Summary
Accelerating Super-efficient Equipment and Appliances[1] Deployment in a Globalized Market Through Multi-Country Coordination: Analysis of the SEAD Program

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Context and Rationale

The global potential for cost and energy savings through appliance efficiency is huge. Appliance penetration and electricity use is increasing rapidly, especially in developing countries. The global electricity consumption of residential refrigerators alone will double to about 1.2 TWh by 2030 and will be responsible for an additional 0.8 Gt of CO_2/year.[3] A recent report by McKinsey estimated that appliances and electronics efficiency could yield up to 0.6 Gt of annual carbon dioxide emissions reductions by 2030 at a net economic savings.

A small set of appliances -- refrigerators, air conditioners, and televisions -- will account for more than 40% of the global residential electricity consumption in 2030 (their current share of consumption is about 30%). Using commercially available technology, it is possible to cost effectively increase the efficiency of these appliances by at least 20% to 40% at a cost lower than that of new supply.[4] There are commercially available refrigerators and air conditioners that consume about 40% less electricity than the current US MEPS (for comparable sizes). In countries where MEPS are less stringent than the US, there will be even higher savings (see Figure A1 for additional information). **Preliminary analysis shows if all the refrigerators sold over the five years beginning in 2014 were about 30% more efficient, the net savings will be about $91 billion and 1.3 Gt of CO_2 over the lifetime of the efficient refrigerators. The net savings and CO_2 reductions will be about ten times higher if a similar program is implemented for all the major energy consuming appliances.**

However, high initial costs, lack of information about energy use, and limited availability hinder the market penetration of efficient products. Policies such as minimum energy performance standards (MEPS), information labels, and financial incentives have been used to accelerate the development and adoption of efficient products (Figure 1).

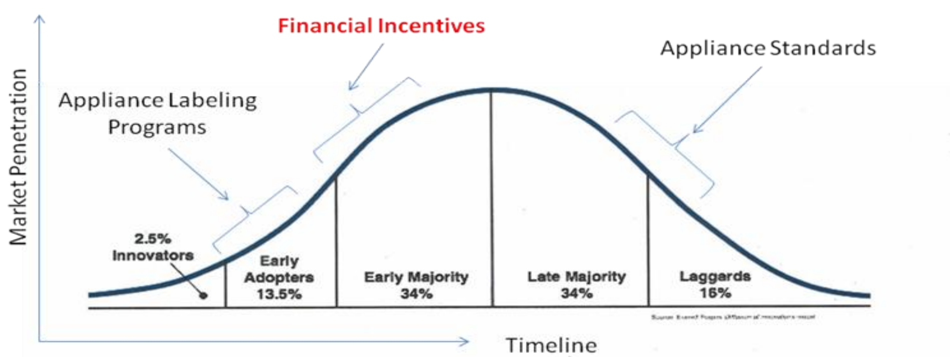

Figure 1: Accelerating Market Penetration of Super-efficient Appliances and Equipment

[1] A super-efficient device is the commercially available best technology or better in terms of energy efficiency. For refrigerators, it is a refrigerator which typically has vacuum-insulated panels and a compressor with an inverter (variable speed drive). See Panasonic super-efficient refrigerator as an example http://www.panasonic.co.uk/html/en_GB/Products/Fridge-Freezers/NR-B30FX1/Overview/2134311/index.html

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[3] Based on analysis presented in: McNeil, M. A., V. E. Letschert and S. de la Rue du Can (2008). *"Global Potential of Energy Efficiency Standards and Labeling Programs"*, LBNL for METI. Available at http://ies.lbl.gov/gedc.

[4] See for example the analysis presented in: Rosenquist, G., M. McNeil, et al. (2006). "Energy efficiency standards for equipment: Additional opportunities in the residential and commercial sectors." Energy Policy **34**(17).

Labeling programs address the barrier of lack of information. **MEPS** have proved to be an effective way to ensure a certain minimum level of energy efficiency. However, MEPS typically do not provide direct incentives for the accelerated development and adoption of super-efficient appliances. Although labels address the information barrier, they do not address the high first-cost barrier of efficient products.

Demand side management (DSM) programs implemented by electricity utilities and/or other entities around the world have used **financial incentives** (e.g. rebates) on efficient products to increase their market penetration by addressing initial cost barriers. For example, California utilities, which run one of the world's largest DSM program, spend more than $500 million/year in providing financial incentives to consumers, retailers, wholesalers, and manufacturers to produce, sell, and buy efficient products.

The experience of recent DSM programs suggests that providing incentives upstream (to the manufacturers) reduces transaction costs and the amount of financial incentives needed to increase the penetration of efficient products. Providing upstream discounts avoids paying for manufacturer and retailer mark-up and for sales taxes on the discounted portion of the incremental cost of producing efficient appliances (see Table A3 for additional information). In order to further reduce transaction costs and take advantage of greater "buying" power, many US utilities have pooled their resources and implemented joint DSM programs (See Figure 2).

Multi Country Coordination

Since appliance manufacturing is highly globalized and concentrated, with **only fifteen global manufacturers accounting for more than 70% of the total production** of "white goods" like refrigerators (see Table A1 for additional information), multi-country coordination on financial incentives, labels, and standards to accelerate the penetration of super-efficient appliances is feasible and cost effective.[5] Coordinated financial incentives programs targeted at manufacturers would enable better planning by manufacturers and thus lower manufacturing costs. Moreover, improvements in component technologies will improve the performance of most models of appliances. For example, reducing the cost of vacuum insulation will reduce consumption of all types of refrigerators, including the different sizes typical in developed and emerging economies.

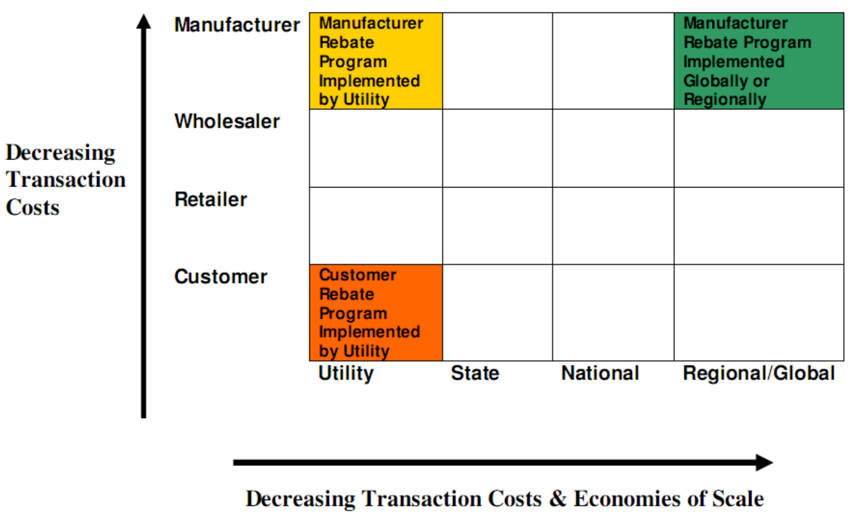

Figure 2 Upstream Implementation Decreases Transaction Costs

A Super-Efficient Refrigerator Example: We illustrate the key aspects of a global/multi-country program such as one that might be coordinated by SEAD through the example of promoting super-efficient refrigerators. Although refrigerators are sold in many different shapes and sizes and have many different features, the modifications made to improve the efficiency of refrigerators are similar. For example, improving insulation (for which vacuum insulation is one of the latest technologies) and improving the efficiency of the compressor (for which using variable speed drives is one of the latest modifications implemented) will significantly improve efficiency of most types of refrigerators (see Table A4 for various efficiency improvement options available which are common across different refrigerator models). Hence manufacturers can exploit significant economies of scale when multiple countries coordinate on promoting efficient refrigerators. The key components of this coordination are as follows.

- **Coordination on the specification of the maximum energy consumption of super-efficient refrigerators (similar to labeling programs)**

Countries can coordinate on what they label as super-efficient refrigerators by specifying the ***maximum energy consumption*** that a refrigerator can have to qualify for the super-efficient label. For example, the commercially available least energy consuming refrigerator model (which uses vacuum insulation and a variable speed compressor available in the EU) consumes about 30% less than a typical US Energy Star refrigerator and about 40% less than a typical Indian Five Star Refrigerator (for comparable size and configuration; see Figure A1 for details). Without countries developing a label that recognizes such a model of refrigerators as super-efficient, it will be difficult for manufacturers to credibly differentiate their super-efficient refrigerators and introduce the model in most countries on a large scale. If countries coordinate on defining the super-efficient label level (which will vary according to refrigerator configuration and volume), it will facilitate the introduction of commercially best available technology in more countries, increasing their production volumes and potentially reducing costs, which in turn will increase their acceptability. This coordination does not require that countries coordinate on their entire labeling program (although it could be beneficial). Even though energy consumption measurement test procedures differ across countries, countries can harmonize them or create a mapping of how the results of different test procedures compare with each other.

- **Coordination on financial incentives to accelerate the penetration of super-efficient refrigerators**

As discussed previously, labeling addresses the information barrier but does not address higher initial costs of super-efficient refrigerators. Countries can coordinate on providing financial incentives (which is one of the key aspects of utility energy efficiency programs), preferably to manufacturers (to reduce transaction costs and incentive magnitude) to address this barrier. As reductions in initial costs will increase the acceptability of super-efficient refrigerators, manufacturers can plan for much larger volumes of super-efficient refrigerators, further driving down their costs, creating a virtuous cycle of increased volumes and cost reductions. If countries with large or rapidly rising sales volumes such as the US, China, and India coordinate on providing financial incentives, manufacturers will get a strong and consistent message that will help them retool rapidly to increase the production of super-efficient refrigerators. There are various ways for countries to select manufacturers and decide the level of incentive needed. One option is to decide the level of incentive based on an estimate of the incremental cost of producing super-efficient refrigerators. This incentive could be made available to any manufacturer who meets the efficiency performance criteria.

Another option is to require the manufacturers to bid for the minimum amount of financial incentive needed per super-efficient refrigerator sold and the volume that they expect to sell. The manufacturers' bids can be stacked-up to a point where the total budget for incentives is exhausted. In this arrangement, the market discovers the level of incentive needed to produce and sell super-efficient refrigerators. This option attempts to address the concern of overpaying the manufacturers and has been previously used with success in programs such as the Poland Efficient Lighting Program. Countries could choose to use financial incentives to promote models that are more efficient than commonly purchased refrigerators and increase the level of incentives with the efficiency level where the super-efficient refrigerators are given the highest level of financial incentive.

- **Coordination on minimum energy performance standards**

Once the market penetration of super-efficient refrigerators has reached a certain level and the costs have sufficiently come down, the savings can be locked in by increasing the stringency of the MEPS to the super-efficient level (which will be the dominant technology after a few years of the labeling and financial incentives program).

Cost and Benefits: Table 1 below shows preliminary estimates of the **total potential savings** and corresponding costs and benefits of a refrigerator market transformation program in different regions of the world, assuming that the program reaches all new sales, and a rough estimate of the funds needed for financial incentives over a five year period. These estimates only provide an order of magnitude of the potential costs and benefits. Costs are overestimated since we have not assumed any decrease in incremental costs of efficient refrigerators over time. These estimates will be revised in the future.

Table 1 Cumulative Costs and Benefits of a Fully-Effective, Five-Year, Global Coordinated Incentives and Labeling Program Targeting Refrigerators (2009 US $)

	OECD	LDC	China	SAS-PAS	Other	Total
NPV of Incremental Societal Cost (ISC) ($ Billions)	8	2	9	8	8	35
NPV of Financial Incentive to Manufactures: 50% of ISC ($ Billions)	4	1	4	4	4	17
Lifetime Electricity Savings from Efficient Refrigerators Sold (TWh)	408	127	443	407	415	1800
NPV of Avoided Cost of Conventional Supply Corresponding to Lifetime Savings ($ Billions)	29	9	31	28	29	126
NPV of Net Societal Benefit ($ Billions)	21	6	22	21	21	91
Lifetime CO_2 Savings (Mt CO_2)	203	121	454	338	251	1367

Note: Incremental Societal Cost is the cost difference between an efficient and average refrigerator sold in each region. Financial incentive costs are estimated to be 50% of the ISE because consumers pay part of the incremental cost of efficient refrigerators. SAS-PAS includes countries such as India, Vietnam, Thailand, Pakistan, etc. Other includes Russia, non-OECD countries in Eastern Europe, Latin America, and the Middle East. Costs and savings are estimated for about 30% reduction in electricity consumption from the baseline. Super-efficient refrigerators can reduce consumption by 40% to 60%. We do not consider these aggressive saving targets because the corresponding cost estimates are uncertain. However, our preliminary analysis shows that the super-efficient efficiency levels can be achieved at a net negative societal cost even considering current costs (see Table A2 and Figure A2 for additional information). These costs are likely to go down in the future with economies of scale and learning.

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Appendix A: Additional Information

Table A1: Market Concentration of White Goods Manufacturers

		Revenue from Appliances Sales ($ Billion)	% of the Total Global Sales	Cumulative Percentage
1	Whirlpool	15.9	13%	13%
2	Electrolux	10.9	9%	22%
3	Haier	9.1	8%	30%
4	Bosh	9	8%	37%
5	Mastsushita	9	8%	45%
6	GE	6.5	5%	50%
7	LG	6.4	5%	56%
8	Indesit	4.1	3%	59%
9	Koc Holding	4	3%	62%
10	Toshiba	3.4	3%	65%
11	Samsung	2.2	2%	67%
12	Sharp	1.4	1%	68%
13	Gorenje	1.2	1%	69%
14	Merloni	1	1%	70%
15	Candy	0.9	1%	71%
16	Daewoo	0.9	1%	72%

Source: Freedonia Market Research

Table A2: Net Present Value (NPV) of Net Societal Gains of Refrigerator Efficiency Improvements in the US

Efficiency Level (percent less than baseline energy use)	**Top-Mount Refrigerator-Freezer***		**Bottom-Mount Refrigerator-Freezer****		**Side-by-Side Refrigerator-Freezer*****	
	3% Discount Rate *(billion 2008$)*	**7% Discount Rate** *(billion 2008$)*	**3% Discount Rate** *(billion 2008$)*	**7% Discount Rate** *(billion 2008$)*	**3% Discount Rate** *(billion 2008$)*	**7% Discount Rate** *(billion 2008$)*
10%	13.39	5.08	0.50	0.19	3.68	1.35
15%	20.16	7.60	0.73	0.27	8.52	3.11
20%	26.57	9.79	2.13	0.70	11.89	3.82
25%	31.08	11.01	1.98	0.40	14.15	3.94
30%	33.86	11.35	1.61	0.01	15.12	3.42
35%	34.26	10.57	1.43	-0.19	16.17	3.20
40%	32.78	8.75	0.60	-0.91	15.73	2.22
45%	31.53	7.18	0.40	-1.12	-	-

Note: Source- US Department of Energy (DOE) Preliminary Technical Support Document: Energy Efficiency Program for Consumer Products: Refrigerators, Refrigerator Freezers, and Freezers. November 2009 (DOE, 2009)
DOE calculated NPV as the difference between the present value of operating cost savings and the present value of increased total installed costs. The NPV results for the representative product classes are shown in as the discounted value of the net savings in dollar terms. The NPV is over a 30 year period (2015-2045)

Table A3: Benefits of Providing of Upstream Discounts

	Base Case	Consumer Rebate Case	Manufacturer Discount Case
Incremental Manufacturer Cost for 45% Reduction in Energy Consumption ($)	**165**	**165**	**165**
Manufacturer Incentive ($)	0	0	**100**
Net Incremental Manufacturer Cost ($)	165	165	65
Manufacture Mark-Up (26%)	43	43	17
Incremental Manufacturer Selling Price ($)	**208**	**208**	**82**
Retail Mark-up (17%) ($)	35	35	14
Sales Tax (7%) ($)	15	15	6
Incremental Retail Price ($)	**258**	**258**	**102**
Consumer Discount ($)	0	**100**	0
Net Incremental Consumer Price ($)	**258**	**158**	**102**
Consumer Payback (@ 13 cents/kWh tariff) (Years)	11.0	6.7	4.3

Note: Cost and mark-up information is for a top mount refrigerator freezer model with 21 cubic feet of capacity (source DOE, 2009). Incremental consumer price and consumer payback drops significantly if the discount is provided upstream to the manufacturer as upstream discounts avoid manufacturer and retailer mark-ups and sales taxes on the discounted portion of the incremental cost.

Table A4: Maximum Reductions Possible using Commercially Available Component Technologies in US Refrigerator Models

Product Class	% Lower Energy	Design Options Used									
		Brushless DC Evaporator Fan	Brushless DC Condenser Fan	Forced Convection	Larger Evaporator	Larger Condenser	Thicker Insulation	VIPs	Variable Speed Compressor	Adaptive Defrost	Variable Anti-Sweat
3	56%	✓	✓		✓	✓		✓	✓	✓	
5	53%	✓	✓		✓	✓		✓	✓	✓	✓
7	45%	✓	✓		✓	✓		✓	✓	✓	
9	55%	✓	✓	✓	✓		✓	✓	✓	✓	
10	51%				✓	✓	✓	✓	✓		
11	75%				✓	✓	✓	✓	✓		
18	52%						✓	✓	✓		

Note: Source DOE, 2009.
Different product classes indicate different refrigerator configurations. For example, product class 3 is a regular size refrigerator with top mount freezer and product class 5 is regular size refrigerator with bottom mount freezer.

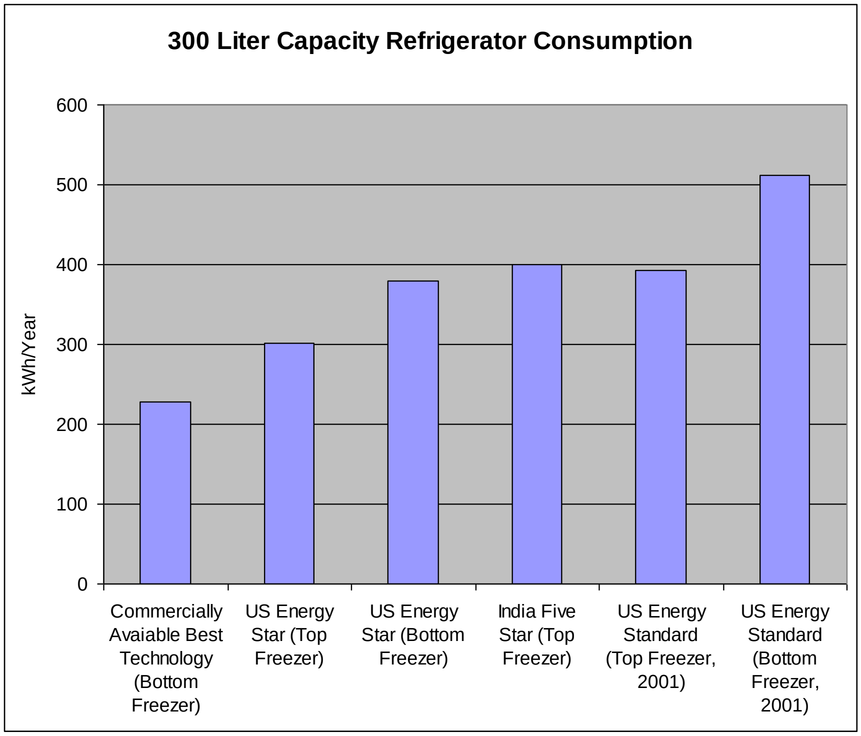

Figure A1: Comparison of Refrigerator Efficiency Levels

Note: These numbers are only indicative of the differences across various standards and labels levels as different countries use different test procedures and may explain some of the differences in the standards and labels levels. Commercially available best technology is a refrigerator which typically has vacuum insulated panels and a compressor with an inverter (variable speed drive) .See Panasonic super-efficient refrigerator as an example http://www.panasonic.co.uk/html/en_GB/Products/Fridge-Freezers/NR-B30FX1/Overview/2134311/index.html

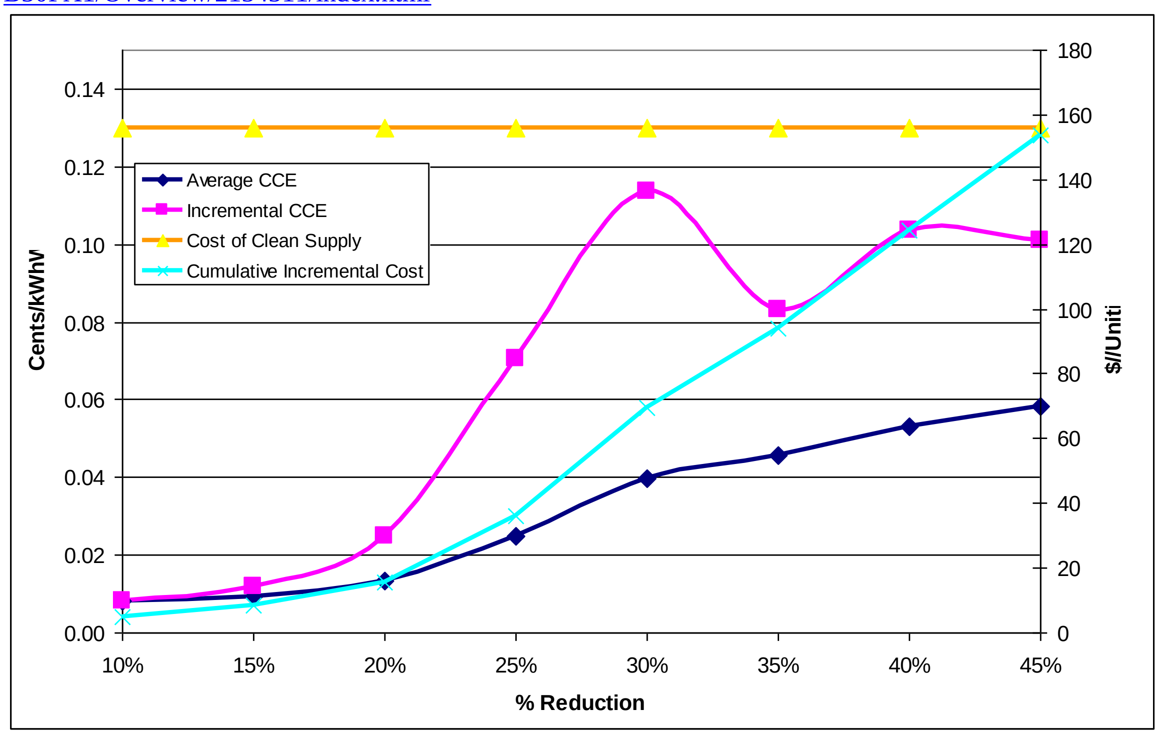

Figure A2: Incremental Cost and Cost of Conserved Electricity at Various Levels of Efficiency Improvement

Note: Estimated based on incremental manufacturer cost data presented in the DOE Technical Support Document (DOE, 2009). Estimates are for a top freezer refrigerator model (product class 3) of a 16 cubic feet of capacity. Similar results are found for other models (bottom freezer and side by side configuration models). Cost of Conserved Electricity (CCE) is estimated assuming a life of 17 years and a real discount rate of 6%. The CCE shown on left Y axis and incremental cost is shown on right Y axis. Incremental manufacturer cost data does not include manufacturer's profits (mark-ups). Average CCE for a certain level of reduction (for example, 45%) is estimated by considering cumulative incremental costs ($157 in this case) and cumulative reduction (45%). Incremental CCE is estimated by considering incremental costs and incremental savings. For example, the incremental CCE of 10 cents/kWh at the 45% level is the CCE of going from 40% reduction to 45% reduction. Cost of clean supply is the cost to supply clean electricity (includes generation transmission and distribution costs). Refrigerator savings are base-load savings hence the avoided cost of clean supply considers cost of clean base-load options such as clean coal, nuclear, and wind. Clean supply cost estimate shown is only indicative.

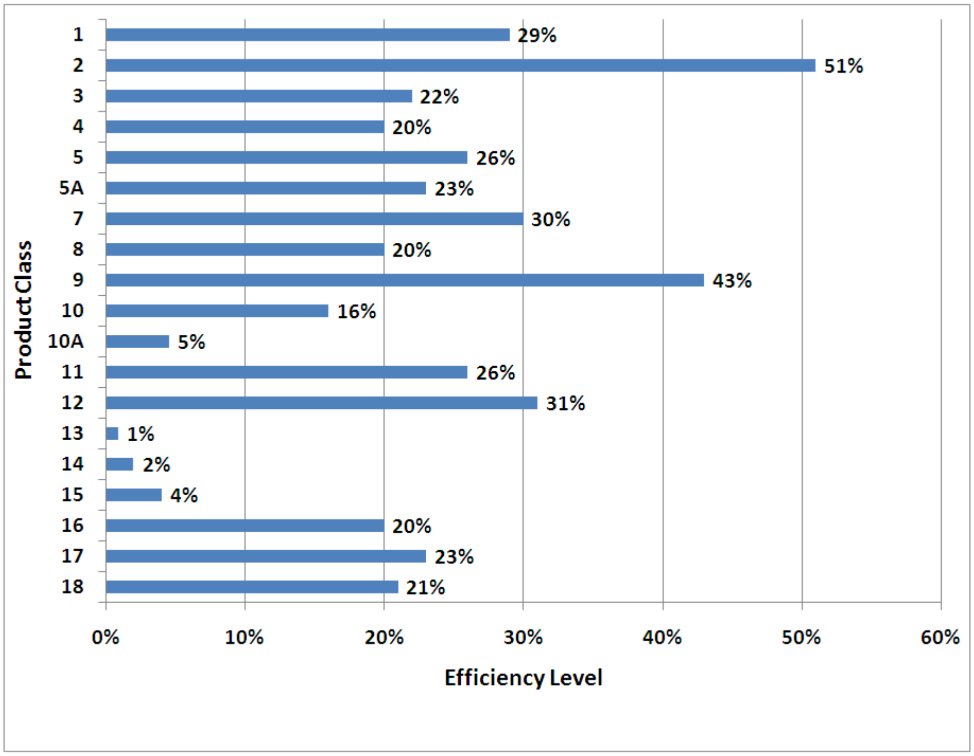

Figure A3: Most Efficient Models Avaiable in the US Markets for Different Product Classes

Note Source: DOE, 2009. As can be seen from Figure A1, A2, and A3 efficiencies of commercially avaiable best technology in the US are much lower than efficiency levels which are cost effective or maximum effciency levels possible.

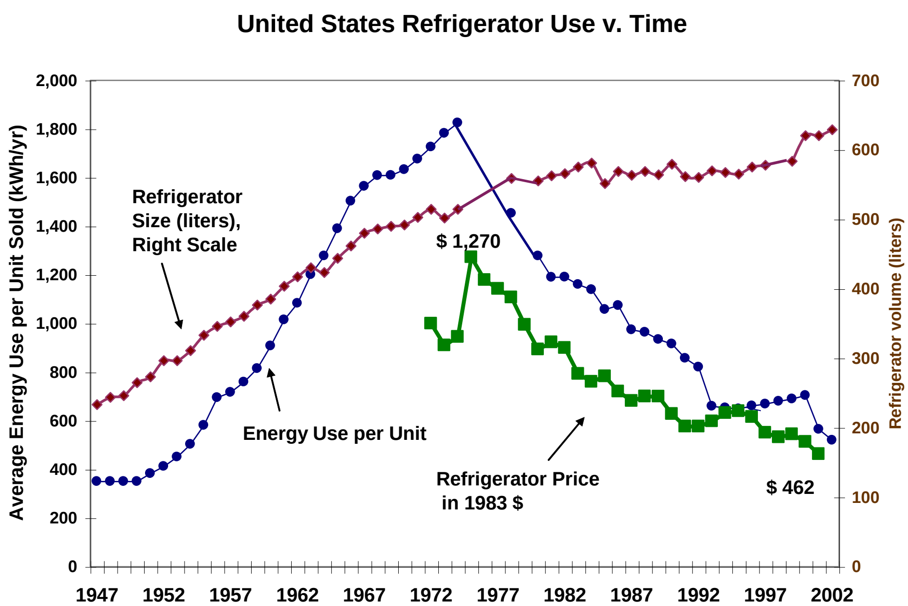

Figure A5: Refrigerator Efficiency Improvement and Price Reductions Over Time

Source: Art Rosenfeld, California Energy Commission.