Assessment of Desktop Computer Graphics Cards Idle Power

Preliminary Results

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I. Purpose

This project aims to develop a representative dataset of discrete graphics card power use in idle mode to support the setting of effective graphics adders in the ENERGY STAR v6 computers specification, as well as in mandatory standards that use the ENERGY STAR computer specification as a framework.

Discrete graphics cards are add-in cards that interface with the motherboard through an expansion slot, as opposed to integrated graphics that are integrated to the motherboard or CPU.

Discrete graphics card adders are a critical element in desktop computer efficiency specifications. If they are set too high, graphics card adders can provide a significant excess margin of energy consumption for the rest of the computer system, which can allow inefficient computers to meet efficiency requirements for standards and labels. On the other hand, setting graphics card adders too low may restrict market access for efficient computers that require graphics cards for specific applications (e.g., computer gaming). Setting graphics card adders at the correct levels will ensure standards and labeling programs support energy efficient computers while excluding inefficient models.

A representative dataset of graphics card energy consumption is needed to set appropriate graphics card adders; while the ENERGY STAR v6 dataset contains a number of graphics enabled configurations; we believe that more data is needed.

The Collaborative Labeling and Appliance Standards Program (CLASP) and the Natural Resources Defense Council (NRDC) initiated this study to collect a representative dataset of graphics card energy consumption in order to assist policy makers who are developing voluntary and mandatory computer efficiency labels and standards.

II. Background

This document presents a preliminary summary of test results and key findings. Until the data has been reviewed and any potential issues have been resolved, this data should be considered preliminary. CLASP and NRDC will publish a final report with final test results, key findings, policy analysis, and recommendations by the middle of 2012.

This study only applies to desktop computers; it does not include notebook computers. Our testing approach could not be applied to notebook graphics due to their higher level of integration and customization. In addition, notebook graphics are not as interchangeable as desktop graphics, making testing more difficult. Finally, notebook graphics are already more efficient than desktop graphics, justifying the focus of our study on the segment where the highest energy saving potential exists.

Ecova's memo "Desktop Graphics Cards Idle Power Measurement: Test Approach and Component Selection Criteria" presents important background information on the project's testing approach and component selection. We highly recommend reading it prior to reading this document.

III. Preliminary Results

On behalf of CLASP and NRDC, Ecova conducted laboratory testing of twelve different graphics cards in six distinct desktop computers. Graphics cards were selected from each ECMA[1] category except for category 6, which represents a relatively small part of the graphics card market. While this data is based upon a limited sample of cards and computers, the careful selection of our sample makes it fairly representative of the desktop graphics card market at the end of 2011. Detailed characteristics of each card, such as manufacturer and memory, are available in Ecova's memo, "Desktop Graphics Cards Idle Power Measurement: Test Approach and Component Selection Criteria."

Energy consumption was measured for the computer system and not the individual graphics cards, because measuring the consumption of the graphics card separately from the computer does not fully account for graphics card energy consumption. When a graphics card is put into a computer it affects the energy consumption of multiple computer components, including the cooling fans, memory, motherboard and central possessing unit (CPU). Energy requirements of the graphics cards were calculated as the difference in energy consumption between the computer system without the graphics card and the computer system with the graphics card. Measuring energy consumption in this manner provides an accurate picture of the energy requirements of discrete graphics cards.

Multiple test runs – three in most cases and two in dual card tests – were conducted with each graphics card in each computer; test results are reported as the average of these multiple measurements. This document will not discuss variability between multiple test runs of the same graphics card in the same computer; however, preliminary data suggests that there is little variability. A full analysis of graphics card variability will be included in the final report.

Single Card Test Results

Ecova conducted laboratory testing of each graphics card in each computer in idle mode, when there is little or no graphics processing required. Energy Star uses idle mode power as a proxy for average power use when the computer is active. It does not require the measurement of active power when the user is actively using the computer.

A summary of graphics card power use in idle mode can be found in Table 1. Power values represent the average power requirement of each graphics card across all computers. Typical Energy Consumption (TEC) values represent the card annual energy requirement derived from power values in different modes per the Energy Star framework. Both power and energy value are based on delta measurements between computers with and without the card.

[1] ECMA is an industry association dedicated to the standardization of Information and Communication Technology (ICT) and Consumer Electronics (CE): http://www.ecma-international.org

Table 1: Average Test Results for Each Graphics Card

Card	GPU	Card Frame Buffer Bandwidth[1] (GB/s)	ECMA-383 (v3)[2]	Short Idle Average Delta[3] (W)	Long Idle Average Delta[4] (W)	TEC E* v6 Draft 1 Average Delta[5] (kWh/yr)	TEC E* v5 Desktops Average Delta[6] (kWh/yr)
GPU1	AMD Radeon HD 6450	12.8	G1	8.2	8.7	36.7	28.8
GPU2	NVIDIA GeForce GT 520	14.4	G1	9.8	12.1	45.9	34.3
GPU3	AMD Radeon HD 6570	28.8	G2	9.8	10.5	44.0	34.5
GPU4	NVIDIA GeForce GT 440	25.6	G2	11.8	14.0	54.5	41.3
GPU5	AMD Radeon HD 6670	64.0	G3	14.0	14.7	62.1	48.9
GPU6	NVIDIA GeForce GTS 450	57.7	G3	17.6	18.2	77.9	61.6
GPU7	AMD Radeon HD 6770	76.8	G4	29.0	26.9	124.4	101.7
GPU8	NVIDIA GeForce GTX 460	95.0	G4	28.2	27.1	122.2	99.0
GPU9	AMD Radeon HD 6850	128.0	G5	18.8	18.8	82.2	65.7
GPU10	NVIDIA GeForce GTX 550	104.5	G5	17.2	18.1	76.6	60.3
GPU11	AMD Radeon HD 7970	264.0	G7	19.1	8.1	69.3	66.9
GPU12	NVIDIA GeForce GTX 590	331.8	G7	72.3	60.3	300.9	253.4

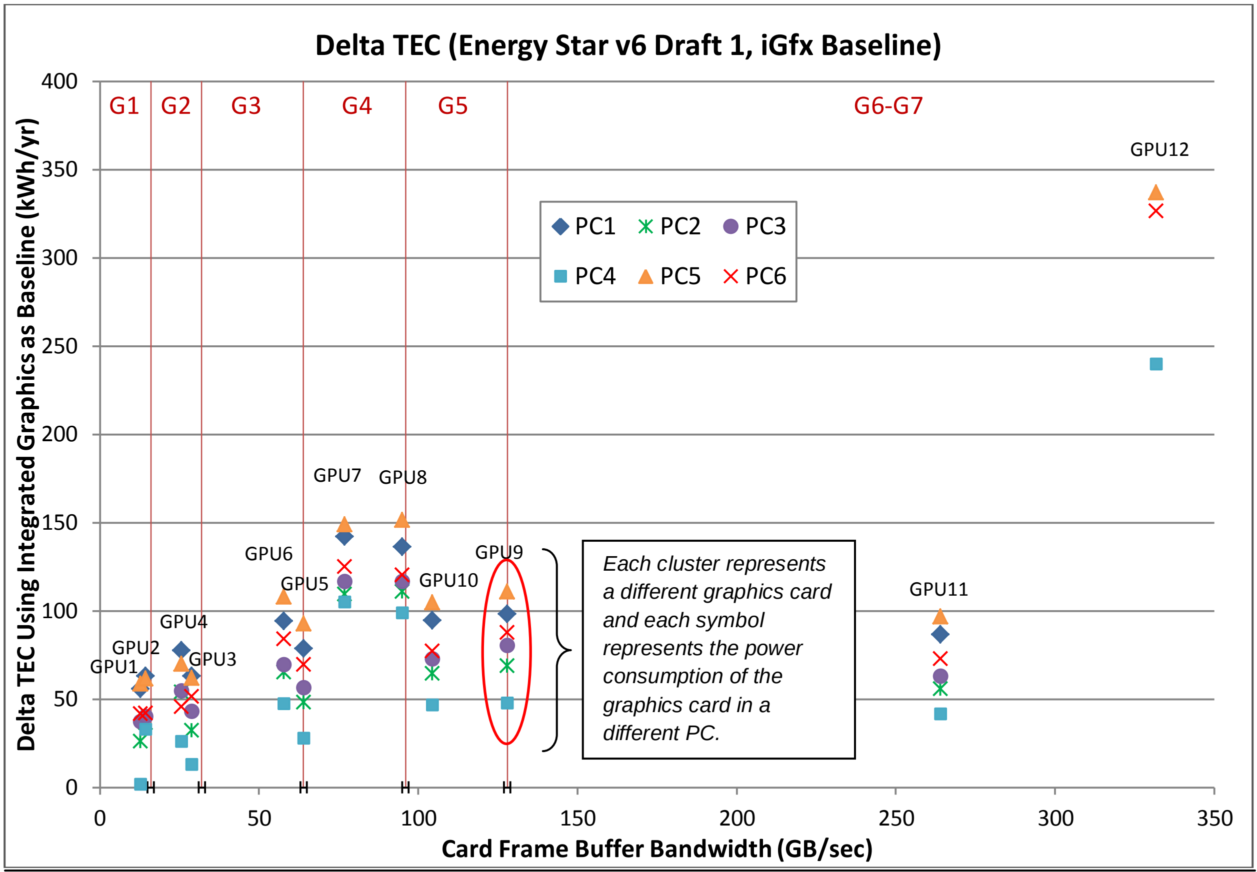
Notes:

1. Card Frame Buffer Bandwidth: a proxy for graphics card performance as defined by ECMA at the link below.
2. ECMA-383 (v3): discrete graphics categories as defined at : http://www.ecma-international.org/publications/standards/Categories_to_be_used_with_Ecma-383.htm
3. Short Idle Average Delta: average difference across the 6 test PCs between system power with the card and system power without the card (using integrated graphics) in short idle mode.
4. Long Idle Average Delta: average difference across the 6 test PCs between system power with the card and system power without the card (using integrated graphics) in long idle mode.
5. Average Delta TEC ES v6 Draft 1: average difference across the 6 test PCs between system Typical Energy Consumption (TEC) with the card and system TEC without the card (using integrated graphics). This TEC value is a weighted average of short and long idle values according to ENERGY STAR Computers v6 draft 1 (45% Off, 5% Sleep, 15% Long Idle, 35% Short Idle).
6. Average Delta TEC ES v5: Same as previous but based on Short idle only and using the ENERGY STAR Computers v5 idle weighting of 40%. ENERGY STAR v5 idle corresponds to Short idle for desktops and Long idle for notebooks and integrated desktops. The blue color code indicates Energy Star v5 throughout this document.

Graphics card testing highlights the following facts (see Figure 1):

1. Graphics card power consumption generally increases with frame buffer bandwidth, however this is not always the case as shown by GPU10 and GPU11 which use significantly lower power than cards with lower frame buffer bandwidth;
2. Power consumption of individual graphics cards varies from computer to computer; and
3. New energy efficiency features may substantially decrease graphics card power consumption as illustrated by GPU11 vs. GPU12.

Figure 1: Delta TEC (ENERGY STAR v6 Draft 1, iGfx Baseline)



Note: GPU12 has only 3 data points because it would only run in 3 of our 6 test PCs due to its high maximum power requirements. GPU11 and GPU12 are both G7 cards. The difference in power consumption may be explained by a special feature of GPU11. GPU 11 is an AMD Radeon 7970, the first card on the market to feature ZeroCore Power Technology designed to dramatically reduce card power consumption in idle mode.

While using an average across several computers represents the simplest approach to reporting incremental energy requirements to run a given discrete graphics card, actual energy requirements for that card will vary from computer to computer (see Table 2).

Preliminary results, displayed in Table 2 below, show that some computer systems consistently used more additional energy to run the graphics cards than other computers. PC 5 consistently required more energy to run the graphics card. This is likely due to the fact that its integrated graphics, which is overridden by the discrete graphics card, is highly efficient. Results also show that some computers consistently used less additional energy to run the graphics cards than other computers. PC 4 consumes less additional energy because its integrated graphics, which is overridden by the discrete graphics card, is inefficient compared to the other computers. PCs 2, 3, and 6 appear to be fairly representative of the average computer.

Table 2: Delta TEC Values (ENERGY STAR v6 Draft 1, iGfx Baseline)

kWh/yr	PC1	PC2	PC3	PC4	PC5	PC6	Average
GPU1	55.6	25.9	37.1	1.6	58.5	41.4	**36.7**
GPU2	62.9	36.3	40.1	33.0	61.5	41.7	**45.9**
GPU3	62.9	32.1	43.1	12.9	61.7	51.3	**44.0**
GPU4	77.3	53.7	54.5	26.1	69.8	45.5	**54.5**
GPU5	78.4	48.2	56.4	27.8	92.6	69.3	**62.1**
GPU6	94.0	65.1	69.3	47.3	107.7	83.8	**77.9**
GPU7	141.7	109.1	116.4	105.0	148.9	125.0	**124.4**
GPU8	136.1	110.6	116.4	98.6	151.3	120.1	**122.2**
GPU9	98.1	68.8	80.2	47.8	110.9	87.5	**82.2**
GPU10	94.5	64.4	72.6	46.7	104.4	76.9	**76.6**
GPU11	86.3	55.8	62.7	41.6	96.4	72.7	**69.3**
GPU12				239.7	336.8	326.3	**300.9**

Note: The color spectrum indicates comparative energy use among the PCs tested for a given graphics card (GPU); red indicates the highest energy consumption and green the lowest.

Results by ECMA Category

Tables 3 and 4 and Figure 2 show results grouped by ECMA category. These tables can be used by policy makers who are developing voluntary and mandatory computer efficiency labels and standards.

Table 3: ENERGY STAR v6 Draft 1 – TEC Delta (kWh/yr)

ECMA-383 (v6)	Min	25th Percentile	Median	75th Percentile	Max
G1	1.6	35.5	40.8	56.3	62.9
G2	12.9	40.3	52.5	62.0	77.3
G3	27.8	54.3	69.3	86.0	107.7
G4	98.6	110.3	118.3	137.5	151.3
G5	46.7	67.7	78.5	95.4	110.9
G6					
G7 (GPU11)	41.6	57.5	67.7	82.9	96.4
G7 (GPU12)	239.7	283.0	326.3	331.5	336.8

Notes:

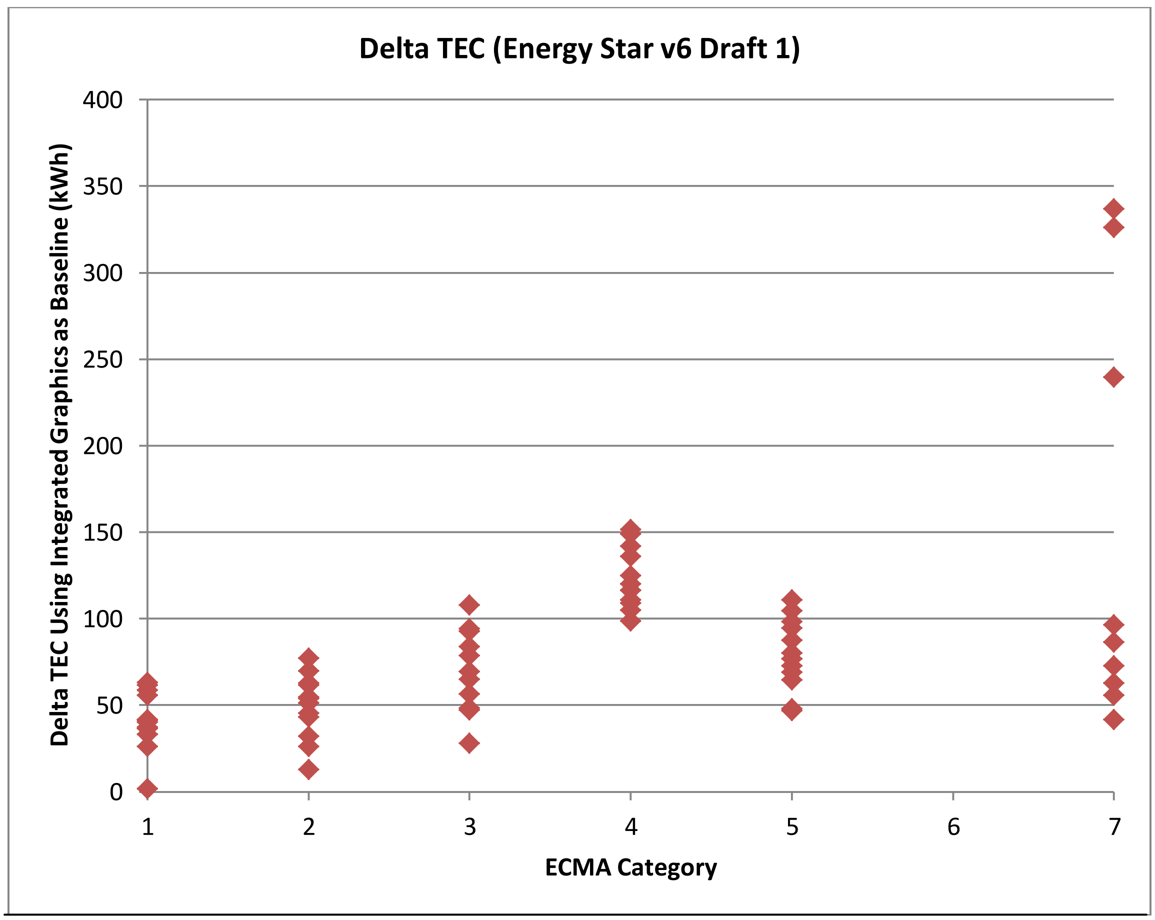
1. GPU12 and GPU11 have been separated because their power consumption in idle mode is substantially different. When standard statistics are applied to these two cards the result does not adequately represent the market. GPU12 may be more representative of the current G7 market and GPU11, which uses AMD's ZeroCorePower technology, may be more representative of the near to mid-term future of desktop graphics card market.
2. Our sample does not include a G6 card, because they represent a small segment of the graphics card market.

Table 4: ENERGY STAR v5 Desktop – TEC Delta (kWh/yr)

ECMA-383 (v6)	Min	25th Percentile	Median	75th Percentile	Max
G1	-6.8	24.9	32.3	47.5	52.1
G2	1.2	32.6	40.7	50.8	63.7
G3	13.0	43.8	55.9	69.6	87.6
G4	70.9	89.4	97.5	115.7	125.1
G5	27.1	54.0	63.8	80.6	89.5
G6					
G7 (GPU11)	37.6	59.3	66.5	81.3	87.9
G7 (GPU12)	196.0	237.3	278.5	282.1	285.7

Figure 2 represents the same data as figure 1 but by ECMA category rather than by card:

Figure 2: ENERGY STAR v6 Draft 1 – TEC Delta



Dual Graphics Card Testing Results (Additional Graphics Adders)

Ecova also conducted testing of computers with dual graphics card configurations – two graphics cards of the same type. Dual graphics card configurations are also known as SLI for Nvidia technology and CrossFireX for AMD technology. Testing was conducted on a smaller number of graphics cards and a smaller number of computers. Dual card tests were only performed on PCs 4 and 6 and on ten cards (excluding GPU2 and GPU4) as other cards and PCs did not support dual-card configurations. A summary of the additional energy required to run a second discrete graphics card is summarized in Table 5.

Table 5: Dual Graphics Card Testing: Results by Card

kWh/yr		PC4			PC6		
ECMA Category	GPU	Single Card d(iGfx)[1]	Dual Card d(single card)[2]	Dual Card d(iGfx)[3]	Single Card d(iGfx)[1]	Dual Card d(single card)[2]	Dual Card d(iGfx)[3]
1	GPU1	1.6	25.4	27.0	41.4	26.2	67.6
2	GPU3	12.9	23.1	36.0	51.3	27.3	78.5
3	GPU5	27.8	29.7	57.5	69.3	31.6	100.9
3	GPU6	47.3	57.6	104.9	83.8	55.2	138.9
4	GPU7	105.0	78.0	183.0	125.0	93.2	218.2
4	GPU8	98.6	106.6	205.2	120.1	131.1	251.3
5	GPU9	47.8	56.2	104.0	87.5	64.4	151.9
5	GPU10	46.7	58.5	105.2	76.9	82.4	159.3
7	GPU11	41.6	33.0	74.7	72.7	47.4	120.1
7	GPU12	239.7	277.3	517.0	326.3	296.0	622.3

Notes:

1. Single Card d(iGfx): TEC delta between single card and integrated graphics
2. Dual Card d(single card): TEC delta between the second card and the first one
3. Dual Card d(iGfx): TEC delta between the second card and integrated graphics

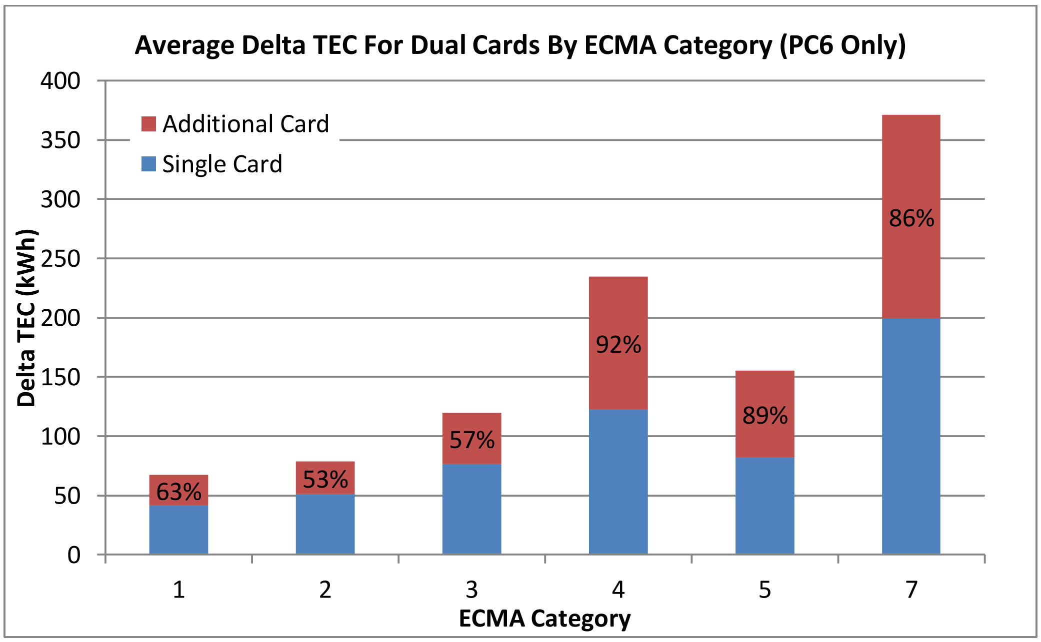
As illustrated by GPU1 in PC4 (Table 5), dual graphic card adders for PC4 are skewed by the fact that there is little difference between PC4's power consumption with integrated graphics versus a single graphics card, because its integrated graphics card consumes a high amount of energy. Therefore, when the second graphics card is added to PC4, it consumes significantly more additional power than the first. This makes PC4's additional power consumption for a second card abnormally high and not representative of the average computer.

As discussed with Table 2, PC6 is much more representative of an average computer. The additional power consumption needed to run a second graphics card is lower than that required for the first card. Second cards require on average only 73% of the power of the first card:

Table 6: Average Delta TEC for Dual Cards by ECMA Category for PC 6

ECMA Category	Average Single Card d(iGfx)	Average Dual Card d(single card)	Dual as % of Single
1	41.4	26.2	63%
2	51.3	27.3	53%
3	76.6	43.4	57%
4	122.6	112.2	92%
5	82.2	73.4	89%
7	199.5	171.7	86%
		Average	73%

Figure 3: Average Delta TEC for Dual Cards by ECMA Category for PC 6



Note: Table 6 and Figure 3 use ENERGY STAR v6 Draft 1 formulae. ENERGY STAR v5 shows similar ratios with different absolute values.

IV. Next Steps

CLASP and NRDC will publish a full report, including final test results, key findings, policy analysis, and recommendations. The final report should be available by the summer of 2012. Prior to the publication of this report, CLASP and NRDC will give stakeholders an opportunity to review data and provide feedback. Testing data will be made available upon request.