

**ENERGY SAVINGS AND THE REDUCTION IN THE EMISSION OF
GREENHOUSE GASES RESULTING FROM THE USE OF FOAM PLASTIC
INSULATION IN REFRIGERATORS AND FREEZERS.
A LIFECYCLE ANALYSIS**

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Abstract

The paper presents a case study of the use of foam plastic insulation in refrigerators and freezers from the perspective of the reduction in energy consumption and greenhouse gas emissions when compared to insulating materials once used in refrigerators and freezers.

The analysis considers the energy consumption and greenhouse gas emissions of the manufacture of each insulation as well as the consumption of energy and emissions during the operation of the appliances.

The results are presented in terms of energy savings and carbon dioxide equivalents of greenhouse gas emissions avoided annually per appliance. Annual savings for the United States are also given. In addition savings are expressed over the expected lifetime of the units and time to payback the energy used and emissions produced in the manufacture of the plastic insulation are given.

Introduction

Mechanical refrigerators have been part of the kitchen hardware in North American homes for about seventy years. With few exceptions every home in North America has a refrigerator and most of these are powered by electricity. (Remote locations may have units fired by propane.) In addition an increasing number of homes have a freezer separate from the refrigerator.

The refrigerator is the appliance in our homes that probably consumes the most electrical energy. Electricity is generated in many parts of North America by burning fossil fuels. The combustion of fossil fuels is a major contributor to the production of carbon dioxide, a greenhouse gas linked to the theory of "global warming".

Conservation of energy results in a reduction in the emission of greenhouse gases and one of the ways to conserve energy with a refrigerator is to insulate the cabinet.

For many years the material which insulated the door and walls of refrigerators and freezers was glass fibre. In the mid to late 1960's refrigerator manufacturers began to use polyurethane plastic foam as insulation. The last use of glass fibre as insulation in the doors of refrigerators occurred around 1992. The reason the change took so long was due to the high cost to redesign and retool the refrigerator cabinet for the new insulation. This retooling has resulted in a larger interior in a refrigerator while retaining the same exterior dimensions. 80 to 90mm (3 to 3.5 inches) of glass insulation can be replaced by 40mm (1.5 inches) of polyurethane while

maintaining the same insulating properties. In addition the rigid nature of the foam insulation has allowed refrigerator designers to reduce the thickness of metal exterior and plastic interior “skins”. This conserves natural resources.

If the refrigerator and freezer of today were to suddenly revert back to glass fibre insulation (wall and door thickness remaining as they are currently) there would be a marked increase in energy consumption and a resultant increase in greenhouse gas emissions. The first sign of a change noticeable to a homeowner would be a higher bill for electricity.

Using a technique known as lifecycle analysis the American Plastics Council has measured the difference in energy consumption and greenhouse gas production between refrigerators and freezers insulated with glass fibre and polyurethane.

The lifecycle analysis takes into account the energy used and the greenhouse gases emitted during the production of each insulating material and the energy and greenhouse gases consumed and produced in the operation of the respectively insulated refrigerators and freezers. The energy required to manufacture the refrigerator or freezer and all equivalent materials in the appliances is not included because they are identical for each case and so will not affect the results.

The studies are based on a consideration of a 19 cubic foot refrigerator and a 15 cubic foot chest freezer. These appliances last a long time in service (normally about 19 years on average) and the calculations compare the foam insulated and the glass insulated devices over their lifetime.

It is assumed that the appliances are all powered by electricity and the electricity is taken from a power grid nationally representative of the various means used to generate power in the United States. In the U.S., electrical energy is derived from plants that run on hydropower, nuclear energy, coal, petroleum, and natural gas. The burning of coal, petroleum and natural gas creates greenhouse gases of which the principal one is carbon dioxide.

The production of the plastic foam insulation requires a “blowing agent” in this case HCFC-141b, itself a greenhouse gas. The calculations take account of the greenhouse gas potential of the blowing agent and releases of it during the manufacturing stage of the appliance. In addition, it is assumed that any blowing agent trapped in the cells of the foam will be released to the atmosphere either during the service life of the appliances or during their disposal

Results

Refrigerator Comparison

Table 1 compares the energy required to manufacture the insulation and operate the polyurethane insulated and glass fibre insulated average refrigerators over their lifetime of 19 years. Table 1 also compares the greenhouse gas emissions resulting from the manufacture of the insulating materials and operation of the units.

Table 1

ENERGY REQUIREMENTS AND GREENHOUSE GAS EMISSIONS BY LIFE CYCLE STAGE FOR THE PRODUCTION OF INSULATION AND REFRIGERATOR USE OVER THE LIFETIME OF A 19 CUBIC FOOT REFRIGERATOR

	Energy (Million Btu)	Greenhouse Gases			
		Carbon Dioxide (lb)	Methane (CO2 equiv)	Nitrous Oxide (CO2 equiv)	HCFC 141b (CO2 equiv)
Average refrigerator (polyurethane insulation)					
Polyurethane insulation production	0.62 (1)	46.9	10.4	0.79	1247.0
Refrigerator use	<u>154</u>	<u>20,760</u>	<u>956</u>	<u>49.7</u>	<u>0</u>
Total	155	20,807	966	50.5	1,247
Average refrigerator (fiberglass insulation)					
Fiberglass insulation production	0.11	20.1	0.61	0.024	0
Refrigerator use	<u>253</u>	<u>33,895</u>	<u>1,575</u>	<u>82</u>	<u>0</u>
Total	253	33,915	1,576	82	0

(1) This total production energy includes 0.19 million Btu of energy of material resource (feedstock energy)

Source: Franklin Associates

As previously mentioned the sources of electrical energy for the operation of the devices are those of the U.S. national grid in which power derived from coal fired units makes up more than 50 percent of the power generated.

The energy content of the insulations and the energy to manufacture them has been taken from various life cycle inventories for the products.

The refrigerator insulated with polyurethane consumes 39 percent less total energy through its production and use phase than the refrigerator with glass fibre insulation. It is evident in the table that the energy to manufacture the insulating materials is insignificant compared to the energy required to operate the devices. The difference in total energy consumption between the two units over their lifetimes may be expressed as savings in fossil fuels. These savings would be:

Natural Gas	16,354 cu. ft.
Petroleum	0.66 barrels of oil
Coal	4953 pounds

The same order holds when the emission of greenhouse gases is considered. In the case of the product insulated with polyurethane 5 percent of the emissions over the life of the unit can be attributed to the manufacture and foaming of the insulation. The manufacture of the glass fibre insulation contributes 0.06 percent of the total greenhouse gas emissions. 93 percent of the difference in greenhouse gas emissions from the manufacture of the two insulating products is due to the assumption that all of the HCFC-14 lb. is lost over the lifetime of the refrigerator. This will only occur if the unit is shredded or landfilled. Although the weight of the blowing agent which is lost is less than two pounds the material has a notable greenhouse gas

potential when expressed in CO₂ equivalents. The significance of this emission pales when the two units are compared on the basis of their respective total emissions over their operating lifetimes. The polyurethane insulated device emits 35 percent less total CO₂ equivalents than the refrigerator with glass fibre insulation.

The value of polyurethane insulation in household refrigerators can be expressed in a striking fashion when one considers the annual avoidance of greenhouse gas emissions and annual energy savings for the total of all refrigerators in the United States.

U.S. statistics indicate that in 1995 there were 106 million refrigerators in homes in the United States. Insulating these units with polyurethane rather than glass fibre results in annual reduced greenhouse gas emissions of 34.9 million tons of CO₂ equivalents and provides annual energy savings of 49.581 million kilowatt hours.

It should be noted that to calculate the savings in greenhouse gas emissions, we have assumed that the energy savings originated from the national power grid. The alternative, favoured by some government agencies and other practitioners is to assume that the savings result from marginal sources of electricity, primarily coal and other fossil fuels. If we had chosen that option the greenhouse gas avoidance would increase from 34.9 million tons CO₂ equivalents annually to 52.8 million tons.

Freezer Comparison

Calculations were also carried out for two average (15 cu. ft.) stand-alone freezers, one insulated with polyurethane foam and the other with glass fibre. The assumptions regarding sources of power and fate of the HCFC 141b blowing agent were identical to those used during the comparison of the refrigerators. Again, the anticipated lifetimes of the devices were 19 years.

The energy and greenhouse gas emissions for manufacture and use of the freezer is shown in Table 2.

Table 2

ENERGY REQUIREMENTS AND GREENHOUSE GAS EMISSIONS BY LIFE CYCLE STAGE FOR THE PRODUCTION OF INSULATION AND FREEZER USE OVER THE LIFETIME OF AN AVERAGE FREEZER

	Energy (Million Btu)	Greenhouse Gases			
		Carbon Dioxide (lb)	Methane (CO ₂ equiv)	Nitrous Oxide (CO ₂ equiv)	HCFC 141b (CO ₂ equiv)
Average refrigerator (polyurethane insulation)					
Polyurethane insulation production	0.59 (1)	44.3	09.9	0.75	1178.0
Refrigerator use	<u>95</u>	<u>12,742</u>	<u>587</u>	<u>30.5</u>	<u>0</u>
Total	95	12,786	597	31.3	1,178
Average refrigerator (fiberglass insulation)					
Fiberglass insulation production	0.11	19.0	0.57	0.023	0
Refrigerator use	<u>155</u>	<u>20,822</u>	<u>972</u>	<u>51</u>	<u>0</u>
Total	155	20,841	973	51	0

(1) This total production energy includes 0.19 million Btu of energy of material resource (feedstock energy)

The energy to operate the freezers is approximately 60 percent of that required for the refrigerators. A portion of the difference may be attributed to the smaller size of the unit but a much larger proportion of the difference is due to the way in which the device is used (less frequent opening of the door), reduced air “spillage” from the chest type of freezer, etc.

In relative terms the differences between the two freezers are similar to the differences between the two refrigerators. The freezer with polyurethane insulation uses 39 percent less total energy than its counterpart with glass fibre insulation. It also emits 33 percent less total CO₂ equivalents of greenhouse gases.

The difference in total energy consumption between the two devices over their lifetimes when expressed in savings in fossil fuels is:

Natural gas	10,108 cu. ft.
Petroleum	0.42 barrels of oil
Coal	3,042 pounds

There are approximately 33.4 million household freezers in use in the United States. Using the national power grid as the source of electrical energy to run the appliances one determines that the freezers insulated with polyurethane rather than glass fibre avoid the emission of 6.4 million tons of CO₂ equivalents of greenhouse gases while saving 9,619 million kilowatts of energy.

If we had used the less conservative approach and not assumed that the power savings were attributed to the national grid but rather to the marginal sources of electricity, coal and other fossil fuels the greenhouse gas avoidance would increase from 6.4 million tons CO₂ equivalents to 9.9 million tons.

Conclusions

Polyurethane is an extremely efficient insulation for use in household refrigeration devices. In the case of refrigerators the carbon dioxide emissions avoided using polyurethane insulation instead of glass fibre over one year is approximately 6 times the amount of carbon dioxide equivalents emitted during the manufacture of the polyurethane. It takes approximately 1.5 months of use of the refrigerator insulated with polyurethane before the energy savings exceed the energy it takes to manufacture the insulation.

In the case of the polyurethane insulated freezer the total of greenhouse gas emissions avoided in one year is 3.5 times the amount of CO₂ equivalents emitted during the manufacture of the insulation. 2.2 months of use of the freezer saves an amount of energy equivalent to the energy used to manufacture the polyurethane.