ENERGY STAR Residential Refrigerators and Freezers Version 5.0 Specification Framework Document

July 11, 2011

EPA recognizes and appreciates Refrigerator and Freezer stakeholders' support of the ENERGY STAR program and your interest in helping EPA shape requirements for this product category. As such, EPA is pleased to share the attached Residential Refrigerators and Freezers Version 5.0 Specification Framework Document with stakeholders. This framework outlines EPA's reassessment of the current ENERGY STAR Refrigerator and Freezer requirements and is intended to facilitate discussion of this assessment and possible resulting modifications to these ENERGY STAR requirements. Included in this document are EPA's initial thoughts on issues such as scope of possible revisions and eligibility criteria. The Agency welcomes stakeholder comments on all topics related to this ENERGY STAR Residential Refrigerators and Freezers program specification revision, including topics not addressed in this document. Please send your comments via email to appliances@energystar.gov no later than August 10, 2011.

I. Introduction & Overview

The ENERGY STAR criteria for residential refrigerators were last revised in April 2008. At that time, the Department of Energy (DOE) set more stringent criteria for full-size refrigerators and refrigerator-freezers, requiring that products use at least 20 percent less energy than the minimum Federal standards to be eligible for ENERGY STAR. Criteria for full-size freezers and compact refrigerators, refrigerator-freezers and freezers remained at their current levels and have not been modified since January 2003.[1]

Towards the end of 2010, EPA began reviewing the ENERGY STAR Residential Refrigerators and Freezers specification to determine whether criteria changes were warranted. Consistent with the ENERGY STAR program's enhancements laid out in the 2009 EPA-DOE Memorandum of Understanding (MOU), EPA has committed to reviewing ENERGY STAR appliance specifications at a minimum of every three years or when market share reaches 35%. As of 2009, the market share of ENERGY STAR qualified refrigerators was 36%. EPA has determined that a criteria change is warranted for the following reasons:

Availability of products exceeding current ENERGY STAR levels. The efficiency of qualified models has increased in recent years. In 2010, 23% of full-size refrigerator models added to the ENERGY STAR qualified products list exceeded the current ENERGY STAR criteria by more than 5 percentage points, qualifying for the Consortium for Energy Efficiency (CEE) Tier 2 or 3 levels (i.e., at least 25% or 30% more efficient than the Federal standard, respectively). There are now refrigerators in the market that exceed the minimum standards by as much as 35%. DOE analysis, developed for the most recent updates to the residential refrigeration test procedure and minimum Federal standards, also indicates that more stringent energy efficiency levels are cost-effective and can provide consumers a payback in a reasonable time frame.

Need to more effectively designate top performers. Today, the vast majority of bottom-freezer models and most side-by-side models available are ENERGY STAR qualified. For example, through a March 2011 online survey of major retailers, EPA found that 78 to 98% of side-by-sides and 87 to 98% of bottom freezer and French door style refrigerators, both more energy-intensive configurations, were ENERGY STAR qualified. In contrast, between 36-55% of less energy-intensive top-freezer models were ENERGY STAR qualified. As a result of this, the ENERGY STAR label becomes less effective at distinguishing what are truly the most energy-efficient products.

[1] Current ENERGY STAR levels for compact refrigeration products specify products use 20% less energy than the minimum Federal standard; the ENERGY STAR criteria for full-size freezers specify products use 10% less energy use than the Federal standard.

Current structure undermines objectives. Currently, the ENERGY STAR residential refrigeration specification requires full-size refrigerators to be 20% more efficient than the applicable Federal minimum energy efficiency standard. The Federal standards, in turn, specify different energy allowances for specific configurations and features (i.e., location of freezer, type of defrost, presence of through the door ice). When this approach is used in the ENERGY STAR program, it obscures the increased energy demand associated with certain product configurations for consumers. There are a number of additional factors that, taken collectively, suggest a different approach could better serve the interests of consumers and the environment. First, as mentioned above, there are a disproportionate number of ENERGY STAR qualified models in most energy-intensive configurations (i.e., bottom-mount freezer and side-by-side). This suggests it may be more cost-effective to design those refrigerators to meet the current ENERGY STAR requirements and that strengthening the current requirements in a uniform way (e.g., from 20% less energy than the minimum standard, to 25%) across product classes may not change this trend. Secondly, configurations such as side-by-side and bottom-mount freezers have both a larger energy allowance per unit volume *and* tend to larger in size than the less energy-intensive top-freezer configuration. Combined, these factors mean that many ENERGY STAR qualified refrigerators consume more energy than non-qualified refrigerators. This reduces the program's ability to distinguish the best choices in terms of energy performance, energy costs, and environmental impact for consumers.

II. Anticipated Scope of Revisions

For Version 5.0, EPA is considering changes to the criteria for full-size refrigerators and refrigerator-freezers with automatic defrost. During its review, EPA consulted a variety of data sources on the residential refrigeration market and held some initial conversations with program stakeholders. ENERGY STAR market share for refrigerators was approximately 36% in 2009 and information EPA collected through conversations with manufacturers, retailers and other stakeholders indicates that market share increased 2010. This increase was driven, in part, by the availability of rebates through the State Energy Efficient Appliance Rebate Program (SEEARP).

ENERGY STAR market share estimates for manual and partial automatic defrost full-size refrigerators, full-size freezers and compact refrigeration products are shown in Table 1. EPA's initial review of 2010 unit shipment data indicates that market share in these product categories remains low.

Table 1. ENERGY STAR Market Share by Product Class for Select Residential Refrigeration Products

Product Category	Estimated ENERGY STAR Market Share (%)
Manual and Partial Defrost Full-Size Refrigerators	13
Full-Size Freezers	17
Compact Refrigerators	3
Compact Freezers	5

Source: DOE (2010). Technical Support Document (TSD) for Refrigerators, Freezers and Refrigerator-Freezers. September 2010.

Despite this low market share, EPA notes that standards for some of these product categories are likely to be strengthened in 2014. In a number of instances, these new levels will meet or exceed the current ENERGY STAR requirements. EPA would need to increase the ENERGY STAR levels before this time so that the ENERGY STAR label continues to serve as a mark of meaningful differentiation. Although there are few products on the market today that can achieve these efficiency levels, EPA expects more efficient models will become available in anticipation of the 2014 standard. As an alternative to strengthening the levels for compact refrigeration and full-size freezer product classes, EPA could sunset certain product categories in 2014. As discussed below, EPA is seeking comment from stakeholders on whether EPA

should revise the criteria for these product classes in this V5.0 revision and recommended timing for these revisions.

Items for Comment & Discussion:

1) EPA invites stakeholders to provide any additional market data, including information on performance of forthcoming models, which could inform this specification revision process.
2) EPA seeks feedback on whether the Agency should consider revisions to the product categories mentioned in Table 1 based on anticipated advances in the market in response to the 2014 standards. Or alternatively, whether some of these product categories should be sunset in 2014 when new standards are in place.

The ENERGY STAR residential refrigeration program does not currently cover products that are marketed as wine refrigerators or beverage centers. In the Version 5.0 specification, EPA plans to clarify the scope of the program in regards to these products to be consistent with an FAQ located on the ENERGY STAR website.[2] Some stakeholders have expressed interest to EPA in seeing the ENERGY STAR program scope expand to cover these categories, noting there is variation in the energy efficiency of such products.

Items for Comment & Discussion:

1) EPA seeks stakeholder feedback on the possibility of extending the ENERGY STAR label to wine refrigerators, beverage centers, or other such products. EPA welcomes supporting information and data for these product categories, and in particular: annual U.S. shipment data and market trends; data on the energy-use of products in the market and shipment-weighted energy use; test procedure availability; information on technologies that can be applied to improve efficiency; and the price premium associated with more efficient products.
2) EPA welcomes comment on other changes in scope that should be considered in this specification revision process.

III. Revisions to the Maximum Annual Energy Use

EPA is considering a revision to the criteria for full-size refrigerators and refrigerator-freezers with automatic defrost, with the following objectives:

(1) To better enable consumers to identify the most efficient refrigerators, irrespective of configuration;
(2) To address disproportionately high market share for certain energy-intensive configurations; and
(3) To address concerns that refrigerators with high absolute energy consumption can qualify for ENERGY STAR.

EPA is considering a new approach (Table 2) that would better differentiate refrigerators, irrespective of configuration, based on annual energy use. However, in recognition of the added consumer utility associated with through the door ice and water service, EPA plans to provide an allowance (aka "functional adder") for this feature. Scatter plots showing the current ENERGY STAR criteria levels relative to refrigerators currently on the market, are included in Appendix Tables 1 and 2, as reference tools.

EPA is considering segmenting full-size refrigerators into three size ranges; the first extending to an Adjusted Volume (AV) of 28 cubic feet (cu-ft), the second extending from 28 cu-ft AV to 33 cu-ft AV, and the third encompassing products with AV greater than 33 cu-ft. An AV of 28 cu-ft corresponds approximately to a product with total volume of 23 cu-ft. EPA has identified this break point because it believes that this is where the market transitions from a "large" refrigerator to a "very large" refrigerator. For instance, manufacturers have noted that refrigerator-freezers with total volume between 19 and 22 cu-

[2] See ENERGY STAR FAQ "Can a wine refrigerator, kegerator, or residential beverage chiller qualify for ENERGY STAR?" here: http://energystar.supportportal.com/ics/support/default.asp?deptID=23018&task=knowledge&questionID=14503

ft are considered ideal for a typical household of four. The second transition point under consideration, 33 cu-ft AV, corresponds to a total volume of about 27-28 cu-ft.

Within these size segments, maximum annual energy use limits would be expressed as a linear function of AV. A review of current refrigerator performance data suggest that the linear functions for each segment could be progressively more challenging. EPA's current intention is to continue to allow all full-size refrigerators to be eligible to earn the ENERGY STAR. EPA does have concerns in terms of how much energy-use can credibly be classified as energy efficient and good for the environment. EPA plans to factor this consideration into its proposed levels for the largest units.

Table 2. Possible Changes to the ENERGY STAR Criteria for Full Size Refrigerators and Refrigerator-Freezers

ENERGY STAR Product Class	DOE Product Class	DOE Description	Maximum Annual Energy Use (kWh/year)
Refrigerator-freezers and Refrigerators; Automatic Defrost; and No Through the Door Ice Service	3	Refrigerator-freezers—automatic defrost with top-mounted freezer without through-the-door (TTD) ice service	*AV ≤ 28.0: TBD* *28.0 < AV < 33.0: TBD* *AV ≥ 33.0: TBD*
	3A	Refrigerators—automatic defrost	
	4	Refrigerator-freezers—automatic defrost with side-mounted freezer without TTD ice service	
	5	Refrigerator-freezers—automatic defrost with bottom-mounted freezer without TTD ice service	
Refrigerator-freezers; Automatic Defrost; and Through the Door Ice Service**	5A	Refrigerator-freezers—automatic defrost with bottom-mounted freezer with TTD ice service	*AV ≤ 28.0: TBD* *28.0 < AV < 33.0: TBD* *AV ≥ 33.0: TBD*
	6	Refrigerator-freezers—automatic defrost with top-mounted freezer with TTD ice service	
	7	Refrigerator-freezers—automatic defrost with side-mounted freezer with TTD ice service	

****Note:** EPA is considering using a separate functional adder (expressed in kWh/year) for refrigerators with through the door ice and water service (DOE product classes 5A, 6 and 7). EPA believes this adder should recognize the most energy efficient designs for through the door ice service and is seeking data on the range of additional energy use associated with this feature.

In light of pending changes to minimum Federal efficiency standards, EPA is considering setting out-year criteria (i.e., Tier 2) for refrigerator-freezers, to be effective approximately 2 or 3 years after the effective date of initial criteria change. This approach enables EPA to better leverage stakeholders' time and Agency resources required to keep the specifications up to date, while also providing manufacturing partners with increased certainty on where ENERGY STAR levels will move to in future years.

Items for Comment & Discussion:

1. EPA welcomes stakeholder feedback on the objectives and approach described in this section.
2. EPA welcomes stakeholder suggestions on alternative approaches to meet the discussed objectives.
3. EPA seeks data and information on best practice designs for minimizing additional energy use associated with through the door ice and water service, to help inform the selection of an appropriate kWh/year functional adder for this feature.

4. EPA seeks comment on the Agency's consideration of setting out-year criteria through this specification revision.

There are a variety of technology options, such as vacuum insulation panels, improved compressors, variable speed compressors, higher efficiency motors, and more sophisticated controls that can be used to improve refrigerator efficiency. DOE's recent rulemaking on residential refrigerator products considered maximum technology[3] that can be used to engineer full-size refrigerators to use 22 to 59 percent less energy (depending on product class) than the 2001 standard. A number of these options are already being used in ENERGY STAR qualified models. Further information on these technologies that can improve efficiency has been included in Appendix Table 1.

IV. Other Considerations

In order to guard against unintended consequences where ENERGY STAR is recommending a product with disproportionally high greenhouse gas (GHG) implications in another phase, the program has screened many ENERGY STAR product categories for non use-phase GHG emissions, such as during the manufacture of the product. Where non-use phase GHG impacts are significant relative to the use phase impact, EPA initiated more detailed research into options for ensuring the program is guarding against unintended consequences.

With this aim in mind, EPA used Economic Input Output Life Cycle Analysis (EIO-LCA) to characterize GHG emissions associated with manufacturing of refrigerators. EPA also examined the end-of-life (EOL) GHG emissions associated with foam blowing agents and refrigerants, relying on the EPA Vintaging Model,[4] a model that has been used by EPA to track and analyze the stock of equipment containing ozone-depleting substances (ODS) and ODS substitutes over time. This model has provided the Agency with a framework for evaluating the impactions of alternative strategies for reducing ODS use. The Vintaging Model estimates U.S. consumption and emissions of ozone-depleting substances and their substitutes (including HFCs) from a variety of industrial sectors, including foams, air conditioning and refrigeration. The model tracks annual vintages of equipment or products placed on the market and estimates the amount of chemical needed to manufacture as well as maintain products (e.g., replacing refrigerant leaked from air conditioning equipment) through their useful life and the associated emissions during manufacture, use and at disposal.

Taken collectively, this research showed that for products that contain refrigerants and foam-blowing agents with high global warming potential (GWP),[5] the GHG emissions associated with the EOL and manufacturing phases are relatively significant relative to the total emissions from the use phase. Figure 1 summarizes this result for residential refrigerators. As a result, EPA is looking more closely at opportunities to reduce GHG associated with the foam-blowing agent, which accounts for the majority of the GHG emissions at EOL.

The majority of refrigerators in the U.S. have up to 1 kg of blowing agent for the insulating foam. The most common foam blowing agents, HFC 245fa, HCFC 141b and HFC 134a, are potent greenhouse gases with GWPs of 1030, 725 and 1430, respectively.[6] Currently, there are no laws in the U.S. requiring recovery and/or recycling of domestic refrigerator or freezer foam. During conversations with manufacturers in 2010 and 2011, EPA learned that a number of manufacturing partners have already switched to low-GWP foam blowing agents for some or all of their products. Low-GWP foam blowing agent options include cyclo and

[3] Defined as the most efficient product possible using available technology without regard to cost.

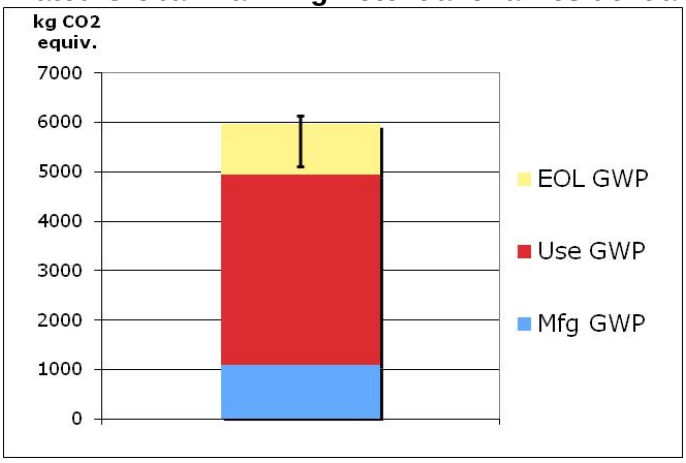
[4] Vintaging Model Version 4.4 from January 2011. For further information on the EPA Vintaging Model see Annex 3.8 of *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2008*, EPA 430-R-10-006, April 2010. Accessible here: http://www.epa.gov/climatechange/emissions/downloads10/US-GHG-Inventory-2010-Annex-3-Addtl-Source-Sink-Categories.pdf

[5] GWP is a relative measure of the amount of heat a greenhouse gas traps in the atmosphere.

[6] 100-year GWPs from IPCC (2007) Fourth Assessment Report: Climate Change 2007.

cyclo-iso pentane blends. A more recently introduced option is HFO-1234ze.[7] Refrigerators sold in Europe and Japan have relied on low GWP hydrocarbon foam blowing agents for a number years. Research collected from the 2009 United National Environmental Program Technology and Economic Assessment Panel indicates that the foam thermal conductivity of cyclo and cyclo/iso pentane blends are, with intensive system optimization, lower than HFC 134a, but slightly higher than HFC 245fa. This indicates that, in some cases, the use of low-GWP foam blowing agents may increase overall product efficiency. The total incremental cost of low-GWP blowing agents is reportedly low, however there is some cost associated with upgrading manufacturing facilities and related safety improvements.

Figure 1. Estimated Global Warming Potential of a Residential Refrigerator



Note: EOL GWP estimate is based on the recovery of refrigerant and no recovery of the foam-blowing agent (HFC-245fa). Upper limit of bar for EOL GWP represents a scenario where neither the refrigerant or foam are recovered, while the lower bar represents recovery of both refrigerant and foam at technologically feasible rates.

Given the availability and low-cost of low-GWP foam blowing agent substitutes, EPA is considering specifying that ENERGY STAR qualified refrigerators be manufactured with low GWP foam blowing agents (e.g., GWP ≤ 25). EPA seeks feedback on how EPA could implement this requirement.

Items for Comment & Discussion:

1. EPA welcomes stakeholder comment on a potential requirement that ENERGY STAR qualified refrigerators be manufactured with low GWP foam blowing agents.
2. EPA also seeks stakeholder feedback on both the current and anticipated market availability of refrigerators that meet both the proposed energy use requirements and do not contain high GWP foam blowing agents.
3. EPA is exploring the extent to which meeting this requirement could be demonstrated through participation in any existing initiatives and welcomes stakeholder feedback on this.

Smart Grid Functionality

Consistent with the principle of enhanced consumer value and in response to the petition EPA received from a joint coalition of industry and efficiency advocate stakeholders (Smart Grid Petition),[8] EPA is evaluating how best to address and encourage smart grid functionality in ENERGY STAR specifications.

[7] See EPA Significant New Alternatives Program (SNAP), Substitutes in Rigid Polyurethane, Appliance, available here: http://www.epa.gov/ozone/snap/foams/lists/applianc.html and for Final Rule on HFO-1234ze, see http://www.gpo.gov/fdsys/pkg/FR-2009-09-30/pdf/E9-23470.pdf

[8] Agreement on Minimum Federal Efficiency Standards, Smart Appliances, Federal Incentives and Related Matters for Specified Appliances. Accessible at: http://www.aham.org/ht/a/GetDocumentAction/i/49956.

For this Version 5.0 specification revision, to enable broader electric power system improvements, EPA intends to propose an allowance (expressed in kWh/year) equivalent to 5% of the minimum performance level for ENERGY STAR refrigerators and freezers that are smart grid capable. Table 3 below helps demonstrate how this approach might work for typical full-size refrigerator-freezers and freezers, using the current ENERGY STAR criteria for illustration.

Table 3. Illustrative Example of Smart Grid Allowance

	Current ENERGY STAR (kWh/year)	Smart Grid Functionality Allowance (kWh/year)	ENERGY STAR with Smart Grid (kWh/year)
Top Freezer (18 cu-ft)	387	19	406
Bottom Freezer (21.5 cu-ft)	462	23	485
Side by Side (23.5 cu-ft)	561	28	589
Upright Freezer (16 cu-ft)	601	30	631

In addition, EPA is weighing a possible complementary approach of highlighting products with smart grid functionality as Smart Grid Capable on the ENERGY STAR Qualified Product List (QPL), so that consumers, rebate programs and other interested stakeholders are better able to identify and advance those products into the market.

Defining Smart Grid Functionality

Regardless of the manner in which EPA ultimately moves forward to help advance smart grid functionality through the ENERGY STAR program (i.e. through an allowance or a special designation or both), it will be important to define the scope of that functionality in a way that is consistent with ENERGY STAR program principles. At a basic level, smart grid functionality involves the capability to receive, interpret and act upon certain demand response signals. This is the foundation for the definition advanced by industry and others as part of the Smart Grid Petition. Given the value proposition ENERGY STAR represents for consumers, EPA believes smart grid functionality in an ENERGY STAR qualified appliance should enable more consumer oriented functionality. A preliminary list of potential consumer-oriented enhancements to the basic definition is presented below. It was developed based on EPA's initial research and builds on what EPA has proposed in the ENERGY STAR Room AC specification.[9] It is intended to serve as a starting point for refrigerators and freezers and the Agency looks forward to discussion with stakeholders to further develop and refine a list of criteria that will ensure consumers receive a base level of value from products with smart grid functionality. EPA prefers to utilize existing industry standards, where available, and seeks feedback from stakeholders as which industry standards could be leveraged in order to meet the intent of these criteria, or recommended variations to these criteria.

- On-board or consumer upgradeable bi-directional communications capability by installation of a communication module, enabling functionality such as standardized self-energy consumption monitoring and reporting, standardized fault detection and reporting, and smart grid interconnection.
- Capability to record a minimum set of data, including key operational parameters and self-energy consumption, and transmit it to authorized device or application upon request.
- Availability to interested 3rd parties of an Interface Specification or Interface Control Document (ICD), as appropriate, such that consumers can benefit from 3rd party offerings including energy management and remote control capabilities.
- Consumer over ride-able response to the following signals requesting scheduled shifts in electrical consumption or immediate reductions in load:
    a. *Delay Load Capability* enabling a refrigerator to respond to a signal requesting a delay of load for a time duration not exceeding 4 hours. Upon receipt of this signal the

[9] EPA proposes this approach in the Draft 2 Room Air Conditioner Version 3.0 Specification, available on the ENERGY STAR website at http://www.energystar.gov/index.cfm?c=revisions.room_air_conditioners_spec

refrigerator would shift defrost cycles beyond the delay period and do one of the following:

i. shift ice maker cycles beyond the delay period, or
ii. reduce average wattage during the delay period by at least 9.6 watts relative to average load over a 24 hour period, and may shift this wattage beyond the delay period.

b. *Spinning Reserve Capability* enabling a refrigerator to respond to a signal requesting the start of a reduced load period for a time duration not exceeding 10 minutes. During this period, the refrigerator would need to restrict its average energy consumption to a maximum of 50 percent of the average load over a 24-hour period (unless there is a consumer initiated function, such as door opening or ice or water dispensing).

Discussion

EPA believes it is important that ENERGY STAR products be future-oriented and flexible. Refrigerator and freezers that are smart grid capable would provide consumers the option to upgrade (via an add-on user-installable communication module, when appropriate) to realize full smart grid and HEMS functionality. This is intended to provide flexibility to stakeholders and consumers.

When appliances and other energy-consuming devices or systems report their energy consumption to a Home Energy Management System (HEMS), consumers can benefit from greater awareness of their home's energy use.[10] Over time, the change is likely to be a shift from getting a bill from at the end of the month to detailed, real-time insight as to how energy dollars are being "spent," which can lead to additional energy savings. HEMS are also expected to suggest and/or automate changes that will optimize energy use and allow consumers to save on their utility bills and reduce their energy consumption. Refrigerators that are properly maintained are more energy efficient; ensuring that faults are detected and reported will keep these products operating at peak efficiency, and could provide consumers with value added functionality by alerting them, for example, when their refrigerator begins to malfunction or when a door has been inadvertently left open.

EPA is interested in enhancing consumer value by ensuring authorized 3rd party devices and applications can be used with smart grid capable products that are associated with the ENERGY STAR program. Such devices and applications will need both an acceptable level of data from the appliance and an ability to remotely control it for purposes of energy management and/or fault detection. EPA proposed a similar set of criteria through the Draft 2 Version 3.0 RAC specification released in May 2011. During the stakeholder webinar to discuss Draft 2, some RAC stakeholders expressed concern over 3rd party data access and remote control capability. In written comments, other RAC stakeholders noted future opportunities for potentially significant consumer benefit will rely on third party ability to fully interact with the appliance as is currently set forth in the draft specification. EPA is seeking further feedback on this these opposing views, and also seeks feedback from refrigerator and freezer stakeholders on how communication criteria can be further developed to provide consumer value and meaningful interaction with 3rd party systems, while mitigating stakeholder concerns. EPA requests detailed stakeholder input regarding the types of data that is relevant to energy management, fault detection, and fault reporting. Similarly, EPA is interested in stakeholder input regarding the level of remote control that is relevant for energy management of smart grid capable refrigerators and freezers. EPA is also seeking feedback on what data elements, if any, should not be made available to third party devices or services.

[10] For example, in a recent 100 home Residential Smart Energy Monitoring Pilot, Cape Light Compact attributed average energy savings from HEMS included in each home, to 9.3% after correcting for weather impacts. See "Residential Smart Home Energy Monitoring Final Evaluation Report," Accessible at: http://www.capelightcompact.org/library/2010/08/3.31.10-Residential-Smart-Home-Energy-Monitoring-Final-Evaluation-Report.pdf

Direct load control programs have been, to date, the most common type of demand response (DR) programs offered in the U.S.[11] Some residential consumers have had the ability to "opt-in" to such programs through their local utility, receiving monetary incentive in return for participation. Such programs have usually focused on achieving "peak shaving" from central air conditioning loads, and to a lesser extent, water heaters and pool pumps.

Smart grid enabled appliances are also being considered for managing peak electricity demand and as a resource to provide reserves to help balance supply and demand to increase grid efficiency, support reliable power system operation, and permit an increasing fraction of renewable energy sources (e.g., see PNNL 2010, *Use of Residential Smart Appliances for Peak-Load Shifting and Spinning Reserves*). Today, these more sophisticated residential DR programs that include plug-in electric vehicles and smart grid enabled appliances are largely limited to pilots and demonstration projects.

Currently, requisite smart grid infrastructure and programs (Advanced Metering Infrastructure (AMI), active Home Area Networks (HAN), variable pricing programs, and appliance demand response (DR) programs) are not in-place to allow consumers to directly benefit from grid interconnection of smart grid enabled appliances. In the future when these programs and infrastructure are deployed, consumers that participate in appliance DR programs will realize additional savings associated with shifting energy consumption of smart grid enabled appliances away from peak times. Refrigerators and freezers that integrate with the grid will be able to receive price or event signals and reduce or delay load in response to both signals received and to consumer preferences. With proper economic incentives for residential consumers, these automated actions will enable consumers to save money on their electricity bills. Consumers will also benefit when any electric power system efficiency and reliability benefits are favorably reflected in their electricity rates. As these new demand response opportunities evolve, EPA believes it is critical that consumers retain ultimate control over their appliances' response to such signals.

Stakeholders have also suggested to EPA that, in the near-term, refrigerators and freezers could be designed to reduce their load during peak periods automatically (e.g., based on an internal clock, that schedules, for example, defrost to occur outside of some pre-defined peak period). This functionality may offer grid benefits as soon as these products are put into service. EPA is requesting further stakeholder feedback on whether these types of features should be considered in the Version 5.0 specification, how they could be best implemented, and how to ensure consumer satisfaction is maintained.

EPA also notes that DOE, to the extent necessary, will be developing test procedures related to smart grid functionality in appliances for the ENERGY STAR program. EPA and DOE representatives participated in an AHAM led meeting to discuss AHAM's smart grid enabled appliance test procedure development efforts.

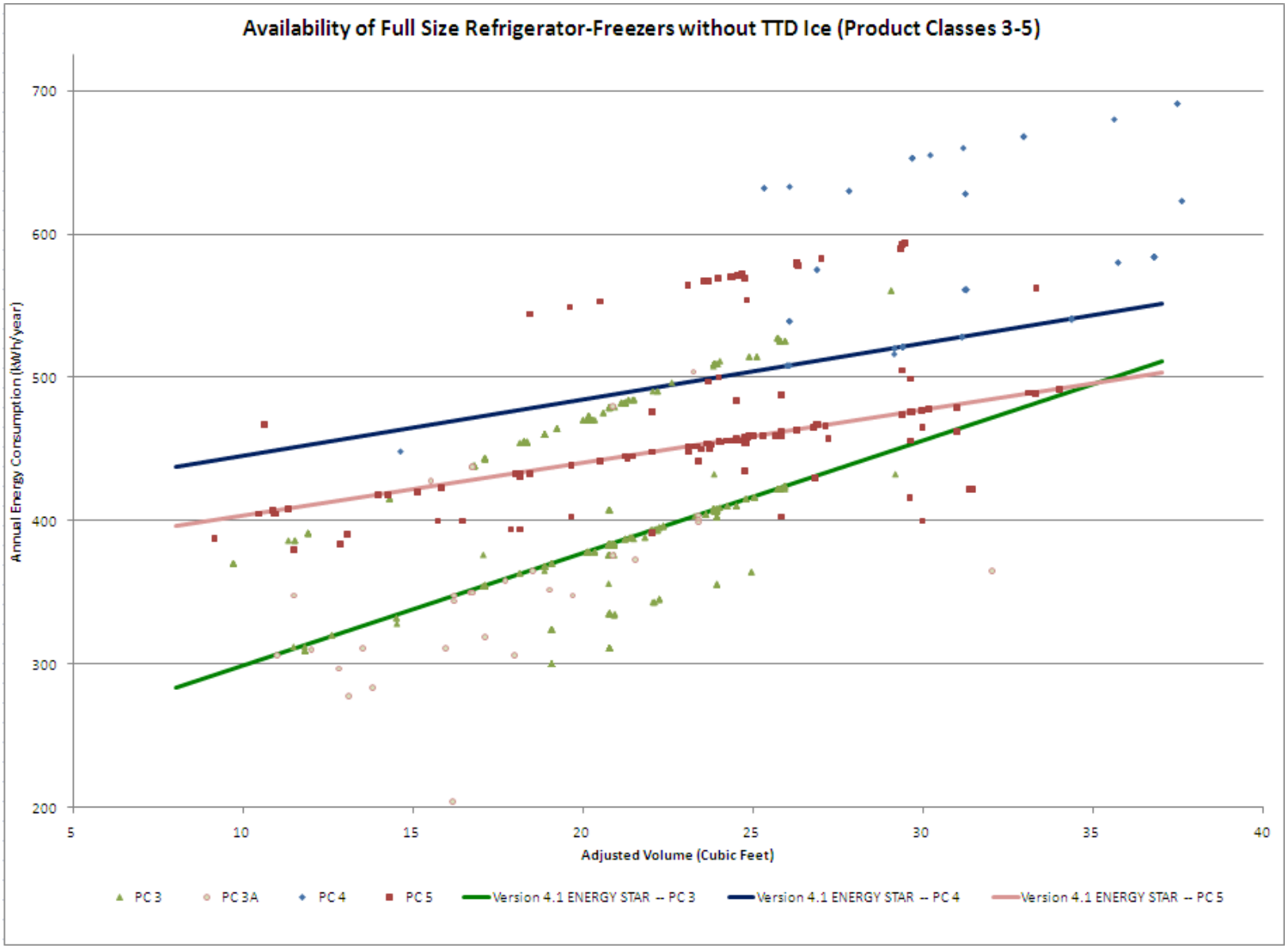
Items for Comment & Discussion:

1) EPA requests stakeholder comment on this proposed approach to facilitating the deployment of smart grid functionality in refrigerators and freezers, including EPA's intent to propose a 5% allowance for refrigerators and freezers with smart grid functionality and/or highlight products with this functionality on the QPL.
2) EPA is seeking feedback from stakeholders on its initial list of criteria intended for the direct benefit of consumers.
3) EPA seeks feedback from stakeholders as to which industry standards could be leveraged to meet the intent of the initial set of criteria discussed in this section, or recommended variations to these criteria.

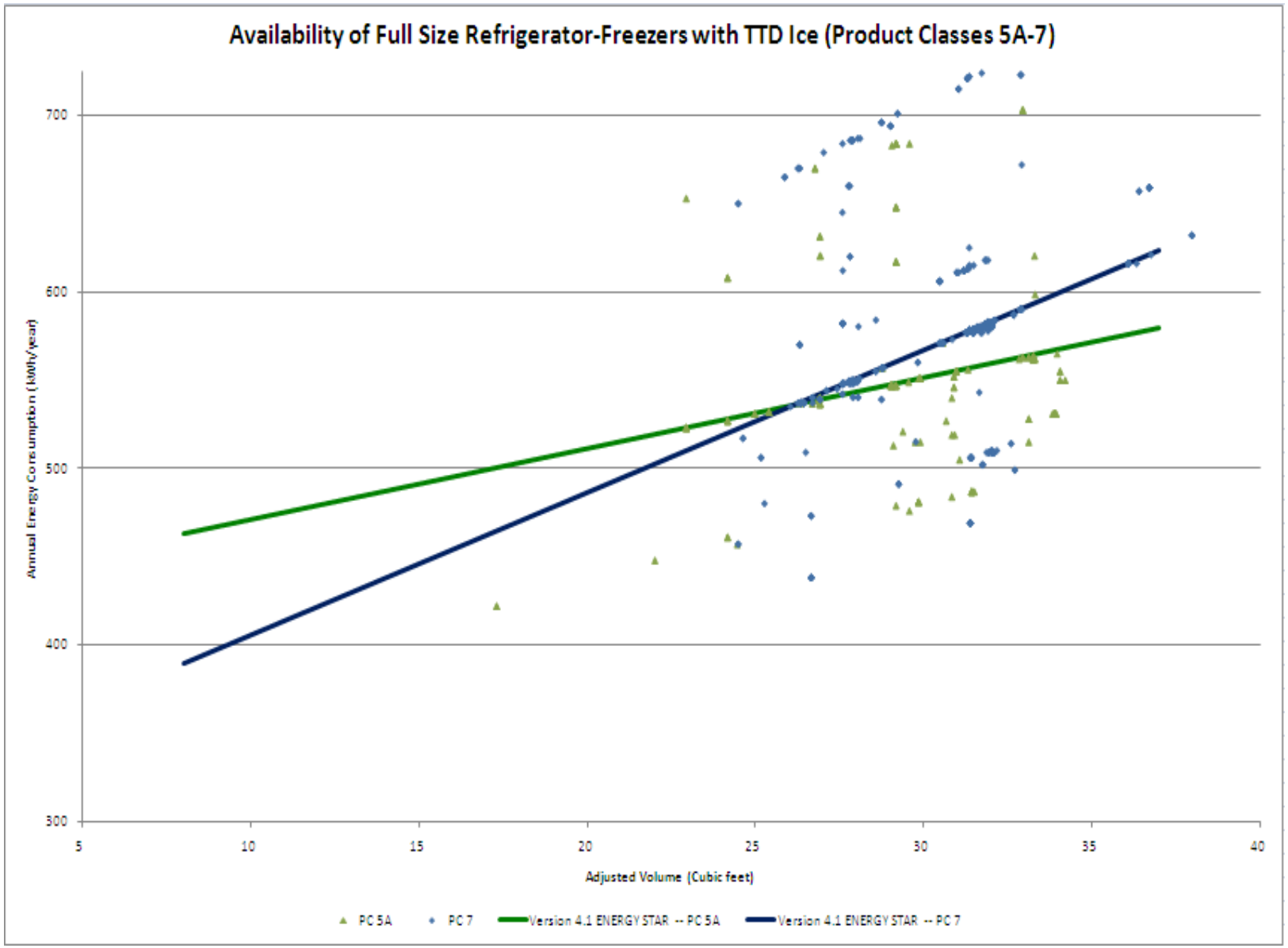
[11] Federal Energy Regulatory Commission (FERC) (2011). *2010 Assessment of Demand Response and Advanced Metering.* Note, in this report FERC defines demand response as: changes in electric use by demand-side resources from their normal consumption patterns in response to changes in the price of electricity, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.

4) EPA seeks stakeholder input regarding the type of appliance data that is relevant to energy management and diagnostics of smart grid capable refrigerators and freezers.
5) EPA seeks feedback on what degree of remote control will enable energy savings without significantly impacting product performance.
6) EPA seeks feedback on specific data elements, such as appliance diagnostics, that stakeholders desire to be kept confidential and not exposed through an Interface Specification or an Interface Control Document (ICD).
7) EPA seeks information on any additional energy use and/or energy savings that may result when a refrigerator or freezer responds to signals requesting reduction or delay in load as defined above and the magnitude of this change in energy use.
8) EPA seeks information on any additional energy use and/or energy savings that may result when a refrigerator or freezer schedules energy use to off-peak periods, in the absence of grid connectivity as defined above and the magnitude of this change in energy use.

Appendix Figure 1



Appendix Figure 2



Appendix Table 1. Summary of Technology Options from DOE Analysis

Option	Applies to	Description	Energy Savings	Tradeoffs/Concerns	Cost
Vacuum-insulated panels (VIPs)	PC 3, 5, 7, 9, 10, 11, 18	VIPs are vacuum-sealed packages filled with a core material (either polystyrene, open-cell polyurethane, silica powder, or glass fiber) that are foamed into place between the cabinet liner and wrapper to decrease heat leakage. This increase in thermal resistivity allows for significant efficiency improvements.	Using VIPs could result in 30% reductions in cabinet load for typical refrigerator-freezers.	Long-term thermal conductivity integrity, i.e., as the pressure increases within the panel, is a concern.	Panels: $3.08/sq ft at 1.2 cm thickness
Improved compressor efficiency	PC 3, 5, 7, 9, 10, 11, 18	Manufacturers can easily convert to higher-efficiency compressors if available.	Compressors with EERs near 6.25 are the best available on the market.	Compressor efficiency decreases with refrigerator capacity.	$10 per 1.0 Btu/Wh
Variable speed compressors (VSCs)	PC 3, 5, 7, 9, 10, 11, 18	VSCs can operate at compressor speeds that best match the thermal load needed at any specific time, thus reducing off-cycle energy consumption. VSCs also use higher-efficiency permanent magnet motors.	There are demonstrated 4%-14% energy savings from using a two-speed compressor with a multi-speed evaporator and condenser fans.	The increase in fan use can negate energy savings from VSCs.	$50 more per unit
Increased evaporator surface area	PC 3, 5, 7, 9, 10, 11	Increasing the face area of the evaporator or adding more tube rows allows the evaporator to transfer heat more efficiently.		Increasing the volume occupied by the heat exchanger requires a reduction in interior volume.	
Increased condenser surface area	PC 3, 5, 7, 10, 11	Increasing the face area of the condenser or adding more tube rows allows the condenser to transfer heat more efficiently.	Increasing the condenser surface area reduces annual energy consumption by 1%-2%.	Increasing the volume occupied by the heat exchanger requires a reduction in interior volume.	
Brushless DC evaporator fan motor	PC 3, 5, 7, 9	Replacing the traditional shaded pole fan motor with a brushless DC motor improves the evaporator fan's efficiency.	Figures vary, but teardown testing indicated a 60-65 percent reduction in fan power.		$3.50
Brushless DC condenser fan motor	PC 3, 5, 7, 9	Replacing the traditional shaded pole fan motor with a brushless DC motor improves the condenser fan's efficiency.	Figures vary, but teardown testing indicated a 60-65 percent reduction in fan power.		$3.75
Adaptive defrost	PC 3, 5, 7, 9	An adaptive defrost system adjusts the time between defrost cycles based on ambient conditions and consumer usage patterns, such as door opening frequency.	DOE estimated a 3-4 percent reduction in energy consumption in the 1995 TSD		$8 without electronic control; no per-unit cost if a unit already has electronic controls
Variable anti-sweat heating	PC 5	Using a humidity sensor and an electronic controller, the system adjusts the time-average wattage of an electric anti-sweat heater based on ambient temperature and humidity conditions to keep all surfaces just above the ambient dew point.		This option is only relevant for bottom-mounted French door refrigerator-freezers	$9.48