Thinking Outside the Refrigerator: Shutting Down Power Plants with NAECA?

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ABSTRACT

Refrigerator energy efficiency standards and derivative programs such as product rebates, early replacement incentives, and the ENERGY STAR label are credited with dramatically increasing the efficiency of new refrigerators over the past few decades. This improvement has contributed to a reduction in total energy consumption of US domestic refrigerators relative to the peak in the mid-1980s. However, per household, US refrigerators still consume more energy than in any other country, and nearly three times as much as when refrigerators first achieved 'saturation' in the US. This paper distinguishes two conceptual frameworks in which refrigerators circulate: one focused on technical—product-level—efficiency improvements, the other on averting global climate change through large absolute reductions in energy consumption. This paper argues that success in the first realm does not guarantee success in the second.

Technical insights gained in the course of eighty years of refrigerator design have not managed to offset the increased overall energy demand due to growth in the number of households. What makes absolute reductions difficult is the compatibility of energy efficiency standards and programs with continuing growth in refrigerator size, in the number of refrigerators per household, and in their average level of energy-consuming features. Together these three non-demographic trends make up about 75% of the nearly five-fold increase in total refrigerator energy consumption since the late 1950s. Without recognizing and reversing the growth in this portion, reducing GHG emissions from refrigerators in line with IPCC goals will not be possible.

Introduction

In this paper I explore how changes in refrigerator energy efficiency have influenced total refrigerator energy consumption. I begin with a short historical sketch of refrigerator energy consumption and the parameters that affect it. In part 2, I examine in greater detail how refrigerators came to use so much energy in the 1960s and '70s. In part 3, I discuss a model that quantifies total refrigerator energy *savings* from energy efficiency standards, and I propose an alternative approach which relies on differentiating economic, technical, and demographic drivers of refrigerator energy *consumption*. In this discussion I pay particular attention to how energy efficiency policies and accounting practices have intersected with efforts to curb CO_2 emissions implicated in global warming.

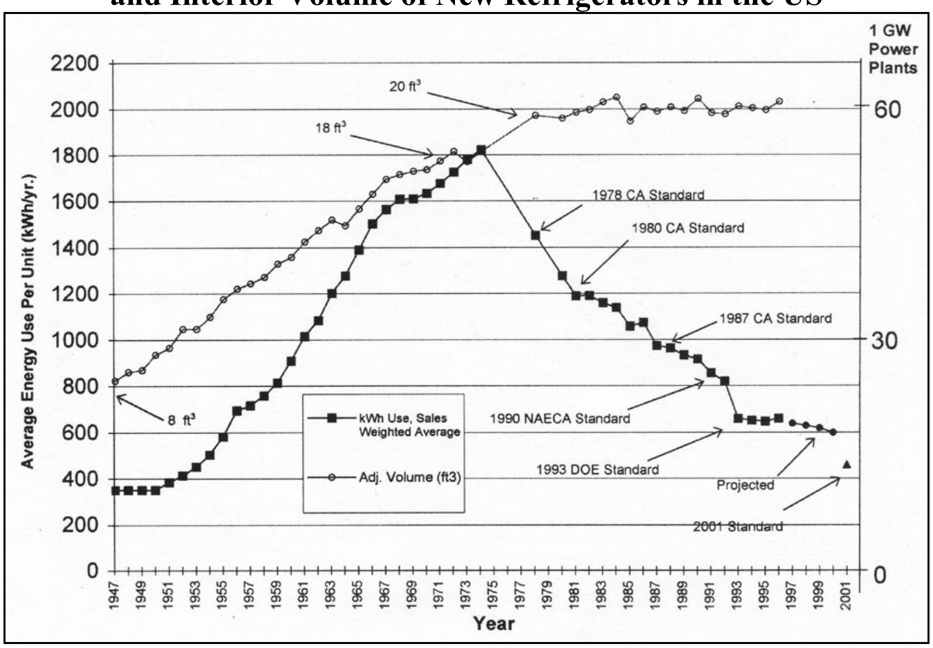
Energy consumption of domestic refrigerators in the US has fluctuated widely since mechanical refrigerators were first introduced in the 1920s. By the early 1940s the unit energy consumption (UEC) of the average new refrigerator had dropped to an all-time low,[1] while the

[1] If Consumer Reports' tests of pre-World War II refrigerators can be taken as representative of the field of refrigerators, then average UEC, as tested in June of 1941, was 264 kWh/yr. Adjusting this to match the Association of Home Appliance Manufacturers (AHAM)'s test procedures developed much later (see fn6) yields an average value of 350 kWh/yr. The average interior volume of the refrigerators tested in 1941 was 6.3 cu ft.

average energy efficiency of these prewar refrigerators was approximately 6 W/cu ft, a ratio not achieved again until the early 1990s. In the three decades following World War II, per-unit refrigerator energy consumption of new models increased dramatically, while average energy efficiency declined. Beginning in the mid-1970s, when the Energy Crisis focused attention on the rapid growth in per unit- and nation-wide energy consumption of refrigerators, research by various groups explored how the energy performance of new refrigerators might be improved (Berman et al. 1976; Center for Policy Alternatives 1974; Stanford Research Institute 1972).

In the wake of this concern, and the research it produced, legislation was introduced at the state and federal levels calling for energy labels, test procedures and appliance efficiency targets (US Congress 1975). With considerable delay the last of these objectives was codified in the *National Appliance Energy Conservation Act* (NAECA) (US Congress 1987). NAECA also specified a schedule for updating the initial requirements through rulemakings conducted by DOE. From the outset these regulations targeted refrigerators ahead of other appliances. Efforts on the part of manufacturers and regulators to improve the energy efficiency of new refrigerators over the past three decades exemplify a new approach to regulation and are celebrated as the quintessential success story of recent energy policy (Geller & Goldstein 1998).

Figure 1. Historic Changes in Average Per-Unit Energy Use and Interior Volume of New Refrigerators in the US

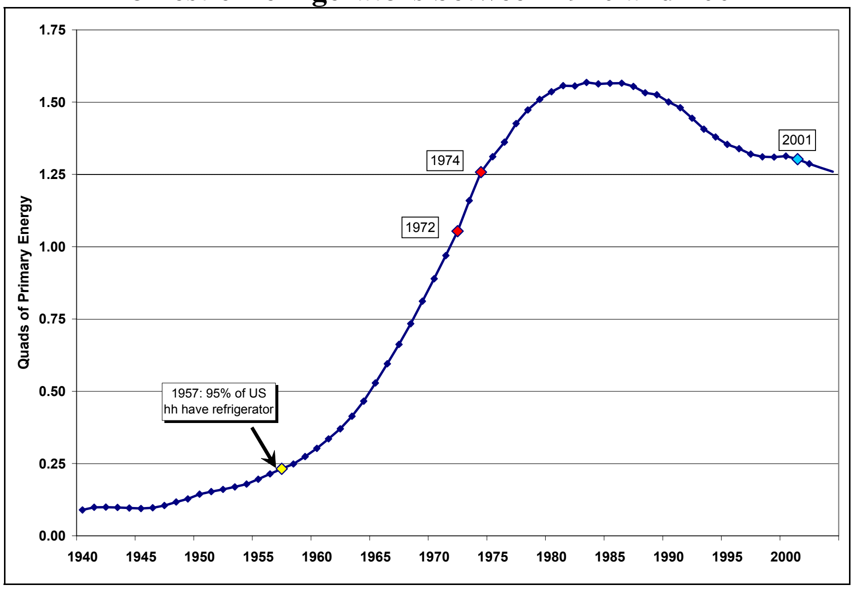


Source: Rosenfeld 1999

Figure 1 reproduces the most common representation of the impetus for and results of US refrigerator energy efficiency policies. During the 1960s average new refrigerator UEC rose sharply, followed by a comparably steep decline over the past thirty years. One way the benefits of energy efficiency are frequently quantified is in terms of the number of power plants that, conceptually, can be shut down or that will not need to be built because the energy saved is equivalent to what the plants would have produced (Rosenfeld 1999; Turiel & Levine 1989). The right-hand scale in Figure 1 indicates this approach.

Although new refrigerators sold in the US in 2001 consumed an average of 565 kWh/yr, or roughly one-third of the 1972 average (AHAM 1996), Figure 2 reveals that the total primary energy dedicated to ‘standard-size’ US refrigerators is higher today than in 1974.[2] This paper seeks to illuminate why the representations in Figures 1 and 2 differ and asks what implications this difference has for relying on energy efficiency to reduce greenhouse gas emissions.

Figure 2. Total Primary Energy Attributed to all US Domestic Refrigerators between 1940 and 2001



Source: Chan 1999, with Modifications by the Author

To improve the energy efficiency of a refrigerator it is necessary to reduce the ratio of *Watts to cu ft*.[3] All else being equal, this change can be expected to result in a reduction in the amount of energy consumed by the refrigerator, as measured in *kWh per year*. However, all else has not remained equal. In the case of refrigerators all relevant parameters (average size, features, energy efficiency) have changed so much over the past fifty years that recent energy efficiency improvements cannot be viewed unqualifiedly as synonymous with, or resulting in, reductions in energy consumption.

Energy efficiency improvements (W/cu ft), which federal policies have pursued for many appliances, including refrigerators, can register as reductions in energy consumption (kWh/year) at three levels—the product; the household; or the nation. Various trends are found to work against achieving each of these. To reduce energy consumption of refrigerators at each level, the sum of the forces acting to reduce consumption must outweigh those that cause it to increase. Besides examining these trends, this paper seeks to identify a baseline against which to measure progress. Although 1972, 1974, and even 1990 are used as baselines for purposes of charting progress in refrigerator energy efficiency as well as energy consumption, I will suggest reasons why an earlier date may be more appropriate.

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[2] Although in the original statute (US DOE 1988) the target was set at 450 kWh/yr for an 18 cu ft Top-Freezer—a proxy for the average model at the time—this figure was later revised upward to 495 kWh/yr. Yet for 2001 AHAM reports the sales-weighted mean as 565 kWh/yr. Because AHAM no longer breaks out this average by class or size of refrigerator it is difficult to determine the extent to which the higher UEC number may be due to the shift toward Side-by-Side models which are permitted to consume more energy per cubic foot than are Top-Freezers.

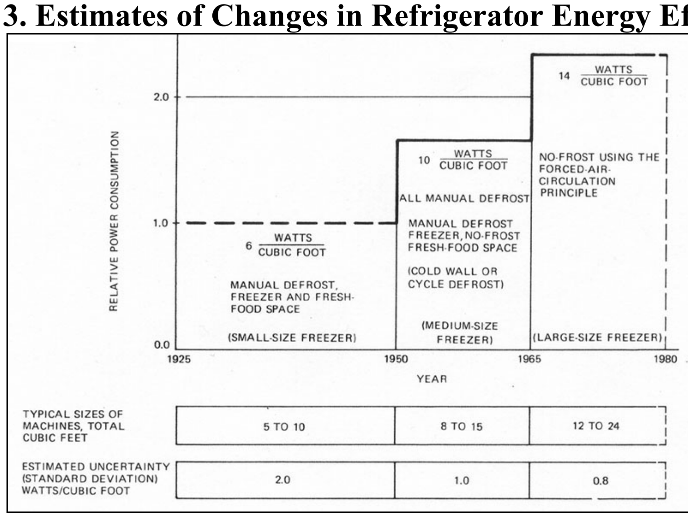
[3] “Energy efficiency,” as used in this paper, refers to the amount of electrical energy consumed per unit volume of a domestic refrigerator, e.g., W/cu ft or kWh/cu ft-year. I follow the usage in the 1974 CPA report, cited above, which places volume or service in the denominator.

Reconstructing Refrigerator In-Efficiency 1960-1975

This section seeks to explain the dramatic increase in refrigerator energy consumption between 1960 and '75 in light of the fact that by the late 1950s nearly all US households were already equipped with a refrigerator (Figure 2). During this period average new refrigerator UEC rose sharply, from about 700 kWh/yr to as much as 1,800 kWh/yr, while national aggregate refrigerator energy consumption increased five-fold.

Figure 3 identifies three phases over which refrigerator energy efficiency decreased.[4] The authors of the report from which Figure 3 is taken suggest that much of the increase in new refrigerator energy consumption is due to *larger freezer compartments* and the adoption of *auto-defrost*, though they also point out that the relationship between refrigerator *size* and efficiency is expected to be the reverse (CPA 1974). Adding energy-using features to a refrigerator, such as auto defrost heaters and fans, will increase the amount of energy consumed by the appliance. This correlation is opposed by a basic physical relationship, that a larger refrigerator will use less energy *per cubic foot*. Figure 3 indicates that both size and features increased over this period. The question is why the increase due to added features was so much greater than the decrease per cubic foot (expected) from growth in volume. (CPA 1974).

Figure 3. Estimates of Changes in Refrigerator Energy Efficiency



Source: Center for Policy Alternatives 1974

To establish a time series of refrigerator energy efficiency I extend backwards AHAM's calculations of average new refrigerator UEC for a given model year beginning in the early 1970s. Figure 3 indicates the overall trend, but does not permit a precise calculation as it does not separate changes in features from increases in interior volume. To perform such a calculation I rely on Consumer Reports' historic record of testing refrigerators, and adjust their findings to match the AHAM/DOE test procedure.

The following discussion attempts to trace changes in energy efficiency by separating out changes in freezer compartment size and defrost method. To do this I estimate declining energy efficiency of the class of refrigerator the NAECA standards are organized around: Top-Freezer

[4] Unfortunately the notation used in this study is potentially confusing, in that their measure of energy efficiency—termed "relative energy consumption"—is measured in Watts/cubic foot. A *decline* in energy efficiency thus correlates with a *rise* in this ratio. Notwithstanding this, I have adhered to their notation, along with the related 'kWh/cu ft-year', to facilitate comparisons with the conventional measure of absolute consumption (kWh/year).

auto-defrost models. I apply the NAECA test criteria and formulas to an early auto-defrost model and compare the results to the first statistics published by AHAM in 1972.[5]

Consumer Reports first tested a refrigerator offering automatic defrost for both the refrigerator and the freezer compartments in August of 1957. I use this refrigerator, an 11.5 cu ft 2-door Top-Freezer made by Westinghouse, not as representative of all auto-defrost refrigerators sold in 1957, but as an early example of a 'true' auto-defrost top-freezer against which to compare later developments of this same configuration (Consumers Union 1957). The UEC of this model, as tested by Consumer Reports, was 620 kWh/yr. I adjusted this figure upward by 220 kWh for comparative purposes, using coefficients derived in (Meier et al. 1993; NEMA 1937).[6] Calculating the adjusted volume (AV) using the NAECA formula [AV = refrigerator volume + 1.63 * freezer volume] this refrigerator's energy efficiency is calculated to be[7]:

$$839kWh / yr / 12.82cuft / 8766hr / yr = 7.5W / cuft$$

Table 1. Refrigerator Energy Efficiency & Energy Consumption Trends 1957-2001

	W/cu ft TF-AD	New Fridge UEC	Quads, total	# of US Fridges in Use
1957	7.5	717	0.23	52,000,000
1972	11.7	1,726	1.25	82,000,000
1979	7.7	1,365	1.51	95,000,000
2001	2.9	565	1.30	145,000,000

Source: Chan 1999; AHAM 1996; Author's Calculations

According to AHAM, the sales-weighted average UEC for Top-Freezers in 1972 was 1,986 kWh/yr (AHAM 1996). The corresponding adjusted volume (AV) was 19.35 cu ft. Dividing these figures yields an average of 11.7W/cu ft. Despite the fifty percent increase in size of top-freezers between the Westinghouse model Consumer Reports tested in 1957 and AHAM's 1972 Top-Freezer average, the energy efficiency (Table 1, column 2) of this category of refrigerators declined by some fifty-five percent.[8] It is worth emphasizing that this trend was not limited to auto-defrost models. Consumer Reports tests reveal a significant increase in UEC for all types of refrigerator through the 1960s.

By 1979 top-freezer auto-defrost (TF-AD) models had returned to the energy efficiency level I estimated for 1957 using Consumer Reports test results. Table 1 compares these two years, 1957 and 1979, and offers additional insight into the discrepancies that can arise between the kind of energy efficiency comparison performed here (column 1), the much cited sales-weighted average new refrigerator UEC (column 2), and the overall energy demand of the refrigerator population (column 3). Having estimated declining energy efficiency during this period, I explore some of the political and economic reasons why these three parameters accelerated so markedly during the 1960s.

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[5] NAECA stipulates a different equation by which permissible UEC is calculated for each class or style of refrigerator (placement of freezer compartment and method of defrosting) and interior volume (US Congress 1987).

[6] These adjustments are based on coefficients derived from ambient temperature- and kWh- measurements taken in kitchens equipped with new refrigerators (Meier et al. 1993). To account for the difference in interior temperature between the two procedures I relied on (Consumers Union 1978; NEMA 1937) which found a 5-10% difference. Using these coefficients, the 620 kWh/yr composite UEC is split into 477 kWh/yr at 70F, and 839 kWh/yr at 90F.

[7] Adjusted Volume (AV) is a way of accounting for the extra energy consumption associated with growth in the relative size of freezer compartments.

[8] In the example above, 46% of the change in TF-AD UEC between 1957 and 1972 was due to an increase in features and size, and 54% was due to a decline in energy efficiency.

Benefits to Industry from Refrigerator Inefficiency

During this period electricity prices continued to fall and interest in designing products to use less energy evaporated (Nye 1995). A review of the appliance manufacturing trade press of the 1960s reveals that both appliance manufacturers and the electric utilities saw an advantage in jointly promoting the sale of refrigerators that used significantly more energy than earlier models. Manufacturers stood to benefit from the higher profit margins which the larger, more feature-laden, models promised, and the electric utilities were eager to build their load. According to a special insert in Electrical Merchandising Week, "The electric utilities, through EEI and NEMA, are directing their sales efforts toward the sales of refrigerator-freezers and combos in order to boost the kwh usage of refrigerators from the present 500 to the 1,300 kwh that the new boxes draw." (EM Week 1962a)

The campaigns, slogans, and pricing policies developed by the investor owned utilities, and government subsidies for expanding cheap energy services, supplied the conditions under which energy consumption, and especially electricity consumption, came to be associated with progress, abundance and the good life. The political and economic arrangements that facilitated this unprecedented growth in US energy infrastructure in the postwar decades drew from and reinforced the idea that rising energy consumption also represented an ideological victory in the Cold War. In an address to the annual convention of the EEI its Vice President argued that, "the use of electrical energy is possibly the best single index of total productivity and the well-being of a people. In terms of both output and capability America is now far ahead." (Vennard 1961).

Refrigerator sales strategies in the 1960s and 70s were inextricably tied to narratives of progress, both social and technical. Dealers and salesmen were exhorted to develop stories for selling larger, high-end products (EM Week 1972). Promotions encouraged dissatisfaction with the refrigerators people already owned. Because saturation had already been achieved, dealers relied heavily on the replacement market, which the trade press acknowledged was threatened by the fact that refrigerators didn't wear out fast enough (EM Week 1962a).

Modeling Savings from Refrigerator Energy Efficiency Standards

Figure 2 reveals the cumulative total energy consumed by US refrigerators. It is based on the most comprehensive examination of the energy history of refrigerators to date. To produce Figure 2 I extended the time series back to 1920, expanded the analysis to include more demographic information, and corrected a few small errors (AHAM 1996).[9] In 2001 the quantity of primary energy attributed to refrigerators was approximately 1.3 Quads or 125 billion kWh. For the past ten years this total has been decreasing at an average annual rate of about 1%.

Retrospective Savings Calculations

Estimates of the amount of energy *saved* due to refrigerator energy efficiency standards start from different premises. This section examines several dominant approaches. As indicated above, the units in which savings from energy efficiency standards are measured vary. Avoided power plants are an example, as are MW, GWh/year, Quads, or even 'millions of equivalent cars (Rosenfeld 1999).'

[9] The main error concerns a discrepancy between the total shipments which are for full size refrigerators, and the sales-weighted UEC which included compact refrigerators after 1984. Both sets of data are supplied by AHAM.

An early study estimated the 1990 and 1993 NAECA standards for refrigerators would save 7,000 MW by 2015 (Geller & Nadel 1994). The authors do not elaborate on their method for determining these savings, but cite figures from (McMahon et al. 1990). Three years later, these estimates were revised downward. The author anticipates 6,000 MW from the first two rounds of standards by 2015 (Geller 1997). Art Rosenfeld uses a much simpler method to determine energy savings from refrigerator standards. Taking 1974 as the base year he multiplies the sales-weighted average new refrigerator UEC in that (peak) year by 150 million refrigerators (the number expected to be operating by 2001). He then subtracts from that hypothetical (and *counterfactual*) quantity the 2001 refrigerator population multiplied by the anticipated new refrigerator UEC in 2001, using it as a proxy for the *eventual* population average (Rosenfeld 1999):

[(1,800 kWh/yr * 150e6 fridges) – (450 kWh/yr * 150e6 fridges) = 200 GWh/yr]

His calculation is based on a choice of inputs that confuses annual averages of new models with mean population values. It also omits the doubling of the refrigerator population expected between 1974 and 2015. Even accepting the "eventual savings" idea, the savings from this example should be closer to 10 GWh/yr. The equation below recalculates this using more realistic inputs (Berman et al. 1974; Chan 1999):[10]

[(1,235 kWh/yr * 87e6 fridges) – (500 kWh/yr * 195e6 fridges) = 10 GWh/yr]

McMahon et al. assume a base case against which to compare the effect of energy efficiency standards in which new refrigerator UEC declines by ¾% p.a. after 1990. Using the decay model updated by Peter Chan, they calculate the difference in energy consumption for the two cases—with and without standards (McMahon, Chan & Chaitkin 2001). The energy savings estimates of these four studies appear in Table 2. I include in the table a reference to power plant avoidance from a non-technical source to suggest how quickly the idea that we avert environmental harm by consuming more efficient products appears in the less technical literature. Meadows writes, "By buying efficient refrigerators, Americans have already cut electricity use enough to avoid building eighty coal-fired power plants (Meadows 1991)."

Table 2. Annual Energy Savings Estimates from Refrigerator Standards, Expected in 2015

Source	peak MW	GWh	Quads	Power Plants	Relevant Stds.
Meadows 1991				*80*	--
Geller & Nadel 1994	7,500	50		10	1990, '93
Geller 1997	6,000	40		9	1990, '93
Rosenfeld 1999		200 (10)		40 (2)	1990, '93, '01
McMahon at al. 2001		62	0.674	12	1990, '93, '01

Source: see Column 1 & Author's Calculations

An Alternate Approach: Accounting for Refrigerator Energy *Consumption*

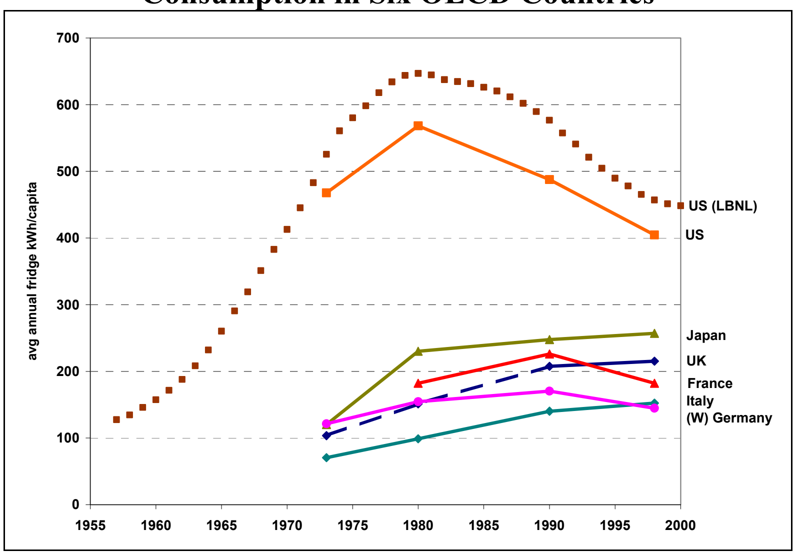
These calculations, which use 1990 or 1974 as a baseline, and suggest that by 2015 refrigerator efficiency standards are expected to save an amount of energy equivalent to the output of as many as ten or twelve power plants, are important in demonstrating the cost effectiveness of this regulatory approach. The prevailing approach to tallying savings from

[10] The number of refrigerators *in use* in 1974 is estimated at 87 million and the population average (rather than average new refrigerator UEC in that year) was estimated to be 1,235 kWh/yr. By 2015 the population is estimated to be almost 200 million refrigerators. I assume the population average UEC in 2015 to be 500 kWh/yr.

refrigerator energy efficiency, as well as the choice of a base year at or beyond the peak new refrigerator UEC, is retrospective—that is, both compare two scenarios whose point of divergence lies in the past.

These calculations, however, are less helpful when it comes to demonstrating refrigerator energy efficiency's contributions to slowing or averting global warming. In this realm a different method of accounting prevails, one which stipulates a reduction goal. All commonly used measures of refrigerator energy consumption, whether per cubic foot (kWh/cu ft-year), per refrigerator (kWh/yr), or for the national population as a whole (Quads/yr), have been declining since the mid-1980s. This decline is the result of the imposition of a series of energy efficiency standards in the 1990s, as I've indicated, but it also reflects a much broader, less easily quantified, reversal of the anomalous developments in refrigerator energy efficiency and consumption prior to 1975. Figure 4 compares historic *per capita* refrigerator energy consumption between the US and several European countries and Japan, revealing just how unusual the US experience during this period was in the history of refrigeration (IEA 2004).[11]

Figure 4. Trends in per Capita Refrigerator Energy Consumption in Six OECD Countries



Source: IEA 2004; Chan 1999

In its initial formulation of the challenge posed by global warming, the Intergovernmental Panel on Climate Change "calculates with confidence that to stabilize most greenhouse gases, reductions of 50-80% in emissions are needed (IPCC 1990)." While such reductions are considered by some to be technically 'feasible,' continuing upward trends in the number, size and features of consumer products, as well as growth in the human population, all work against achieving such absolute reductions. Stipulating a reduction goal for a specific technology applies this logic to a concrete case by inverting the framing common to the analyses reviewed above; and US refrigerator history supplies a way to calibrate such a goal. Because refrigerators were historically designed to operate with minimal energy, (Nye 1995) by the late 1950s the US achieved what was considered at the time to be 'saturation' requiring only a small fraction of the

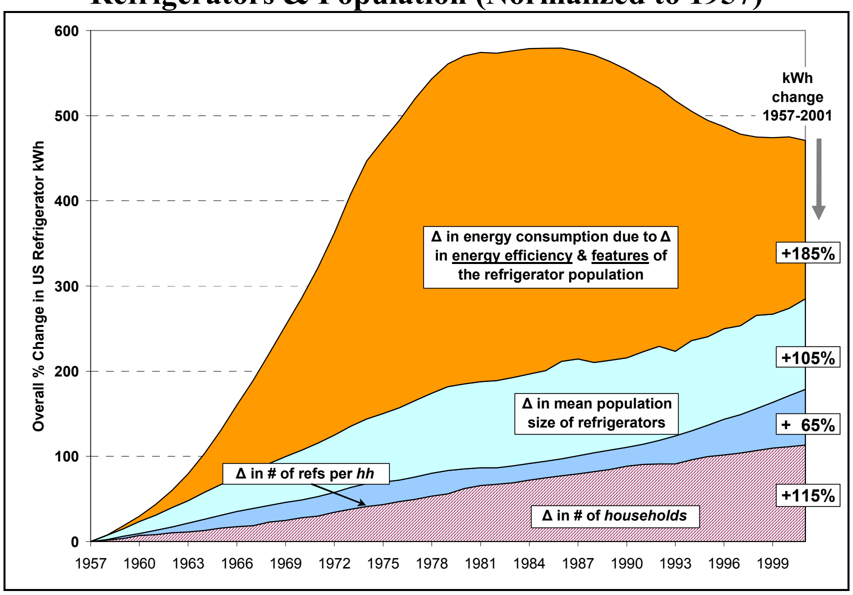
[11] These six countries (representing 94% of the IEA-11 population) experienced saturation of refrigerators in households between 70 and 190 kWh/person-year, with the US achieving saturation earliest at roughly 130 kWh/person-year. The dotted line indicates a longer time series for the US, derived from Chan 1999.

total energy consumption domestic refrigerators would demand in the decades to come. This subsequent growth in electrical load was due to four factors: (1) an initial decrease in refrigerator energy efficiency, (2) a swift adoption of auto-defrost and derivative features, (3) continued growth in size *and* number of refrigerators per average household, and (4) population growth.

All but the first of these have continued since 1972, albeit at reduced rates. The reversal of the decline in new refrigerator energy efficiency has been substantial and nearly uninterrupted for the past three decades. The combination of these four trends resulted in a peaking of total primary energy consumption attributed to domestic refrigerators in the mid 1980s at close to 1.6 Quads/yr, and a subsequent decline in total primary energy demand for refrigerators of about 15% to about 1.3 Quads in 2001 (Figure 2).

Framing refrigerator energy consumption in terms of global warming policy suggests a different approach to selecting a baseline against which to measure progress. One benchmark in this effort is of course 'saturation' of refrigerators (one per average household). By 1957 more than 95% of the roughly 49 million US households were equipped with a refrigerator, with some 44 million new refrigerators purchased just in the dozen years since 1945. Another relates to the anomalous shift in priorities on the part of US refrigerator manufacturers during the 1960s (Figure 4). I argue that this wholesale disregard of energy thrift introduced a bias into subsequent accounting in the US that needlessly constrains what might be considered feasible reductions in energy consumption. The late 1950s coincide with both of these benchmarks.

Figure 5. Change in Total U.S. Refrigerator Energy Consumption due to Changes in Refrigerators & Population (Normalized to 1957)



Source: Chan 1999; Author's Calculations

From this historical vantage point (Figure 5) the 2001 population of US domestic refrigerators is found to consume some 470% more energy than did the population of US refrigerators in 1957. I have redrawn the total primary energy curve from Figure 2 and separated out the contributions from growth in population, the number of households, and the number and size of refrigerators per household, normalized to 1957. One-quarter of the increase since 1957 is due to population growth (here represented as growth in the number of households, which increased at twice the rate of population). Another 14% can be attributed to increases in the *number* of refrigerators in use per household. Increases in the *size* of the average refrigerator are responsible for 22% of the growth,[12] with the remaining 39% due to changes in *energy efficiency* and in the *level of features* of the average refrigerator. The percentages on the right-hand side of Figure 5 represent changes in *total refrigerator energy consumption* due to each of these factors.

Identifying a baseline and a reduction goal for a specific technology or product is necessarily somewhat arbitrary. Reduction goals represent a compromise between what those identifying a goal consider reasonable or achievable and what they believe to be necessary, both of which can be expected to change over time. Reducing the total energy consumption of US domestic refrigerators to 1957 levels as proposed here will—in the absence of other changes—do little to avert global warming. As an example of how to struggle with the problem for one non-trivial category of everyday object, however, it could yield invaluable insights and serve as an exemplar, or as a catalyst for other changes.

Although energy efficiency advocates already consider the refrigerator to have achieved this status (Geller & Goldstein 1998), I have shown that the prevailing approach to calculating savings is at odds with the practice of identifying an aggregate (and absolute) reduction goal common to global warming policies. Though retrospective in its accounting of savings, refrigerator energy efficiency does not incorporate lessons from US refrigerator history prior to 1970, or address countervailing trends impinging on overall refrigerator energy consumption.

Conclusion

Energy efficiency standards and derivative programs applied to domestic refrigerators in the US have elegantly combined significant reductions in new refrigerator UEC with continuing growth in the size, number, and features of domestic refrigerators. Global warming policy, however, takes a different approach, one that tracks energy *consumed*, not energy *saved*. Refrigerator energy efficiency policies, though they are expected to yield savings on the order of perhaps ten large power plants after 25 years (taking 1990 as the base-year), are not expected to contribute savings in line with reduction goals thought necessary for stabilizing atmospheric concentrations of greenhouse gases (IPCC 1990; Rosenfeld, Kaarsberg & Romm 2000).

Total refrigerator energy consumption in the US has been declining by approximately 1% per year for the past ten years. This rate is expected to slow to zero over the next decade and a half before once again climbing, as the upward trends in Figure 5 start to eclipse the trend toward increasing the efficiency of the refrigerator population (Chan 1999). Total primary energy consumption due to refrigerators is expected to be approximately 1.1 Quads in 2020, or nearly five times the level estimated for 1957.

Given mounting concerns over energy consumption as a contributor to global warming, and the highly visible role domestic refrigerators have come to play in the policy realm where strategies for combating global warming are articulated, identifying a reduction *target* seems necessary and useful. While the 'performance' of US refrigerators in the late 1950s was arguably lower than today's, the urgency of global warming would seem to demand identifying and pursuing a goal that doesn't preclude consideration of past socio-technical configurations. The near-invisibility of smaller, less featured, refrigerators in the US today thwarts attempts to pursue the reductions suggested here. Not only are such refrigerators increasingly hard to find, few

[12] To calculate average size I converted the AV figures supplied by AHAM back into unadjusted volume using coefficients derived from the CEC's historical refrigerator database. I then extrapolate this analysis backwards before 1972, matching it to existing information, e.g., (CPA 1974).

people are able to identify them as having any relevance to the questions posed in this paper. Consumers have become habituated to increasingly large "full-size" refrigerators as the standard. However, a persistent consumer may discover the occasional inexpensive 11-12 cu ft TF refrigerator on the US market, labeled as using a mere 300+ kWh/yr. Widespread adoption of such models could conceivably facilitate an eventual return to much lower levels of energy consumption, but neither the NAECA statute, Consumer Reports, nor appliance dealers give such models any recognition or exposure.

The present compatibility of energy efficiency programs with continuing growth in refrigerator size, in the number of refrigerators per household, and in their average level of features has generated about 75% of the increase in total refrigerator energy consumption since refrigerators first achieved saturation in US households. Reversing the growth in this portion in line with IPCC goals is conceivable, but only by also paying close attention to total consumption.

Acknowledgements

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