January 22, 2013

Mr. Robert Meyers
United States Environmental Protection Agency
Office of Air and Radiation
1200 Pennsylvania Ave NW
Washington, DC 20460

Subject: Comments regarding Version 6.0 Draft 3 Computer Specification

Dear Mr. Meyers:

This letter comprises the comments of the Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE) and San Diego Gas and Electric (SDG&E) and Northwest Energy Efficiency Alliance (NEEA), in response to the Environmental Protection Agency (EPA) ENERGY STAR Computer Specification Version 6.0 Draft 3. The comments cover several outstanding topics in order of importance with a key summary:

1. **Base TEC Limits:** Version 6.0 energy limits should be based on 2012 data. Integrated and traditional desktops should have separate categories. We recommend specific Base TEC limits based on analysis of this up-to-date data.

2. **Discrete Graphics Adders:** The proposed Draft 3 discrete graphics adders are far too high relative to recent test data. We propose Version 6.0 levels based on recent, substantive testing in an accredited laboratory. A memo further explaining this effort will follow next week.

3. **Categorization:** Desktops and integrated desktops warrant two distinct categories because they serve different functions and consume energy differently, just like notebooks and desktops do.

4. **Switchable Graphics Incentive:** We have concerns with the draft 3 switchable graphics incentive proposal that should be resolved in order to make this incentive effective and avoid unintended consequences that would impact the effectiveness of the overall specification.

5. **Power Supply Efficiency Incentive:** We support NRDC's proposal for Power Supply Efficiency Incentive to increase the incentive to 3%-6%, if not 2% and 4%, for both desktops and notebooks; the Draft 3 incentive proposal appears too insignificant to encourage a change in design.

6. **Information Requirements:** We recommend reporting requirements regarding switchable graphics and power supplies for qualified products and for this data to be submitted into the Qualified Products List.

7. **Energy Efficient Ethernet** (New Topic): EPA should require or incentivize Energy Efficient Ethernet enabled as-shipped on all computers.

8. **Display Adder:** In future specification developments we strongly urge ENERGY STAR to characterize integrated displays more thoroughly in order to assign an appropriate idle mode power allowance for displays of integrated desktops and laptops.

Three of the four the signatories of this letter collectively referred to herein as the California Investor Owned Utilities (CA IOUs and NEEA), represent some of the largest utility companies in the Western United States, serving millions of customers. As energy companies, we understand the potential of appliance efficiency voluntary standards to cut costs and reduce consumption while maintaining or increasing consumer utility of the products.

The Northwest Energy Efficiency Alliance (NEEA) is a non-profit organization working to maximize energy efficiency through the market transformation of energy efficient products. Voluntary standards are a key component to this process. NEEA is supported by, and works in collaboration with, the Bonneville Power Administration, Energy Trust of Oregon and more than 100 Northwest utilities on behalf of more than 12 million energy consumers.

1. Base TEC Allowances

CA IOUs and NEEA feel strongly that <u>EPA should develop Version 6.0 typical energy consumption (TEC) levels based on product data from only 2012 models.</u> Computer released in 2012 are significantly more energy efficient than 2010 and 2011 models.

<u>Additionally, we recommend separating traditional and integrated desktops into distinct categories so that each type is equally incentivized to be designed efficiently (more in Section 3). In the following tables, please find proposed TEC limits recommendations in both scenarios for which there were 2012 data, based on analysis primarily performed by NRDC:</u>

<u>Separate</u> Traditional and Integrated Desktops Categories:

Table 1: Traditional Desktops Base TEC Allowances

Category	Draft 3 TEC Limit (kWh/yr)	CA IOUs and NEEA and NEEA Proposed TEC Limit (kWh/yr)	Resulting Estimated Pass Rate (w/o gfx adders)
DT 0	69	50	29%
DT I1	112	75	25%
DT I2	120	100	18%
DT I3	135	100	28%
DT D1	118	85	No data
DT D2	137	95	No data
Weighted average			25%

Table 2: Integrated Desktops Base TEC Allowances

Category	Draft 3 TEC Limit (kWh/yr)	CA IOUs and NEEA and NEEA Proposed TEC Limit (kWh/yr)	Resulting Estimated Pass Rate (w/o gfx adders)
DT 0	69	37	22%
DT I1	112	62	25%
DT I2	120	78	13%
DT I3	135	78	32%
DT D1	118	65	No data
DT D2	137	75	No data
Weighted average			25%

<u>Combined</u> Traditional and Integrated Desktops Categories:

Table 3: Combined Desktops Base TEC Allowances

Category	Draft 3 TEC Limit (kWh/yr)	CA IOUs and NEEA and NEEA Proposed TEC Limit (kWh/yr)	Resulting Estimated Pass Rate (w/o gfx adders)
DT 0	69	45	25%
DT I1	112	70	26%
DT I2	120	93	16%
DT I3	135	93	27%
DT D1	118	80	No data
DT D2	137	90	No data
Weighted average			25%

Notebooks:

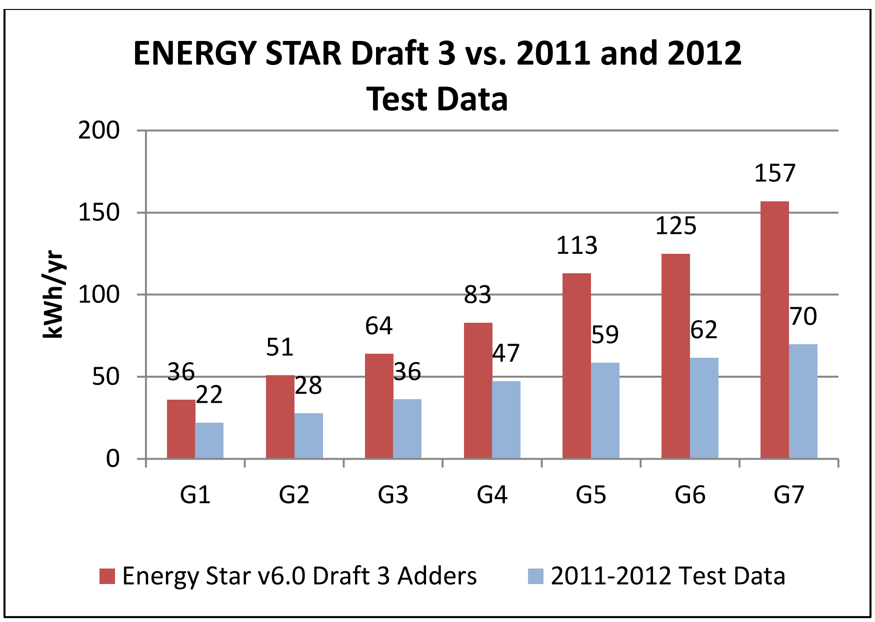
Table 4: Notebooks Base TEC Allowances

Category	Draft 3 TEC Limit (kWh/yr)	CA IOUs and NEEA and NEEA Proposed TEC Limit (kWh/yr)	Resulting Estimated Pass Rate (w/o gfx adders)
NB 0	14	14	Insufficient data
NB I1	22	21	21%
NB I2	24	24	18%
NB I3	28	26	Insufficient data
NB D1	16	14	26%
NB D2	18	16	Insufficient data
Weighted average			25%

2. Discrete Graphics Adders

We propose Version 6.0 levels based on recent substantive testing that demonstrates the actual energy consumption of discrete graphics cards is significantly lower than the calculated amounts using the proposed formula based on theoretical estimates. We feel the EPA-proposed Draft 3 discrete graphics adders are too generous.

Figure 1: Draft 3 Adders vs. 2011-2012 Test Data



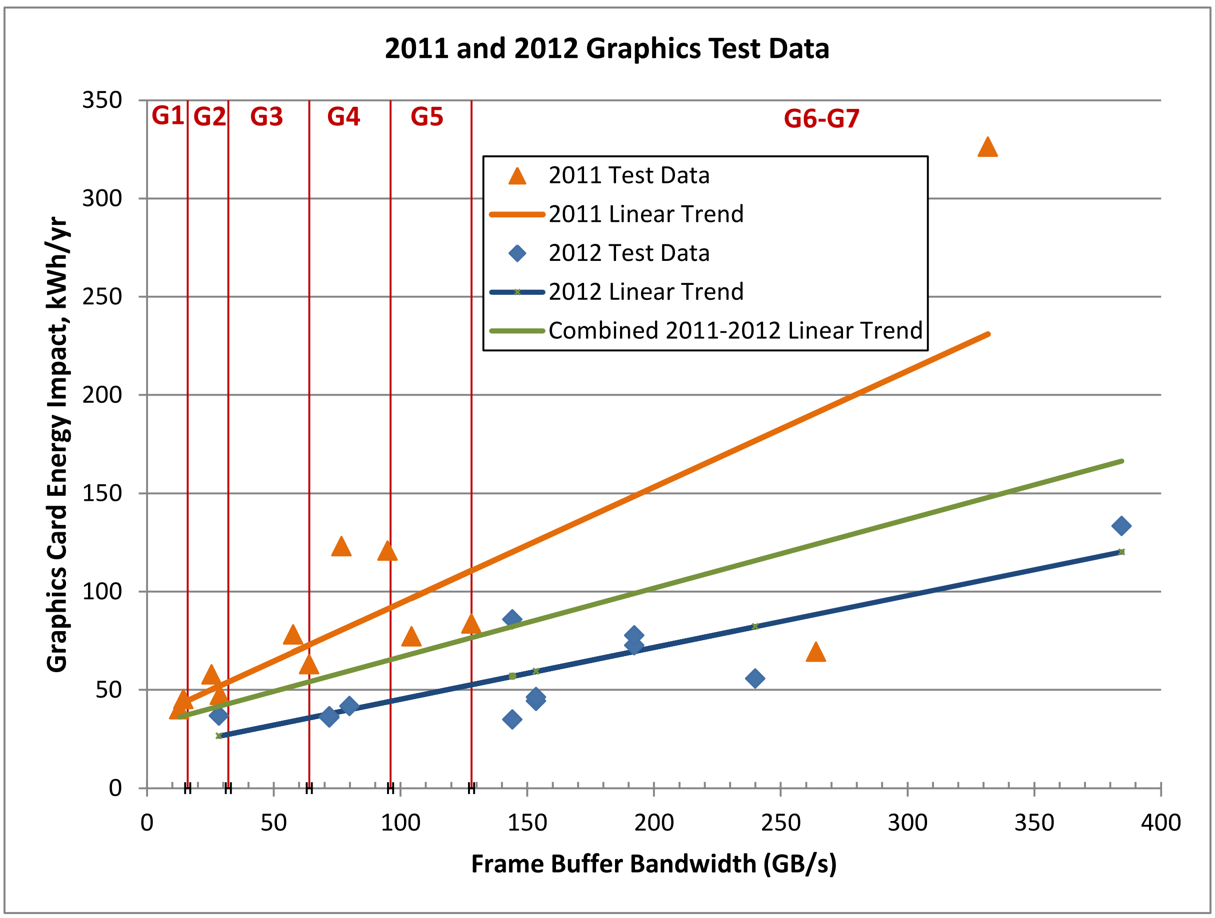
The blue bars represent the combination of the results of two graphics card power measurement projects:

1. The 2011 graphics card data is from the NRDC and Collaborative Labeling and Appliance Standards Program (CLASP) study of a sample of 12 desktop discrete graphics cards representative of 2011 GPU technology.
2. The 2012 graphics card data is from a similar study just completed by Pacific Gas & Electric on a sample of 12 desktop discrete graphics cards representative of 2012 GPU technology. The 2012 graphics card sample consists of eight G7 cards, three G4 cards and one G2 card, all of them utilizing 2012 GPU architectures (AMD GCN and Nvidia Kepler), which represent best-practices in terms of graphics card energy efficiency in idle mode as of 2012.

EPA's Draft 3 proposed adders (in red) are approximately twice as high as the tested energy consumption for graphics cards of both studies and more than twice as high as the 2012 data alone.

Figure 2 below shows the dramatic improvements in energy efficiency of 2012 (blue line) vs. 2011 (orange line) graphics technology. The green line represents the combination of 2011 and 2012 data.

Figure 2: 2011 and 2012 Graphics Test Data



CA IOUs and NEEA and NEEA propose to set Version 6.0 levels based on 2012 data, as represented by Table 5. This represents a broad sample of products already available in the market today, and will be the majority of the market in 2013-2014.

Table 5: Desktop discrete graphics adders based on 2012 test data (kWh/yr):

G1	G2	G3	G4	G5	G6	G7
21	25	32	40	48	51	57

The combined results show that the power requirements of G7 graphics cards in idle mode and the resulting impacts on system typical energy consumption are much lower than the EPA-proposed Draft 3 adders, by as much as 87 kWh/yr for 2012 cards. To put this in perspective, 87 kWh/yr is higher than the base allowance for category DT1 desktop. This would allows systems that use 2012 or later G7 cards, which will be most or all of the G7 cards sold by the specification's effective date, to unfairly qualify.

High-end graphics (G5 and higher) are becoming increasingly common in consumer and some segments of the commercial desktop markets, and this will likely continue as the price of high-performance graphics continues to drop following Moore's Law. These data suggest that graphics adders as currently proposed will lead to very high qualification rates for desktops equipped with G5 or higher discrete graphics. In addition, this will incentivize manufacturers to propose more configurations using G5-G7 graphics than the market would otherwise demand, due to the fact that it will be easier to qualify for ENERGY STAR in high-end vs. low-end graphics categories.

Draft 3 proposes a strong framework for the Version 6.0 specification, adjusting graphics adders to appropriate values is a simple fix and will ensure the specification is effective.

Draft 3 proposed graphics adders are based on outdated data and an inaccurate methodology that uses graphics card internal idle power levels to derive adders. Our latest data shows that the energy efficiency of discrete graphics in idle mode has improved dramatically in the past year, and the methodology developed by NRDC and CLASP, based on system-level measurements, is much more accurate than the draft 3 methodology.

CA IOUs and NEEA and NEEA recommend that graphics adders be aligned with the combined 2012 test data. 2012 data is the most representative of graphics technology that will be on the market by the end of 2013 when the specification becomes effective.

Adder values higher than those required by 2011-2012 graphics cards would result in excessive qualification rates for computers equipped with G5-G7 graphics cards, and would fail to drive higher market adoption of high efficiency graphics cards.

Notebooks

CA IOUs and NEEA & NEEAsupport EPA's approach of setting notebook graphics adders to be 37% of desktop adders.

It is particularly important that discrete graphics adders for notebooks not be too high because of the broad availability of graphics switching technology in notebooks. If discrete graphics adders are too generous, they can provide a perverse incentive for manufacturers not to implement graphics switching when connected to AC power in order to benefit from the higher graphics adder.

3. Categorization

CA IOUs and NEEA and NEEA support EPA's adoption of the ITI categorization proposal for desktops, though recommend that EPA separate desktops and integrated desktops into distinct categories because they serve different functions and consume energy differently, just as notebooks and desktops.

A. Functional Differences: There are three key functional distinctions between desktops and integrated desktops:

   1) Traditional desktops are fully upgradeable, whereas integrated desktops have minimal upgradability.
   2) Traditional desktops offer more flexibility with the choice of display: users can either reuse existing displays, or upgrade to different displays over the life of the product.
   3) Integrated desktops offer sleeker designs and form factors, a significant element behind their consumer demand.

B. Energy Consumption Differences: Due to size and space constraints, integrated desktops tend to utilize more efficient architectures and components. Grouping the two form factors together results in setting levels that are either too lenient for integrated desktops, resulting in unduly high qualification rates, or too stringent for traditional desktop, resulting in very few being able to qualify. Separating both categories will ensure that ENERGY STAR encourages the most efficient designs for each form factor.

These differences should enable EPA to categorize them separately, just as categorization exists between notebooks and desktops. The categorization of computers with discrete and integrated graphics in separate categories is even less substantial, but still warranted.

Alternatively, EPA could consider creating an upgradability adder for traditional desktops, and base desktop levels on integrated desktops, however we believe that separate categories are a simpler approach.

Lastly, integrated desktops represent approximately 30% of total desktop models of the Qualified Products List, and their share of the desktop market is growing. There are enough of them in each category to set separate standards.

4. Switchable Graphics

CA IOUs and NEEA and NEEA support EPA's intention to provide an incentive for manufacturers to implement switchable graphics, but several issues exist with the **Draft 3 proposed language. We recommend the following five adjustments to make the incentive more robust:**

1. The definition of switchable graphics lacks details, such as whether it is automatic or user-initiated, and what graphics rendering conditions should minimally trigger the switch. **We recommend that the switch between discrete and integrated graphics must be automatic, and must be triggered at a minimum in idle mode per the ENERGY STAR test method.** Switchable graphics should also be enabled by default as shipped, and not require any user involvement during initial setup so as not to encourage users to disable the functionality before they even try it.
2. Draft 3 does not propose a test method for determining which computers have switchable graphics. As this functionality is not always obvious in computer specs and documentation, **it should either be included in the test method, or at a minimum be a mandatory reporting requirement by manufacturers as part of the information requirements.** The following information should be reported:
    a. Does the computer have automatic switchable graphics capability?
    b. Is it enabled by default in AC power mode?
3. We believe that EPA's intent is that <u>notebooks capable of switchable graphics may not claim any graphics adders</u>. This would provide a strong incentive for manufacturers to enable switchable graphics in AC mode, and eliminate the need for an additional incentive. **If this is the case CA IOUs and NEEA and NEEA strongly support this approach, however this needs to be clarified in the specification.** It also requires that the declaration of switchable graphics capability be reliable and trustworthy, and therefore mandatory as part of information requirements. If EPA chooses not to require mandatory testing or reporting of switchable graphics, or to allow notebooks to claim graphic adders even if they have the capability, we would favor that the incentive of (50% * G1 adder) be extended to notebooks, however we strongly prefer the first approach given the high penetration of switchable graphics capability in current notebooks.
4. For desktops, we believe the proposed incentive of (50% * G1 adder) is appropriate: it provides a meaningful but reasonable incentive. **We caution against making this incentive scalable across graphics categories** as suggested by some stakeholders, as this could rapidly result in disproportionate incentives. Scalable incentives could eventually be higher than the energy consumed by discrete graphics cards in idle, given that we are already seeing some latest generation G7 cards consume less than 40 kWh annually.
5. The switchable graphics adder should be more clearly communicated and placed into Table 10.

5. Information Reporting Requirements

CA IOUs and NEEA and NEEA recommend the following reporting requirements for qualified products and for this data to be made publically available on the Qualified Products List:

- Does the computer have automatic graphics switching capability in idle mode (Y or N)?
- Is graphics switching enabled by default in AC power mode (Y or N)?
- Report certified efficiency levels of the power supplies at 10 percent load as well as at each load level specified by the standard external and internal power supply test protocols.

The graphic switching information requirements are critical to the effectiveness of the graphics switching incentive.

The power supply efficiency information requirement will help evaluate the efficiency of power supplies used in qualified products and will inform the development of future revisions of the specification.

6. Power Supply Efficiency Incentive

CA IOUs and NEEA and NEEA support NRDC's proposal for Power Supply Efficiency Incentive to increase the incentive to 3%-6%, or at a minimum 2%-4%, for both desktops and notebooks; the Draft 3 proposal (1.5%-3% for desktops and 0.75%-1.5% for notebooks) seems too lenient to encourage a change in power supply design, especially for notebooks.

7. Energy Efficient Ethernet

CA IOUs and NEEA and NEEA recommend that EPA require or incentivize Energy Efficient Ethernet (EEE) (the IEEE 803.2az standard), to be enabled as-shipped on all computers. EEE can reduce the power draw of a Gigabit port, typically drawing .7W regardless of actual transfer speed to .1W, nearly the levels of a 100 Megabit port for low data rates. To achieve any benefit of EEE, however, the devices on both ends of an Ethernet connection must have EEE enabled.

EPA plans to include an incentive for EEE in the ENERGY STAR Small Network Equipment Program Requirements document to encourage adoption. To achieve savings related to EEE, we recommend EPA similarly encourage EEE in computers by requiring it to be implemented and enabled when shipped in all ENERGY STAR qualified products.

8. Display Adder

Overall, we feel it important that the ENERGY STAR Version 6.0 requirements identify only the top performing models within a category. When determining adder allowances for units with integrated displays, ENERGY STAR should ensure that a loophole is not created for a computer to been given more power allowance than would be reasonable or justified based on actual performance. <u>Moving forward we strongly urge ENERGY STAR to characterize integrated displays more thoroughly in order to assign an appropriate idle mode power allowance for displays of integrated desktops and laptops.</u>

With respect to the functional adder allowance for the displays of integrated desktops and notebooks, we understand that ENERGY STAR analyzed data from the dataset used in the development of the Version 6.0 ENERGY STAR Displays Specification. In looking at the stand-alone display dataset, we calculated what the adder would be for notebooks and integrated desktops, given each models screen area and resolution, and compared them to the stand-alone displays' reported on mode power. For integrated desktops, we only looked at models with a diagonal screen size of 32-inches and below to reflect the typical integrated desktop market. For notebooks, we only looked at models with a diagonal screen size of 22-inches and below to reflect the typical notebook market.

In regards to the adder allowance for integrated desktops, over 14 percent of the dataset we examined, or 364 models, had a calculated adder that would exceed the on mode power of the stand-alone unit. When we examined the integrated display adder for notebooks, there were no models that had a calculated adder that exceed the on mode power of the stand-alone unit. At this time it is difficult to draw any conclusions from this preliminary analysis, but understand from conversations with ENERGY STAR that the proposed adders are appropriate.

Table 6: Analysis of Integrated Display Functional Adder Using Stand-alone Display Dataset

	Diagonal Screen Size Range (inches)	Total Models	Average Calculated Adder as Percent of On Mode	Percent of Total Models with Calculated Adder of > 100% of On Mode
Integrated Displays	$0 < d \leq 32$	2530	79%	14.4%
Notebook	$0 < d \leq 22$	1834	35%	-

PG&E has conducted power testing on four notebook models in idle mode. Results show that the power draw of just the display ranges from 14 to 37 percent of the overall power drawn in idle mode for these laptops. Regarding the displays adder, as ENERGY STAR receives test data for Version 6.0 qualifying products, we request that EPA closely monitor the idle mode power information to ensure the proposed display adder is appropriate and modify if necessary. In order for ENERGY STAR to better understand the power consumed by integrated displays (and therefore assign an adder value), it is important to know what percentage of the overall power consumed in idle mode is just for the display.

In conclusion, we would like to reiterate our support to EPA for establishing a voluntary specification for computers. We thank you for the opportunity to be involved in this process and encourage EPA to carefully consider data collected and the recommendations outlined in this letter.

Sincerely,

Rajiv Dabir
Manager, Customer Energy Solutions
Pacific Gas and Electric Company

Michael Williams
Manager, Design & Engineering Services
Southern California Edison

Chip Fox
Residential Programs and Codes & Standards
Manager
San Diego Gas and Electric Company

Ty Stober
Market Transformation Initiative Lead
Northwest Energy Efficiency Alliance

MEMORANDUM

In support of the comment letter submitted by the California Investor Owned Utilities and the Northwest Energy Efficiency Alliance on January 22, 2013

To: Pacific Gas and Electric Company

From: Ecova's Research and Policy Team

Date: January 25, 2013

Subject: Updated Discrete Graphics Processing Unit Testing Results

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MEMORANDUM SUMMARY

This memorandum presents the results of work funded by the Pacific Gas and Electric Company to evaluate the impact that discrete graphics processing units (GPUs) have on desktop computer idle mode electricity consumption. This work builds on a similar study funded by the Collaborative Labeling and Appliance Standards Program (CLASP) and the Natural Resources Defense Council (NRDC). In this memo, we confirm the hypothesis presented in the previous work that GPUs would rapidly become more efficient. Market research revealed that two thirds of NVIDIA's and one quarter of Advanced Micro Devices' current discrete desktop GPU product lineup utilize the Kepler architecture or ZeroCore design respectively, which deliver significant savings relative to GPUs that use older architectures. In general terms, the Kepler architecture allows the GPU to scale the power it demands to match the task it is completing generating significant savings during the idle state.[1] The ZeroCore design allows the GPU to power down some components when the computer screen is off or not displaying content.[2] More than 80% of the GPUs released in 2012 use these more efficient technologies, and the remaining 20% are simply older GPUs that have been relabeled and re-released. In other words, our market research suggests that Kepler and ZeroCore represent a new standard for GPU efficiency and a compelling opportunity that will enable computers that utilize discrete graphics cards to be more efficient without sacrificing graphics processing performance. Test results indicate that these latest

[1] See: http://www.nvidia.com/content/PDF/kepler/NVIDIA-Kepler-GK110-Architecture-Whitepaper.pdf

[2] See: http://www.amd.com/la/Documents/amd_powertune_whitepaper.pdf

architectures can save anywhere from 20% to 75% of discrete GPU energy consumption depending on the performance class of the card (generally, the greater the frame buffer bandwidth of the card, the greater the savings).

GRAPHICS PROCESSING UNIT SELECTION

Ecova's market research demonstrates that a total of 18 discrete GPU products were released between December 2011 and December 2012 by the two dominant discrete GPU manufacturers, NVIDIA and Advanced Micro Devices (AMD). Fourteen of these products utilize one of the two competing advances in efficient GPU design – NVIDIA's Kepler architecture or AMD's ZeroCore design – and the remaining four are simply rebadges of older products (relabeled and re-released). Ecova purchased via third-party retail channels 12 out of these 14 next-generation discrete GPUs, not available as of December 2011, when the original CLASP-NRDC graphics card testing took place. In the appendix, we provide a table that describes all discrete desktop GPUs released in this time frame, indicates whether or not they were tested in this study, and identifies the cards that use the new technologies.

A broader survey of all available discrete GPU products (via a study of NVIDIA's and AMD's product pages) indicates that two thirds of NVIDIA's and one quarter of AMD's entire discrete desktop GPU lineup (all GPUs rather than GPUs released in 2012) utilize either Kepler or ZeroCore.[3] This suggests that the industry is in the midst of a paradigm shift to more efficient GPU designs.

TESTING AND ANALYSIS METHODOLOGY

Ecova tested the 12 purchased discrete GPUs in six desktop computers. The desktop systems in which the GPUs were tested capture a range of systems from mainstream budget systems to enthusiast gaming machines. These systems were identical to those used in the original CLASP-NRDC study with the exception of one PC (PC4 in the

[3] See: http://www.geforce.com/hardware/desktop-gpus and http://www.amd.com/us/products/desktop/graphics/Pages/desktop-graphics.aspx

CLASP-NRDC study), whose motherboard was replaced with a more recent motherboard. Ecova applied the same methodology and test procedure that was used in the previous study to calculate differences in short and long idle power associated with discrete graphics cards and to translate these differences into typical electricity consumption (TEC) using the ENERGY STAR Draft 6 version 2 test procedure for computers.[4]

All testing occurred in Ecova's lab, an EPA-recognized, CEC approved, and ISO/IEC 17205 accredited laboratory.[5] Equipment used for the testing consisted of high-precision laboratory-grade, true power meters and controlled power sources. Ecova's measurement equipment is calibrated by an ISO/IEC 17025 accredited calibration laboratory.

RESULTS

Figure 1 presents the results of the latest round of discrete GPU measurements, presented as incremental electricity consumption (additional energy use required to operate the discrete GPU compared to the baseline system configuration) using the ENERGY STAR Version 6 Draft 2 duty cycle. We group GPUs by their ECMA performance category and show estimates of incremental TEC based on tests from six different desktop systems. Due to incompatibilities with certain desktop builds (e.g. undersized power supplies that could not support the new GPUs), two of the cards could not be measured on all systems (NVIDIA 04G-P4-2690-KR and NVIDIA N660). The cards impact the systems in different ways depending mainly on power supply configuration (size and efficiency) and motherboard type.

[4] See: CLASP, NRDC and Ecova, *Assessment of Desktop Computer Graphics Card Idle Power*, March 13, 2012, http://www.clasponline.org/en/ResourcesTools/Resources/StandardsLabelingResourceLibrary/2012/~/media/Files/SLDocuments/2012/DesktopGraphicCardTesting/2012-3_PreliminaryResults_AssessmentOfDesktopComputerGraphicsCardIdelPower.pdf

[5] For detailed information see http://www.energystar.gov/index.cfm?c=third_party_certification.tpc_labs and http://l-a-b.com/accredited-labs?field_scope_text_value=ecova&title=&field_state_value=All&field_country_value=All

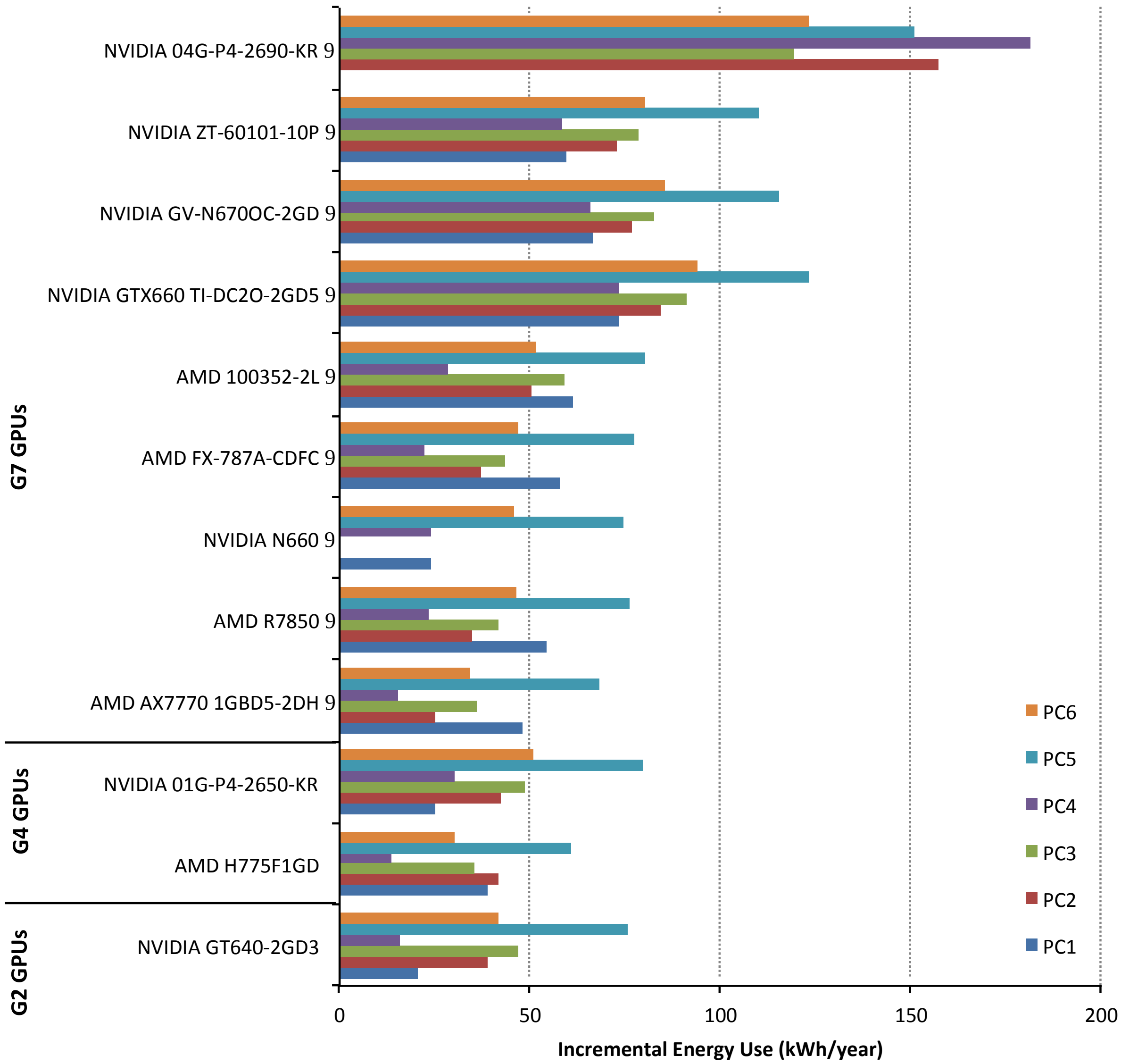
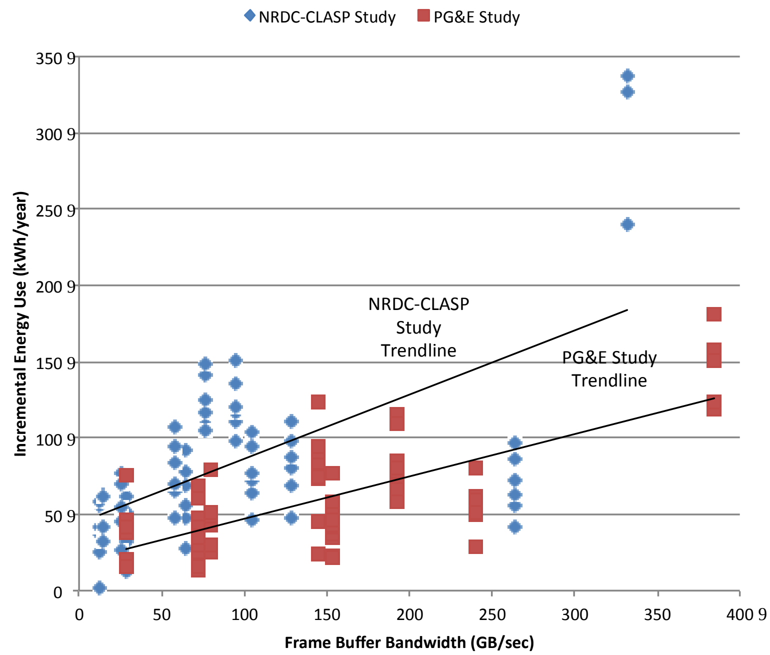


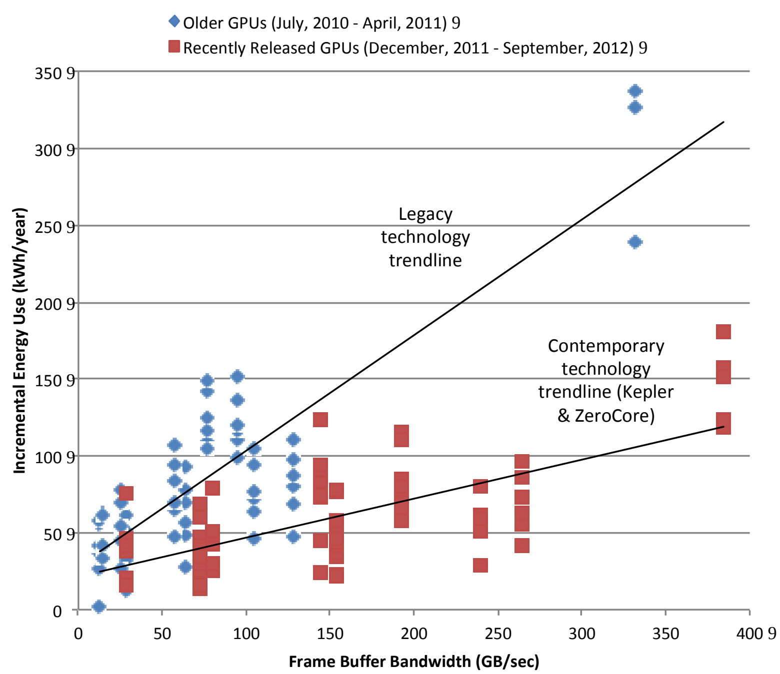
Figure 1: PG&E-Funded Discrete GPU Measurements of Incremental TEC (kWh/year)

The results of this study demonstrate a significant reduction in GPU energy consumption for cards with the latest architectures. The current generation of GPUs tested in this work demand less power in short and long idle modes and lead to significantly less additional electricity consumption in desktop computers using the ENERGY STAR Version 6 Draft 2 duty cycle.

Figure 2 below encompasses two graphs showing the additional typical electricity consumption (TEC), calculated using the ENERGY STAR Version 6 Draft 2 methodology, associated with using a discrete GPU as a function of GPU frame buffer bandwidth (an objective performance characteristic in which larger frame buffer bandwidth values are associated with higher graphics performance). In general, the vertical spread in data points for the same frame buffer bandwidth reflects the same card being tested in multiple desktops. Figure 2a shows the original CLASP-NRDC discrete GPU dataset alongside the recently completed PG&E dataset. As mentioned above, in the time since the CLASP-NRDC study was conducted, a number of new products have entered the market with Kepler and ZeroCore technologies, generally reducing the energy required to operate a GPU across a range of performance categories. However, the original CLASP-NRDC work included measurements of one card using the new technology (the AMD HD 7970). If we instead separate the datasets based on technology vintage (i.e. those products that use the contemporary architectures vs. legacy products), a clearer and more dramatic picture emerges, and we can see a significant gap between the energy performance of the newest GPUs and legacy products. Figure 2b illustrates that the latest crop of discrete GPUs consume far less power for a given level of performance (as indicated by frame buffer bandwidth) compared to technologies readily sold a little over a year ago.



(a) NRDC-CLASP and PG&E discrete GPU datasets



(b) Legacy and contemporary discrete GPU datasets

Figure 2: Incremental Energy Use of Discrete GPUs

Table 2 below compares current GPU results to older GPU results by ECMA GPU category.[6] ECMA categories are based on frame buffer bandwidth – the higher the category, the higher performance the GPU.[7] The table shows a significant reduction in energy consumption that is most striking in higher performance GPU categories – current G7 cards consume nearly 80% less electricity than their predecessors.

Table 1: Comparison of Electricity Consumption of Current GPUs to Older GPUs in kWh

ECMA Category	Older Technology (additional kWh)	Current Kepler/ZeroCore Technology (additional kWh)	% Decrease
G2	49	40	19%
G4	123	40	67%
G7	301	73	76%

A comprehensive set of detailed results are found in the appendix.

CONCLUSION

The results presented here indicate that there has been a recent paradigm shift in discrete desktop GPU efficiency. The current generation of GPUs, that are a significant and growing portion of all discrete desktop GPUs sold today, are radically more efficient than their recent predecessors, reducing energy consumption between 20 and 75%. These savings demonstrate a compelling opportunity for efficiency in desktop computers.

[6] Note: categories G1, G3, and G5 were omitted as there were no new products available in these categories to test.

[7] See: http://www.ecma-international.org/publications/standards/Categories_to_be_used_with_Ecma-383.htm

APPENDIX: DISCRETE DESKTOP GPUS RELEASED BETWEEN DECEMBER 2011 AND DECEMBER 2012

Manufacturer	Model	Release Date	Efficient Design	Tested?
AMD	HD 7970	12/22/2011	ZeroCore	Tested in CLASP-NRDC study
AMD	HD 7950	1/9/2012	ZeroCore	Yes
AMD	HD 7770	2/15/2012	ZeroCore	Yes
AMD	HD 7750	2/15/2012	ZeroCore	Yes
AMD	HD 7870	3/5/2012	ZeroCore	Yes
AMD	HD 7850	3/5/2012	ZeroCore	Yes
NVIDIA	GTX 680	3/22/2012	Kepler	Yes
NVIDIA	GT 620	4/3/2012	None - rebadge of older GPU	No
NVIDIA	GT 630	4/24/2012	None - rebadge of older GPU	Original GPU tested in CLASP-NRDC study
NVIDIA	GTX 690	5/3/2012	Kepler	Yes
NVIDIA	GTX 670	5/10/2012	Kepler	Yes
NVIDIA	GT 610	5/15/2012	None - rebadge of older GPU	Original GPU tested in CLASP-NRDC study
NVIDIA	GT 640	6/4/2012	Kepler	Yes
NVIDIA	GTX 660 Ti	6/16/2012	Kepler	Yes
AMD	HD 7970 GHz Edition	6/22/2012	ZeroCore	No, OEM only GPU[8]
NVIDIA	GTX 660	9/13/2012	Kepler	Yes
NVIDIA	GTX 650	9/13/2012	Kepler	Yes
NVIDIA	GTX 650 Ti	10/9/2012	Kepler	No, released post testing

[8] This GPU is only available to Original Equipment Manufacturers (OEMs) and cannot be procured through retail channels.

APPENDIX: DETAILED RESULTS (CLASP-NRDC & PG&E DATA)

Configuration	GPU	PC	Efficient Design?	FBB (GB/s)	ECMA Category	Short Idle (W)	Long Idle (W)	Delta TEC From Baseline PC (kWh)	Release Date
Baseline	Baseline	PC1	N/A	N/A	N/A	42.29	41.20	0	N/A
Baseline	Baseline	PC2	N/A	N/A	N/A	36.62	29.36	0	N/A
Baseline	Baseline	PC3	N/A	N/A	N/A	30.03	26.88	0	N/A
Baseline	Baseline	PC4	N/A	N/A	N/A	74.54	58.36	0	N/A
Baseline	Baseline	PC5	N/A	N/A	N/A	49.06	43.91	0	N/A
Baseline	Baseline	PC6	N/A	N/A	N/A	60.02	56.40	0	N/A
Baseline	Baseline	PC4-1	N/A	N/A	N/A	71.51	71.40	0	N/A
Single	GPU1	PC1	No	12.8	1	55.96	51.59	56	4/18/2011
Single	GPU1	PC2	No	12.8	1	42.37	35.68	26	4/18/2011
Single	GPU1	PC3	No	12.8	1	38.73	34.80	37	4/18/2011
Single	GPU1	PC4	No	12.8	1	72.60	64.08	2	4/18/2011
Single	GPU1	PC5	No	12.8	1	62.57	56.92	59	4/18/2011
Single	GPU1	PC6	No	12.8	1	69.65	65.44	41	4/18/2011
Single	GPU2	PC1	No	14.4	1	57.15	54.43	63	1/9/2012
Single	GPU2	PC2	No	14.4	1	44.17	39.38	36	1/9/2012
Single	GPU2	PC3	No	14.4	1	39.07	36.33	40	1/9/2012
Single	GPU2	PC4	No	14.4	1	78.39	74.47	33	1/9/2012
Single	GPU2	PC5	No	14.4	1	63.17	57.78	61	1/9/2012
Single	GPU2	PC6	No	14.4	1	69.43	66.18	42	1/9/2012
Single	GPU3	PC1	No	28.8	2	57.69	53.09	63	6/4/2012
Single	GPU3	PC2	No	28.8	2	43.77	37.10	32	6/4/2012
Single	GPU3	PC3	No	28.8	2	40.05	36.26	43	6/4/2012
Single	GPU3	PC4	No	28.8	2	74.88	67.42	13	6/4/2012
Single	GPU3	PC5	No	28.8	2	63.25	57.76	62	6/4/2012
Single	GPU3	PC6	No	28.8	2	72.02	67.42	51	6/4/2012
Single	GPU4	PC1	No	25.6	2	60.47	57.63	77	6/4/2012
Single	GPU4	PC2	No	25.6	2	47.85	44.04	54	6/4/2012
Single	GPU4	PC3	No	25.6	2	42.25	39.84	54	6/4/2012
Single	GPU4	PC4	No	25.6	2	77.31	71.75	26	6/4/2012
Single	GPU4	PC5	No	25.6	2	65.02	59.82	70	6/4/2012
Single	GPU4	PC6	No	25.6	2	70.39	66.82	45	6/4/2012
Single	GPU5	PC1	No	64	3	61.28	56.58	78	6/4/2012
Single	GPU5	PC2	No	64	3	47.58	40.44	48	6/4/2012
Single	GPU5	PC3	No	64	3	43.03	39.42	56	6/4/2012
Single	GPU5	PC4	No	64	3	78.26	70.86	28	6/4/2012
Single	GPU5	PC5	No	64	3	70.28	64.90	93	6/4/2012

Configuration	GPU	PC	Efficient Design?	FBB (GB/s)	ECMA Category	Short Idle (W)	Long Idle (W)	Delta TEC From Baseline PC (kWh)	Release Date
Single	GPU5	PC6	No	64	3	75.94	72.01	69	6/4/2012
Single	GPU6	PC1	No	57.73	3	64.89	59.97	94	6/4/2012
Single	GPU6	PC2	No	57.73	3	51.02	45.32	65	6/4/2012
Single	GPU6	PC3	No	57.73	3	45.99	42.41	69	6/4/2012
Single	GPU6	PC4	No	57.73	3	82.67	75.42	47	6/4/2012
Single	GPU6	PC5	No	57.73	3	74.05	67.53	108	6/4/2012
Single	GPU6	PC6	No	57.73	3	79.45	74.85	84	6/4/2012
Single	GPU7	PC1	No	76.8	4	76.86	68.41	142	6/4/2012
Single	GPU7	PC2	No	76.8	4	61.80	53.66	109	6/4/2012
Single	GPU7	PC3	No	76.8	4	57.50	51.38	116	6/4/2012
Single	GPU7	PC4	No	76.8	4	97.06	85.76	105	6/4/2012
Single	GPU7	PC5	No	76.8	4	83.91	75.93	149	6/4/2012
Single	GPU7	PC6	No	76.8	4	89.63	82.47	125	6/4/2012
Single	GPU8	PC1	No	95.04	4	74.79	68.95	136	6/4/2012
Single	GPU8	PC2	No	95.04	4	62.27	53.73	111	6/4/2012
Single	GPU8	PC3	No	95.04	4	57.26	51.94	116	6/4/2012
Single	GPU8	PC4	No	95.04	4	94.78	86.21	99	6/4/2012
Single	GPU8	PC5	No	95.04	4	84.75	75.79	151	6/4/2012
Single	GPU8	PC6	No	95.04	4	88.20	82.08	120	6/4/2012
Single	GPU9	PC1	No	128	5	65.95	60.67	98	6/4/2012
Single	GPU9	PC2	No	128	5	52.44	44.83	69	6/4/2012
Single	GPU9	PC3	No	128	5	48.73	44.28	80	6/4/2012
Single	GPU9	PC4	No	128	5	83.10	74.77	48	6/4/2012
Single	GPU9	PC5	No	128	5	74.61	68.70	111	6/4/2012
Single	GPU9	PC6	No	128	5	80.27	75.72	87	6/4/2012
Single	GPU10	PC1	No	104.5	5	65.08	59.91	94	4/18/2011
Single	GPU10	PC2	No	104.5	5	50.85	45.16	64	4/18/2011
Single	GPU10	PC3	No	104.5	5	46.82	42.95	73	4/18/2011
Single	GPU10	PC4	No	104.5	5	82.27	75.90	47	4/18/2011
Single	GPU10	PC5	No	104.5	5	73.06	67.36	104	4/18/2011
Single	GPU10	PC6	No	104.5	5	77.72	73.59	77	4/18/2011
Single	GPU11	PC1	Yes	264	7	66.65	50.05	86	4/18/2011
Single	GPU11	PC2	Yes	264	7	53.11	33.33	56	4/18/2011
Single	GPU11	PC3	Yes	264	7	48.31	31.94	63	4/18/2011
Single	GPU11	PC4	Yes	264	7	85.26	65.03	42	4/18/2011
Single	GPU11	PC5	Yes	264	7	74.16	58.73	96	4/18/2011
Single	GPU11	PC6	Yes	264	7	79.71	65.78	73	4/18/2011
Single	GPU12	PC4	No	331.8	7	130.49	110.24	240	3/24/2011

Configuration	GPU	PC	Efficient Design?	FBB (GB/s)	ECMA Category	Short Idle (W)	Long Idle (W)	Delta TEC From Baseline PC (kWh)	Release Date
Single	GPU12	PC5	No	331.8	7	130.59	110.03	337	3/24/2011
Single	GPU12	PC6	No	331.8	7	139.50	119.24	326	3/24/2011
Single	GPU13	PC1	Yes	72	4	52.47	47.33	39	2/15/2012
Single	GPU14	PC1	Yes	80	4	48.10	47.18	25	9/13/2012
Single	GPU15	PC1	Yes	154	7	56.98	48.47	54	3/5/2012
Single	GPU16	PC1	Yes	144	7	47.96	46.51	24	9/13/2012
Single	GPU17	PC1	Yes	72	4	55.07	48.25	48	2/15/2012
Single	GPU18	PC1	Yes	154	7	57.70	49.52	58	3/5/2012
Single	GPU19	PC1	Yes	240	7	58.58	50.19	61	1/9/2012
Single	GPU20	PC1	Yes	144	7	59.22	57.90	73	8/16/2012
Single	GPU21	PC1	Yes	192	7	57.55	56.39	66	5/10/2012
Single	GPU22	PC1	Yes	192	7	56.02	54.73	60	3/22/2012
Single	GPU24	PC1	Yes	29	2	47.01	45.85	20	6/4/2012
Single	GPU13	PC2	Yes	72	4	39.35	39.26	42	2/15/2012
Single	GPU14	PC2	Yes	80	4	39.77	38.93	42	9/13/2012
Single	GPU15	PC2	Yes	154	7	40.26	31.73	35	3/5/2012
Single	GPU17	PC2	Yes	72	4	37.78	30.14	25	2/15/2012
Single	GPU18	PC2	Yes	154	7	40.99	32.01	37	3/5/2012
Single	GPU19	PC2	Yes	240	7	41.39	41.27	51	1/9/2012
Single	GPU20	PC2	Yes	144	7	49.40	48.26	84	8/16/2012
Single	GPU21	PC2	Yes	192	7	47.74	46.41	77	5/10/2012
Single	GPU22	PC2	Yes	192	7	46.76	45.42	72	3/22/2012
Single	GPU23	PC2	Yes	385	7	66.41	64.13	157	5/3/2012
Single	GPU24	PC2	Yes	29	2	38.86	38.06	39	6/4/2012
Single	GPU13	PC3	Yes	72	4	35.37	35.30	35	2/15/2012
Single	GPU14	PC3	Yes	80	4	38.55	37.78	48	9/13/2012
Single	GPU15	PC3	Yes	154	7	39.50	30.66	42	3/5/2012
Single	GPU17	PC3	Yes	72	4	37.96	29.59	36	2/15/2012
Single	GPU18	PC3	Yes	154	7	40.13	30.39	43	3/5/2012
Single	GPU19	PC3	Yes	240	7	40.81	40.64	59	1/9/2012
Single	GPU20	PC3	Yes	144	7	48.35	47.39	91	8/16/2012
Single	GPU21	PC3	Yes	192	7	46.45	45.40	83	5/10/2012
Single	GPU22	PC3	Yes	192	7	45.47	44.44	78	3/22/2012
Single	GPU23	PC3	Yes	385	7	55.28	52.55	119	5/3/2012
Single	GPU24	PC3	Yes	29	2	38.15	37.46	47	6/4/2012
Single	GPU13	PC4-1	Yes	72	4	76.79	69.29	13	2/15/2012
Single	GPU14	PC4-1	Yes	80	4	78.90	77.23	30	9/13/2012
Single	GPU15	PC4-1	Yes	154	7	79.36	70.80	23	3/5/2012

Configuration	GPU	PC	Efficient Design?	FBB (GB/s)	ECMA Category	Short Idle (W)	Long Idle (W)	Delta TEC From Baseline PC (kWh)	Release Date
Single	GPU16	PC4-1	Yes	144	7	77.47	75.49	24	9/13/2012
Single	GPU17	PC4-1	Yes	72	4	77.22	69.88	16	2/15/2012
Single	GPU18	PC4-1	Yes	154	7	79.21	70.23	22	3/5/2012
Single	GPU19	PC4-1	Yes	240	7	80.26	72.65	28	1/9/2012
Single	GPU20	PC4-1	Yes	144	7	88.83	86.90	73	8/16/2012
Single	GPU21	PC4-1	Yes	192	7	87.00	85.42	66	5/10/2012
Single	GPU22	PC4-1	Yes	192	7	85.14	83.87	58	3/22/2012
Single	GPU23	PC4-1	Yes	385	7	113.35	111.64	181	5/3/2012
Single	GPU24	PC4-1	Yes	29	2	75.35	74.38	16	6/4/2012
Single	GPU13	PC5	Yes	72	4	59.15	54.63	61	2/15/2012
Single	GPU14	PC5	Yes	80	4	62.46	61.10	79	9/13/2012
Single	GPU15	PC5	Yes	154	7	63.92	55.42	76	3/5/2012
Single	GPU16	PC5	Yes	144	7	61.36	59.89	74	9/13/2012
Single	GPU17	PC5	Yes	72	4	61.39	55.14	68	2/15/2012
Single	GPU18	PC5	Yes	154	7	64.29	55.27	77	3/5/2012
Single	GPU19	PC5	Yes	240	7	64.50	56.79	80	1/9/2012
Single	GPU20	PC5	Yes	144	7	72.61	70.86	123	8/16/2012
Single	GPU21	PC5	Yes	192	7	70.66	69.20	115	5/10/2012
Single	GPU22	PC5	Yes	192	7	69.44	68.22	110	3/22/2012
Single	GPU23	PC5	Yes	385	7	79.14	76.73	151	5/3/2012
Single	GPU24	PC5	Yes	29	2	61.38	60.51	75	6/4/2012
Single	GPU13	PC6	Yes	72	4	65.65	61.48	30	2/15/2012
Single	GPU14	PC6	Yes	80	4	69.52	68.30	51	9/13/2012
Single	GPU15	PC6	Yes	154	7	70.60	62.45	47	3/5/2012
Single	GPU16	PC6	Yes	144	7	68.37	66.97	46	9/13/2012
Single	GPU17	PC6	Yes	72	4	67.22	61.12	34	2/15/2012
Single	GPU18	PC6	Yes	154	7	70.76	62.20	47	3/5/2012
Single	GPU19	PC6	Yes	240	7	71.79	63.39	51	1/9/2012
Single	GPU20	PC6	Yes	144	7	79.27	78.43	94	8/16/2012
Single	GPU21	PC6	Yes	192	7	77.42	75.90	85	5/10/2012
Single	GPU22	PC6	Yes	192	7	76.17	74.92	80	3/22/2012
Single	GPU23	PC6	Yes	385	7	86.47	83.93	123	5/3/2012
Single	GPU24	PC6	Yes	29	2	67.18	66.79	42	6/4/2012