I. Bashmakov
A. Perevozchikov, S. Sorokina

Center for Energy Efficiency
and

N. Antonov
ENIN

Consumer Information on Energy Efficiency of Refrigerators

November 1993

1. Electricity Consumption of Refrigerators and Freezers

Refrigerators and electric stoves, which account for a substantial portion of residential electricity consumption in Russia, were examined for the creation of a consumer information program. Electricity consumed by refrigerators was responsible for 22.5-23.8 percent of total residential electricity consumption in 1990, at 18.5 billion kWh (see Table 1). This share was 19.2 billion kWh, or 3.8 percent higher in 1992. In the USA, refrigerators account for only 12% of residential energy consumption[1]. In the same years, refrigerator electricity consumption per capita in Russia was 125 and 129 kWh, and per family -- 407 and 429 kWh, respectively.

Electric ranges accounted for 11.8-12.9 percent of residential electricity consumption, at 9.2 billion kWh in 1990 and 11 billion kWh in 1992. Per capita consumption was 62 and 74 kWh in these years, respectively. The saturation level for stationary electric ranges was relatively low -- only about 14 per 100 families or about 6.1 million units.

Refrigerators were targeted for the development of an energy efficiency information program for two primary reasons:

- refrigerators account for the greatest consumption in of all appliances in the electricity budget of the average residential consumer;
- better statistical data is available for refrigerators than other appliances.

2. Refrigerators in Use

An estimated 45.5 to 47 million refrigerator units were estimated in use in 1992. Among these, 7.5-8 million units (17%) have 2- and 3-chambers. Refrigerators with glass fibre thermal protection constitute about 10-20% of all stock.

The State Committee on Statistics gives two different saturation indicators for refrigerators: per 100 families and per 1000 inhabitants. Since 1985 those saturation indexes have stabilized (see Table 2). By international standards, the numbers are high, as 95-100 percent of families have refrigerators in most developed countries. However, the penetration of freezers in Russia is much lower then in many developed countries.

The current saturation level of refrigerators per person and per family was reached in 1985 and has not changed for more than 7 years. There are two possible explanations for this phenomena:

- real saturation, or
- poor statistical data.

With a population of 148.7 million in Russia and 308 units per 1000 people, the authors estimate 45.8 million units. The average family size is 3.24. Therefore, with 148.7/3.24=45.9 million families. With 95 refrigerators per 100 families, an estimated 43.6 million refrigerator units exist. The numbers presented by the State Statistical Committee are controversial. It is likely that the stable saturation indices for refrigerators over seven years result from poor statistics. In this paper, the authors suggest an accumulated refrigerator stock of 45.8 million units in 1992 (see Table 3).

From 1985-1992, the growth level of refrigerator units was extremely moderate -- 0.8 percent per year (See Figure 1).

3. Production of Refrigerators

In 1990, Russia produced 3.8 million refrigerators and was forth among the world's leading producers behind the USA (6.2 million units), Japan (5.1 million), and Italy (4.7 million). Russian production was about 36 percent of the Western European level, 61 percent of the US level, and 75 percent of the Japanese level.

The Russian refrigerator market is one of the largest in the world. The dynamics of refrigerator production, external trade, and shipments in 1985-1992 are shown in Table 3. According to the data:

- The level of production was more or less stable from 1980-1990. In 1992, two main factors led to a decline in the production volume: reduction of exports and a decline in internal demand;
- Exports declined by 37 percent, with deep reduction to NIS countries— by 4.6 times. The growth of exports to other countries was not sufficient to compensate the NIS export decline;
- Import went down 2.7 times with imports from NIS declining by 4.8 times compared with 1990. At the same time, imports from other countries grew by 3.7 times. In other words, refrigerator imports focused on western models, the share of which increased ten fold from 4.8 percent in 1990 to 46 percent in 1992;
- Data for commercial sector purchase of residential-type refrigerators (for offices, hotels etc.) were estimated by the authors;
- Retail trade of refrigerators in 1992 was just 40.5 percent of the 1990 level, a sharp reduction compared with the relatively stable levels of 1980-1990. The reduction may be attributed in part to lower incomes and higher prices;

- A trend in the growth of larger-volume refrigerators in retail trade is readily observed. The share of larger-volume refrigerators grew from 23 percent in 1980 to 52 percent in 1990 and declined to 43 percent in 1992;
- The reduced purchasing of larger-volume refrigerators could be seen as a result of less disposable income. However, this reduction may be also result from a change in the structure of refrigerator market, in which many greater players have appeared in recent years. Customers now may purchase their refrigerators not only in retail shops, but also from small firms and agents who have direct relationships with producers. These shipments are not included in statistics of retail trade.

4. Factors Affecting Refrigerator Demand

4.1. Evolution of Incomes and Prices

A number of reasons exist for the decline of refrigerator production and apparent consumption in Russia in early 90's. Major factors of any demand function are: disposable income and relative price (see Table 4).

Analysis of the data presented in Table 4 leads us to the following conclusions:

- Real private consumption of goods and services declined sharply in 1990-1993. According to the official statistics in 1993, consumption is at only 30 percent of the 1990 level;
- Purchases of refrigerators have declined less than this would indicate;
- Examining the reduction of appliances purchased in the structure of consumer expenditures, it is clear that income factors can exert an extremely negative influence the demand for refrigerators;
- The average price of a refrigerator increased 175 fold in January 1993 compared with 1990, in nominal terms, and, if corrected by the consumer price index, doubled. In October 1993, the range of prices for most popular Russian models was 300-500.000 rubles, or 600-1020 times greater than in 1990;
- Both disposable income and relative price factors led to the January 1993 outcome, in which the average refrigerator costs 5.6 times the average monthly income per capita in urban areas.

4.2. Smolensk Families Survey (mid-1993)

In mid-1993, a survey was conducted to identify the level of saturation of refrigerators and freezers by families in the City of Smolensk. Results of this survey are shown below (per 100 families):

1-door refrigerators	-	76
2-door refrigerators	-	30.5
Total refrigerators	-	107
Freezers	-	9.3
Total	-	116

The average saturation level of refrigerators and freezers for urban Russian families was 106 units per 100 families in 1992. One reason for the relatively high figures in Smolensk is that these appliances are produced locally ("Smolensk" model). No shortage of refrigerators was experienced in local retail shops, which was the case in many other regions from 1985-1991.

From 1992-1993, of large residential appliances, the saturation rate for refrigerators was the highest. During this period 10 percent of families bought refrigerators, half of which were replacements of old units and half first purchases.

Refrigerators, as well as some other appliances, are considered a good investment for mid-income people to protect their earnings from skyrocketing inflation. This is one reason for a slower decline in the purchase of refrigerators compared with the decline of expenditures. To a certain extent, demand was formed by the existing supply in retail stores.

We found that, generally, women initiate the purchase of refrigerators. Therefore, information programs should be targeted to a female audience. For example, TV advertising for the most efficient models may be more effective during serials, rather than hockey or soccer games.

The saturation level largely depends on the economic and social position of a family, listed by socio-economic standing, in decreasing degree:

- Staff of new commercial organizations;
- Workers of state enterprises (which have comparatively high wages in Smolensk);
- People who have pensions and go on working.

Inquiries into which size refrigerators families would like to buy in the near future, led to the following responses:

1-door - 3.5 percent;
2-door - 22.0 percent;
freezer - 18.5 percent.

Therefore, the saturation level of freezers will double in Smolensk.

5. Characteristics of Refrigerators, available on the Russian Market

A special survey was taken of all models of refrigerators available presently on the Russian market. A similar survey was also conducted on the supply of refrigerators in Moscow. Fifteen retail stores selling appliances were visited by CENEf staff during two weeks in late October and early November 1993.

Nine technical and economic characteristics were collected or calculated based on primary information for each model:

- Freezer volume;
- Refrigerator volume;
- Adjusted volume;
- Electricity consumption with ambient temperature 32 ^{o}C;
- Electricity consumption with ambient temperature 25 ^{o}C;
- Specific energy consumption per unit of adjusted volume;
- Power requirements;
- Retail price (minimum and maximum values).

Technical information was taken from the technical passports supplied with the units on sale. Price information was recorded from labels on display in the shops visited.

Adjusted volumes were calculated based on following approach:

Adjusted volume = Volume of fresh food compartment+
K*Volume of fresh food compartment,

where

$$K = \frac{(\text{Tambient - Tfreezer})}{(\text{Tambient - Tfood})}$$

K= 1.55 for 1 star (freezer T=-6 ^{o}C);
= 1.85 for 2 stars (freezer T=-12 ^{o}C);
= 2.15 for 3 ad 4 stars (freezer T=-18 ^{o}C).

A database for 97 NIS and foreign made refrigerators was organized. This database was divided by six subgroups:

- Single door refrigerators with compressors (56 models);
- Two door refrigerator-freezers with one compressor (19 models);
- Two door refrigerator-freezers with two compressors (2 models);
- Single door absorption-type refrigerators (8 models);
- Two doors absorption-type refrigerators (2 models);
- Foreign-made (other than NIS countries and Baltic States) refrigerators (10 models).

All technical data are presented in Table 5. Electricity consumption per day adjusted for volume related is shown in Figure 2. The majority of models examined have a higher than 1 kWh/day electricity consumption rate. For comparison, daily electricity consumption of refrigerators on the Swiss market is plotted in Figure 3. The majority of these units have electricity consumption less than 1 kWh/day. That is, foreign models are efficient then NIS-manufactured models.

Visual comparison of four-star two door NIS-made models with similar refrigerator-freezers available on the European market (see Figure 4, note that the data represent *annual* electricity consumption) show that 6 of 19 NIS models are below baseline for Europe.

6. Refrigerators and Freezers Energy Standards and Testing Procedures

Since 1976 Russian national codes have regulated energy consumption by residential refrigerators and freezers. Comparisions of efficiency levels of domestic models and foreign equipment standards and testing procedures are also described in this chapter.

6.1. Russian Standards

The Russian National Code (GOST) GOST 16317-76 is the primary refrigerator standard. Article 3.8 of this GOST, entitled "Residential Electric Refrigerators. General Technical Characteristics", limits energy consumption. The GOST sets the upper limits of energy consumption:

- Depending on the size of the refrigerator with freezing chamber for refrigerator-freezers with polymeric insulation;
- At +32^{o}C ambient temperature;
- At the average temperature in the refrigerating chamber of +5^{o}C, and;
- At the average temperature in the freezing chamber of -6^{o}C;
- With a minimum useful volume for a freezing chamber:
    - Under 7% of the total volume for refrigerators of up to 180 liters;
    - Under 9% for 181-300 liter refrigerators, and;
    - Under 10% for more refrigerators of more than 300 liters (see Table 6).

For refrigerators with a nominal temperature in the freezing chamber of -12°C, energy consumption may not exceed the values prescribed by GOST by more than 25 percent; if the temperature in the freezing chamber is -18°C, then energy consumption may not exceed the GOST level by more then 50%. For refrigerators with metal inner chambers, energy consumption may account for double the value of those with polymeric ones.

If the volume of the freezing chamber exceeds the minimum prescribed by GOST, energy consumption values will also differ:

$$P=Pt(1+E),$$

with Pt = energy consumption (see Table 2);
E = coefficient dependent upon the freezing chamber volume.

The E coefficient is defined by the following formula:

$$E = \frac{1.25}{100}\left(\frac{V_1}{V}100 - A\right),$$

with V_1 = freezer chamber volume, in liters;
V = total volume of refrigerator, in liters;
A = minimum volume of freezer chamber, in percent (7%, 9%, 10%, see above).

In 1984, a new GOST was adopted, N 16317-76* (see Table 7). It introduced stricter requirements for refrigerator electricity consumption for two categories of refrigerators: first quality category refrigerators by 10 percent, and highest quality category refrigerators by 25 percent[(1)].

On July 1, 1988, GOST 16317-87 was adopted, further increasing energy consumption norms. Ambient temperature was replaced by 25°C, which had a positive effect of prompting technology improvement.

On January 1, 1991, the regulations of GOST 16317-87 were again revised (see Table 8), but domestic industry failed to meet the standards (see Figure 7). The majority of models produced from 1990-1993 in the NIS achieved levels set by the 1984 GOST for the first quality category, but few models were in accordance with the 1991 standards.

In 1987, standards were common among all former Soviet republics. The 1987 standards were recognized as national standards by each former republic after break up of the former USSR. These standards and testing procedures are still valid throughout the NIS. The countries of the NIS are among few countries worldwide which have standards for energy efficiency of refrigerators.

A comparison of the standards introduced in Russia over time shows that efficiency requirements have about doubled since 1976 (see Table 9).

6.2. US Standards

1 Retail prices for domestic manufactured refrigerators or, rather, raises on retail prices set by planning bodies used to depend on the quality category.

The US is another country which has energy efficiency standards for refrigerators. Standards for 1987 and 1992 are presented in Table 10. They are not directly comparable with Russian Standards because of differences in testing procedures. In the USA, energy consumption is measured at +32^{o}C. The temperature in the refrigerating chamber can be +7^{o}C and in the freezing chamber -15^{o}C, differing from the Russian and European testing procedures which require 0-(+5^{o}C) and -18^{o}C respectively. Another difference is the manner in which data are presented. In many European models, energy consumption over 24 hours is measured. The US standards are based on calculations of annual consumption. Stricter energy efficiency standards for refrigerators and freezers has greatly reduced electricity consumption by this type of appliances (see Figure 5).

Comparing three NIS models with American models, one can conclude that the STINOL-101 (Russian-made by Italian license) consumes 402 kWh annually meeting the US 1992 standard of 541 kWh; for the Minsk-126 corresponding numbers are 547 and 534, and for the NORD-223, 558 and 821, respectively. STINOL-101 is most efficient model its type in Russia. No other NIS model meets the 1992 US standards.

6.3. European Standards

The European Community is working presently on developing energy efficiency standards for refrigerators. Different studies are devoted to the selection of the proper approach to this problem. One French study proposes use the baseline presented at Figure 4 as first standard (the regression line is described by the formula, 0.915*AV+216). This formula allows for less efficient models than the 1992 US standards for an automatic defrost, top-mounted freezer model with adjusted volume of 9 cubic feet. Two of three NIS models mentioned in the preceding section would meet this European standard. The approach and methodology proposed by the French study is very close to the first step proposed by Danish experts (see Figure 6). If the second step suggested is enacted, significant improvement would be made in energy efficiency of models on sale in Europe.

The test procedures of the International Standard Organization (ISO) are in use in Europe. Only refrigerators and freezers have uniform test procedures throughout the European Community. To measure the energy consumption of refrigerators with freezers, the ambient temperature of the test chamber is +25 ^{o}C. The freezer keeps frozen food at -18 ^{o}C.

Three refrigerators are selected from a batch. Their average energy consumption may exceed that stated by the manufacturers by 10%. Moreover, energy consumption of one of these three may exceed the nominal value by 15%. Energy consumption is measured at +25^{o}C.

6.4. Japanese Standards

Japan presently uses standards set in 1983 which improved upon standards set in 1978 (see Table 11). Electricity consumption is calculated on a monthly basis. Only one of the three above-selected NIS models meet the 1983 Japanese standards. These standards are stricter than the proposed European ones and are about equal to the 1992 US standards.

Japanese testing procedures measure average yearly energy consumption based on operating conditions: 100 days at +30^{o}C and 265 days at +15^{o}C (average temperature is +19^{o}C).

International comparison brings us to the conclusion that the absolute majority of NIS made refrigerators will not meet the US and Japanese refrigerator efficiency standards.

7. Worldwide Progress on Improving Energy Efficiency of Refrigerators

The efficiency of new refrigerators and freezers has increased substantially in many countries since the 1970's:

- In the USA, by 112 percent in 1972-1990 (measured in terms of refrigeration volume per unit of electricity);
- In Japan, by 400 percent in 1972-1987;
- In South Korea, electricity consumption of typical 200 liter refrigerator declined from 670 to 240 kWh/year (by 2.8 times) in 1980-1987[2].

Today's mix of new refrigerators are larger and have more features such as greater use of automatic defrost. To compare energy efficiency of refrigerators, the notion of an "energy factor" (a measure of efficiency based on adjusted volume per unit of electricity use) was developed[3].

A number of measures has reduced the electricity consumption of new refrigerators produced. The measures include:

- Shifting from fiberglass to polyurethane foam insulation;
  Increasing insulation thickness;
  Use of more efficient motors and compressors;
  Use of larger heat exchanger;
  Removal or reduction of electric resistance heaters.

From this list, it is clear that the a doubling of efficiency took place without major innovations or radical product redesign.

In the US and other countries, efficiency gains in refrigerators and other appliances were stimulated by market forces as well as minimum efficiency standards (see Figure 7). Standards were first adopted in California in the mid-1970's. After California strengthened its standards and other states passed similar legislation, consensus national appliance efficiency standards were adopted in 1987. The national standards for refrigerators went into effect in 1990. As was the case for automobiles, the standards caused efficiency to rise despite that real energy price fell in recent years[4].

In other words, worldwide experience from developed as well as in developing countries shows that it has been possible to improve the energy efficiency of refrigerators in a relatively limited period of time.

8. Estimation of Potential Energy Efficiency Improvements

According to H. Geller, in Brazil, 250-360 liter refrigerators typically consume 650 kWh/yr using the same standard test that is conducted in the US. In Russia, this number is 500-600 kWh/yr. The best models produced in Europe and Japan in this size range consume just 175-300 kWh/yr. Table 12 lists the top-rated refrigerators produced worldwide[5].

First of all, it should be recognized that data for the most efficient models presented in Table 11 were published in 1986. Therefore, if this data set is used for the estimation of the technical potential for energy efficiency improvements in refrigerators, the estimate will be conservative, because the reference is already 7 years old.

Engineering analysis recently conducted in Denmark has shown that, based on minimization of life cycle costs, (sum of purchasing price and discounted operating expenses over the lifetime of the refrigerator) optimum specific energy consumption is:

for 200 liter single door units -- 0.39 kWh/day;

for 300 liter single door units -- 0.46 kWh/day;
for 200 liter two door models -- 0.55 kWh/day, and
for 300 liter two doors units -- 0.96 kWh/day[6].

These data agree with data for the best foreign models presented in Table 12, and therefore the later may be used as a basis for the evaluation of technological potential.

The optimum energy use indices presented in the Dutch study will serve as a basis for the 1997 efficiency standards in the Netherlands.

Comparison of the energy efficiency indices of NIS and foreign refrigerators (see Table 13) gives a grounds for following energy efficiency potential estimates:

- The most efficient Russian single door refrigerators models are 1.75 to 4.84-fold less efficient and average models are 2 to 5.9-fold less efficient than the most efficient foreign models;
- The efficiency gap for two door refrigerators is much smaller: the best Russian made models are about 1.5-1.9 times less efficient than best foreign models;
- Using these data, the potential for efficiency improvements by model and adjusted volumes are conservatively estimated as follows (in kWh/liter of adjusted volume):

		Best Foreign	Average Russian	Efficiency Gain
Single door:				
100-170 l	-	0.4	2.8	2.4
170-280 l	-	0.5	2.3	1.8
281-350 l	-	0.8	1.7	0.9
Two door	-	1.0	1.5	0.5

To estimate the total potential for energy conservation due to energy efficiency improvements by 2010, the next set of assumptions concerning four another factors were used:

Population	-	162 million
Refrigerator saturation per 1000 people	-	330

Ownership by volume and type of refrigerator (in percent):

	1992	2010
Single door:		
100-170 l	30%	10%
171-280 l	30%	20%
280-350 l	20%	20%
Two door	20%	50%

Saturation of refrigerators is essentially at the maximum, therefore very modest growth of this index is expected, from 308 to 330 per 1000 people, or about 110 per 100 families. In the early nineties, 95 percent of EC families and 100 percent of US families owned refrigerators and this index has been relatively stable since the 1970's[7].

According to the above assumptions, the average volume in 2010 is going to be 40 liters higher than the 1992 level. It is difficult to expect more significant growth. In Germany, the average refrigerator-freezer size declined from about 300 l in 1960 to 270 in 1990 and is expected to stabilize at this level up to 2010[8]. The potential was estimated based on these assumptions(See Table 14).

Based on evaluation of the energy efficiency potential, the following important conclusions could be made:

1. It is possible to reduce energy consumption by refrigerator stock in Russia from 18 billion kWh in 1992 to 14.6 billion kWh in 2010 by replacing existing models with the most efficient among presently available worldwide on the background of growing refrigerator stock and average size;

2. With the base price of the average refrigerator US$500, and additional energy efficiency components 20 percent greater (an additional US$100), if the refrigerator population is 53.5 million units in 2010, costs for energy efficiency improvements will be 53.5*100=5.4 billion US dollars;

3. Energy conservation due to efficiency gains is estimated equal 15 billion kWh per year in 2010 (equivalent of power produced by three nuclear power reactors 1 GW capacity each, with total investment costs about 6 billion US dollars), and cumulative conservation is equal to 144 billion kWh over 16 years (1994-2010[9]);

4. Having 7 c/kWh electricity tariffs, residential consumers will save 1 billion US dollars on their electricity bills every year since 2010, and cumulative savings are 8.5 billion US dollars over 16 years (1994-2010);

5. Annually 3.4 million toe of fossil fuels could be saved due to refrigerators energy efficiency improvements, or cumulatively 29 million toe over 16 years with export value about 4 billion US dollars.

Therefore, a program costing 5.4 billion US dollars (very rough estimate based on foreign experience) could bring multiple economic benefits: reduction of investment costs in building new power plants; reduction of electricity bills, and growth of export revenue. These benefits significantly overweigh the costs.

Absolute reduction of electricity consumption by refrigerators and freezers is not an absurd dream of an energy efficiency extremist. In the US, around 48 billion kWh were saved in 1989 due to efficiency improvements in new refrigerators during 1972-89 (about the same time period we are considering). This is equivalent to nearly 6% of total residential electricity use or power supplied by eleven large (1000 MW) power plants.

Increased energy efficiency also offers significant environmental benefits. In the US, refrigerator efficiency improvements led to approximately 10 million metric tons of avoided carbon emissions in 1989. Given the extreme cost effectiveness of these improvements, carbon emissions were reduced at a net cost of negative $308 per ton[10].

In the US from 1980-1990, energy consumption by refrigeration appliances was relatively stable -- about 2 QBTU (72 mtce). Introduction of the 1993 standards will reduce it to 1.5 QBTU[11]. A similar result is expected in the EC: the introduction of new standards for refrigerators is expected to reduce energy consumption from about 70 TWh to about 57 TWh in 2010[12].

9. Cost Efficiency of Additional Energy Efficiency

9.1. Levelized Cost Approach

Experience around the world has shown that more efficient refrigerators are cost-effective for consumers and society overall. The increase in initial costs for producing highly efficient models is typically 5-15%, and additional costs are paid back through operating cost savings typically within a few years in the US (see Table 15). A 2.4 fold reduction of electricity use can be achieved with marginal costs below electricity price for residential consumers (7.6 c/kWh)[13].

Assessments by contractors for the U.S. Department of Energy (DOE) as well as independent analysts indicate that a one-third reduction in electricity use from commonplace efficiency measures costs about $40 at the retail level. Using a 6% real discount rate, the cost of energy saved is only $0.009/kWh. Based on the 1989 average residential electricity price of $0.076/kWh, efficiency improvements adopted in recent years show a societal benefit-cost ratio of 8.4. At these prices, consumers realized a net economic savings of about $3.2 billion in 1989[14].

A highly efficient refrigerator (200 liter model, without a freezer compartment) produced in Denmark consumes only about 90 kWh/yr, or
about 180 kWh/yr less than the typical model of equivalent size. Incremental initial costs of this model is just $25, and cost of saved energy is only $0.011/kWh[15].

There is no any strong relationship between energy efficiency and price of refrigerator on the Russian market presently (See Figure). Cloud of points on the graph show that for the same efficiency prices vary by two fold, and for the same price it is possible to buy two-three fold more efficient model.

Using this approach to estimate the cost-efficiency of additional investments and data from Table 5 for two door models -- STINOL-102 (at a purchase price of 546000 rubles and annual consumption of 401 kWh) and NORD-214 (at a purchase price 485000 rubles and annual consumption of 820 kWh)-- the cost of kWh saved is estimated to be 21.4 R/kWh with 0.12 discount rate over a life-time of 15 years. This number is less than the fall 1993 tariff for residential consumers in Russia, but higher than the production costs of many Russian utilities. If a utility will cover half of the incremental cost to motivate consumers to buy efficient models, for every STINOL-102 unit purchased, the utility will invest 30500 rubles and save 419 kWh/yr. The cost of saved energy in this case is just 10.7 R/kWh, a measure which would be cost effective for the majority of Russian utilities.

9.2. Life-Cycle Cost Approach

The concept of life-cycle costs (LCC) allows purchase decisions to be based not only on purchase price for a given refrigerator, but also operation costs (life-cycle costs are the sum of purchase price and discounted electricity costs over life-time of the refrigerator).

Improvement of energy efficiency could be justified until LCC begin to decline. In the ADEME study, reduction of refrigerator energy consumption by 35.5 percent is still economic (see Table 16).

In the above-mentioned Danish study, LCC criteria were used to estimate the optimum efficiency of refrigerators in order to determine standards set (see Table 17). The efficiency levels determined are close to the levels of the most efficient world models used in technical energy efficiency potential evaluation (see Table 14). Therefore, these models are not only technically, but also economically, the most efficient, at least at Danish market.

To illustrate the applicability of this approach to the Russian market, three two door refrigerator models were taken from the list presented in Table 3: STINOL-102, Minsk-130-1, and NORD-223. The last model has the lowest purchase price, but the highest energy consumption (see Table 18). Minsk-130-1 has the highest purchase price and a higher energy consumption than the STINOL-102.

The return on additional investments in energy efficiency depends to a large degree on electricity price. The November 1993 price is 12 rubles/kWh. Two additional price levels were also calculated: 50 rubles, and 100 rubles.

In case of the STINOL-102, return is 27 years, and would not be a reason for purchasing a more energy efficient unit at the electricity price of 12 R/kWh. But, electricity prices are expected to grow. No later than 1998, it is anticipated that residential consumers will no longer receive subsidies for electricity. With an electricity price of 50 rubles/kWh, return is slightly less than 3 years for STINOL and 14.5 years for Minsk-130-1. With prices of 100 rubles/kWh, the return on the STINOL and Minks-130-1 are 1.5 years and 7.2 years, respectively. Clearly, taking into account growing energy prices, the decision to purchase the STINOL-102 over the NORD-223 is an economic choice. This investment decision will pay for itself in 1.5-3 years.

If the utility were to provide rebate for purchase of the STINOL equal to the half of purchase price, the return would be 6 years even at an electricity price of 12 R/kWh, 1.5 years at 50 R/kWh and 0.7 years at 100 R/kWh. This could motivate even low income customers who have very high payback requirements to buy STINOL-102.

LCC depends on tariffs and discount rates (see Table 19 for three models mentioned above). To quantify these costs, a life-time of the 15 years was chosen for the refrigerator. No agreement exists on the average life-time, which varies in studies from 12 to 20 years[16].

The only case in which STINOL has slightly higher LCC is at an electricity price of 12 rubles/kWh. Even only slightly higher tariffs put the STINOL-102 in the first place as the most economic model. LCC of 50 rouble/kWh electricity tariff and a 12 percent discount rate is 81 thousand rubles lower than for the NORD-223. The Minsk-130-1 is more economical than NORD-223 only at an electricity price of 100 rubles/kWh and a 5 to 10 percent discount rate.

In other words, an educated consumer should choose the STINOL for economic reasons at an electricity price of 15 R/kWh, with other considerations equal. The problem is how to educate consumer.

10. Analysis of the Experience of Developed Countries to Promote Energy Efficient Domestically Produced Appliances through Information Programs

Information programs primarily address a lack of information on specific technologies. Another goal often encountered is to expand and intensify the market for energy efficient products. Many programs cover both objectives by increasing the target audience's awareness, acceptance and support of particular energy conservation programs. Experience in implementing information programs indicates that, by themselves, such programs are often unable to bring about substantial energy savings. These programs are most effective when combined with other approaches which directly facilitate financing and implementing energy efficiency measures.

The general range of information related programs is broad. They can be grouped as follows:

Education and Training:
- Seminaries and Courses;
- Publications;
- Data Bases;

Programs of Technical Assistance:
- Calculations Assistance;
- Professional Guidelines;
- Specific Design Tools;

- Energy Audits;
- Direct Installation of Equipment;

Performance Testing, Efficiency Labels and Directories;
Energy Rating;
General Information Programs.

It is important to have accurate information on the energy efficiency of equipment sold in Russia before any effort to promote energy conservation is made. Those who buy equipment can use the ratings for comparative shopping. In the future, when utilities start aggressively pursuing energy conservation, it will assist them to determine which models of equipment to promote and what impacts the equipment will have on electric load.

Public officials and representatives of governmental organizations can also use statistical information to track the progress of manufacturers in improving efficiency. At the same time accurate information is a precondition to establish and enact the standards for minimum efficiency.

Many countries test electrical equipment for safety and quality, but the majority of them do not include energy efficiency in their testing programs. In the US, the federal government requires efficiency ratings of refrigerators, water heaters, air conditioners and other appliances and equipment. Manufacturers conduct performance tests and manufacturers' associations oversee the program, making spot checks on the accuracy of submitted information.

In Russia, the technical descriptions and passports of domestic appliances usually have information on energy consumption, but it has never been required to present this information on the labels. As a result, the benefits of purchasing energy efficient models were not evident to a consumer. In the US, it is required that most residential appliances displayed in stores be labeled with information on estimated annual energy costs (ENERGYGUIDE).

Once implementation of general information programs start, their major pitfall must be kept in mind. Providing general conservation information through brochures and advertisements may raise public awareness, but will not have a significant impact on consumer behavior. This is especially true in a tough economic situation, such as at present, when the living standard has dropped drastically for the majority of the population and attention is focused on surviving rather than on improving living conditions.

Experience acquired in the implementation of information programs in other countries shows that these programs appear most effective when they inform consumers about simple, specific steps they may take, at the same time as providing estimates of how much energy and money can be saved. General appeals to the public to save energy are usually less effective. In addition, it is important that the information provider be respected by the recipient (for example, if information is provided by an organization respected in the local community or if it is provided face-to-face).

Another general finding from implementation of information programs, is that they work best when they are part of a comprehensive effort including technical assistance, correct pricing signals, financing and, possibly, efficiency regulation.

The U.S. Environmental Protection Agency's (EPA) Green Lights Program can serve a good example of application of this comprehensive approach. This program is directed towards a clear goal: pollution prevention. The design of Green Lights is fairly illustrative. A clear means for achieving this goal is promotion of energy efficient lighting to corporate America, an approach which is combined with the following activities.

When a corporation or government joins the Green Lights Program, it signs a Memorandum of Understanding (MOU) with EPA, which establishes clear obligations of both sides.

The participant agrees:

- to survey its facilities;
- within 5 years after signing the MOU to upgrade 90 percent of square footage, where it is profitable and where lighting quality is maintained or enhanced;
- to appoint an implementation manager to oversee the participation in the Program.

EPA provides Partners with:

- computer software package enabling them to survey lighting systems in facilities, assess lighting options and select the best energy efficient upgrade;
- computer data bases on available funds for the program financing provided by any third party;
- enlisting the Partner in Ally Programs, which include lighting manufacturers, lighting management companies and electric utilities that have agreed to educate customers about energy efficient lighting;
- enlisting the Partner in Endorser Programs - associations and other organizations of those promoting Green Lights;
- ready-to-use promotional materials;
- technical support on the part of the Lighting Services Group;
- technical services hotline, workshops and Lighting Upgrade Manual;
- enlisting the Partner in the National Lighting Product Information Program, which produces consumer reports about lighting and promotes valuable product information.

The design and implementation of Green Light Program helps participants to overcome the following hurdles:

- low priority of lighting in corporate vision, since signing the MOU makes it an organizational priority;
- lack of information and expertise;
- difficult financing;
- restricted markets for energy efficient lighting technologies, which results in consumer unawareness of the benefits of these technologies and keeps the prices high due to low production;
- split incentives between landlords and tenants, since the Green Lights Program has developed a special lease contract that removes this barrier.

11. Refrigerators Energy Labeling

Refrigerator energy labeling was chosen as a first step towards accumulating experience on energy efficiency information programs on Russian soil to learn what will work and will not work in Russia.

In the refrigerator market, consumers are not easily identified. In such markets, it is important to influence the presentation of products. Labeling and other informational programs could be used for this purpose.

The US is a pioneer in energy labeling of refrigerators on display in retail stores. The European Community established a refrigerator and freezers labeling program in 1993[17]. To understand what labeling exists for refrigerators in Russia, CENEf staff conducted a labeling survey of 20 Moscow retail shops.

Among them, 15 were primarily specialized on selling NIS-manufactured refrigerators, 3 sold both NIS and Western refrigerators, and 2 sold exclusively Western-made refrigerators.
Several interesting findings about labeling were identified:

- labels on refrigerators in display halls have information on price in every store;
- 94 percent of labels on NIS made models contained information on freezer and fresh food compartments volumes;
- only three of the ten Western-made models had labels with volumes information on them;
- to identify the volumes of foreign models, someone have to look inside the refrigerator compartment or ask a selling person. In 30 percent of cases, salespeople failed to answer the question on refrigerator volume. For two "Goldstar" models, no information was available and the volume information presented in Table 3 is based on visual estimates;
- only in one store, all models of NIS-manufacture displayed had labels with information on daily electricity consumption;
- according to the opinion of salespeople, no more than 5 percent of customers are presently interested in electricity consumption data, but with the growth of tariffs for electricity, awareness will grow;
- one store manager expressed the willingness to put efficiency labels on refrigerators on display;
- only two stores sell models of only one or two NIS suppliers;
- every salesperson in stores selling NIS made refrigerators has technical passports on all models displayed. These passports are easily available on request. Among the data presented in technical passport, there is an index of daily energy consumption with 25 ^{o}C ambient temperature (see Figure 9);
- only one among 10 Western-made models surveyed (an Italian model) had a label with information on daily energy consumption. It took 20 minutes to get electricity consumption information on two of three German models displayed from salesperson (who spent ten minutes on looking for catalog and identifying there necessary information). For the rest of seven models, no information was available on electricity consumption on units displayed or from salespersons or user's guides.

These observations lead to the following conclusions:

- awareness of prospective buyers of electricity consumption of refrigerators is low and a definite need exists for information programs to increase this awareness;
- information of electricity consumption per day is readily available for NIS made models, but the daily consumption numbers presented in technical passports tell nothing to the customer of monthly or annual consumption (electricity bills are to be paid every month). The labels do not provide information on costs to run models under different tariffs;
- economic motivation is important to stimulate customer to buy an efficient model;
- lack of visibility of economic information prevents customer from understanding the benefits of purchasing energy efficient models, therefore economic information should be included in labels on displayed units;
- information on electricity consumption of Western is usually unavailable. These models shall also have labels with information on electricity consumption and the running costs of the unit.

I. Bashmakov has designed an ENERGOCOMPASS label for refrigerators on display in Russian stores (see Figures 10 and 11 for correspondingly Russian and English versions).

This label contains the following information:

- name of model;
- name of producer;

- number of stars;
- volume of refrigerator compartment;
- volume of freezer compartment;
- purchase price;
  graphical and numerical information on 24 hour and annual electricity consumption for this model against the best and worst NIS-made model;
- table with data on annual electricity bills with five different electricity tariffs: 6; 12; 30; 50; and 100 rubles per kWh.

This table was constructed to enable customers to see the annual electricity bill of the least efficiency model and then the bill of model in question, followed by the bill of the best model. In order to avoid negative advertising, the brand names of the most and least efficient models are not shown on the label. All refrigerators were divided into categories based on volume and features, and the most and least efficient models for each group were identified. Because of expected increases in energy prices, a wide range of tariffs was shown to inform a customer on potential price growth in the future.

Technically, it is not difficult to produce and reproduce the label, which is important considering that prices and electricity prices are both dynamic.

Several experiments in separate stores should be implemented in order to develop as clear and readily understandable a label as possible.

To make energy labels obligatory, special additions to the "Rules of Trade" should be made.

The information program should be accompanied by articles in newspapers with wide circulation to assist people to understand the concept of refrigerator labeling. Because, as a rule, women pay electricity bills and initiate the purchase of refrigerators, articles should be directed to a female audience.

Presently, TV advertising is a good means of giving out information in Russia. If information presented on ENERGOCOMPASS can be explained clearly on TV, understanding of the ENERGOCOMPASS label will be improved significantly. Again, as women are the primary decision makers in refrigerator purchases, advertising clips should be shown during popular serials which are widely watched by a majority of Russian women.

The three components of a labeling program discussed above could bring significant benefits with very low costs. Every purchase of more efficient models saves 400 kWh annually, compared to the least efficiency model.

12. Five Steps of a Labeling Program Implementation Plan

To implement a Russia-wide labeling program, a five step plan was developed. Following this program step by step will clarify the ENERGOCOMPASS concept, explain it to manufacturers, sellers and customers, develop regulation on labeling requirements, and finally introduce ENERGOCOMPASS to consumers. The five steps are presented below:

1. Experimental use of ENERGOCOMPASS label in several retail stores. Identification of problems with its use and resolution of these problems.
2. Launching of a campaign in the Russian press to explain the idea of the ENERGOCOMPASS and economic and environmental benefits of buying more efficient refrigerators.
3. Approach producers of the most efficient models to finance the development of TV advertisements to inform customers and explain the ENERGOCOMPASS concept.

4. Approach the Ministry of Fuel and Energy to consider financing of energy labeling program on refrigerators.
5. Introduce the requirement of energy labeling for refrigerators in the draft law "On Improving Energy Efficiency" developed by CENEf.
6. Development of some kind of up-dating mechanism and procedures for monitoring program results.

If this plan were successfully implemented, it would be the first Russian energy efficiency labeling program.

Table 1. The Structure of Electricity Consumption in the Residential Sector, bln kWh (%)

Processes	1990	1992
Total Residential Sector, including:	77.6(100.0)	85.2(100.0)
lighting	20.1(26.0)	20.5(24.1)
appliances	37.7(48.7)	39.3(46.1)
refrigerators and freezers	18.5(23.8)	19.2(22.5)
stationary electric range and portable electric range	9.2(11.8)	11.0(12.9)
stationary electric range	6.2 (8.0)	7.0 (8.2)
low temperature processes (heating, hot water, and AC)	10.5(13.5)	14.4(16.9)

Note: In the "Refrigerators and Freezer" item 90% of electricity is consumed by refrigerators.

Table 2. Index of Refrigerator Saturation

	1980	1985	1990	1992
Saturation per 100 families				
Total	89	95	95	95
Urban	103	106	106	106
Rural	59	66	66	66
Saturation per 1000 people				
Total				
Urban	277	307	308	308
Rural	315	345	345	345
	168	210	210	210

Sources: Peoples Economy of the Russian Federation. 1990; and 1992. Statistical Yearbook. State Statistical Committee of the Russian Federation. Moscow 1991, and Moscow 1992; Russian Federation in Numbers in 1992. State Statistical Committee of the Russian Federation. Moscow. 1993.

Table 3. Dynamics of Refrigerator Stock in Russia (10^3 units)

	1980	1985	1990	1992

Production	3600	3453	3774	3187
Export			1045.6	656.3
NIS			632.6	137.1
Others			413.0	519.2
Import			283.8	105.1
NIS			270.8	56.9
Others			13.0	48.2
Non Retail[1)]			321.2	1544.0
Retail trade				
Total	2644	2334	2691	1091
>200 dm^3	599	1054	1407	471
Service sector[2)]			300[3)]	300[3)]
Stock	38226	43870	45584	45799

1) Direct selling from factories; Selling from warehouses and through small firms.
2) Hotel, offices and others.
3) Authors estimate.

Table 4. Factors Affecting Demand for Refrigerators

	Units	1985	1990	1991	1992	1993
Private consumption of goods						
and services	bln.					
Current	rubles					
Constant (1990)		202.2	288.3	517.5	3867	17137[1]
Index	1990=	235.4	288.3	258.75	94.9	65.05[2]
	100	81.7	100	89.8	32.9	30.1[3]
Share of furniture and						
appliances in average income						
Urban areas						
Rural areas	%	7.4	8.6	8.9	NA	NA
Average refrigerator	%	5.7	5.3	5.7	NA	NA
Price (ARP)						
current	rubles	304.5	490.2	1054.8	19628	297000[4]
Constant	rubles	354.4	490.2	527.4	481.7	998.8
ARP/average monthly salary		2.0	2.48	2.84	4.98	5.6

[1] Direct selling from factories and small non retail firms.
[2] Hotels, offices, and others.
[3] Estimate.
[4] Average selling price. First week of November 1993.

Table 6. Electricity Efficiency Standards for Residential Refrigerators (at a Temperature in the Freezing Chamber of -6°C) - in Accordance with GOST 16317-76

Total inner volume, liters	Daily energy consumption by refrigerators (kWh)		Total inner volume, liters	Daily energy consumption by refrigerators (kWh)	
	compressor	absorption		compressor	abortion

40	1.22	2.1	160	1.65	3.95
50	1.25	2.3	180	1.72	4.15
65	1.3	2.5	200	1.8	4.4
80	1.35	2.7	240	2	-
100	1.42	3	300	2.3	-
120	1.5	3.3	400	2.8	-
140	1.58	3.55			

Note: Ambient temperature +32^{o}C; average refrigerating chamber temperature of compressor refrigerators +5oC, abortion refrigerators +7^{o}C.

Table 7. Electricity Efficiency Standards for Residential Refrigerators by Category (at a Temperature in the Freezing Chamber -6^{o}C) in Accordance with GOST 16317-76*[1]

Total Inner Volume, liters	Daily Energy Consumption, kWh		Total Inner Volume, liters	Daily Energy Consumption, kWh	
	compression	absorption		compressor	absorption
60	1.09	-	200	1.55	2.2
	0.90			1.29	2.0
80	1.15	1.95	220	1.64	2.3
	0.96	1.75		1.36	2.1
100	1.21	-	240	1.71	2.4
	1.01			1.42	2.2
120	1.26	2.05	260	1.8	2.5
	1.05	1.85		1.5	2.3
140	1.35	2.1	280	1.84	
	1.12	1.9		1.57	
160	1.41	-	300	1.92	
	1.18			1.64	
180	1.46	-	350	2.12	
	1.18			1.81	
			400	2.32	
				1.98	

[1] Numerator indicates values for the first quality category of refrigerators; denominator - for the highest quality category of refrigerators.

Table 8. 1991 Refrigerator Standards, kWh/day

Volume	Single door	Double door
140	0.760	
180	0.830	1.03
220	0.880	1.1
240	0.912	1.08
260	0.910	1.09
280		1.12
300		1.14

350 400		1.2 1.55

Table 10. US Standards for Refrigerators and Freezers[1]

			Annual Energy Consumption (kWh)	
Appliance	Defrost	Style	Efficiency Jan. 1, 1987	Efficiency Jan. 1, 1992
Refrigerators	Manual	All	17.3 AV+340	13.7 AV+267
Refrigerator-freezers less than 9 cubic feet	All	All[3]	24.7 AV+486	17.4 AV+344
Refrigerator-freezers 9 cubic feet or larger	Manual	All[2]	24.7 AV+486	17.4 AV+344
	Partial automatic	All	24.7 AV+486	17.4 AV+344
	Automatic	Top mounted[3] freezer	24.1 AV+487	16.7 AV+336
	Automatic	Side mounted freezer	30.3 AV+535	22.4 AV+395
	Automatic	Bottom mounted freezer	30.3 AV+535	22.4 AV+395
	Automatic	Top mounted freezer with through the door ice service	26.8 AV+540	18.5 AV+374
	Automatic	Side mounted freezer with through the door ice service	33.6 AV+594	24.8 AV+438
Freezers	Manual	Upright	21.4 V + 480	14.5 V + 324
	Automatic	Upright	33.7 V + 755	21.3 V + 477
	All	Chest	14.8 V + 384	10.9 V + 282

[1] AV = adjusted volume = [1.63*freezer volume (ft3)] + refrigerator volume (ft3); V = freezer volume (ft3).

1. This classification includes refrigerators with partial automatic defrost systems.
2. This classification includes refrigerators with automatic defrost systems.
3. This classification includes refrigerator-freezers with internally mounted freezers.

Table 11. Targeted Improvement Ratio of Refrigerating Units

Division	Formula for monthly basic electricity	Correlation formula for 1978	Market share (1978) based	Target improvement

	consumption (1983 as target year)		on number of shipped units	ratio
Units with self-defrosting systems, with freezer at the top	W=0.053V+25.63	W=0.066V+32.04	ca.23%	ca.20%
Units with reinforced circulation systems with freezer at top	W=0.114V+16.89	W=0.152V+22.52	ca.56%	ca.25%
Units with freezer on the side	W=0.131V+21.40	W=0.164V+26.75	ca.2%	ca.20%
Refrigerator without freezer	W=0.049V+13.35	W=0.053V+14.51	ca.19%	ca.8%
Note: In this chart, W and V show the following figures. W: Basic Electricity Consumption Rate (Unit: kWh) V: Effective detailed figures for electrical refrigerator (Concerning refrigerators with freezer compartment, the figure is derived by multiplying the figure for the freezer by 1.74 plus the figure of the refrigerating compartment) (Unit: 1)				Average ca.20%

Table 12. Some of the Most Energy-Efficient Refrigerators Produced in the World

Brand and location	Model	Capacity l	Electuse[a] kWh/yr	Elec use[1] kWh/day	Unit elecuse kWh/l/yr	Unit electuse[2] kWh/lAV/yr
Single door models						
Hitachi (Japan)	RX717	170	180	0.49	1.06	0.44
National (Japan)	NR214R	205	190	0.52	0.93	0.47
Gram (Europe)	K244	231	200	0.55	0.87	0.49
Electrolux (Europe)						
AEG (Europe)	RF930	245	220	0.60	0.90	0.81
Bosch-Siemens (Europe)	KS380	330	275	0.75	0.83	0.74
Gram (Europe)						
	KK3650	346	290	0.79	0.84	0.75
	K395	371	315	0.86	0.85	0.77
Two door models						
National (Japan)	NR305HVP	300	275	0.75	0.92	0.75
Mitsubishi (Japan)	MR3126	310	290	0.791.1	0.94	0.76
Toshiba (Japan)	GR415AS	410	430	8	1.05	0.85
National (Japan)	NR434TR	425	445	1.22	1.05	0.85
Electrolux (Europe)	TR1120C	315	475	1.30	1.51	1.23
Gram (Europe)						
	KF355	337	550	1.51	1.63	1.33

Whirlpool (U.S.)	ET17HKXR	485	750	2.05	1.55	1.26

[a] Electricity use is based on standardized tests which are not the same in Europe, Japan, and the U.S. Therefore, the consumption values for different locations are not directly comparable.

[b] It was proposed that refrigerator volume is 10 percent of refrigerator volume for single door refrigerator and 20 percent for two doors refrigerator.

Source: Calculated based on: H. S. Geller. Improving End-Use Electrical Efficiency: Options for Developing Countries. American Council for an Energy-Efficient Economy, Washington, DC. July, 1986. p. 25.

Table 13. Comparison of Russian Made and Most Efficient Foreign Made Refrigerators Energy Efficiency (kWh/l AV/year)

Adjusted Volume	Most Efficient Foreign Models	Most Efficient Russian Models	Average Russian Model
Single Door			
170-200	0.44(100)	2.13(484)	2.59(588)
201-240	0.47(100)	2.14(455)	2.29(487)
241-280	0.49(100)	1.67(341)	2.02(412)
281-350	0.81(100)	1.42(175)	1.66(205)
Two Doors			
351-400	0.75(100)	0.84(112)	1.40(187)
401-500	1.10(100)	1.10(100)	1.59(145)

Sources: Data from Table 5 and Table 12.

Table 14. Potential for Energy Conservation due to refrigerators Energy Efficiency Improvements

Adjusted Volume (l)	Specific Energy Consumption (kWh/l AV)		Energy Consumption in 2010 (billion kWh)		Energy Conservati on (10^9 kWh)
	Average 1992	Average 2010	with 2010 efficiency	with 1992 efficiency	
100-170	2.8	0.4	0.29	2.02	-1.73
171-280	2.3	0.5	1.20	5.53	-4.33
281-350	1.7	0.8	4.04	8.59	-4.55
Two doors	1.5	1.0	9.09	13.63	-4.54
Total			14.62	29.77	-15.15

Source: Estimated by Authors.

Table 15. Refrigerator Conservation Supply Curve for the US

Efficiency Measure	Elect. Use (kWh/yr)	Elect. Savings (kWh/yr)	Cost of Saved Marginal (c/kWh)	Energy Average (c/kWh)
Baseline	677	-	-	-
Condenser anti-sweat heater	572	195	1.3	1.3
Adaptive defrost	487	85	3.0	2.0
EER=5.3 compressor	466	21	6.4	2.5
0.75" aerogel insulation	374	92	6.8	3.8
1.00" aerogel insulation	320	54	3.5	3.8
1.25" aerogel insulation	285	35	5.4	3.9
1.50" aerogel insulation	260	25	7.5	4.1
1.75" aerogel insulation	242	18	10.5	4.4
2.00" aerogel insulation	228	14	13.4	4.7
Two-compressor system	188	40	20.0	5.9

(1) 18 cubic foot refrigerator/freezer with automatic defrost.

Source: Goldstein, et al., 1990 (Ref.24 ?).

Table 16. Results of Cost-Effectiveness Analysis for Refrigerator-Freezers for European Community, (**** -1 compressor, adjusted volume = 325 l)

Combination of Design Options	Elec. Cons. kWh/yr	Energy Savings (a) kWh/yr	Savings (a) %	Cumul. Payback (b) years	Life-Time Cost (c) ECU 91
0 Baseline	516				
1=0+compressor direct aspiration	449	67	13.0	1.61	936
2=1+increase door thickness (+15 mm)	420	96	18.6	1.76	893
3=2+increase wall thickness (+15 mm)	351	165	32.0	3.45	875
4=3+improve door leakage	333	183	35.5	4.62	869

(a) savings compared to baseline
(b) for payback calculations, electricity cost of 0.0928 ECU/kWh
(c) discount rate 9%, average life-time = 13 years.
1 ECU = 1.07 $US.

Source: ADEME Study.

Table 17. Survey of the Life-Cycle Cost Analysis for Denmark

Product Class	Baseline Energy Use	Optimum Energy Use	Index Energy Use	LCC Decrease	Cost per saved kWh
	kWh/day	kWh/day	Base=100	DKK	DKK/kWh
Refrigerator 100l	0.63	0.26	41	683	0.21
Refrigerator 200l	0.77	0.39	51	537	0.30
Refrigerator 300l	0.87	0.46	53	594	0.30
Refrigerator with frost box 200l	1.05	0.55	52	631	0.30
Refrigerator-Freezer 300l	1.55	0.96	62	1256	0.20

DKK - Danish kraun.
Average price of electricity in Denmark is 0.39 DKK

Table 18. Investment and Operational Costs of Three Refrigerator Models.

Model	Adj. Vol.	Purch. Price, 1000 rubles	Spec. elect cons. kWh/ l AV/ year	Eleccons kWh/ year	Operational Costs, 1000 rubles		
					12 R/kWh	50 R/kWh	100 R/kWh
STINOL-102	403	546	0.996	401	4.83	20.05	40.1
MINSK-130-1	421	648	1.414	595	7.14	29.75	59.5
NORD-223	401	485	2.044	819	9.86	40.98	82.0

Source: Calculated by authors.

Table 19. Life Cycle Costs (1000/rubles, October 1993 prices)

	Electric Tariff rub./kWh	Discount rate (%)			
		5	7	10	12

STINOL-102	12 30 50 100	596 671 754 963	590 656 729 912	583 638 699 851	579 628 683 819
MINSK 130-1	12 30 50 100	722 833 957 1266	713 810 919 1190	702 784 874 1101	697 770 851 1043
NORD-223	12 30 50 100	587 740 910 1336	574 709 858 1231	559 672 797 1108	552 652 764 1043

Source: Calculated by authors.

References

1. Milhone J.P. The Role of Efficiency Standards in the United States. in International Energy Conference on Use of Efficiency Standards in Energy Policy. Proceedings. Sophia-Antipolis, 4-5 June 1992. IEA/OECD. 246 p.

2. Levine M.D., Geller H., Koomey J. Nadel S., and L. Price. Electricity End-Use Efficiency: Experience with Technologies, Markets, and polices Thought the World. LBL and ACEEE. March 1992.,94 p.

3. Howard S. Geller. SAVING MONEY AND REDUCING THE RISK OF CLIMATE CHANGE THROUGH GREATER ENERGY EFFICIENCY.

4. Howard S. Geller. SAVING MONEY AND REDUCING THE RISK OF CLIMATE CHANGE THROUGH GREATER ENERGY EFFICIENCY.

5. Howard S. Geller. IMPROVING END-USE ELECTRICAL EFFICIENCY: OPTIONS FOR DEVELOPING COUNTRIES. July, 1986.

6. P.B. Pedersen. Engineering Analysis Concerning Energy Efficiency Standards for Refrigerators and Freezers in Denmark. //in International Energy Conference on Use of Efficiency Standards in Energy Policy. Proceedings. Sophia-Antipolis, 4-5 June 1992. IEA/OECD. 246 p.

7. B. Lebot and A. Szabo. Preparing Minimum energy Efficiency Standards for European Appliances. // in International Energy Conference on Use of Efficiency Standards in Energy Policy. Proceedings. Sophia-Antipolis, 4-5 June 1992. IEA/OECD. 246 p.

8. B. Geider, H. Klleberger, and U. Wagner. Future Structure Development in Domestic Power Consumption. //in International Energy Conference on Use of Efficiency Standards in Energy Policy. Proceedings. Sophia-Antipolis, 4-5 June 1992. IEA/OECD. 246 p.

9. According to the ADEME study cumulative 306 TWh could be saved over the period 1995-2010 in the European Community through the introduction of refrigerators and freezers energy standards (ADEME. Etude sur la reglementation des performances energetqiues des appareils electromenagers. Commission of the European Communities, DG XVII, Brussels. Belgium. October 1991). The EC population was in 1990 325 million, or 2.2 times more than in Russia. Estimated EC potential is 2.1 times larger than in Russia. This comparison of results gives additional confidence to the potential estimate made by the authors for Russia.

10. Howard S. Geller. SAVING MONEY AND REDUCING THE RISK OF CLIMATE CHANGE THROUGH GREATER ENERGY EFFICIENCY.

11. J. E. McMahon. Quantifying the Benefits and Costs of U.S. Appliance Energy performance Standards. //in International Energy Conference on Use of Efficiency Standards in Energy Policy. Proceedings. Sophia-Antipolis, 4-5 June 1992. IEA/OECD. 246 p.

12. B. Lebot and A. Szabo. 1992.

13. Howard S. Geller. SAVING MONEY AND REDUCING THE RISK OF CLIMATE CHANGE THROUGH GREATER ENERGY EFFICIENCY.

14. Howard S. Geller. SAVING MONEY AND REDUCING THE RISK OF CLIMATE CHANGE THROUGH GREATER ENERGY EFFICIENCY.

15. Electricity End-Use Efficiency: Experience with technologies, Markets, and Polices throughout the World. ACEEE. March 1992.

16. See Greiger and others (18 years); B. Lebot and A.Szabo (13 years); P. Pedersen (12 years.

17. B. Lebot and A. Szabo. 1992.