SAVINGS

Richard Ling and Harold Wilhite
Ressurskonsult A/S

Norway's energy use has increased dramatically in the past decade, due in part to the increasing use of household appliances; thus, appliance use is a rich area for investigation of the potential for energy savings. This paper is an examination of this potential in Oslo, Norway, based on survey data from a random sample of 1360 households. The energy savings potential for appliances can be related to the age of the existing stock of appliances and to the relative inefficiency of the average appliance sold on today's market. Survey data on the ages of appliances is used to estimate potential savings if the existing stock of appliances was completely replaced with the best available technology. There is a vast potential savings available simply through the replacement of existing appliances with more efficient models. The largest savings are available for refrigerators and freezers but there is also a large potential associated with clothes washers, dryers and dishwashers. The potential savings are distributed among several different groups in society. In terms of building type, the largest potential savings are in detached homes and duplexes and the least potential is among those who live in buildings with more than five residences. If one considers a family's life cycle, then the largest potential savings is among those with adolescent children and the elderly, and the smallest potential is among those with infant children.

INTRODUCTION

Due, in part, to the increasing saturation of household appliances, domestic energy use in Norway has increased in the past decade. It behooves us to examine the role of appliances in Norwegian homes, their potential for saving energy and measures which could be employed in order to realize the potential. This paper is an examination of these issues for Oslo, Norway, based on survey data from a random sample of 1360 households. In this paper we examine the savings potential for appliances. As a point of departure we use the savings which would result if the existing stock were completely replaced with the best available technology, an idea which is impossible in practice, but is useful for examining the energy savings potential for appliances.

The energy savings potential for appliances can be related to the age of the existing stock of appliances and to the relative inefficiency of the average appliance sold on today's market. The age of the appliances have a direct effect on their energy consumption. For example, the average refrigerator in use in 1973 used almost twice as much energy as the average machine sold in 1988. Although the efficiency of appliances has been increasing over the last 15 years, our research shows that there is a large existing stock of older, less efficient, appliances in Oslo (Mills 1989; Nilsson 1990; Nørgård 1989; Norwegian Ministry of Petroleum and Energy 1989; Schipper 1990; Schipper 1989; Schipper and Wilson 1989a; Schipper and Wilson 1989b; Tyler and Schipper 1989).

There is also a wide variation in the efficiency of appliances on the market today. The consumption of the average appliance purchased today is often far higher than that of the most efficient available. If one, again, takes the example of refrigerators, there is a model on the market in Norway which uses only a third of the energy of the average machine sold.

THEORETICAL BACKGROUND

It is useful to set appliance use in the context of the entire household energy budget. According to Van Raaij and Verhallen, household energy use is a process which is related to the physical structures of the home, its equipment, the resident's attitudes toward energy use and their habits (1983). Elements which affect appliance energy consumption include age and consumption characteristics, how the appliance is used and knowledge of more efficient ways to use it (Kempton and Montgomery 1982; Kempton et al. 1982; Kempton and Layne 1988).

Household energy decision making is also an important issue when trying to understand household energy consumption. When purchases are made there is a complex of considerations made which often have little to do with energy conservation but rather with personal economy, style of the home and specific features of the appliance (Davis and Rigaux 1974; Mills 1989; Rubin 1976; Gullistad 1984). Family lifestyle also plays a role in purchase decisions (Wilk and Wilhite 1983; Wilk and Wilhite 1985; Ling and Wilhite 1990). Customers selections are obviously made within the realm of what is available on the market, so that inefficient choices may stem from inefficient options (Mills 1989). Finally, purchase decisions are made with the predispositions and the folk knowledge that people have collected through their life experiences. This knowledge may be only a rough approximation of the actual consumption of an appliance, or it may even be far off the mark (Kemption et al. 1988; Mills 1989).

METHOD

The size and social structure of the savings potential of appliances has been examined using data from a questionnaire developed for the Oslo/Helsinki Electrical billing project. This project is an examination of the effect of electrical billing techniques on energy consumption. As a portion of the project a questionnaire was sent to a random sample of 3600 homes in Oslo. It asked for information on types of electrical equipment in the home, age structure of the families, the type of home, its size, and ownership status. There were 1360 households, or about .054% of the total population of Oslo, which were ultimately included in the sample. These respondents are a random sample of households from all sections of the city providing us with a very rich database which describes some of the energy related activities of homes in Oslo.

The first step in the examination of the potential savings was to determine the ages of appliances in our sample. This was done using information from the questionnaire. We asked if the respondents owned a refrigerator, freezer, washing machine, dish washer and/or clothes dryer. If the respondent owned the appliance we asked for its age.

The second step in calculating the savings potential was to estimate the average annual consumption of the various appliances. The annual consumption of appliances sold in 1988 was compared to the average consumption of appliances sold in 1972. Every appliance considered here has shown an increased efficiency in the last 15 years, which means that the average consumption of the existing stock of appliances is declining (Mills 1989; Nilsson 1990; Nørgård 1989; Norwegian Ministry of Petroleum and Energy 1989; Schipper 1990; Schipper 1989; Schipper and Wilson 1989a; Schipper and Wilson 1989b; Tyler and Schipper 1989; Ling and Wilhite 1990).

The third step in the process was to estimate the savings potential for each of the appliances if they were replaced today with the best technology commercially available in 1988. This was calculated by subtracting the consumption of the most efficient appliance from the annual consumption of the appliance owned by the respondent. The most efficient appliance in 1988 was chosen as a benchmark simply because data for all of the appliances was available. This technique is also similar to the technique used by Bodlund et al. in their examination of Swedish electrical consumption

(1989; see also Mills 1989a). This resulted in estimates which are similar in magnitude and direction to those suggested by Schipper (1989). These estimates for the savings potential by machine were then multiplied by the number of machines of a given age in our sample. These results were then summed in order to find the total savings potential for a given appliance for homes in our sample. This potential was examined by specific types of social groups (Ling and Wilhite 1990). Finally, the payback for the different appliances was calculated based on the Danish cost estimates of Nørgård, adjusted to Norwegian prices.

ANALYSIS

Here we discuss (1) the appliance saturation and age characteristics, (2) the total energy saving potential for the appliances, (3) the social structure of the savings potential and (4) the payback for the five appliances. In addition, the total savings potential of all appliances will be discussed.

Appliance Saturation, Age and Potential Savings

Refrigerators and Combination Refrigerators/ Freezers. Refrigerators and "combis" were the most common appliance in the study. According to Tyler and Schipper there was almost 100% saturation of refrigerators/combis in 1985 in Norway (Ling and Wilhite 1990; Tyler and Schipper 1989). The saturation for our sample was 97%. Refrigerators/ combis were the most energy craving machines of all those which were examined. Aside from freezers, refrigerators/combis had the highest average age of any of the appliances. The average age of the refrigerators/combis in our sample was 8.1 years with a standard deviation of 6.7 years. Given the high level of saturation, the high average age of the machines in Oslo and the availability of an energy efficient alternative, there is a large potential energy savings associated with replacing refrigerators/ combis (Ling and Wilhite 1990).

In our questionnaire there was no distinction made between refrigerators and combis. This meant that in order to calculate the average annual electrical consumption for refrigerators/combis we needed to weight the consumption of refrigerators and combis. The average refrigerator sold in Norway in 1988 used about 270 kWh/year while the average consumption of a combi was almost three times as much at 800 kWh/year (Mills 1989; Nilsson 1990; Nørgård 1989; Norwegian Ministry of Petroleum and Energy 1989; Schipper 1990; Schipper 1989; Schipper and Wilson 1989a; Schipper and Wilson 1989b; Tyler and Schipper 1989)[1]. As of 1985 the ratio of refrigerators to combis was 7:3 in Norway (Ling and Wilhite 1990). This means that the average consumption for the stock of refrigerators and combis was 429 kWh/year. The best refrigerators available on the market use as little as 90 kWh/year while the best combi available uses around 550 kWh/year (Ling and Wilhite 1990). If one assumes the current ratio of refrigerators to combis, then the lowest potential consumption would be 228 kWh/year.

Figure 1 shows that there would be substantial savings if one were to immediately replace all refrigerators/combis with the best technology available (Ling and Wilhite 1990). Refrigerators/ combis represent the largest area for potential savings. The reduction in consumption would be almost 360 MWh/year for our sample (Ling and Wilhite 1990).

Freezers. The diffusion of freezers showed a strong surge through the late 70's and early 80's. During that period the saturation grew at a rate of about 2% per year. In the early 80's however, the growth rate had declined to about .5% per year. The saturation level for all of Norway in 1985 was about 75%. The saturation rate for our sample in Oslo was about 74% in 1989 (Ling and Wilhite 1990). The average age of the freezers in our sample was 8.5 years. This is the highest average age of any appliance in our sample. For freezers there was a standard deviation of 6.1 years.

The average annual electrical consumption of a freezer sold in Norway in 1988 was about 400 kWh/year. The average consumption for machines in use was 500 kWh/year. There has been a reduction in consumption of about 30% over the last 15 years or an average efficiency increase of about 17 kWh/year. This best machines available use

[1] *The same set of articles was used as a reference for all five appliances. To save space the reference will only be given here.*

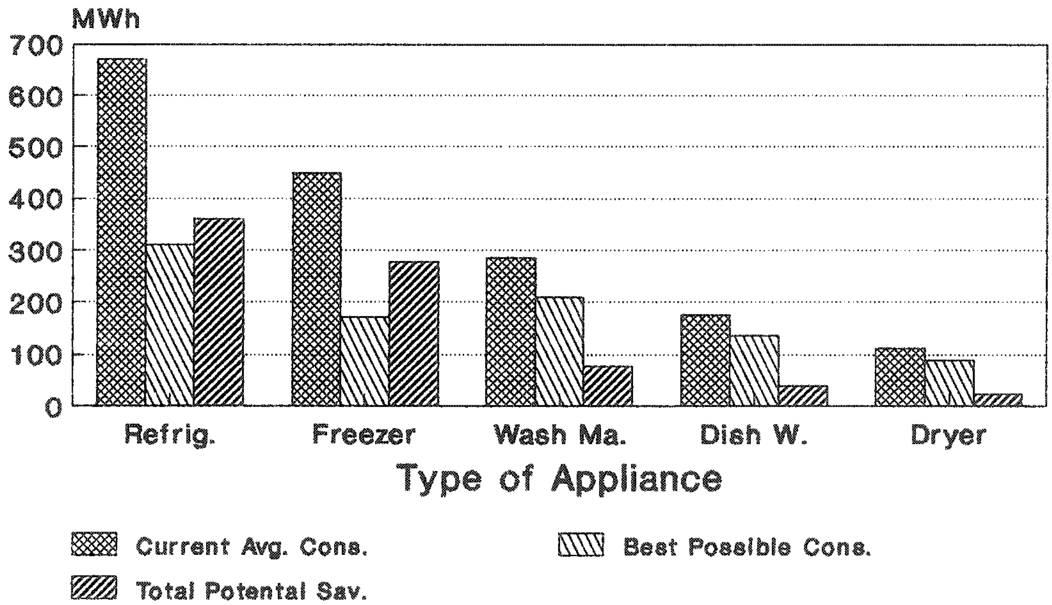

Figure 1. Estimated and Potential Consumption for Electrical Appliances, Oslo, 1989

about 180 kWh/year while advanced technology machines use as little as 100 kWh/year.

As with refrigerators there would be substantial savings if one were to immediately replace all freezers with the best technology available. Next to refrigerators, freezers represent the largest area for potential savings with a reduction of almost 277 MWh in consumption for our sample (Ling and Wilhite 1990).

Washing Machines. Washing machines have had a slow steady growth through the 70's into the 80's. They have grown at a rate less than 1% per year through that period. According to Tyler and Schipper, the saturation level for all of Norway in 1985 was about 83% (1989). Our data indicates that the saturation rate for our sample in Oslo was about 66% in 1989 (Ling and Wilhite 1990). The difference is probably due to a lack of space in apartment buildings and access to collective washing machines in the city. The average age of the washing machines in our sample was 6.5 years with a standard deviation of 5.0 years.

According to the Norwegian Ministry of Petroleum and Industry the average annual electrical consumption of a washing machine sold in Norway in 1988 was about 300 kWh/year. The average energy consumption for a machine in use was 400 kWh/year. The high consumption level is due to the fact that the machines heat their own water. There has been a reduction in average consumption of a washing machine of about 20% over the last 15 years. This indicates that the consumption of the machines decreased by about 6.6 kWh/year. This best machines available in 1988 used about 240 kWh/year while advanced technology machines used about 115 kWh/year.

As shown in Figure 1 there would be a savings of about 78 MWh/year if one were to immediately replace all machines in our sample with the best technology available in 1988 (Ling and Wilhite 1990). This figure must be treated with care however. As with dishwashers and clothes dryers, consumption, and the energy savings potential, is dramatically effected by different washing habits. It is possible, for example, that a preponderance of laundry can be washed in cold water, thus reducing the need for energy. This is particularly true of urban settings where work and life produce fewer dirty clothes. In addition, the development of new types of soap reduce the need for hot water

(Nørgård 1989:141). Thus, the estimates of savings potential may be low.

Dish Washers. Dishwashers have achieved the least market penetration of the five appliances considered here. As of 1985 only 20% of Norwegian homes had them. The penetration in our sample was somewhat higher (34%) (Ling and Wilhite 1990). This is probably because of the urban character of the sample. People living in cities have greater access to stores where machines are sold and they are perhaps more open to the idea of buying new types of appliances. City dwellers have access to a wider range of diversions outside of the home and there are more women in the work force. The effect of all of these factors may be that there is more of an emphasis on convenience. Shipper and Wilson's data shows a leveling off in saturation rate to about .5% over the last 5 years of their data (1989b).

The average annual electrical consumption of a dishwasher sold in Norway in 1988 was about 360 kWh/year (Ling and Wilhite 1990). This is a reduction in consumption of about 33% over the last 15 years. This means that, on average, the efficiency of the machines has increased by about 11.3 kWh/year. The best machines available use about 310 kWh/year while advanced technology machines use as little as 165 kWh/year. The ultimate technical potential of dishwashers appears to be around 35 kWh/year for the mechanical operation of the dishwasher, plus perhaps another 75 kWh/year for heating the water, which is a common function of Norwegian dishwashers. The minimum amount of energy used in washing dishes manually may also be about 75 kWh/year (Ling and Wilhite 1990; Nørgård 1989).

Figure 1 indicates that there would be relatively little potential realized if one were to immediately replace all dishwashers with the best technology available. This is largely because the collection of dishwashers in our sample is so new, and thus, relatively energy-efficient. The reduction in consumption would be slightly less than 40 MWh (Ling and Wilhite 1990). As one might guess, however, there is a considerably larger potential to be tapped if homes adopted the most efficient forms of manual dishwashing, (i.e. a cold rinse, cleaning with soap in a sponge and a hot rinse). There is a potential savings of 144.5 MWh if these practices were to be adopted among only the 30% of our sample who owned dishwashers (Ling and Wilhite 1990).

Clothes Dryers. The saturation level of clothes dryers has doubled between 1970 and 1985. Like other appliances they showed a surge in growth in the 70's and a leveling off during the 80's. During the 70's they had a growth rate of about 1-1.5% per year. In the early 80's however, the growth rate has declined to between 1% and .5% per year. According to Tyler and Schipper the saturation level for all of Norway in 1985 was about 33% (1989). Our data indicates that the saturation rate for our sample in Oslo was about 21% in 1989. This was the least saturation of any appliance for our sample (Ling and Wilhite 1990). It might be that dryers--and dish washers which also had a low saturation level--are luxury appliances (Langston and Williams 1988). As with clothes washing machines this difference has a rural/urban aspect. A large portion of our sample lived in smaller homes and apartments without space for clothes washing facilities. This is not usually the case in more rural settings.

The average age of the dryers in our sample was 4.8 years with a standard deviation of 3.7 years. This is the lowest average age and the tightest standard deviation of all the appliances examined here and is, perhaps, an indication of the novelty of private ownership of a dryer. There are three other commonly used clothes drying systems in Norway--a country with a lot of rain and thus, a lot of experience in drying clothes. In many apartment complexes there is a commonly owned dryer for the entire complex, which displaces the need for a privately owned dryer. Another alternative is clothes lines, which can be found in large outdoor and small collapsible indoor versions and which are backed with a strong ideology of producing clean, good smelling clothes and bedding. Finally, many Norwegians, particularly those who own private homes, have a drying cabinet, which is a small cabinet with a heating element. It is often built into the homes. About 10% of our sample had such appliances. These respondents tended to be somewhat older than those with dryers. This technology was popular in the 1950's before the widespread introduction of dryers.

These last two alternatives have the additional advantage of being gentler on clothes. Thus, dryers represent a relatively new technology which must compete with several entrenched alternatives. This probably accounts for the relatively low average age of the stock of dryers in our sample. By contrast, a friend recently described how some parents put their children's outer winter garments in the dryer for a few minutes before the children use them in order to "pre-heat" them. Such practices augur for the acceptance of dryers as, if nothing else, an aid to good parenting.

The average annual electrical consumption of a dryer sold in Norway in 1988 was about 440 kWh/year. The average consumption for a machine in use was 520 kWh/year. This efficiency increase represents a reduction in consumption of about 13% over the last 15 years. Thus the average consumption of the machines has decreased by about 17 kWh/year. In 1988 the best machines available used about 350 kWh/year, while advanced technology machines use as little as 180 kWh/year.

As shown in Figure 1 there would be substantial savings if one were to immediately replace all machines with the best technology available. The reduction in consumption would be about 23 MWh (Ling and Wilhite 1990). Of course, if clothes lines were used instead of clothes dryers there would be considerably more savings. Our sample would save about 112 MWh of such a program went into effect (Ling and Wilhite 1990).

Energy Saving Potential for the Five Appliances Considered Here. The total energy savings potential for the five appliances considered here is somewhat different from the individual savings potentials. It combines the efficiency of the appliances held by respondents and the total number which they owned. This statistic provides insight into the total energy used for appliances, not the consumption of individual appliances.

It has been suggested that the saturation levels for some appliances are being reached. After a strong growth in the 1970's the growth rate for most appliances has leveled off (Schipper and Wilson 1989a, Schipper and Wilson 1989b). As noted above the efficiency of the appliances has also been increasing, but this may also level off (Schipper 1989; Nilsson 1990).

The total energy savings potential for our sample was about 776 MWh/year for the five appliances included in the study (Ling and Wilhite 1990). Obviously, the largest influences on the total consumption was for those appliances which consumed the most energy and which had the highest saturation rates, i.e. refrigerators/combis and freezers. Since these two appliances also had the highest average age of any appliance in the sample, they are prime targets for energy conservation activity such as rebates or efficiency labeling programs. If consumers were better informed of the comparative consumption characteristics of refrigerators/combis and freezers and of appliances in general, they might be more willing to include its consideration in their purchase decision. Currently, there is little, if any, information on efficiency available (Dalen, Glesne and Hamre 1989; Mills 1989). A system of consumption labeling would facilitate the adoption of energy-efficient appliances (Norwegian Ministry of Petroleum and Energy 1989).

The Social Structure of the Savings Potential

Next we turn to an analysis of specific types of social groups in our survey which have particularly high or low energy savings potentials. The energy savings potential of each of the appliances plus the total energy savings potential was examined by the type of building that the respondent lived in, i.e. detached home or large apartment building, the floorspace in the home, the ownership status of the respondent, and the structure of the family.

Refrigerators. An analysis of our sample shows several groups which have a high energy savings potential. These are (1) those living in single homes, (2) those who own their homes (3) those with adolescent children (Ling and Wilhite 1990). The groups which seem to have the lowest potential for energy savings are those who rent, who live in larger buildings and who have no children. Another, unexpected, result is that the elderly have a very low energy savings potential when compared to families with adolescent children. Refrigerators are the only appliance for which the elderly did not have the largest potential savings. This seems to indicate that when the children move out, the parents take the opportunity to buy a new refrigerator. It might be that the parents also give the old refrigerator to the children, or perhaps keep it as a second refrigerator, though we do not have enough data to support these assertions. There is an indication that a refrigerator is a indispensable appliance, particularly among the elderly. Skumatz, for example, reports that the elderly in the U.S. were more likely to have refrigerators and freezers than other groups (1988).

Freezers. There are several groups which have older freezers, and thus have greater energy savings potential. These include (1) those living in larger single homes and duplexes, (2) those who rent and (3) those with no children and elderly respondents (Ling and Wilhite 1990). One can summarize by saying that the greatest potential for saving when it comes to freezers is among who are either in a pre-establishment phase of their lives, or those who have been established for a longer period of time. The pre-establishment group may be living on their own for the first time and are putting together a life from the hand-me-downs offered to them from friends and family. The other group which has a high potential is those families who have been through child rearing and whose children have been emancipated long ago. They are established both economically and socially. One can assert that there is nothing to be gained, in their eyes, from having the latest technology, or the latest look in their home. It is far more important that their freezer functions properly.

The groups which have the lowest potential for energy savings are those living in larger coop buildings, with small apartments. In addition, there is a small potential for those who have infant children. This corresponds to the nest building developed by Wilk and Wilhite (1983; 1985). It is possible that new parents justify the purchase of a freezer to correspond to the birth of a child. They might feel that they will save on food costs or that since they will likely need to move into a larger home in the near future and thus it is alright to put up with appliance.

Washing Machines. The greatest energy savings potential for washing machines is among those living in individual homes and duplexes and among elderly respondents (Ling and Wilhite 1990). The groups which seem to have the lowest potential for energy savings are those living in larger buildings and those who have infant children (Ling and Wilhite 1990).

Dish Washers. As with washing machines, the largest potential for reducing energy consumption are those living in individual homes and duplexes, and in the homes of the elderly (Ling and Wilhite 1990). By contrast, families who live in buildings with more than five apartments and families with infant children have a significantly smaller savings potential when it comes to dishwashers (Ling and Wilhite 1990). This finding shows that those who are in an developmental phase of their lives tend to have newer technology. Those who are established, however, are not as likely to have newer energy-efficient technology.

Clothes Dryers. There are two groups in our sample which have a particularly high savings potential in relation to clothes dryers. These groups are elderly respondents and those living in large homes. By contrast the least energy savings potential for dryer owners is for those who live in small homes and apartments and those with infant children (Ling and Wilhite 1990).

Here again there is a contrast between established homes and those which are just being established. Since the dryers in the latter of the two tend to be newer, it they also tend to be more efficient. There is not the "hand-me-down" effect here that one can see with, for example, freezers where young homes in the pre-establishment phase have the oldest, most energy inefficient technology. This is, of course, because of the low saturation of clothes dryers in Norway.

Energy Saving Potential for the Five Appliances Considered Here. Those who have the greatest total energy savings potential for the five appliances which are examined here are those who own large detached homes and those with several adolescent children. By contrast, the smallest total potential is among renters of small apartments in large apartment buildings and those with no children (Ling and Wilhite 1990). This suggests that appliance energy saving programs should focus on detached homes. One might, for example develop a refrigerator rebate program, using direct mail advertising campaign focused on those who have recently purchased a new home. The program could offer a rebate on a new refrigerator when the old refrigerator is traded in and scrapped. Such a program would also have benefits in terms of reduced CFC emissions. As we have mentioned energy labeling of appliances would stimulate more energy efficient investments.

Additional Cost to Manufactures for Energy Efficiency

In the following section we will examine the additional cost to manufacturers if they were to produce energy efficient appliances. We will report the payback period for the additional cost if the manufacturer were to pass the cost directly to the consumer, admittedly a naive assumption. Of course the traditional definition of payback is the extra cost to the consumer at the point of purchase. Additional cost to the manufacturer, however, is not always passed directly to the consumer. That cost is often decided by other considerations (Mills 1989). Additional cost may, for example be absorbed by the producer to enhance competitiveness, or it may be magnified several times when the manufacturer feels that extra-market considerations dictate purchasing. The discussion is based on the estimates of Nørgåard (1989). For the purpose of comparison, industry often considers a payback period of less than 3 years as a boundary (Mills 1989).

Refrigerators. A reduction of 180 kWt/year per machine can be achieved with an additional cost to the manufacturer of approximately 200 Kr (The current exchange rate is about 6.5 Kr to the dollar). This means a payback period in Norway of about 2.7 years for new machines if the costs were passed directly to the consumer (Ling and Wilhite 1990). An additional investment of 60-100 Kr. could save another 40 kWh/year or 3.7 - 6.2 year payback period in Norway.

Freezers. A reduction of 220 kWt/year per machine can be achieved with an additional cost to the manufacturer of approximately 200 Kr. for better insulation and additional steel. This means a payback period in Norway of about 2.3 years for new machines. An additional investment of 130 Kr. could save another 80 kWh/year or a four year payback in Norway.

Washing Machines. There is no additional cost associated with the most efficient machine on the market as opposed to the normal machine on the market.

Dish Washers. In the case of dishwashers a reduction of 145 kWt/year per machine can be achieved with an additional cost to the manufacturer of approximately 150 Kr. investments in insulation and better motors. This means a payback period in Norway of about 2.7 years for new machines if the costs were passed directly to the consumer.

Clothes Dryers. There is no extra cost involved in reducing the consumption of the average clothes dryer sold in 1988 by 90 kWh/year to the level of the most efficient sold in that year. An investment of 390 Kr. could result in savings of 200 kWh/year. This represents a pay back period for Norway of about 4.9 years.

SUMMARY

A general conclusion is that there is a vast potential savings available simply through the introduction of efficient appliances. The realization of this potential is based on the introduction of more and more efficient appliances into the market place, an assumption which may or may not be realized (Mills 1989; Schipper 1990). Another element is the stability of saturation of the appliances. The experience in Norway shows that saturation can grow rapidly in certain periods (Schipper and Wilson 1989b). The largest savings are available for refrigerators and freezers. There is also a large potential associated with clothes washers, dryers and dishwashers.

The potential savings are distributed among several different groups in society. If one considers the type of building in which the home is located, the largest potential savings are in detached homes and duplexes and the least potential is among those who live in buildings with more than five homes. In terms of a family's life cycle the largest potential savings is among those with adolescent children and elderly and the smallest potential is among those with infant children. This finding is similar to findings from the U.S. (Schipper 1990) and it supports the findings of Wilk and Wilhite (1983; 1985).

The findings of several different studies suggest that the purchase of energy-efficient appliances need not be more expensive than the purchase of their less efficient counterparts. Further, research shows that there is a need for knowledge among consumers as it relates to the energy use characteristics of appliances i.e. energy labeling (Dalen Glesne and Hamre 1989; Kempton and Montgomery 1982; Kempton et al. 1982; Kempton and Layne 1988; Nørgård 1989; Mills 1989). Such labeling would aid in the selection of energy-efficient appliances and it would prod manufacturers to produce more efficient appliances.

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