The Impact of Refrigerator Standards on United States Households

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ABSTRACT

This paper addresses criticisms of Federal appliance efficiency standards and whether or how the imposition of efficiency standards on household refrigerators and freezers in the US affects prices, supply, and various other attributes. The study is based on historical data about changes in standards for household refrigerators in California, national standards established by the US Department of Energy, along with data about the size, styles, energy consumption, reductions in emissions, and the costs of refrigerators from 1940 to the present.

Using historical data from the Association of Home Appliance Manufacturers (AHAM) and *Consumer Reports*, the paper traces changing styles, size, price, reliability, and energy consumption of refrigerators. Changes in standards are alleged to disrupt markets, which left to their own devices would optimize cost, efficiency, consumer choice, and reliability. This paper shows that standards have contributed to an overall reduction in unit energy consumption and CO_2 emissions at the aggregate level and have reduced household costs for energy. At the same time, Americans have taken back some of the gains through the purchase of progressively larger units, increased market share of more energy intensive styles, and features such as automatic defrost, through-the-door ice and water, and other innovations. The data do not support critics' arguments of standards who charge that the imposition of federal energy efficiency standards increase the cost of equipment for end users and limit availability. In constant dollars, unit price increases across a broad range of styles and sizes associated with standards, if they occur, seldom last more than a year or two and then return to earlier levels or continue to decline. Sales volumes are more closely correlated with economic activity than the imposition of standards. Energy consumption has been consistently reduced. The reliability of units has improved over time but varies by style and features. This analysis will serve as a model for the examination of the effects of standards on other energy using equipment.

Introduction

Appliance standards have been a contentious issue in American culture but have become more so recently with the so called "culture wars" (Hoffman, 2012). This paper explores some of the issues surrounding standards by examining the history and impact of refrigerator standards in the United States.

The process of establishing appliance standards has a complex history involving both state and Federal levels of government, utilities, nongovernmental organizations promoting energy efficiency, manufacturers, trade associations, and others. The history starts with a fairly narrowly defined set of players and a somewhat contentious and adversarial process that evolves toward a more collaborative process with many diverse players.

The paper begins with a brief discussion of data sources followed by a brief history of the technology, a discussion of the evolution of the standards setting process, and finally, a discussion of changes in size, cost, reliability, and energy consumption.

At various times it has been argued that standards:

- Represent a burden to households because of increased unit costs
- Fail to produce savings that offset costs

- Produce a take back effect by encouraging the purchase of larger or more energy intensive units with more features
- Push the technological envelope to the limit
- Suppress sales
- Result in less reliable units
- Result in units with shorter lives

As we shall see, the data support few of the supposedly negative effects of standards. Data about changes in appliance lifetimes are not yet available.

The Data Sources

One of the authors has had a long time interest in the energy efficiency of refrigerators and began collecting the data on which the analysis in this paper is based many years ago. There are two primary sources of data: reviews of refrigerators taken from *Consumer Reports*, a magazine with the goal of assisting customers to make wise purchasing decisions, and data from the Association of Home Appliance Manufacturers (AHAM).

The *Consumer Reports* data includes physical characteristics, pricing, and consumption data for specific types of refrigerators and freezers, for example, Top Freezer refrigerators with automatic defrost. Articles appear roughly annually and describe from a few to several like models. In some years there has been more than one review usually describing models of a different style and in other years none. Because there has been a consistency and standard format in the reports, trend analysis is possible. Perhaps the most important attribute is that this data has the pricing information, which when adjusted to constant 2011 dollars, allows comparison of prices over time (EIAa, EIAb). This data extends from the 1940s to the present.

The AHAM data picks up in the 1970s and provides information about style, size, consumption and shipment weighted averages as well as annual unit shipments by state. Thus, it is possible to examine national and state trends by style, size, and consumption of the refrigerator and freezer purchases of American consumers.

The historical data about refrigerator standards can be combined with the *Consumer Report* and AHAM data sets to examine the effects of standards on the:

- Cost of refrigerators
- Energy cost savings
- Benefits take back
- Technological envelope
- Sales

Refrigerator Standards in the United States

As a result of the first and second Oil Embargos of 1973 and 1977-78 and the resulting energy crises, new emphasis was placed on improving the energy efficiency of equipment such as cars and trucks that used fossil fuels and refrigerators and freezers that used electricity. The first efficiency standards for refrigeration equipment resulted from studies at the Lawrence Berkeley National Laboratory (LBNL). The standards were put forward to establish maximum energy usage in annual kWh per year. Separate standards were established for different styles of refrigerators such as Single Door units with Manual Defrost (SD-M), two door units with a Top Freezer with and without Automatic Defrost (TF-M, TF-A), and Side-by-Side door with Automatic Defrost (SS-A). There were separate

standards for units with icemakers or through-the-door ice or water service. There were seven refrigerator standards and three freezer standards for maximum annual usage.

The standards allowed for increased usage for larger sized units. The volume was adjusted to compensate for the higher usage required for colder temperatures in the freezer compartment depending on the temperature setting of 38 degrees in the fresh food compartment and 15, 5, or 0 degrees depending on the type of refrigerator or freezer. The standard was of the form:

Maximum Energy Use (kWh/yr) = 8.07AV + 233.7, where AV is the adjusted volume, and

AV = 1.189V for a Top Freezer Automatic, and

AV = 1.23625V for a Side-by-Side Automatic

These standards were first established in California on November 3, 1977. Subsequent revisions to these standards occurred in California in 1979 with an optional code in 1980. An additional revision occurred in California in 1987. Because California accounts for such a large fraction of refrigerators shipped, establishing standards in California was instrumental in demonstrating the technologies to improve the energy efficiency of refrigerators and set the stage for the introduction of Federal standards that went into effect January 1, 1990. These were followed by revisions to strengthen the Federal standards in 1993 and 2001 and revised standards that take effect September 15, 2014.

Table 1 illustrates the maximum energy usage for one common style of refrigerator and three typical sizes under the nine standards described above. The style is the Top Freezer Automatic for 15, 18 and 21 cubic foot total volume. The table illustrates a decline of 78% to 80% in the maximum allowable usage from 1977 to 2014. The actual decline in average usage is likely even greater because pre-1977 refrigerators used substantially more energy than the 1977 maximum usage. Based on this table, the maximum allowable energy usage has improved over nearly 35 years at a rate of about 4 percent per year. Table 1 also demonstrates that the 1987 California standard prepared the market for the 1990 U.S. standard. The 1992 California standard was the precursor to the 1993 U.S. standard.

Table 1. Maximum Allowable Energy Use for Top Freezer Automatics for Three Sizes and Nine Standards

Year	Location	15 cu ft	18 cu ft	21 cu ft
1977	California	1740	1992	2244
1979	California	1399	1582	1764
1980	California	1380	1560	1740
1987	California	917	1003	1089
1990	US	870	974	1058
1992	California	634	693	753
1993	US	640	697	755
2001	US	451	486	521
2014	US	378	406	435

The Spread of the Standards

California has become a leverage point for the broader adoption of codes and standards in other parts of the country because:

- California has been at the forefront of adopting and pushing for improved energy efficiency.
- California is a very large market so that the adoption of codes and standards in California means that manufacturers either have to carry additional product lines, one for California and one for the rest of the country, or they change their product line to meet the California standards.

The American Council for an Energy Efficient Economy (ACEEE) and the Appliance Standards Awareness Project (ASAP) have selectively leveraged and promoted California and other standards in other states. The Appliances Standards Awareness Project provides a list of States that have adopted appliance efficiency standards since 2001.

Manufacturers are not necessarily opposed to standards. In fact, some welcome them because they help to level the playing field for manufacturers who want to innovate, but who are concerned that the state-by-state process might lead to a patchwork of standards that might require multiple product variations and attendant increased costs due to logistics and inventory.

Recognizing the pull for more efficient products as well as the need to develop more efficient products and the realities of multiple standards, manufacturers have become more collaborative in the standards setting process. ACEEE and the Appliance Awareness Project have been instrumental in facilitating these collaborations. The Consortium for Energy Efficiency (CEE) has also played a major role.

Federal Standards

The U. S. Department of Energy (DOE) has the authority to set energy efficiency standards under several legislative acts.

- DOE was first authorized to set mandatory energy efficiency standards for thirteen household appliances and products under the National Energy Conservation and Policy Act (NECPA), which was enacted in 1978.
- The NECPA was amended and updated in 1987 by the National Appliance Energy Conservation Act (NAECA). NAECA superseded existing state requirements and actually set the first national efficiency standards for several types of home appliances, including refrigerators, freezers, furnaces, and air conditioners. NAECA also established a schedule for possible updates of the standards.
- The Energy Policy Act of 1992 (EPAct) added lamps (incandescent and fluorescent), small electric motors, office equipment, and plumbing products as products for which DOE was to set energy efficiency standards

By the mid 1990s, DOE was falling behind in developing appliance energy efficiency standards. Congress advised DOE to correct the standards-setting process and to bring together stakeholders (such as manufacturers and environmentalists) for assistance. To resolve this problem, DOE in September 1995, announced a formal effort to consider further improvements to the process used to develop appliance efficiency standards, calling on energy efficiency groups, manufacturers, trade associations, state agencies, utilities, and other interested parties to provide input to guide the Department. On July 15, 1996, the Department published a Final Rule: Procedures for Consideration of New or Revised Energy Conservation Standards for Consumer Products (61FR 36974). The rule describes the process DOE now uses in setting appliance energy efficiency standards.

There were other drivers of efficiency. The Montreal Protocol came into effect in 1989. In 1994 Federal EPA regulations restricted the use of R12 refrigerant. This restriction provided an opportunity to modify refrigerator compressors to increase efficiency. In anticipation of the switch from CFCs and the possibility that it would result in a five percent increase in energy consumption, the California IOUs

and other utilities created the Super Efficient Refrigerator Prize. Whirlpool won the prize and started shipping refrigerators to dealers in 1995. Whirlpool stopped selling the units in 1998 due to low sales, but Ledbetter, *et. al.* have stated that "SERP appears to be responsible for much of the increase in the overall efficiency levels of Whirlpool's side-by-side units as well as a modest increase in the efficiency levels of other brands."

Other drivers are the DOE AND EPA Energy Star guidelines and the CEE tiers. Energy Star refrigerators are 20 percent more efficient than the Federal standards. CEE Tier 1 is the same as the Energy Star guideline and the Tier 2 and 3 units are 25 and 30 percent more efficient than the Federal Standard. Many consumers now use the Energy Star Label as a guide for what to buy. Consortium utility members can use the CEE Tiers to set the minimum specifications for incentive programs. The effect of the Energy Star and the CEE Tiers is to create demand for more efficient units that provides an incentive for manufacturers to develop equipment that will meet strengthened Federal Standards.

Change in Size

Over the years the size of refrigerators has increased. Figure 1 shows the increase in the average adjusted size of the shipment weighted average of refrigerators in the US. There was a fairly rapid rise in the volume of refrigerators between 1970 and 1980 and then another substantial rise in volume after 1999.

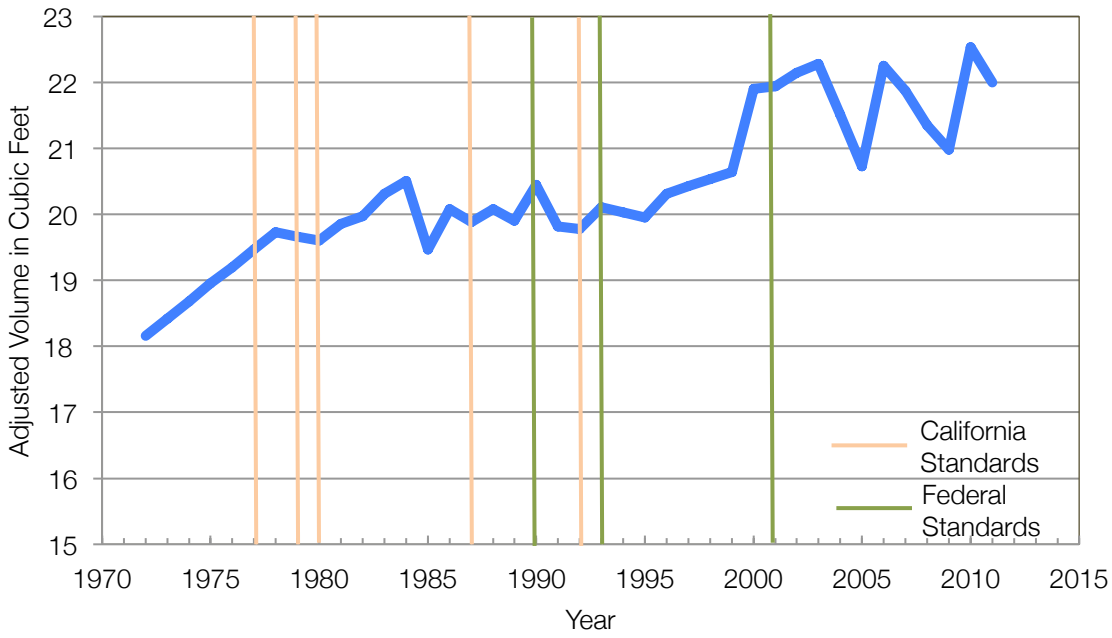

Figure 1 The Shipment Weighted Average Adjusted Volume of Refrigerators Shipped by Year

The demand for larger sized refrigerators has been driven by several factors. Housing shifted to suburban homes on large lots that were often removed by distance from grocery stores thereby increasing storage requirements. Multiple wage earners in households had reduced time for shopping thus creating demand for more storage. New single-family homes had larger kitchen areas. Apartments were being built with larger kitchen areas. The increased availability of packaged and prepared foods generated a need for larger volume freezers and therefore refrigerators. Features such as automatic ice

making and through-the-door ice and water decreased the available useful volume of units which in turn led to the need for increasing total volume to off-set the volume required for the features.

Without the introduction of the increasingly restrictive maximum efficiency requirement, it is quite likely that the energy usage for refrigeration would have increased with size. Maximum energy usage requirements meant customers could have larger refrigerators without paying an energy penalty.

The Price of Refrigerators

A frequent contention is that standards result in an increase in the prices of a product. Figure 2 shows the prices of three styles of Top Freezer Automatics in constant 2011 US dollars. Each point represents the average of three to 38 units based on price data from the reviews from *Consumer Reports* for the given year. There is a clear linear pattern of decline in constant dollar prices averaging $20 to $38 per year. Visual inspection of the intersection of the curve with the years in which standards took effect does not appear to show any measureable effect.

Also Figure 2 shows that 14 to 16 cubic foot Top Freezer Automatics were common in the market between 1961 and 1974. Seventeen to 19 cubic foot units were common in the *Consumer Reports* rating from 1971 to 1992. Nineteen to 21 cubic foot units began to be common in the *Consumer Reports* ratings about 1988 and in particular after 1995. The prices of units in each size category declined in price at different rates.

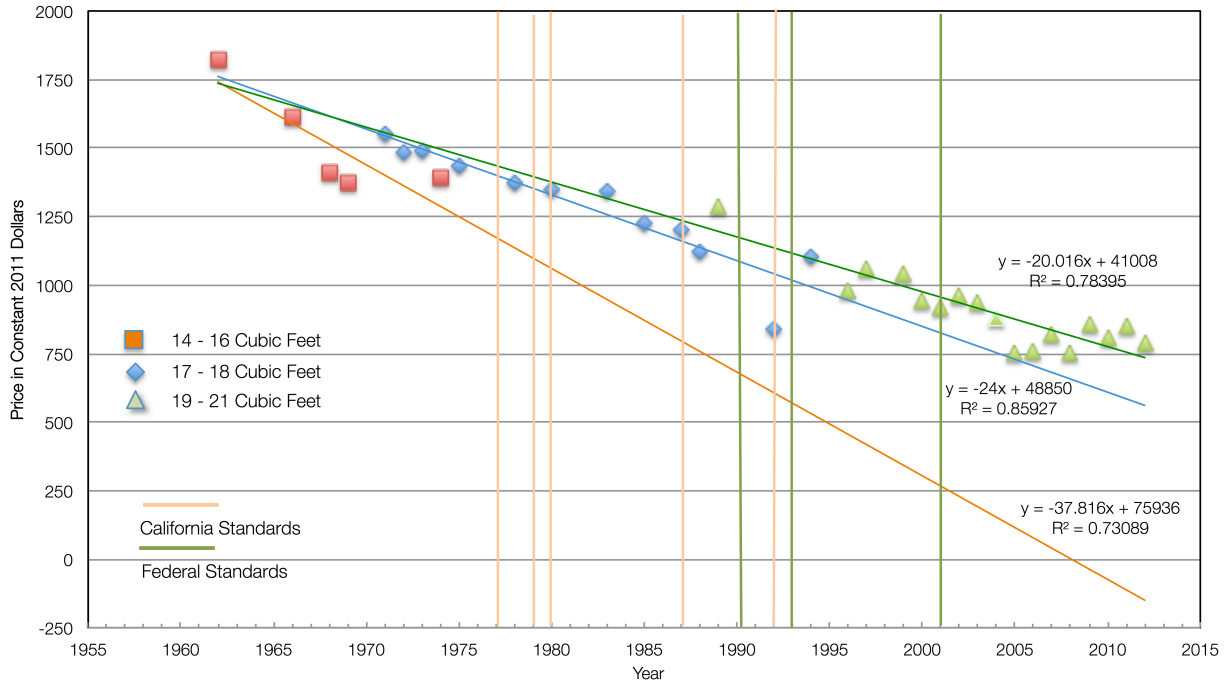

Figure 2 Prices of Top Freezer Automatics in Constant 2011 US Dollars by Size Category of the Units

Until about 1977, the 17-18 cubic foot units were about the same price or slightly more than the 14-16 cubic foot units. The demand for 14-16 cubic foot units declined after 1977 and *Consumer Reports* discontinued reporting on them. Today such units can be purchased in a range from $350 to $600. The price of 17-18 cubic foot units declined at the rate of $24 per year compared to $24 for the 19 cubic feet or greater units. In other words, while the prices of top freezer refrigerators declined overall over 40 years, there was some take back in the form of the purchase of larger units from 1989 to 2012

with an attendant higher price. There is no evidence that standards resulted in changes in prices for top freezer refrigerators other than some slight decreases in prices just before standards changed, probably due to manufacturers moving stock that did not meet the new standards, and in some instances an increase for a year to two after standards were imposed, probably due to the opportunity to raise prices while stocks were low, after which they resumed their downward trend.

In the *Consumer Reports* data, the sizes of Side-by-Side refrigerators began to increase after 1993. There were basically two size classes, 19-21 cubic foot units and 23-25 cubic foot units (Figure 3). When size was taken into account, the average cost of the larger units declined by about $31 per cubic foot annually and the smaller units by $29 per cubic foot.(Figure 3). However from 1990 on, the price of the larger Side-by-Side units were an average $300 dollars higher than the 19-21 cubic foot models. Clearly, some portion of the difference was due to the larger size but there may also have been other value added features that contributed to the price differential.

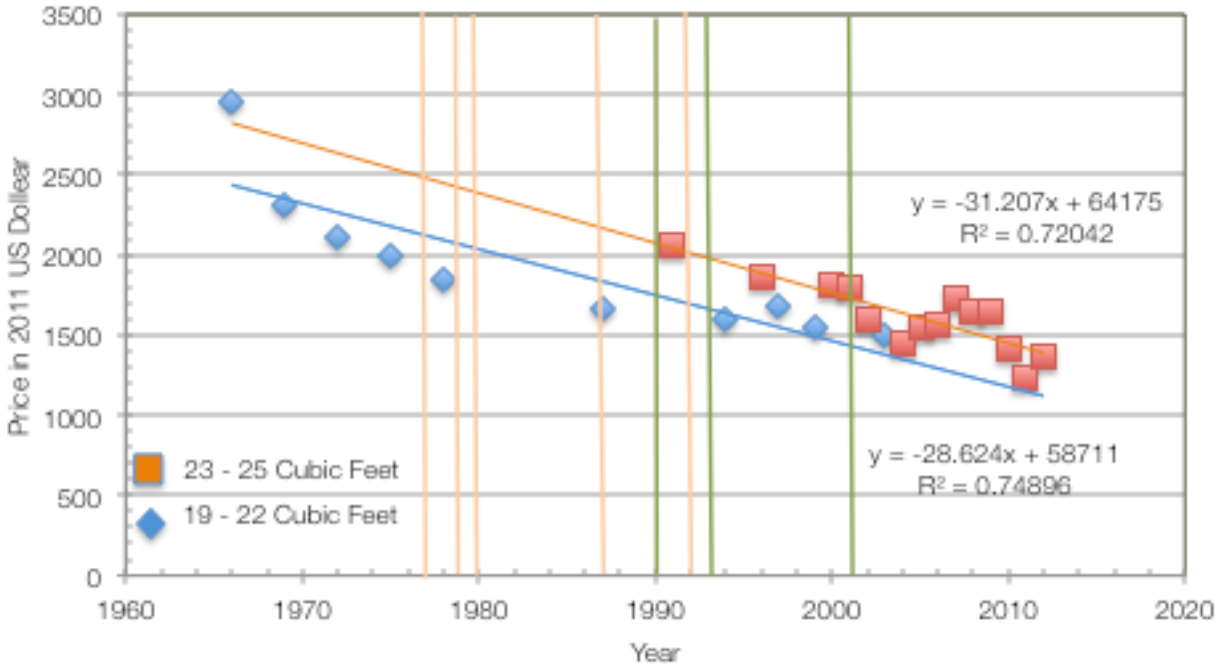

Figure 3 Prices of Side-by-Side Refrigerators by Size Category of Units

The Reliability of Refrigerators

Consumer Reports conducts an annual appliance reliability survey. The survey asks respondents who purchased an appliance five years (or a longer interval) previously whether they have had the unit repaired in the intervening years. The percent of units having had repairs by brand and style is reported annually.

Figure 4 shows the percent of repairs for the four brands of Top Freezer Automatic Refrigerators with no icemaker. In the 1975 to 1985 interval the percentage of repairs ranged from 14 to 22 percent. The percentage of repairs declined to between four and seven percent in the 1998 to 2002 interval and then remained there. Over the years, the Whirlpool products typically had better reliability but other brands had reasonable repair records as well. The intervals were chosen so that they bracket standards years. In looking at the data, the repair rates have been stable in the periods following the 1993 and 2001 standards. Frigidaire was an exception and had a three percent increase in repairs in the interval between 1993 and 1998 but the rate declined after that. Whirlpool seems to have had an increase in

repairs in the interval starting in 2005, which is well after the 2001 standard. That is likely attributable to other technology changes, perhaps the introduction of more sensors and electronic controls.

Figure 5 shows the percentage of repairs by selected intervals for three styles of Whirlpool refrigerators, a Top Freezer Automatic with no icemaker, a top freezer with an icemaker, and Side-by-Side Automatic with an icemaker.

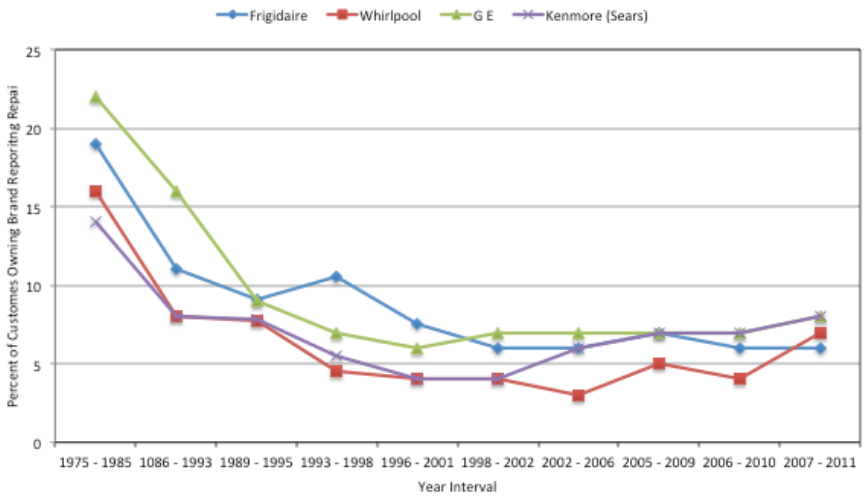

Figure 4 Percent of Repairs to Top Freezer Automatics by Brand in the Interval

The percentage of repairs has declined over the years. However, the three time series do show some periods of increase. As noted previously the reliability of the TFA without the icemaker declined from eight percent in the 1986-1993 interval to three percent in the 2002-2006 interval and then increased again to about seven percent. The TFA model with ice maker declined from about 16 percent in the 1986-1993 interval and then leveled off to between seven and eight percent after the 1995-2001 interval. The SS-A model declined from about 22 percent in the 1986-1993 interval to around 8 percent in the 2001-2006 interval then increased to around 14 percent for the intervals after 2001.

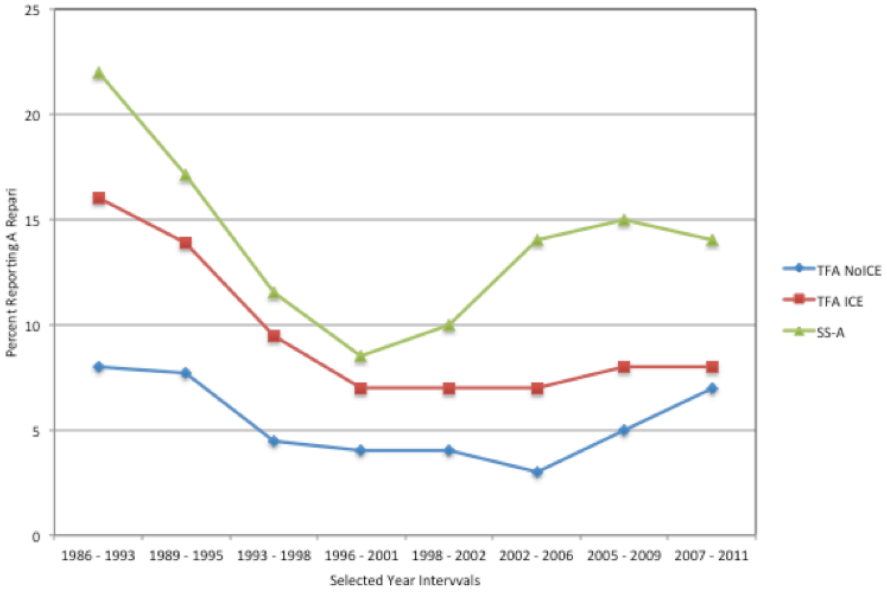

Figure 5 Repair Record for Three Styles of Whirlpool Refrigerators

This graph shows that reliability has been improving with time for these models and in the case of the Side-by-Side models quite dramatically. Secondly, the icemaker appears to account for many of the reliability issues. Note the relatively consistent differences in percentage of repairs between the icemaker and non-icemaker models. Thirdly, the Side-by-Side models show a percentage increase in repairs after the 2002-2006 interval. There are several potential explanations. This is the point at which the larger Side-by-Side units were starting to be sold. This may also be the point where the increased use of sensors, controls, channeling of air flow, and other new features were added increasing repairs. Whether the technological changes were driven by the standards or the demands for the large units is unclear. However, overall there is little evidence that the standards resulted in decreases in reliability. The overall trend has been for greater reliability

Shifts in Energy Consumption

Figure 6 shows the average annual energy consumption for all refrigerators and for four styles of refrigerators from 1972 through 2011 based on average annual shipment weighted data reported by Association of Home Appliance Manufacturers (AHAM). As noted above, the energy consumption of refrigerators began to decline after 1972. The downward trend continued after the first energy efficiency standard (California 1977) and the second Oil Embargo of 1977-78 until 1981 following the 1980 revised California standard. The decline moderated some until the impact of the revised 1987 California standard caused a drop in total usage in 1987 that continued until the advent of the 1990 U. S. standard. Following 1990, standard usage continued to slowly decline until a more precipitous drop occurred with the advent of the 1993 U.S. standard. After 1993, usage increased very slowly as the average size of refrigerators increased and with the shift to styles such as Side-by-Side Automatic that have higher usage.

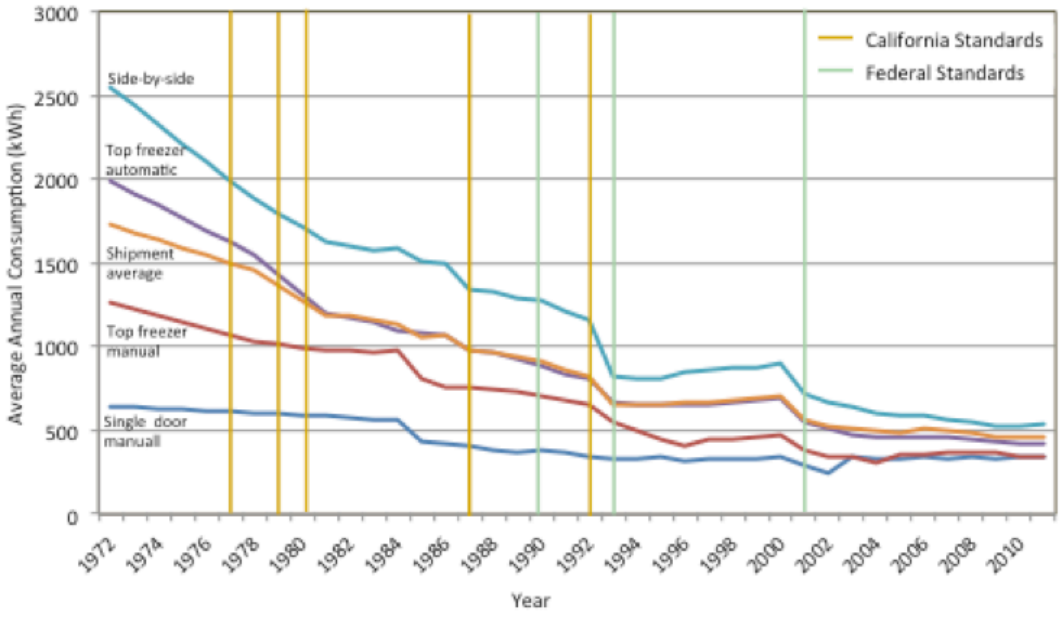

Figure 6 Average Consumption of All Refrigerator Units Shipped and Consumption by Four Types by Year Based on AHAM Data with Standards Effective Dates

The slow increase continued until the advent of the 2001 standard that resulted in a decline in average usage. Usage stabilized from 2004 through 2008 followed by a small decline in 2009 and 2010. The decline represents increased sales of Energy Star units 20% more efficient than the 2001 Federal standard. The 2014 standard is only 10% less than 2001 standard. If past experience is any guide to the

future, usage should continue to slowly decline until a more pronounced drop in average usage in 2014 when the full impact of the 2014 standard comes into effect. The shift in the definition that included mini refrigerators in the same category as single door models is clearly seen in 1984.

Energy Savings

Cumulative savings for customers were estimated by refrigerator style based on the following assumptions and procedures.

- The first life of a refrigerator is 14 years.
- The average consumption of the particular style of refrigerator was estimated for the years immediately preceding the year of a standard.
- The savings were estimated by subtracting the energy consumption for the year in question from the average consumption for the particular style in the years preceding the standard. For example, the savings for a 2001 refrigerator was the average consumption for the years 1993 to 2000 less the consumption of a refrigerator manufactured in 2001. For 2002, the national savings would be the average consumption for the years 1993 to 2000 less the consumption for 2002 times the number of units of that style shipped in that year.
- This level of savings is assumed to be maintained over 14 years after which it is assumed that the refrigerator is no longer in use. This actually reduces the savings because many refrigerators continue to operate well beyond 14 years.
- The units shipped for years beyond 2011 were assumed to be the same as those in 2011.

Figure 7 presents the annual estimated savings cumulated from standards for four styles of refrigerators in GWh. The estimated cumulative annual savings reached approximately 28,000 GWh in 2011. Two styles, the Side-by-Side units and the Top Freezer Automatics, account for most of the savings.

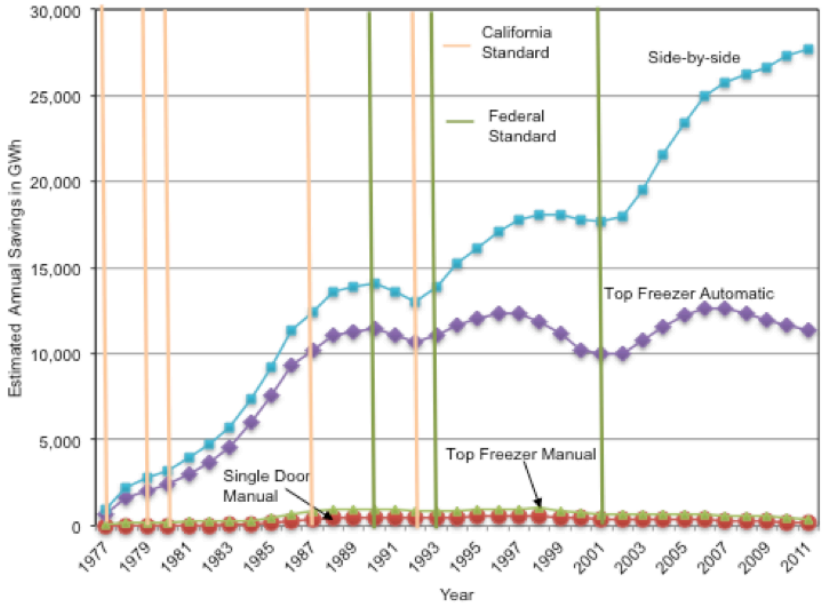

Figure 7 Annual Estimated Savings in GWh Resulting from Standards

From 1977 to 2005 the largest amount of savings was from the TFA models. In 2006 the savings from Side-by-Sides exceeded those of TFAs both because of the larger savings per unit and because of the increasing number of units shipped.

Through 2009, there were 615 coal fired generating units with an average size of 546 MW in operation. Between 1990 and 2009 the capacity of the coal fleet remained virtually unchanged. Between 2003 and 2007 the capacity factor was around 73 percent dropping to 64 percent in 2009. Using these data and assuming that line losses are about 7 percent, the average 546 MW generating unit produces 2,847 GWh of usable electricity annually. Based on that, the standards prevented the need for approximately 9.75 546 MW coal plants in 2009 (Sourcewatch).

While the preceding analysis addresses overall total annual savings for the country as a whole, individual consumers benefit as well. Figure 8 shows the first life savings accruing to householders in the year they purchased.

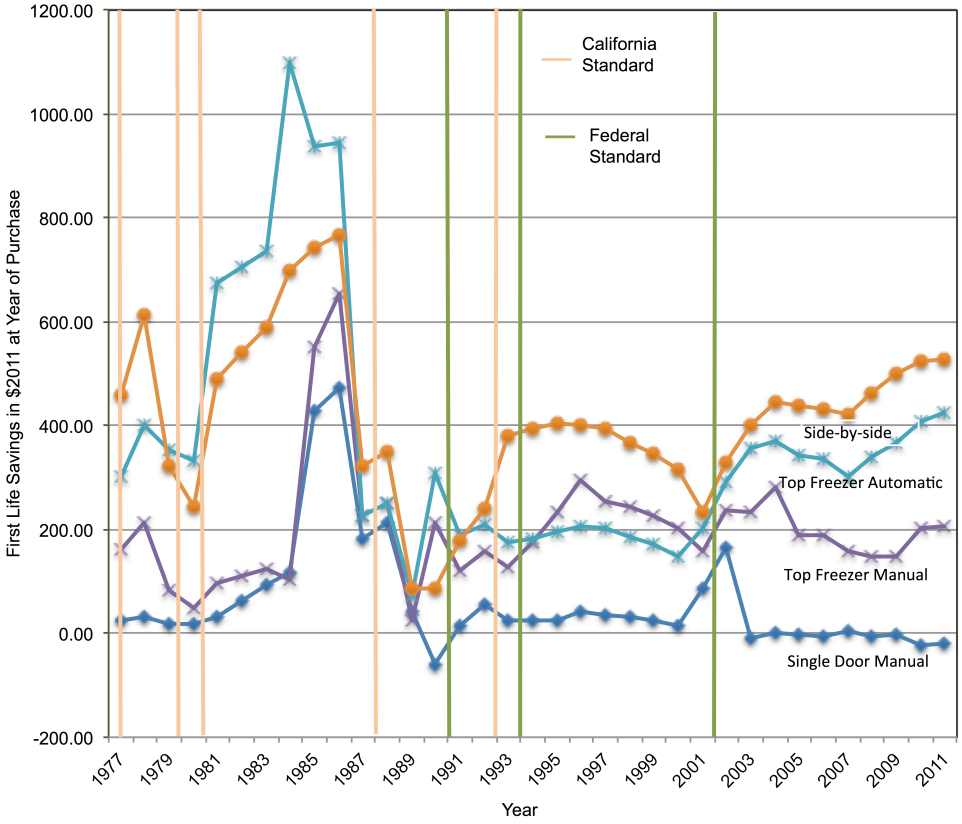

Figure 8 Household First Life Savings in $2011 at Year of Purchase

The data show that savings vary by style. Some of the largest dollar savings accrued between 1977 and 1987. Single Door Manual machines produce few dollar savings. Top Freezer Manual savings hover around $200 for the first life of a refrigerator for the period from 1987 to 2011. The savings for Top Freezer Automatics were about the same, $200, between 1990 and 2001 and then increased from $200 to slightly more than $400 in 2011. The savings for Side-by-Side units increased from about $85 in 1989 to about $380 in 1993 when the standard kicked in and hovered there until about 1997 when the savings declined to about $233, which lasted until 2001 when savings again increased to about $525 in 2011. This latter pattern shows the effect of the 1993 standard, the take back effect of households purchasing large Side-by-Side units, and the effect of the standard taking hold after 2001 as well as continuing innovation.

Summary and Conclusions

This paper addresses the effects of refrigerator appliance standards on refrigerator prices, reliability, and energy consumption. At one time or another, opponents of standards have argued that standards:

- Represent a burden to households because of increased unit costs
- Fail to produce savings that offset costs
- Produce a take back effect by encouraging the purchase of larger or more energy intensive units with more features
- Push the technological envelope to the limit
- Suppress sales
- Result in less reliable units
- Result in units with shorter lives

This detailed analysis finds little support for any of these effects.

Over time, the size of refrigerators has increased. This has been true of Top Freezer Automatics and Side-by-Side units. The increases in size are a result of increases in the size of freezer units. The demand for larger units reflects a host of trends in distance from food retailers, increased use of prepared foods, warehouse shopping, larger volume dwellings, and other factors.

Since 1960, the prices of refrigerators in $2011 have decreased an average of $18 to $30 per year depending on the size and style of the units. In a few instances slight increases in prices were observed for a year or two when standards changed, but the overall decline picked up and continued immediately thereafter.

The reliability of refrigerators has improved over time as measured by the percentage of units being serviced during an initial five-year interval. The data suggest that icemakers are a source of reliability problems and that the increased use of icemakers may be a source of the concern about the reliability of refrigerators over all.

Since 1993, the overall estimated energy savings from standards has moved from 14,000 GWh annually to more than 28,000 GWh annually in 2011. The savings have been driven by changes in efficiency for Top Freezer Automatics and Side-by-Side units and the increased purchase of Side-by-Side units with their attendant larger savings. The 28,000 GWh represents the output of more than nine average size coal generating units.

In addition to the declining real cost of refrigerators, purchasers benefit from annual energy savings. Purchasers of Side-by-Side units have benefitted the most but purchasers of Top Freezer Automatics are not far behind. Since 2001, purchasers of Side-by-Side units have seen an increase in first lifetime savings from $200 to $585. The increase for purchasers of Top Freezer Automatics has been from $200 to slightly more than $400.

Overall, we conclude that codes and standards have been highly beneficial to society in general and to households purchasing new units.

References

Appliance Standards Awareness Project, http://www.appliance-standards.org/sites/default/files/State_standards_status_gridNovember2010update.pdf

Association of Home Appliance Manufacturers, various reports

Consumer Reports, various issues since 1970.

EIAa, http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0810, last viewed May 9, 2013.

EIAb, http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb1501, last viewed May 9, 2013.

Hoffman, Andrew J. “Climate Science as Culture War.” Stanford Social Innovation Review. Fall 2012. Found at: <http://www.ssireview.org/articles/entry/climate_science_as_culture_war> Last viewed May 6, 2013.

Ledbetter, Marc, Jonathan Norling, Sandi Edgemon, Graham Parker, and J. William Currie. 1999. U.S. Energy – Efficient Technology Procurement Projects: Evaluation and Lessons Learned. PNNL-12118. Richland, Washington: Pacific Northwest National Laboratory.

Sourcewatch, http://www.sourcewatch.org/index.php?title=Existing_U.S._Coal_Plants, last viewed My 10, 2013.