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DOMESTIC REFRIGERATION APPLIANCES IN POLAND:

POTENTIAL FOR IMPROVING ENERGY EFFICIENCY

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Abstract

This report is based on information collected from the main Polish manufacturer of refrigeration appliances. We describe their production facilities, and show that the energy consumption of their models for domestic sale is substantially higher than the average for similar models made in W. Europe. Lack of data and uncertainty about future production costs in Poland limits our evaluation of the cost-effective potential to increase energy efficiency, but it appears likely that considerable improvement would be economic from a societal perspective. Many design options are likely to have a simple payback of less than five years. We found that the production facilities are in need of substantial modernization in order to produce higher quality and more efficient appliances. We discuss policy options that could help to build a market for more efficient appliances in Poland and thereby encourage investment to produce such equipment.

1. INTRODUCTION

The energy efficiency of energy-using equipment was historically not a high priority in Poland or other centrally-planned economies, in part because energy prices were very low. As a result, the efficiency of the equipment in most areas is well below the levels typical in Western Europe or the U.S. As Poland and the other former centrally-planned economies address the challenge of transforming their economies and improving environmental conditions, improvement of energy efficiency has become an important policy goal.

In association with a larger study of energy use and energy efficiency in Poland,[1] we undertook a more detailed analysis of the potential to improve energy efficiency in a single end use, domestic refrigeration appliances. Much of the information presented in this report is based on discussions with the largest Polish manufacturer of domestic refrigeration appliances, a tour of their factory, and technical information provided by the company. As we were not able to conduct independent testing of Polish refrigeration appliances within the scope of this project, the findings on energy efficiency are not definitive, but they are probably reasonably accurate. A number of questions remain unanswered, calling for further research.

As shown in Figure 1, ownership of refrigerators rose rapidly in the 1970s, and became nearly universal by 1989.[2] In the 1970s very small (130 liter) refrigerators of Polish and Soviet manufacture were most popular. A two-door Polish refrigerator-freezer (220-240 liters) came on the market in the late 1970s, followed in the mid-1980s by a similar Soviet model. Based on interviews with Polish manufacturers, the Polish Foundation for Energy Efficiency (FEWE) estimates that 70% of the total refrigerator stock of around 12 million units consists of models in the larger size range.[3] The average retail price in early 1993 was $265 for small units (130-170 liter) and $375 for larger models.[4] Imported models from Western Europe are considerably more expensive.

Ownership of freezers rose during the 1980s, and climbed further to nearly 30% of homes in 1991. An estimated two-thirds of freezers in use are quite small (50-60 liters), as many households bought these small freezers to supplement the refrigerator they already owned. The remainder of the freezer stock is of 120-140 liter size. (In addition, there are an estimated 0.3-0.4 million freezers with over 150 liters volume used by commercial enterprises.) Upright (front-open) freezers are more common in cities, while larger chest freezers are more popular in rural areas, where they are used for storing meat. The average price in early 1993 was $280 for small models and $375 for the larger domestic model.

The average energy consumption in use of Polish appliances is not known with precision. Table 1 shows estimates made by FEWE based on spot metering of a small sample of devices. Multipying these values by the estimated number of units in use approximates total electricity consumption by each type of appliance. Refrigerators and freezers account for an estimated 20% and 5% respectively of total household electricity use.[5]

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[1] S. Meyers, L. Schipper, and J. Salay, "Energy Use in Poland, 1970-1991: Sectoral Analysis and International Comparison," LBL-33994, Lawrence Berkeley Laboratory, Berkeley, CA, July 1993.

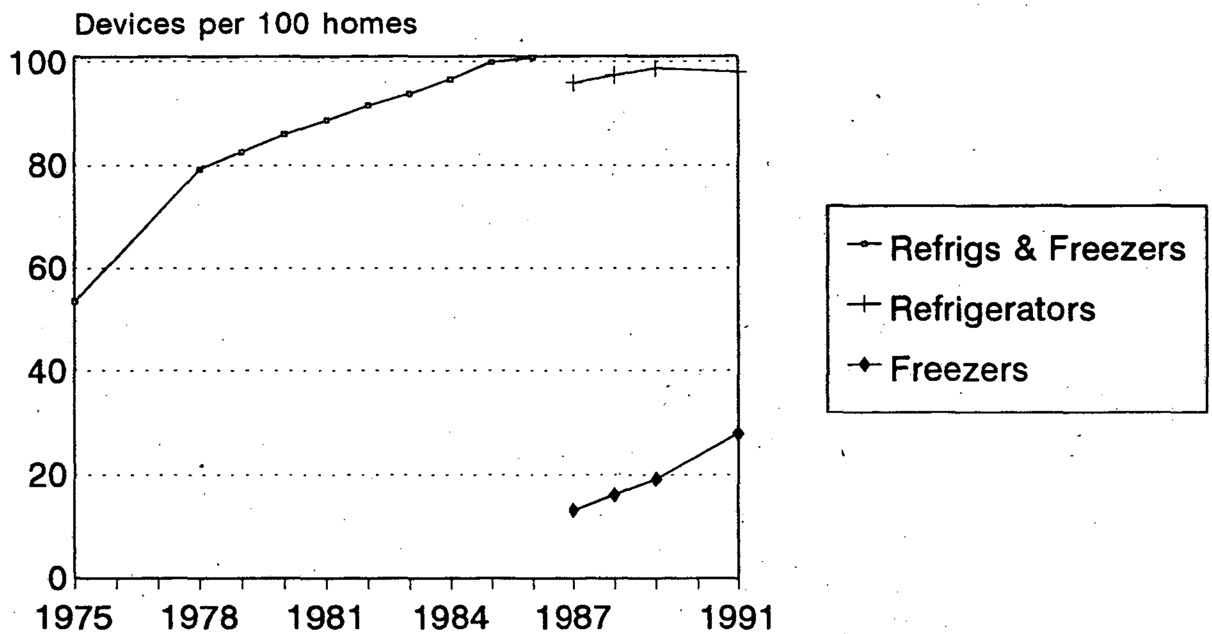
[2] Data on appliance saturation are from the Central Statistical Office (GUS), *Rocznik Statystyczny 1992*, Warsaw.

[3] Estimates of the market shares of different appliance types and data on prices were provided by the Polish Foundation for Energy Efficiency (FEWE).

[4] The larger models include both two-door refrigerator-freezers and refrigerators with a frozen food compartment.

[5] Electricity use by Poland's 11 million households accounted for nearly 30% of total electricity sales in 1991. Electricity use by non-farm households accounted for nearly 22% of total electricity sales; private farms accounted for approximately another 7%, and the majority of their electricity use is for household purposes rather than farm machinery.

Poland: Refrigerators and Freezers
1975-1991



Source: Polish Central Statistical Office (GUS)

Fig. 1

Device	Avg kWh per device	Number (millions)	Total use (TWh)
Refrigerators	--	11.91	5.41
135-170 l.	410	3.57	1.47
220-240 l.	475	8.34	3.94
Freezers	--	2.27	1.34
50-60 l.	560	1.50	0.84
120-140 l.	650	0.77	0.50
TV sets	--	4.80	15.28
Storage water heaters	--	2.00	1.16
All end uses	--	--	~26.5*

Table 1. Estimated annual electricity consumption of appliances in Polish homes

Source: Polish Foundation for Energy Efficiency, unpublished material.
Average consumption is based on spot metering of a small sample.
* Refers to the sum of residential sales and the estimated household part of agricultural sales.

As shown in Table 2, Polish production of refrigerators and freezers has been fairly steady since 1985 at 500-600 thousand per year despite the severe economic recession of 1990-91. Imports, which were mainly from the Comecon countries and were equal to domestic production in 1985, fell greatly after the collapse of the Comecon trading structure. The domestic demand for refrigerators and freezers declined considerably in 1991 as the economic situation forced consumers to cut back on expenditures.

Table 2. Polish production and trade of refrigeration appliances (thousand units)

	1985	1989	1990	1991
Production	578	516	606	563
Export	145	184	218	180
Import	600	448	378	151
Domestic supply	1033	780	766	534

Source: Central Statistical Office

Based on interviews with Polish manufacturers, FEWE estimates that around two-thirds of the refrigerators sold in 1991 were of the larger size (220-240 liters). For freezers, an estimated 38% of 1991 sales were small (50-60 liters) units, 27% were medium-size (100-200 liters) units, and 36% were large commercial units.

2. PRODUCTION OF REFRIGERATION APPLIANCES IN POLAND

This section provides information about Polar Industry, a state-owned company that accounts for around two-thirds of total production of refrigeration appliances in Poland. It is based on discussion with W. Babiarz, manager of the design department and deputy chief designer of Polar, and on a visit to the Polar factory in Wroclaw in July 1992.

Polar started the production of domestic refrigerators and freezers in 1950. In 1970, the factory was enlarged to manufacture domestic clothes-washers. Annual production in recent years has been around 250 thousand refrigerators and 100-120 thousand freezers. Some 15-20% of their refrigerators are small-capacity units of the absorption type. Around 40% of their refrigerators and freezers are exported under the "Sidex" trademark, mostly to Western Europe. Their refrigerators range in size from 130 to 240 liters. The 240-liter model has a separate freezer compartment with automatic defrost.

The appliances produced by Polar are well behind the state-of-the-art in Western Europe and have not seen significant technological improvements in 15 years. The first refrigerators were produced with a license from Gorenje (in former Yugoslavia). Little by little, Polar developed its own expertise and made various modifications to the initial design. Currently, Polar has its own industrial designs and practices, but the last new product designed entirely at Polar was in 1975.

Although Polar has been using polyurethane foam for insulation since the 1970s, many of the components used in their products are outmoded. Hermetic compressors mainly come from a company in the former East Germany and are rather inefficient. Polar also purchases better compressors from foreign companies such as Unidade Hermetica (Spain) and Danfoss (Denmark), but these are only used in refrigerators and freezers intended for export. They make their own door seals.

The visit to Polar's factory made clear the very poor overall quality of the industrial installation. The tooling plant has not changed since its foundation. Working conditions seem unpleasant: old machine tools, very noisy surroundings, and dirty buildings. The phasing of refrigerator production is rather old-fashioned. The cabinet is built in one part of the building. The refrigeration unit, which consists of a compressor, an evaporator and the condenser, is assembled in another. It is tested for 90 minutes, and then mounted on the cabinet. This implies that there is a trap on the backside of the cabinet to introduce the evaporator. Even if the trap is covered by an insulation sheet, it allows thermal losses. The sealing around the doors is also not optimized to limit heat gains inside the cabinet.

The laboratory for research and development activities was built at the same time as the factory, but it is now being redesigned. Measurement tools, test chambers and other monitoring apparatus are quite old. There is not a single computer in the R&D building. This is very surprising in a research laboratory, and is an illustration of the low investment capabilities of the company.

Polar recognizes the need to modernize. The main problem is lack of money for upgrading its production capacity. There is a need to employ new techologies in the manufacturing process as well as in the products themselves.

Polar is adjusting to the new business environment in Poland. From 7000 workers in 1989, the company decreased to 5000 workers in 1992, but there is still over-employment. Polar is still state owned, but it now has to make new kinds of strategic decisions (marketing, product development, new suppliers, etc.) that it never faced under the central planning regime. There was no marketing under the old regime, only production targets. Product quality and energy efficiency were unimportant. Everything that could be made could be sold. Now, Polar is beginning to recognize that improving product quality is necessary, and they are looking more carefully at the features of Western imports.

Polar faces competition from producers to the East: Sniga (Lithuanian), Donbass (Russian), and Minsk (Belarus) all produce cheap refrigerators that are subject to low import duties. At the higher end of the market, they could face competition from Western products. In addition, their exports will soon meet tougher energy requirements in Western Europe. Meeting the CFC-reduction targets of the Montreal Protocol will also require investment.

Because the export market is important to Polar, its staff is very interested in the future of EC regulation regarding domestic appliances, particularly concerning energy labelling and minimum efficiency standards. Many questions were asked on the technical approach and on the analysis of energy efficiency standards for domestic refrigeration appliances being carried out for the Commission of the European Communities (discussed below). Questions were also asked on the introduction, organisation, control, and certification of energy labelling and efficiency standards.

2.1. Energy Efficiency of Polar's Refrigeration Appliances

The test chambers of Polar perform the same test procedure that is used throughout the EC (the EN 153 norm, which follows the recommendations of the ISO). Thus, it is possible to make a reasonably accurate comparison of the energy efficiency of Polish refrigerators and freezers with those made in Western Europe. Polar's electricity use measurement is made with electromechanical counters and is not as accurate as the one used in Western European chambers, but the margin of error is relatively small.

We analyzed the technical information collected from Polar using the same methodology as in a recent study of European refrigerators and freezers performed for the Commission of the European Communities.[6] The methodology used is in many aspects similar to the U.S. DOE approach as far as appliance category definition and use of the adjusted volume instead of the total volume.

Under test conditions, the energy consumption of refrigeration appliances depends on the appliance volume and on the temperature difference between the surroundings and the inside of the appliance. For devices with more than one compartment, the energy consumption depends on the relative size of the refrigerator and frozen food compartments. Therefore, it is preferable to use the *adjusted volume* rather than the net volume of the appliance. To calculate the adjusted volume, a correction is made for the relative contribution of compartments with different temperatures to the total energy consumption. The adjusted volume is the sum of the volumes of the compartments, with each weighted by the difference in temperature between the interior of the compartment and the ambient temperature. In the test procedure EN153, the ambient temperature is set at 25°C.

In the United States, the minimum efficiency standard uses the same type of calculation for adjusted volume, but the values for the weighting coefficients are different because both the ambient temperature and the storage temperatures are different than in Europe. This is the main reason why it is not possible to compare the energy efficiency of European and U.S. refrigeration appliances.

We assume that the energy consumption of domestic refrigeration appliances can be expressed as a linear function of the adjusted volume. The use of linear equations for energy consumption in relation to volume holds only when applied to well-defined product categories. A typical category of refrigeration appliances groups devices that offer a common service rendered to the user. For example, the service rendered of a frozen food compartment depends on the temperature at which frozen food is kept. The EN153

[6] Group for Efficient Appliances (Ademe/DEA/NOVEM). *Study on Energy Efficiency Standards for Domestic Refrigeration Appliances*. Performed for the Commission of the European Communities, Directorate General for Energy - DG XVII. March 1993.

test procedure identifies refrigeration appliance categories based on the temperature of the frozen food compartment (FFC), and proposes a star rating system to define appliance categories (see below). The star rating of the frozen food or freezer compartment refers to its ability to maintain a specified temperature and, in the case of a four-star freezer, to freeze a certain amount of product within a 24-hour period.[7]

Refrigerators (with or without frozen food compartment) and combined refrigerator-freezers are primarily devoted to storing fresh foods at a temperature above 0°C. According to the EN153 test procedure, the storage temperature normally is 5°C. Freezers (categories F1 and F2) are used to freeze foods and store frozen foods at a temperature of -18°C.

It should be noted that in Europe the very large majority of the refrigeration appliances use natural convection. Forced convection appliances offering the possibilty of frost-free operation just entered the market 5 to 10 years ago, and their market share is still very low. Frost-free appliances are not put in a separate category but their energy efficiency is treated with an adjustment factor applied to their energy consumption in order to take into account the extra consumption due to the frost-free system.

The information on energy consumption and volume used in this analysis comes from commercial brochures. Best would have been to get the data from an independent laboratory, since commercial brochures are known to present data in a more optimistic way. The brochures mainly present the gross volumes of the compartments rather than the utilizable volumes that interest us. Thus, we estimated the utilizable volume of the compartments.

Table 3 gives various statistics on the refrigeration appliances made by Polar, including the energy use reported in product brochures. From these data we plotted the annual energy use vs. adjusted volume for units in each applicable category (see Figures 2 through 6). (The category R2 refers to refrigerators with a 2-star FFC; R4 refers to refrigerator-freezers.) To provide an additional point of reference, the Figures also include appliances manufactured by Calex, the main producer in the former Czechoslovakia. The figures depict how the energy consumption of the Eastern European models compares with that of similar models produced in the EC. The line with an index value of 1.00 is obtained by a linear regression on a scatterplot of all models produced in the EC in each category. (The data are from the study for the Commission of the EC cited above.) *Note that this line does not reflect the average energy use of all appliances actually sold in the market, but rather the average of all comparable models on the market.* The other lines in the Figures refer to consumption levels that are a given percentage above or below the reference line.

[7] The internal temperature shall not exceed -6°C for an FFC rated with 1 star, -12°C for an FFC rated with 2 stars, and -18°C for an FFC rated with 3 or 4 stars.

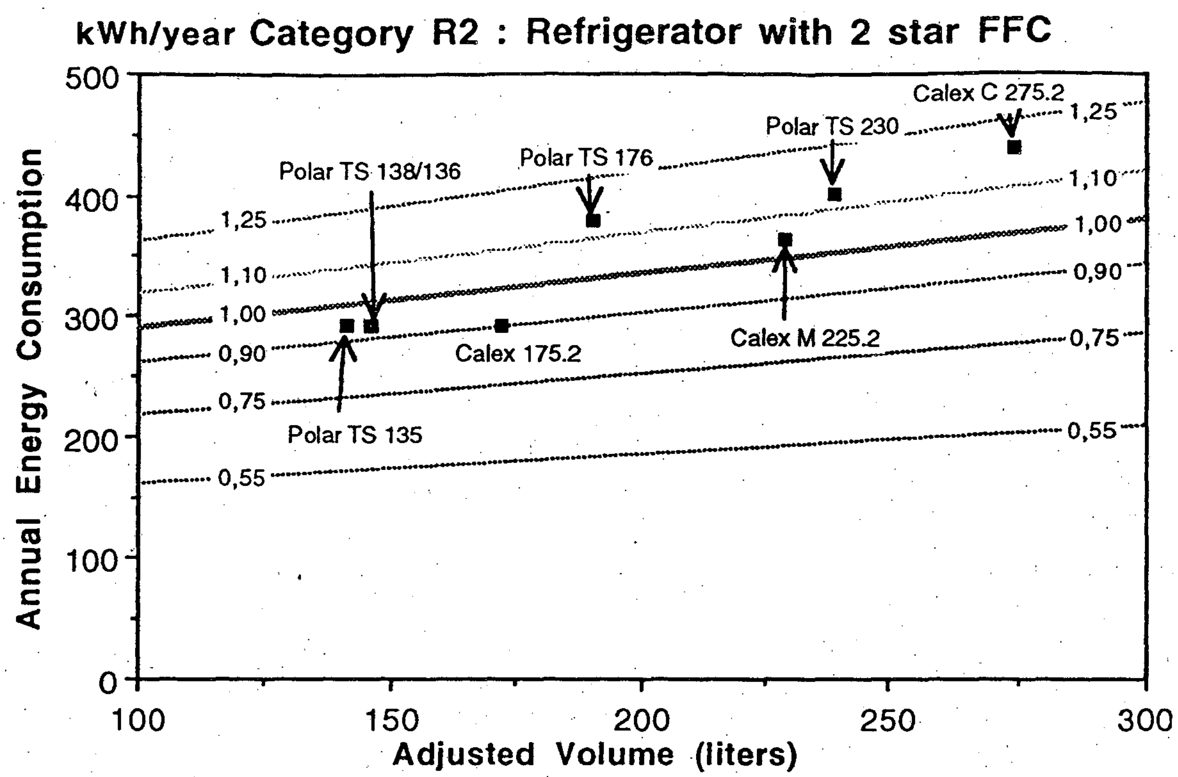


Figure 2

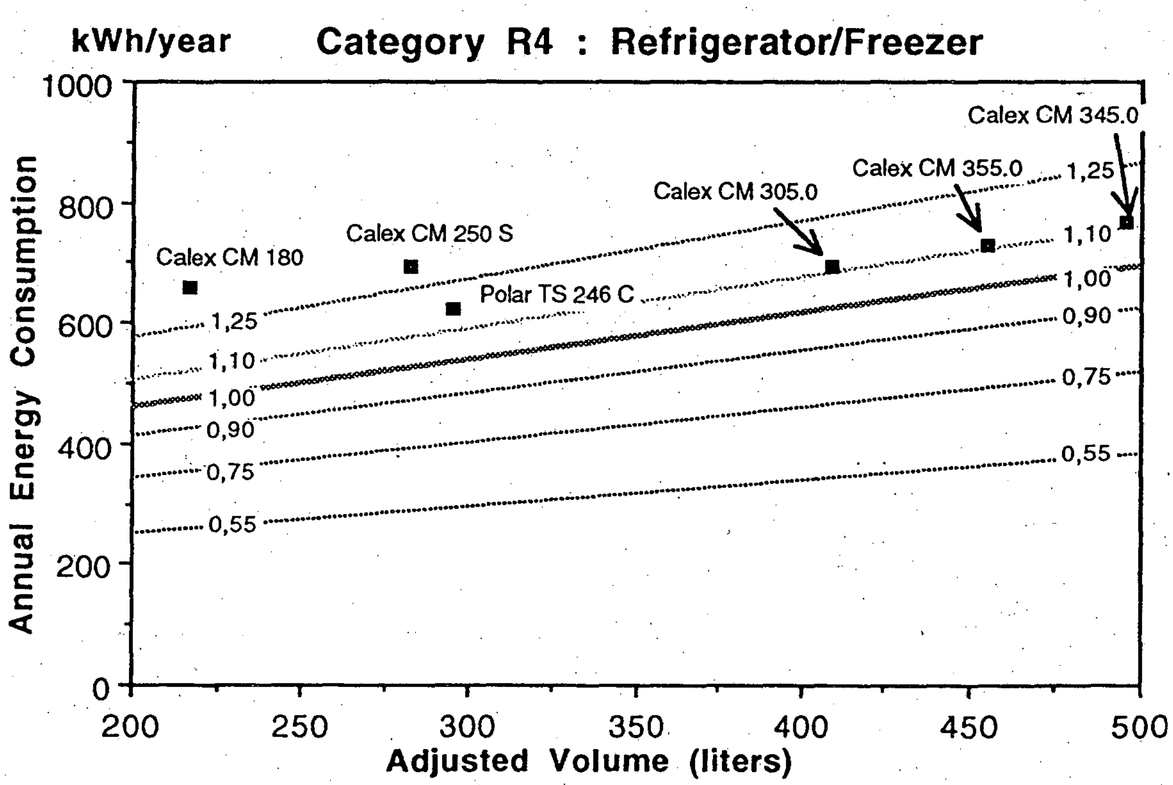


Figure 3

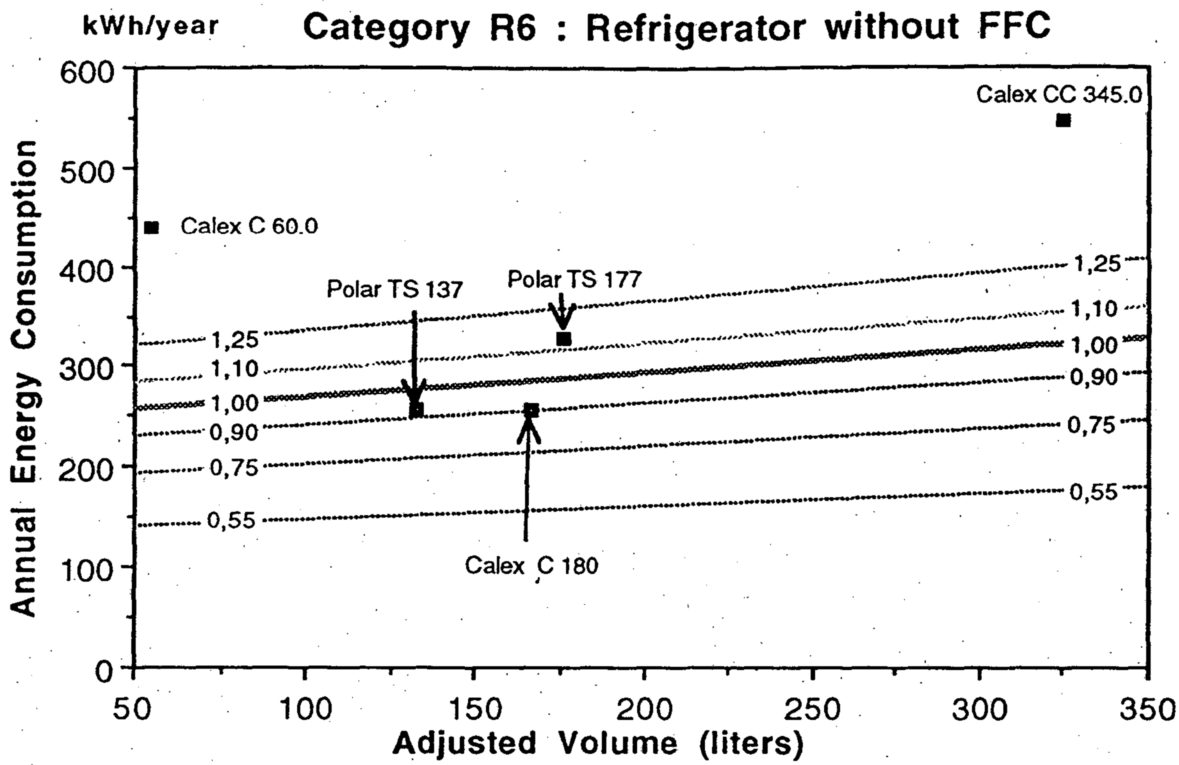

kWh/year
Category R6 : Refrigerator without FFC
Annual Energy Consumption
Adjusted Volume (liters)
600
500
400
300
200
100
0
50
100
150
200
250
300
350
Calex C 60.0
Calex CC 345.0
Polar TS 137
Polar TS 177
Calex C 180
1,25
1,10
1,00
0,90
0,75
0,55

Figure 4

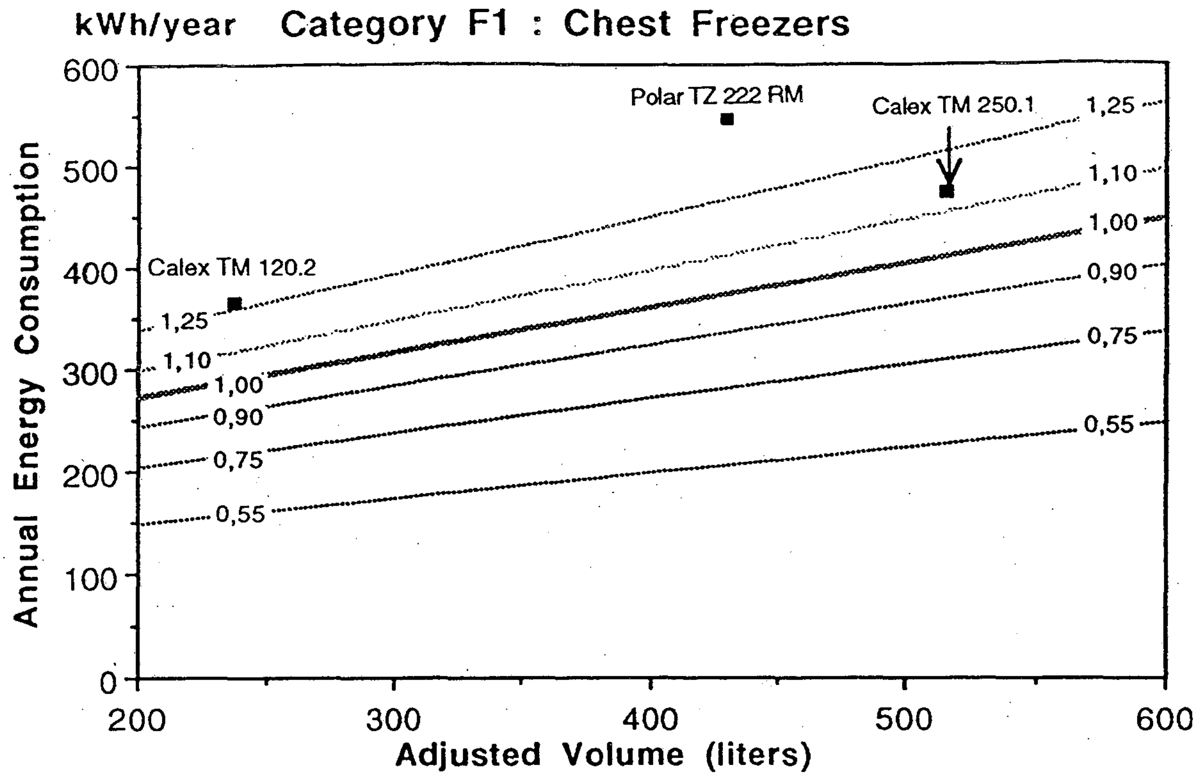


Figure 5

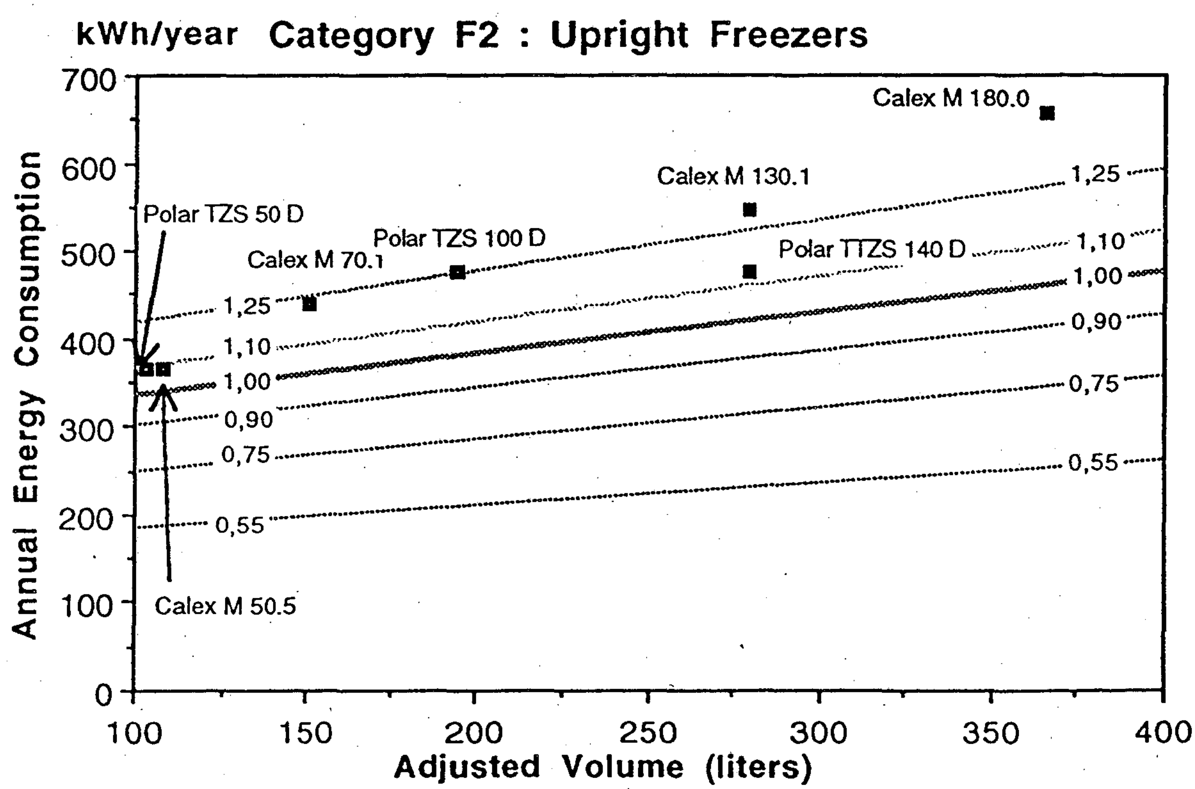


Figure 6

Table 3. Statistics on Polar refrigeration appliances

Model #	Star rating	GEA cat.	Total volume (liters)	Freezer volume (liters)	Energy cons. (kWh/day)	Produc. 1991 (units/yr)	Retail cost-7/92 ('000 Zl)[a]
REFRIG. W/FFC							
TS 138/136	2	R2	132	16	0.80	60,000	2235
TS 135	2	R2	132	10	0.80	60,000	2235
TS 176	2	R2	176	16	1.04	40,000	2605
TS 137	0	R6	132	0	0.70	5,000	2330
TS 177	0	R6	176	0	0.90	5,000	--
TS 230	2	R2	226	15	1.10	10,000	2880
REFRIG-FREEZER							
TS 246 C	4	R4	240	48	1.70	50,000	4120
FREEZERS							
TZS 50 D	4	F2	50	48	1.00	5,000	2000
TZS 100 D	4	F2	100	90	1.30	60,000	2780
TZS 140 D	4	F2	140	130	1.30	20,000	3500
TZ 222 RM	4	F1	210	200	1.50	20,000	3090

Source for volume and energy use data is Polar product brochures.
a. The exchange rate in 7/92 was 13,500 Zloty per U.S. dollar.

The relative energy efficiency of the Polar appliances varies among categories. For refrigerators with a 2-star frozen food compartment (FFC), the very small Polar models use slightly less energy than the EC average, whereas the larger 2-star models use about 10% more. The same applies for refrigerators without a FFC (of which relatively few are produced). Polar's 4-star refrigerator/freezer uses roughly 15% more electricity than the EC average.

Based on the estimate cited earlier that around two-thirds of Polish refrigerator sales are of larger models, it may be that the relatively-efficient small models are mainly intended for the export market and may utilize the imported and more efficient compressors. In general, the compressors used for very small refrigerators are less efficient than those available for larger sizes, so the models produced in the EC in the very small sizes (which occupy a tiny share of the EC refrigerator market) are mostly not very energy-efficient.

For upright freezers, the most popular Polar model (TZS 100D) uses 25% more than the EC average, while the other two models use around 10% more. For chest freezers, the Polar model's energy use is nearly 50% higher than the EC average.

2.2. Potential for Improving Energy Efficiency

The above comparison makes obvious that there is considerable room for improving the energy efficiency of most of Polar's models. An engineering analysis of the impact of making particular design changes to Polar's models was beyond the scope of this study. To illustrate the degree of improvement that can result from introducing various measures, we present results from the study (cited above) that was done for the Commission of the EC by the Group for Efficient Appliances (GEA). While the study refers to the situation in Western Europe, the results illustrate the approximate magnitude of savings that might be achievable in Poland and elsewhere in Eastern Europe.

The main design options for improving the energy efficiency of refrigerators and freezers that are technically feasible using today's mass production equipment are: (1) Increased door insulation; (2) Increased cabinet insulation; (3) Increased evaporator surface; (4) Increased condensor surface; (5) Increased evaporator heat capacity; (6) Increased condensor heat capacity; (7) Use of a higher-efficiency compressor; and (8) Decreased door leakage. Application of these options results in somewhat higher initial cost in exchange for energy savings over the lifetime of the appliance. The cost-effectiveness of the options depends on the value of the future energy savings that they bring, which in turn depends on the price of electricity and the discount rate used.

The GEA estimated the extra cost and energy savings resulting from application of the above measures relative to baseline models in each appliance category.[8] We modified the GEA economic analysis by using the expected residential electricity price in Poland in late 1993, which is about $0.07/kWh (converted using exchange rate), and by using a 10% rather than a 5% discount rate (reflecting the greater opportunity cost of capital in Poland).[9] As shown in Table 4, many of the energy-saving design options in the R2 refrigerator, R4 refrigerator-freezer, and upright freezer categories (in which the majority of devices made in Poland fall) have a simple payback period of less than five years and a cost of conserved energy less than $0.07/kWh.[10] If we select the most efficient design that has a payback of five years or less (relative to the baseline model), the annual energy savings would be 43% for the R2 refrigerator, 32% for the R4 refrigerator-freezer, and 37% for the upright freezer. The estimated increase in purchase price for these designs (under Western European conditions) is 10%, 8%, and 8%, respectively.

The baseline models used in the GEA analysis consume slightly less energy than the EC average shown in Figures 2 through 6. In those categories where the Polar appliances use more energy than the baseline model, the degree of energy savings resulting from moving to the more efficient design should be greater than cited above. Lack of information on the technical specifications of the Polar appliances precluded us from estimating the degree of improvement that would result from application of particular design options, but there is obviously much scope for reducing energy use.

The economics of making design changes to Polish appliances are more uncertain. Whereas the additional cost of particular design options can be estimated with reasonable accuracy for Western Europe, the situation in Poland is less clear. The extra cost of using a more efficient compressor can be easily determined, but many of the measures to enhance efficiency would be connected with an overall re-tooling of the production facilities. In this situation, calculating the marginal cost of energy-saving design options is complicated. Even so, the GEA analysis suggests that substantial energy savings are available for a relatively modest increase in cost.

Some degree of improvement is possible with Polar's existing plant. For example, Polar could use the more efficient compressors that are currently mounted only on units intended for export on units for the domestic market. Polar is currently working on a new refrigerator-freezer designed to address both CFC phasing out and improvement in energy efficiency. We are uncertain as to how much more efficient and costly this unit will be relative to existing models.

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[8] The additional cost refers to the purchase price; the manufacturer costs were multipled by an estimate of the average markup factor for the refrigerator and freezer industry.

[9] The expected price is from the Polish Ministry of Industry and Trade, as given in material provided by FEWE.

[10] The cost of conserved energy expresses the annualized, discounted incremental capital cost of a measure divided by the annual energy savings.

Table 4. Costs and energy savings for refrigerator and freezer design options: Western Europe results modified for Poland

	Purchase price (US$)	Energy use (kWh/year)	Payback period (years)	Cost of conserved energy (US cents/kWh)
REFRIGERATOR WITH 2-STAR FFC				
0 Basecase model	578	335.3	-	-
1 = 0 + Incr. door insul. (+15 mm)	585	299.4	2.2	2.8
2 = 1 + Decreased door leakage	586	293.1	2.3	2.9
3 = 2 + Optimized compressor	599	257.9	3.1	4.0
4 = 3 + Increased cabinet insul. (+15 mm)	626	204.3	4.3	5.4
5 = 4 + Incr. door insul. (+15 mm)	633	191.4	4.4	5.6
6 = 5 + Increased cabinet insul. (+15 mm)	659	166.4	5.6	7.1
7 = 6 + Doubled evap. heat capacity	673	161.8	6.4	8.1
8 = 7 + Doubled condensor heat capacity	684	159.0	7.0	8.8
REFRIGERATOR-FREEZER 4-STAR				
0 Basecase model	947	591.1	-	-
1 = 0 + Incr. door insul.	960	520.2	2.2	2.4
2 = 1 + Improved compressor	967	496.6	2.4	2.7
3 = 2 + Increased door insul. to 35/65 mm	973	481.9	2.8	3.1
4 = 3 + Decreased door leakage	976	475.5	2.9	3.2
5 = 4 + Increased cabinet insul. to 45/65 mm	1000	429.2	3.8	4.2
6 = 5 + Increased cabinet insul. to 60/80 mm	1024	398.9	4.7	5.1
7 = 6 + Doubled condensor surface	1075	345.0	6.0	6.6
8 = 7 + Doubled condensor heat capacity	1101	321.5	6.6	7.3
9 = 8 + Doubled evaporator surface	1121	314.2	7.3	8.0
10 = 9 + Doubled evap. heat capacity	1172	298.8	8.9	9.8
UPRIGHT FREEZER				
0 Basecase model	697	439.8	-	-
1 = 0 + Improved compressor	700	387.0	0.6	0.7
2 = 1 + Decreased door leakage	702	376.8	0.8	0.9
3 = 2 + Increased door insul. to 35 mm	706	362.9	1.3	1.5
4 = 3 + Increased cabinet insul. to 45 mm	724	319.8	2.6	2.8
5 = 4 + Increased door insul. to 50 mm	728	310.4	2.8	3.0
6 = 5 + Increased cabinet insul. to 60 mm	746	286.0	3.7	4.0
7 = 6 + Doubled condensor heat capacity	753	276.4	4.0	4.4
8 = 7 + Doubled evaporator surface	798	246.6	6.0	6.6
9 = 8 + Doubled condensor surface	846	219.9	7.0	8.7

Source for cost and energy use data: Group for Efficient Appliances, *Study for the Commission of the European Communities on Energy Efficiency Standards for Domestic Refrigeration Appliances*, March 1993.

The cost of conserved energy assumes a 10% real discount rate. The simple payback uses an electricity price of $0.07 per kWh. Equipment lifetime: R2 refrigerator -- 12 years; Refrigerator-freezer R4 -- 16 years; Freezer -- 16 years. Basecase model volume (liters): R2 refrigerator -- 169 + 19 (FFC); Refrigerator-freezer R4 -- 171 + 86; Freezer -- 167.

2.3. Potential Energy Savings from Improving Energy Efficiency

Lack of data precludes us from making more than a very rough estimate of the magnitude of electricity savings that could result from improving the energy efficiency of refrigeration appliances made in Poland. Apart from the uncertainty as to how much specific consumption (kWh/day) could be reduced through application of various design options, an important piece of missing information is the volume of sales of various models on the Polish market.

The following exercise uses the Polar data to give a rough indication of the magnitude of potential electricity savings (see Table 5). First, let us assume that the energy consumption of each of the Polar models is brought down to the EC "average" specific to its product category and adjusted volume (the solid line in Figures 2-6). Note that the energy use of Polar's three small refrigerators is already below the EC average, so we assume no savings for these models, which together accounted for about half of Polar's refrigerator production in 1991. Second, let us assume that the production volume of these models is the same as in 1991 (in fact, some change in the market is likely as the economy recovers). Relative to the old energy consumption levels, the resulting annual electricity savings would amount to 18.2 GWh, which is equivalent to the output of 3.5 MW of generating capacity operating at 60% capacity factor. Approximately 60% of the overall GWh savings are accounted for by freezers. Not all of the savings would occur in Poland, however, since some of the appliances are exported. Although only 60% of Polar's production goes to the domestic market, the share of energy savings in the domestic market would probably be greater, since the exported models appear to be more efficient. Note also that these savings only consider appliances made by Polar, which account for about two-thirds of total Polish production.

Table 5. Electricity savings from improving the energy efficiency of Polar refrigeration appliances: an illustration

Model #	GEA category	Test energy use Polar (kWh/yr) A	EC average (kWh/yr) B	EC best (kWh/yr)	Production 1991 (units/yr) C	Electricity savings (GWh/yr)
REFRIG. W/FFC						
TS 138/136	R2	290	310	250	60,000	--
TS 135	R2	290	305	250	60,000	--
TS 176	R2	380	330	245	40,000	2.00
TS 137	R6	255	275	--	5,000	--
TS 177	R6	330	280	--	5,000	0.25
TS 230	R2	400	350	245	10,000	0.50
REFRIG-FREEZER						
TS 246 C	R4	620	525	375	50,000	4.75
FREEZERS						
TZ 222 RM	F1	550	365	160	20,000	3.70
TZS 50 D	F2	365	340	--	5,000	0.13
TZS 100 D	F2	475	380	255	60,000	5.70
TZS 140 D	F2	475	415	275	20,000	1.20

Source for actual energy use data is Polar brochures. The EC average refers to the point on the reference line (1.0) in Figures 2-6 that corresponds to the adjusted volume of the Polar model. Data for EC best were taken from graphs in the GEA study cited in Table 4.
a. If (A-B) is less than zero, savings are zero.

3. POLICY OPTIONS FOR IMPROVING EFFICIENCY OF REFRIGERATION APPLIANCES

In the past, Poland's communist government had some regulations with respect to energy efficiency for production of certain appliances, but they were not strictly enforced. In recent years, there has been discussion about instituting energy labelling requirements for appliances, but the government has not taken any action, perhaps waiting until the EC determines its own procedures.

In Western Europe, the prospects for establishing an energy labelling scheme and minimum efficiency standards for appliances appear favorable. In 1990, the Nordic countries (Sweden, Norway, Denmark, and Finland) established a commission of experts (NORDNORM) to prepare the ground for appliance labelling and minimum efficiency standards. The Commission of the EC is planning to institute energy labelling for refrigerators and freezers in 1993. Minimum efficiency standards, based on the GEA study cited above, may follow.

While imports from the EC countries play only a small role in the Polish market for most major appliances, actions taken by the EC will have a significant impact on Polish appliance production, since the EC market is important to Polar. Unless Polar makes improvements in energy efficiency, energy labelling could hurt sales in the EC somewhat, since it would indicate the relatively low efficiency of their appliances (depending on which models it exports). Minimum efficiency standards could pose a more serious problem. The ability of Polar to meet the EC's efficiency standards may depend on whether they are able to attract the capital investment needed to modernize their appliance production. If they succeed in such modernization, some technical improvements would undoubtedly be incorporated in models for the domestic market as well as the export market, although the domestic models would probably not be as energy-efficient as the export models due to the need to maintain lower prices in order to sell in the domestic market.

Once EC labelling requirements are established, it would be a simple matter for the Polish government to mandate such labels for appliances sold in Poland. How such requirements would affect the appliances imported from the former Soviet Union is uncertain; it would be necessary to ascertain whether the manufacturers in these countries are following the appropriate testing procedures. It is likely that these manufacturers would also want to export to the EC market and would thus conform to the procedures adopted by the EC.

Whether energy labelling would have much affect in moving the Polish market toward higher energy efficiency is uncertain. Studies of the impact of appliance energy labelling in North America, where it has been required for many years, suggest that labelling has a relatively small effect on consumer decision-making.[11] In part, this reflects the lack of emphasis that retailers have placed on labels. Labelling may stimulate design changes by manufacturers concerned that the poor comparative performance of their products could negatively affect their reputation.

If it wished to have a greater effect on appliance efficiency, the Polish government could establish minimum efficiency standards based on the EC procedures. Given the differences in the Polish market (including lower electricity prices), these standards would probably be less stringent than those that may be adopted in the EC. Over the longer run, Poland might want to move toward the EC standards, since it seeks membership in the EC, but it would be desirable to determine the efficiency levels that are most beneficial for the Polish situation. Adoption of the EC testing and labelling procedures by Poland would make it simple to exclude from the market those appliances that did not meet a given standard.

In considering minimum efficiency standards, the Polish government must take account of the need for considerable capital investment to modernize appliance production. It must also bear in mind that most Polish consumers are very sensitive to the initial cost of an appliance. On the other hand, more efficient appliances will help consumers by mitigating their risk from rising electricity prices. Many energy-saving measures can be incorporated at relatively low cost, provided the capital investment for re-tooling can be spread over a large enough production. In this context, minimum efficiency standards could help in reducing the risk associated with investment in modernizing appliance production by guaranteeing a domestic market for the improved models. Given the size of the Polish market, and the considerable potential for replacement of existing appliances as the economy recovers, such a guarantee could prove attractive to foreign companies considering investment in Poland. Such investment would bring both capital and technical expertise.

Minimum efficiency standards would eliminate the least energy-efficient appliances from the market, but would not necessarily encourage manufacturers to go very far beyond the standard. If the standard is relatively weak, the incorporation of additional energy-saving design options is likely to be cost-effective from a societal perspective.

Programs conducted by electric utilities to encourage end-use efficiency could play an important role in stimulating consumer interest in more efficient models. Programs that pay a rebate to customers who purchase energy-efficient models have proven popular and successful in the U.S. Providing

[11] Marbek Resource Consultants, "Survey of Appliance Labelling Programs," Ottawa, Canada, March 1990.

incentives to appliance retailers to promote high-efficiency models is another option used by some U.S. utilities. An alternate approach that is simpler to administer involves directly subsidizing the price of more efficient models through payments to the manufacturers (use of this method in Poland could raise questions of fairness with respect to foreign manufacturers). Any utility payments to encourage appliance efficiency must be evaluated in the larger context of utility involvement in demand-side management (DSM). Preliminary work towards creation of an integrated resource planning framework in which the range of DSM options can be analyzed is now underway for the Polish power sector.[12]

A final approach that bears consideration is for the government to encourage large housing companies that purchase appliances in bulk to purchase high-efficiency models, thus providing a market for producers. The government could provide credible information showing the cost savings of these models. This approach has been fostered in Sweden.[13] Financial support for the purchase of the high-efficiency models could potentially come from utilities as part of DSM activities. Such a program might also be supported with funds from the UNDP/World Bank Global Environmental Facility.

4. CONCLUSION

The energy efficiency of refrigeration appliances produced in Poland for domestic sale is substantially lower than the average for similar models made in Western Europe. The cost-effectiveness of various design options for increasing energy efficiency is uncertain, but it appears likely that considerable improvement would be economic from a societal perspective. Over time, such improvement could have a substantial impact on electricity generation requirements, and, along with other electricity end-use efficiency measures, defer the need to build new power plants or allow for the closing of the most polluting coal-fired power plants.

The facilities of the main Polish manufacturer of refrigeration appliances are in great need of modernization or perhaps even replacement with a new factory. It will probably require much capital investment, most likely from a Western appliance company, to produce appliances of higher quality and efficiency than the current models. Improvement in efficiency will be necessary if the company is to continue to export to Western Europe, which is probably essential to its viability.

Government policies and utility energy efficiency programs could help to build a market for more efficient appliances in Poland, and thereby reduce the risk of investment in new production capacity. The impending introduction of a testing and labelling scheme in Western Europe will provide a basis for labelling in Poland, as well as for minimum efficiency standards. A realistic appraisal of the investment needs of the Polish companies is required. The European Bank for Reconstruction and Development or the International Finance Corporation could play a role in financing private investment in the Polish appliance industry.

A more in-depth analysis of the design options available to Polish manufacturers, examining their energy savings and potential cost in full production, would facilitate the development of appropriate policies and programs. Support for such analysis, which must be conducted collaboratively with the Polish companies, should be a high priority for technical assistance.

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[12] D. Wolcott, J. Dybowski, and E. Hille, "Implementing demand-side management through integrated resource planning in Poland," *The Energy Efficiency Challenge for Europe, Proceedings of the 1993 ECEEE Summer Study* (June 1-5, Rungstedgard, Denmark).

[13] H. Nilsson, "Market transformation by technology procurement and demonstration," *Proceedings of the ACEEE 1992 Summer Study on Energy Efficiency in Buildings*, Vol. 6, Washington, DC: American Council for an Energy-Efficient Economy.

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