NATURAL RESOURCES DEFENSE COUNCIL

California Energy Commssion
DOCKETED
12-AAER-2A
TN 70852
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May 9, 2013

California Energy Commission
Dockets Office, MS-4
Re: Docket No. **12-AAER-2A**
1516 Ninth Street
Sacramento, CA 95814-5512

Enclosed are the Natural Resources Defense Council's (NRDC) Responses to CEC's Invitation to Participate in the Development of Appliance Energy Efficiency Measures 2013 Appliance Efficiency Pre-Rulemaking on Appliance Efficiency Regulations: Docket Number 12-AAER-2A on Consumer Electronics.

The enclosed DVD includes responses on these 4 categories in one pdf:

- Computers with CLASP-NRDC report listed in the response as attachment 7;
- Displays;
- Game Consoles; and
- Set-Top Boxes and Small Network Equipment with attachments.

The DVD also includes excel spreadsheets that accompany the response on computers and includes:

- NRDC Computers Attachment 1. ENERGY STAR v5.2 Qualified Product List May 1, 2013
- NRDC Computers Attachment 2. ENERGY STAR v6.0 Dataset v2
- NRDC Computers Attachment 3. NRDC Dataset – Desktops
- NRDC Computers Attachment 4. NRDC Dataset – Notebooks
- NRDC Computers Attachment 5. NRDC Power Supply Data and Analysis
- NRDC Computers Attachment 6. NRDC Active Load Test Data
- NRDC Computers Attachment 8. NRDC Stock and Energy Use Estimate

Thank you for the opportunity to respond.

Sincerely,

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NRDC
THE EARTH'S BEST DEFENSE

NRDC's Response to CEC's Invitation to Participate in the Development of Appliance Energy Efficiency Measures

2013 Appliance Efficiency Pre-Rulemaking on Appliance Efficiency Regulations: Docket Number 12-AAER-2A - Consumer Electronics - Computers

May 9, 2013

Submitted by:
Pierre Delforge, Natural Resources Defense Council

On behalf of the Natural Resources Defense Council and our more than 250,000 members and online activists in California, we respectfully submit this response to the Energy Commission's Invitation to Participate in the Development of Appliance Energy Efficiency Measures, posted on March 25, 2013. This response addresses the Commission's questions on computers.

Summary

Personal computers (desktops and notebooks) represent the second largest electronic energy end-use in the U.S., after televisions, and on-par with data centers. There are approximately 40 million installed computers in California and per NRDC estimates they consume roughly 7-8 TWh annually, or 2.5 percent of California electricity end-use. The energy consumed by these computers is equivalent to the electricity use of all the households in the city of Los Angeles, and costs Californians $1 billion in annual electricity bills.

There is a wide range of energy use between computers of similar performance and functionality, reflecting differing levels of adoption of energy efficiency best-practices.

The only existing energy efficiency standard for computers in the U.S. is the ENERGY STAR labeling program. While this voluntary program encourages innovation and accelerates the adoption of energy efficiency best-practices in segments of the market that are sensitive to this type of recognition, the program is not intended to ensure that all products on the market meet minimal levels of energy efficiency. This requires minimum energy performance standards.

Thanks to the ENERGY STAR program for computers, there is an extensive amount of information available on computer energy use, both from the Qualified Product List and from separate data collection and analysis efforts conducted as part of the ENERGY STAR specification development process. This includes data on power supply efficiency and graphics cards energy use. In addition, the California IOUs have done research and analysis to demonstrate cost-effective pathways for improving the energy efficiency of typical modern computers. This provides CEC with a wealth of data to determine the appropriate standards levels that are technologically feasible and cost-effective.

The ENERGY STAR specification provides a robust and mature framework that CEC can leverage to develop balanced and effective performance-based computer standards. While CEC can adjust the specifications limits and adders to meet the requirements of mandatory standards, the categories, eligibility criteria for functionality allowances, and test method should be usable as is for CEC standards. It is important to note that the ENERGY STAR framework deals with the energy used by computers in idle, sleep and off modes, when the user is not actively using the computer. It does not in any way constrain the energy used by computers to perform work or deliver content.

Performance-based standards based on the ENERGY STAR framework give industry the flexibility to meet energy limits in the most cost-effective manner, fostering competition and innovation. They also ensure that new features are designed using efficiency best-practices from the beginning, and in particular using minimal power when the user is not actively using the computer.

Contents

1. Basic Information

There are approximately 40 million installed computers in California and per NRDC estimates they consume roughly 7-8 TWh annually[i], or 2.5 percent of California electricity end-use. The energy consumed by these computers is equivalent to the electricity use of all the households in the city of Los Angeles, and costs Californians $1 billion in annual electricity bills.

1.1 Product Definition and Scope

ENERGY STAR is the de facto international standard for product scope and definitions on computers. It is used as the basis for virtually all computer standards and labeling programs internationally, see the section describing international standards further down.

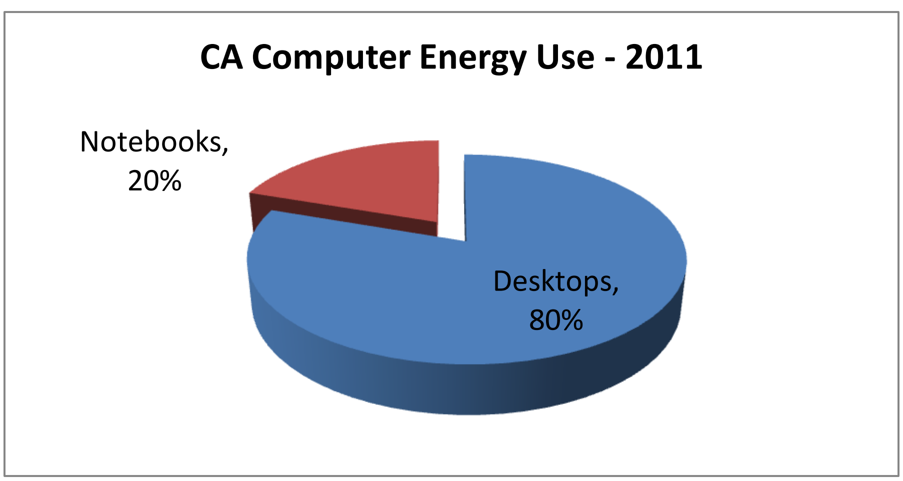
As discussed in the Existing Standards and Standards Under Development, NRDC recommends using the new v6.0 ENERGY STAR framework which is better suited to the current market and will ensure California computer standards are more effective and remain effective for a longer period of time.

1.2 Desktops, Notebooks, tablets, Thin Clients, Workstations

Despite Their Decline, Desktops Still Represent the Vast Majority of Computer Energy Use

Over four fifths of that energy today is consumed by desktops - While a strong shift from desktops to notebooks is evident is sales numbers, and desktops sales have been declining in absolute numbers, desktops are not expected to disappear anytime soon: both consumers and businesses still buy desktop computers for reasons ranging from performance to security, reliability and upgradeability. Desktops will continue to be responsible for the majority of aggregate computer energy use for most of the decade because a typical desktop still uses 4 to 5 times as much energy as a typical notebook.

Figure 1: California Computer Annual Energy Use

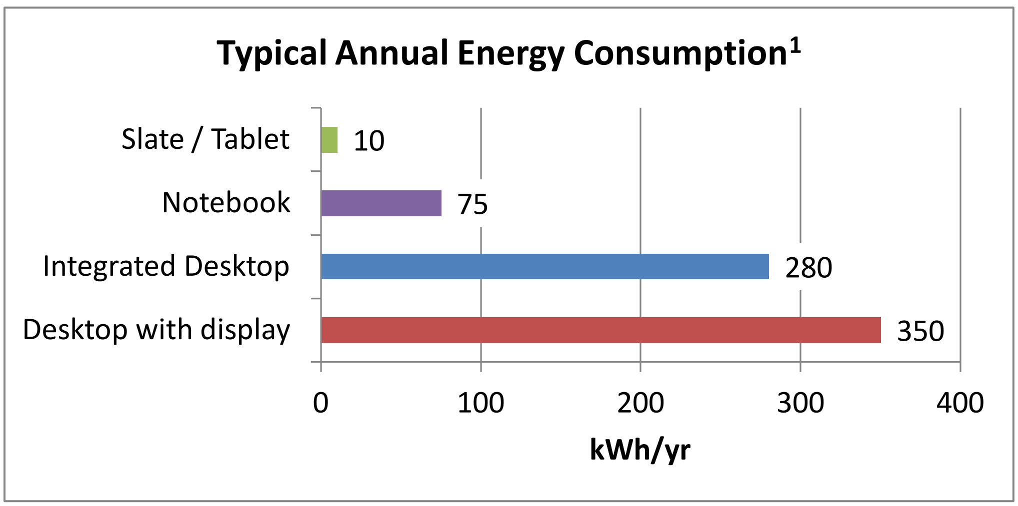


This ratio is due to change significantly however, as sales of notebook computers outnumbered sales of desktop computer by a nearly two-to-one margin in 2012. This change will take a while to make its way through the installed base as desktop computers tend to last 5 years whereas notebooks are replaced every 3 years. NRDC estimates that by the end of the decade, aggregate notebook energy use should be roughly on par with that of desktops, which makes it important to consider energy saving opportunities in both notebooks and desktops.

There is a Wide Spread of Energy Use Between The Different Types of Computers

Figure 2 shows the large difference in unit energy use between the different computer form factors, including display energy. The magnitude of the differences shows clearly that there is much more at play than just performance differences: desktops, and to some extent notebooks, use less efficient components and architectures than notebooks and slates respectively.

Figure 2: Comparison of Annual Energy Use by Different Types of Computers



(1) iPad3, desktop and notebook TEC per averages of Dec 2012 ENERGY STAR qualified product list, including v6 display adder, and 30% overhead for active use and accessories per section 6.1

Energy Saving Opportunities

Both desktops and notebooks present significant opportunities for energy savings. Desktops present the largest opportunity because they have access to unlimited power from the wall outlet and therefore have little incentive to conserve energy. As a result they have not seen the same level of effort and innovation to increase their energy efficiency as notebooks. Traditional desktops consume 4 to 5 times as much energy as equivalent notebooks.

Integrated desktops (also known as “All-in-One” computers), are approximately 20-30% more efficient than traditional desktops due to their use of some notebooks components in order to manage thermal and space constraints in a smaller form factor. However much more can be done toward energy efficiency as evidenced by the comparison with notebooks.

Notebooks have a natural incentive to conserve energy due to battery life concerns, however they still use 6 to 7 times as much energy as slates (aka tablets like the Apple iPad). This is in part due to the fact that notebooks are still primarily used plugged in, with battery-powered operation being a secondary mode, while slates are designed to be used primarily on battery power. The slates stronger battery life imperative and smaller form factor has resulted in innovative slate designs optimized to conserve power to a higher degree than notebooks. In particular, slates feature instant-on sleep modes allowing devices to seamlessly go to and wake up from sleep when not in use contrary to legacy notebook designs which still feature inconvenient wake-up times. Slates are also capable of scaling power down when not performing any task, allowing for very low power idle modes.

Pressed by the higher portability and usability of slates, notebooks are continuing to evolve as evidenced by the "Ultrabook" designs and architecture innovations such as Intel's Haswell architecture[ii] which introduces new sleep states designed to compete with the ultra-low power idle modes of slates.

Slates (aka Media Tablets)

Slates, such as the Apple iPad and Samsung Galaxy Tab, are already very energy efficient due to their ultra-compact form factor and being designed for mobility and maximum battery life. As such they are a lower priority for mandatory energy efficiency standards than notebooks. The only operational energy use not covered by the battery life incentive is that of charging efficiency, but slates battery charging efficiency is covered by California's battery charger standards and by the potential future federal DOE BCEPS standards. We therefore recommend not to include slates in computer efficiency standards at this time, and to monitor this market to determine the need for future coverage.

Thin clients and Workstations

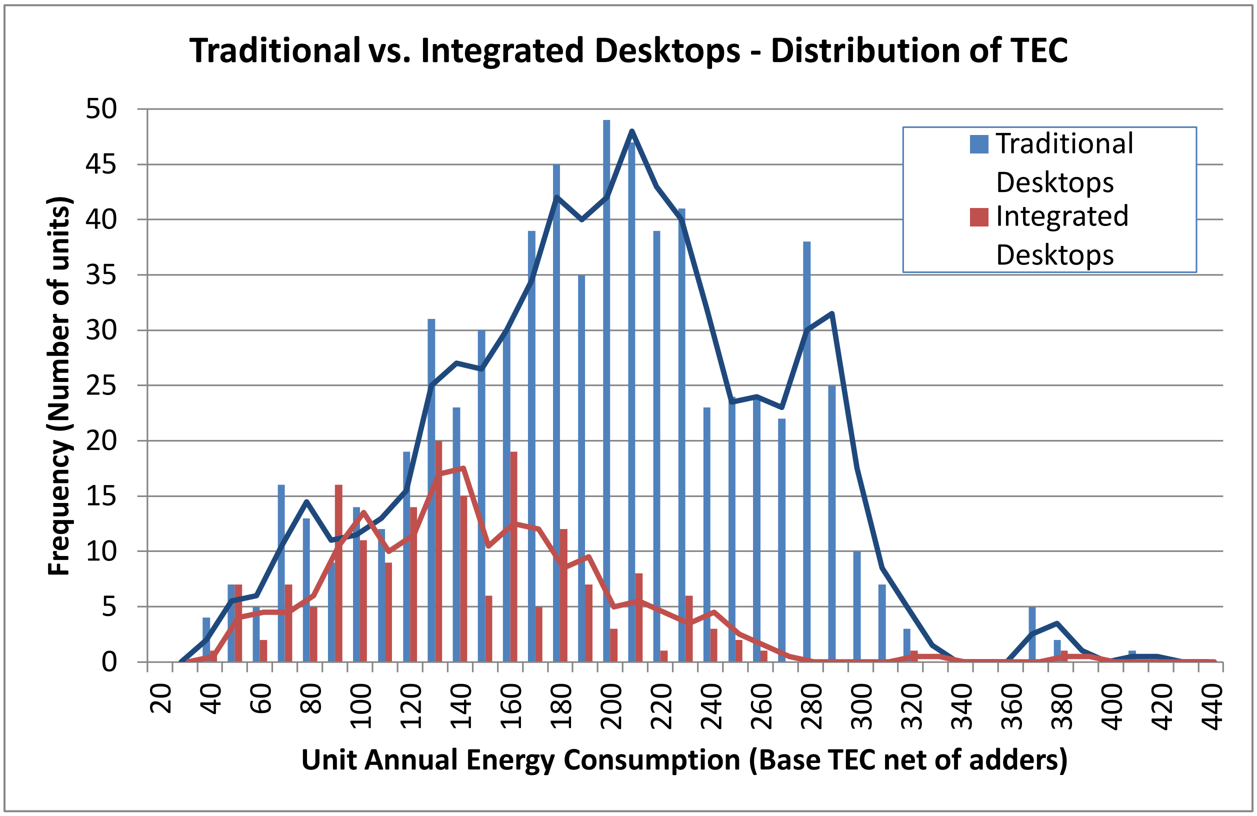
Thin clients and workstations represent a small market share compared to traditional desktops and notebooks. We recommend that they be covered in a simplified manner, similar to the EU Ecodesign regulation which only sets power supply efficiency and power management requirements for thin clients and workstations.

1.3 Traditional and Integrated Desktops Should be Separated into Distinct Categories

As of draft 3 of the v6.0 ENERGY STAR specification, traditional desktops from integrated desktops were still sharing the same categories. NRDC strongly recommends separating these two form factors into distinct categories because they have different energy profiles, different functions, and as the market share of integrated desktops is growing, it is becoming increasingly important to set standards that achieve the most cost-effective energy savings for each form factor.

Integrated desktops have different energy profiles from traditional desktops - An analysis of the QPL shows that integrated desktops (iDTs) have very different energy profiles from traditional desktops (DTs): iDTs use on average 30% less energy than DTs.

Figure 3: Integrated vs. Traditional Desktops Energy Distributions in QPL



Due to space and heat management constraints, integrated desktops tend to utilize more efficient architectures and components. Grouping the two form factors together would result in setting levels that are either unnecessarily lenient for integrated desktops, or overly stringent for traditional desktops. Separating both categories will ensure California standards effectively eliminate the most inefficient models in each category.

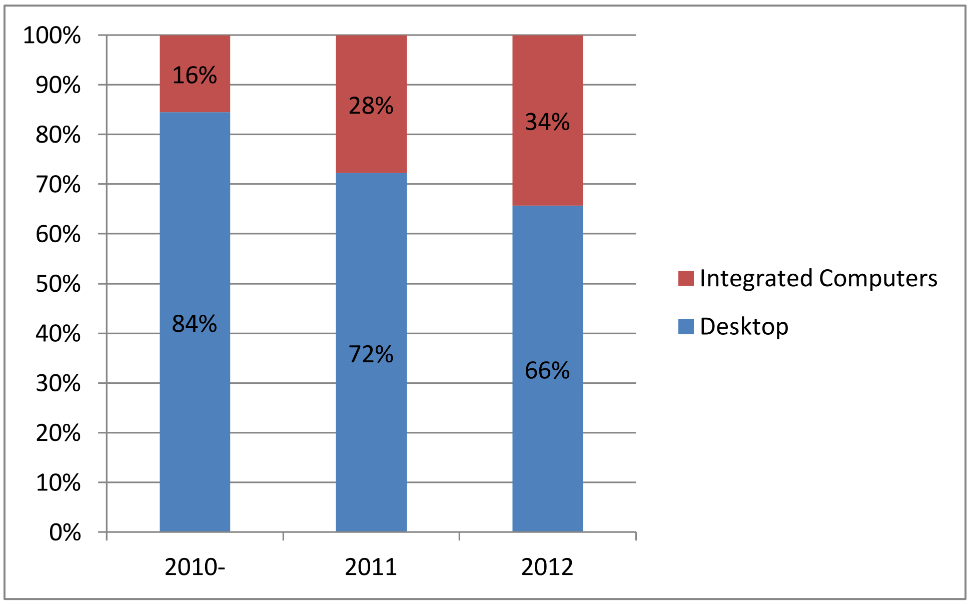
Integrated desktops provide functions energy profiles from traditional desktops - Differences are not limited to energy use, integrated and traditional desktops also provide different functions:

- Traditional desktops are fully upgradeable, whereas integrated desktops have limited upgradability.
- 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.
- Integrated desktops offer sleeker designs and form factors, which is the main raison d'être of this type of computers.

These differences in functions are comparable to the differences in function between notebooks and desktops. Alternatively, CEC 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.

Integrated desktops are increasingly popular and represent a growing share of desktops

Figure 4: Share of Integrated vs. Traditional Desktops in QPL over Time



For the multiple reasons outlined above, traditional and integrated desktops should be separated into distinct categories to achieve the most cost-effective energy savings for each form factor.

1.4 Sources of Test Data: Computer Energy Use

There are two primary datasets available to help with standard setting:

1. The EPA v6.0 Computer Specification dataset, coverage products up to Sep. 2011
2. The NRDC dataset that refreshed the EPA dataset up to December 2012

Both are derived from the ENERGY STAR v5.2 Qualified Product List, but they cover different periods and have different levels of information details available.

There is also a third dataset that EPA has recently developed with a similar goal and coverage to NRDC's, but it has not yet been made public at this time.

This section discusses the strengths and limitations of the EPA and NRDC datasets , and of the public QPL they are derived from.

1.4.1 V5.2 Qualified Product List (QPL)

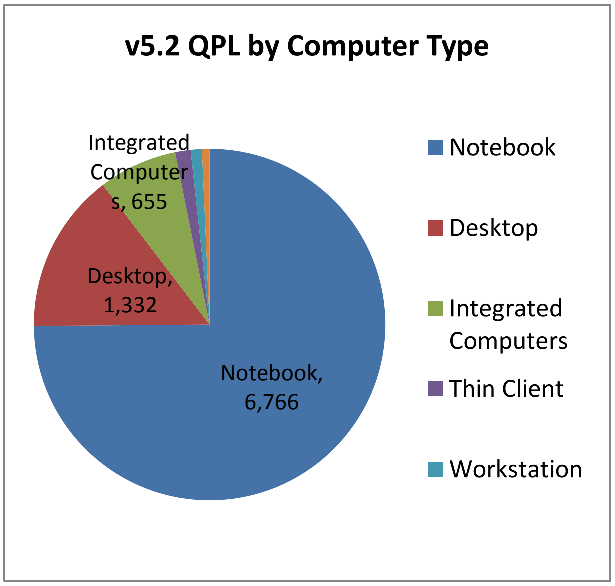
The ENERGY STAR Qualified Product List (QPL) is the most comprehensive publicly-available energy use data that we are aware of. However, the v5.2 QPL as published by EPA has the following limitations that limit its usefulness for the purpose of standard setting.

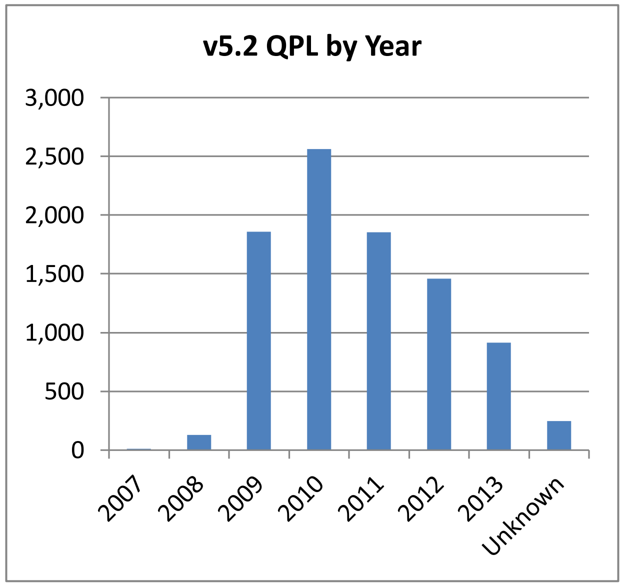
1. **Data quality issues**: the QPL data contains errors and format inconsistencies which makes it difficult to use as-is for data analysis.
2. **Based on the v5.2 framework**: The v5.2 QPL uses v5.2 categories and adders, not the v6.0 draft categories and adders which are recommend using for the CEC standards.
3. **Does not contain all required v6.0 information:** The v5 QPL does not provide all the information necessary for v6.0 categorization, such as number of processor cores and discrete graphics frame buffer bandwidth. This information needs to be inferred from other product information.
4. **Duplicates:** There are a high number of duplicates entries in the QPL due to some manufacturers submitting model-level information while others submit family level information. This can lead to a significant overweighting of some manufacturers' products vs. others.
5. **Partial historical information**: the QPL is a snapshot of qualified products available for sale at a given time. Products no longer available for sale are supposed to be removed from the QPL . However in practice not all manufacturers do this consistently, which means that the QPL includes some but not all outdated products no longer available for sale.

V5.2 QPL Dataset Summary

Name	v5.2 QPL May 1, 2013
Description	Computer Qualified Product List as published by EPA May 1, 2013
Origin	Original: EPA. Modifications: NRDC added a calculated field (Year Available), a pivot table and a summary tab.
ESTAR Framework Version	v5.2
Limitations	- Data quality issues - Does not contain information required for v6.0 categories and adders - Many duplicates - Partial historical information

Figure5 and 6: v5.2 QPL Dataset Summary





1.4.2 ENERGY STAR v6.0 Dataset V2

To help with the v6.0 specification development process, EPA needed a dataset based on products representative of the entire market, not just qualified products. EPA collected complementary data on non-qualified products from industry in September 2011, and combined this dataset with the September 2011 QPL. The consolidated dataset underwent a clean-up and conversation process by EPA and ENERGY STAR stakeholders to help inform the v6.0 specification development.

The main benefit advantage of this dataset is that it covers not just ENERGY STAR-qualified products but also non-qualified products through the stakeholder data collection process.

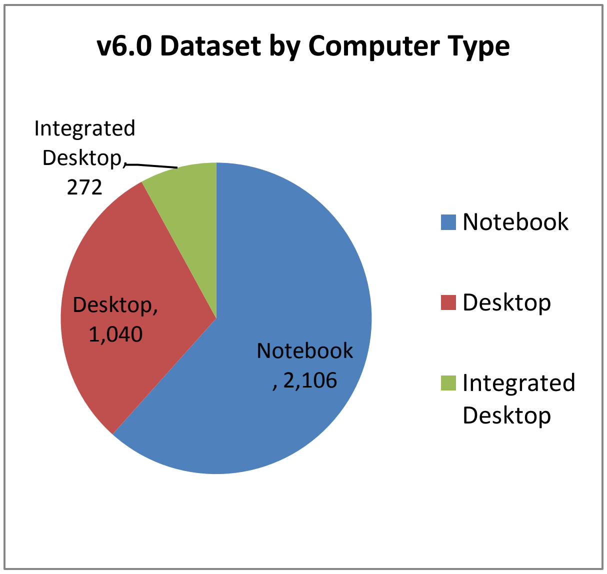
Its main limitation is that it only covers products until September 2011, which misses the latest 18 months worth of products and efficiency gains in computer technology. This is particularly problematic because the last 18 months have seen significant progress in terms of energy efficiency in the computer market.

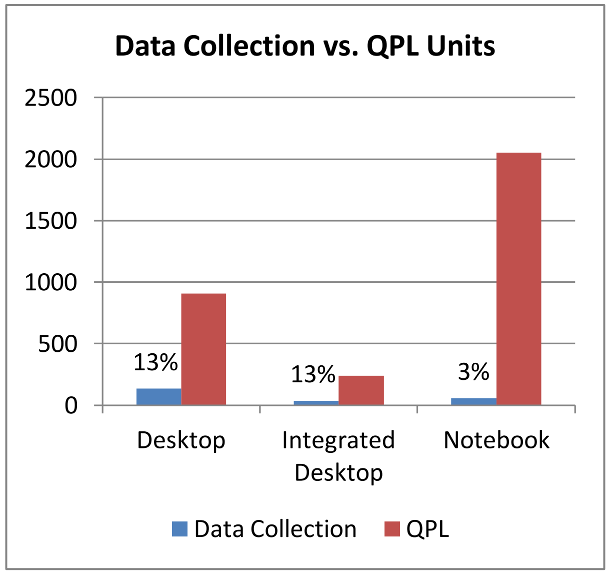
V6.0 Dataset v2 Summary

Name	ENERGY STAR v6.0 Dataset V2
Description	Dataset developed by EPA and stakeholders for the purpose of the EStar v6.0 specification development. Contains both QPL as of September 2011 and some non-qualified products (called "Data Collection") provided by manufacturers. QPL was cleaned-up and v6.0 information added manually to enable v6.0 categorization and adder calculations.
Origin	Original: EPA. Modifications: NRDC added calculated fields and analysis and summary tabs.

ESTAR Framework Version	v5.2 and v6.0
Limitations	- Only covers products until Sep. 2011 - Does not contain date available on market, which does not enable filtering out outdated products, or analyzing market evolution over time.

Figure 7 and 8: v6.0 Dataset Summary





1.4.3 NRDC Dec. 2012 Dataset

To overcome the limitations of both the standard QPL and the v6.0 computer dataset dated Sep 2011, NRDC developed its own dataset using a more recent version of the QPL (December 2012), cleaning it up and converting it to v6.0 categories and duty cycle.

NRDC's conversion process was similar to the EPA process for developing the v6.0 dataset, but with more recent data and with some additional steps to increase its usefulness (disaggregation of multi-category models, historical data):

1. Consolidation of QPLs from Dec. 2010, Dec. 2011 and Dec. 2012, marking each record with the date it was first introduced in the QPL, and eliminating duplicates.
2. Clean-up of data, particularly fields required for v6.0 categorization such as processor speed and memory. Units that could not be cleaned up for lack of, or conflicting information were marked invalid and ignored in the analysis
3. Addition of missing information such as number of processor cores, derived from processor name. Units for which this could not be determined were marked invalid and ignored in the analysis

4. Removal of duplicates by flagging a single representative unit for all units with the exact same power and processor signature

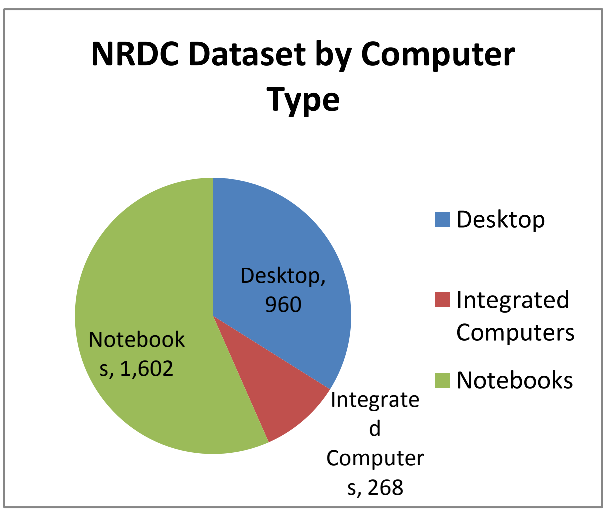
The main drawback of the NRDC dataset is that it is derived from the public QPL and does not have the same level of detail as the EPA dataset. In particular it does not have the information required to calculate graphics and storage adders at an individual product level.

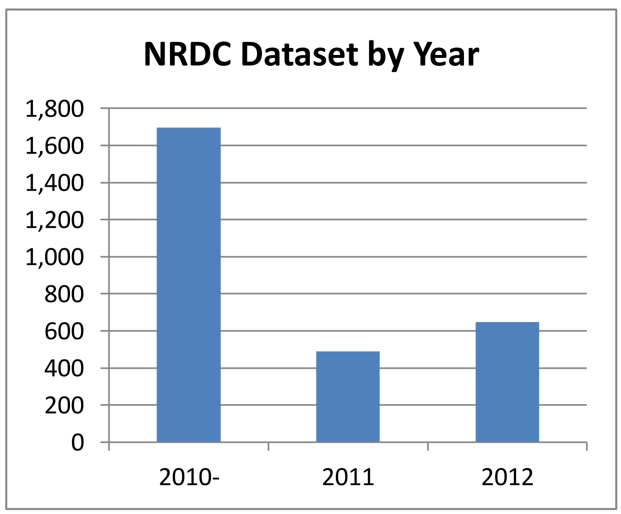
Note that the EPA 2012 refreshed v6.0 dataset may contain some of that information, to be confirmed when EPA releases it. **Until then, we recommend CEC uses the NRDC dataset as the most representative of the current market.**

NRDC Dataset Summary:

Name	NRDC Dataset
Description	NRDC enhanced dataset based on 2010-2012 QPLs. This dataset is similar to the EPA v6.0 dataset, with coverage extending to Dec. 2012, and year information that allows filtering and trend analysis.
Origin	EPA QPLs Dec. 2010, Dec. 2011, Dec. 2012. NRDC clean-up, duplicate removal and conversion to v6.0 categories.
ESTAR Framework Version	v5.2 and v6.0
Limitations	Does not contain adder information at product level. Adders can be added uniformly across all products for the purpose of pass-rate analysis.

Figure 9 and 10: NRDC Dataset Summary





1.5 Existing Standards and Standards Under Development

1.5.1 ENERGY STAR for Computers

The ENERGY STAR program is the building block for most voluntary and mandatory computer efficiency program worldwide.

The version currently in effect is v5.2. v5.0 was developed in 2008 and has been in effect since July 1, 2009. Version 6.0 is currently under development[iii]. Draft 3 was published on Nov. 29, 2012 and amended on Jan. 3, 2013, the final draft is expected mid May 2013. The final specification is expected to be adopted early summer 2013 and go into effect Q1 2014.

The New v6.0 ENERGY STAR Framework is Better Suited to California Standards than the Outdated v5.2 Framework

The ENERGY STAR v5 framework was developed in 2008. The computer market has evolved considerably since then and is now at a stage where v5 categories no longer adequately represent products available in the market.

V5 categories are defined largely based on number of processor cores and amount of memory. The market has evolved considerably over the past few years relative to these two factors: dual- and quad-core processor machines with 4+GB of memory represented the high-end of the market in 2008 but are now mainstream, and this trend is expected to continue over the foreseeable future.

There are very few products left on the market in category A, entry and mainstream products are increasingly migrating towards categories C and D, leading to a situation where two categories will cover most of the market. This does not allow for appropriate differentiation for performance-based standard setting. And this situation will worsen over the next few years as this migration toward higher categories continues.

The v6.0 categories, due to be finalized by EPA around June 2013, are much better suited to the current market and will ensure California computer standards are more effective and remain effective for a longer period of time.

1.5.2 International Minimum Energy Performance Standards (MEPS)

Mandatory computer energy performance standards are already in effect in China, Australia and New Zealand, and South Korea. The European Union is expected to adopt standards in Q2 2013.

South Korea: e-Standby Program, effective since July 30, 2012. Voluntary with mandatory warning label for products that fail. Based on EStar v5.2 framework and TEC limits, with additional power allowance for memory, discrete graphics, storage, TV tuner and removable audio card.

China: Standards (GB 28380-2012) are in effect since September 2012. They consist of multi-level standards based on the ENERGY STAR v5 framework. Grade 3 is less stringent than ENERGY STAR and is mandatory. Grades 1 and 2 are voluntary with Grade 2 being equivalent to ENERGY STAR and Grade 1 more stringent.

Australia and New Zealand: Standards have been in effect since April 2013. They are based on ENERGY STAR v5 with higher graphics adders by ECMA categories.

European Union: Standards are expected to be adopted in Q2 2013. They are based on ENERGY STAR v5.2 with higher graphics adders and lower TEC levels. Tier 1 is expected to become effective in July 2014 and Tier 2 in January 2016.

2. Operations, Functions and Modes

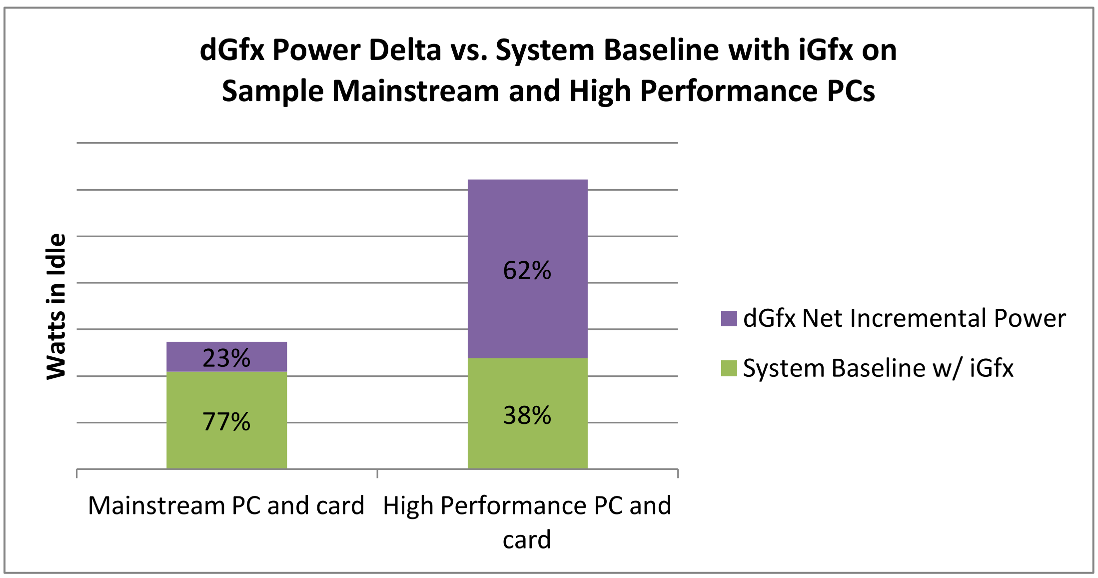
2.1 Power Use of Computers and Components

2.1.1 Discrete Graphics Cards

NRDC, CLASP and PG&E have developed an extensive dataset on the energy use of discrete graphics cards. This dataset provides critical information that facilitates the setting of appropriate graphics adders. The data shows that graphics card energy efficiency in idle mode has improved dramatically between 2011 and 2012, paving the way for much lower graphics adders than would have been the case until recently.

Discrete graphics cards (or add-in graphics cards), represent a large share of a computer energy use when present. High-end graphics cards can use more power in idle than the rest of the computer altogether, as illustrated by the comparison of ENERGY STAR's v6.0 Draft 3 graphics adders base TEC limits.

Figure 11: Net Power Delta of Sample Discrete Graphics Cards on Low-End and High-End Systems

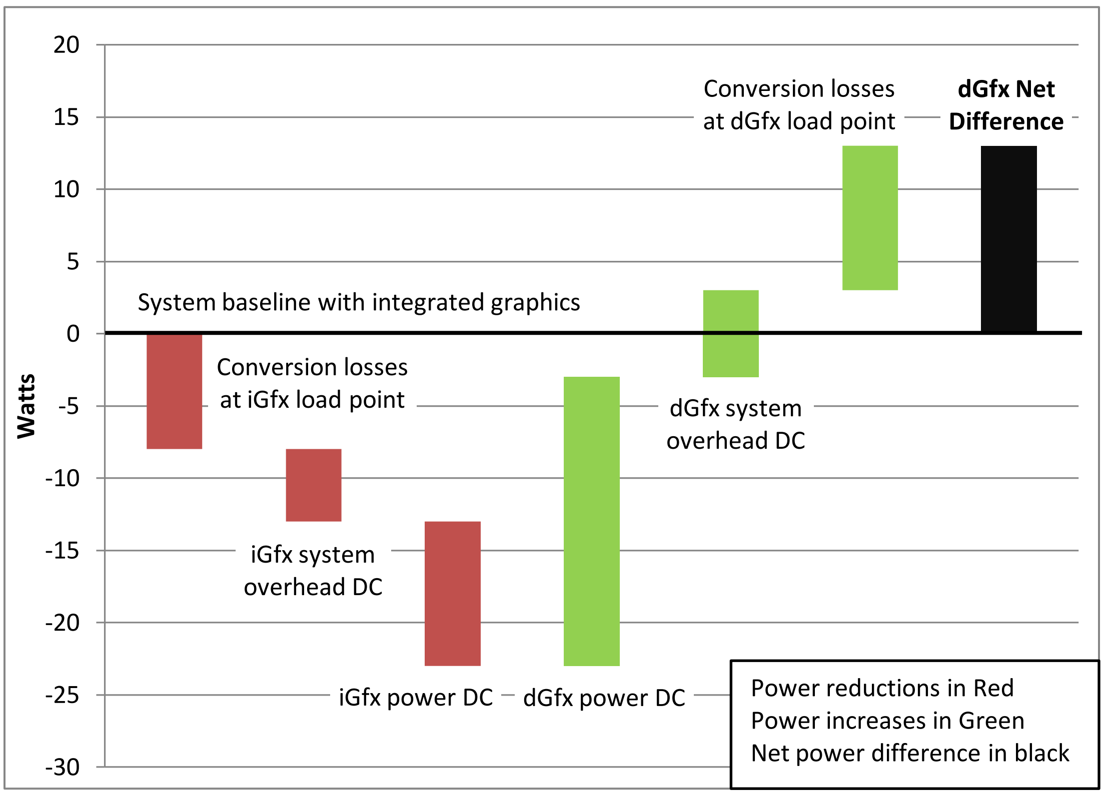


Note: Figure 11 uses data from two sample configurations. It is not meant to represent an average, but to illustrate the relative impact of discrete graphics.

Graphics adders are used to adjust energy limits depending on graphics capabilities. Due to their large size relative to other allowances, setting graphics adders at the right level is critical for the effectiveness of computer standards. 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. 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 support energy efficient computers while excluding inefficient models.

Measuring the power draw of a graphics card at the card level does not provide a relevant measurement of what the adders should be. This is because the power impact of a graphics card on a computer includes many other factors than the power use of the card itself: adding a discrete graphics card enables the integrated graphics card to be switched off, it changes the consumption of other components such as CPU and memory, and it changes the load point and therefore the efficiency of the power supply.

Figure 12: Changes in System Power When Adding a Discrete Graphics Card[1]



To address this issue, NRDC, CLASP and PG&E commissioned two studies[iv] that determined the net power impact of the cards by measuring the difference in system-level power demand between a computer with the card and the same computer without the card using integrated graphics. This approach provides a more accurate assessment of the net power impact of a discrete graphics card on a computer system.

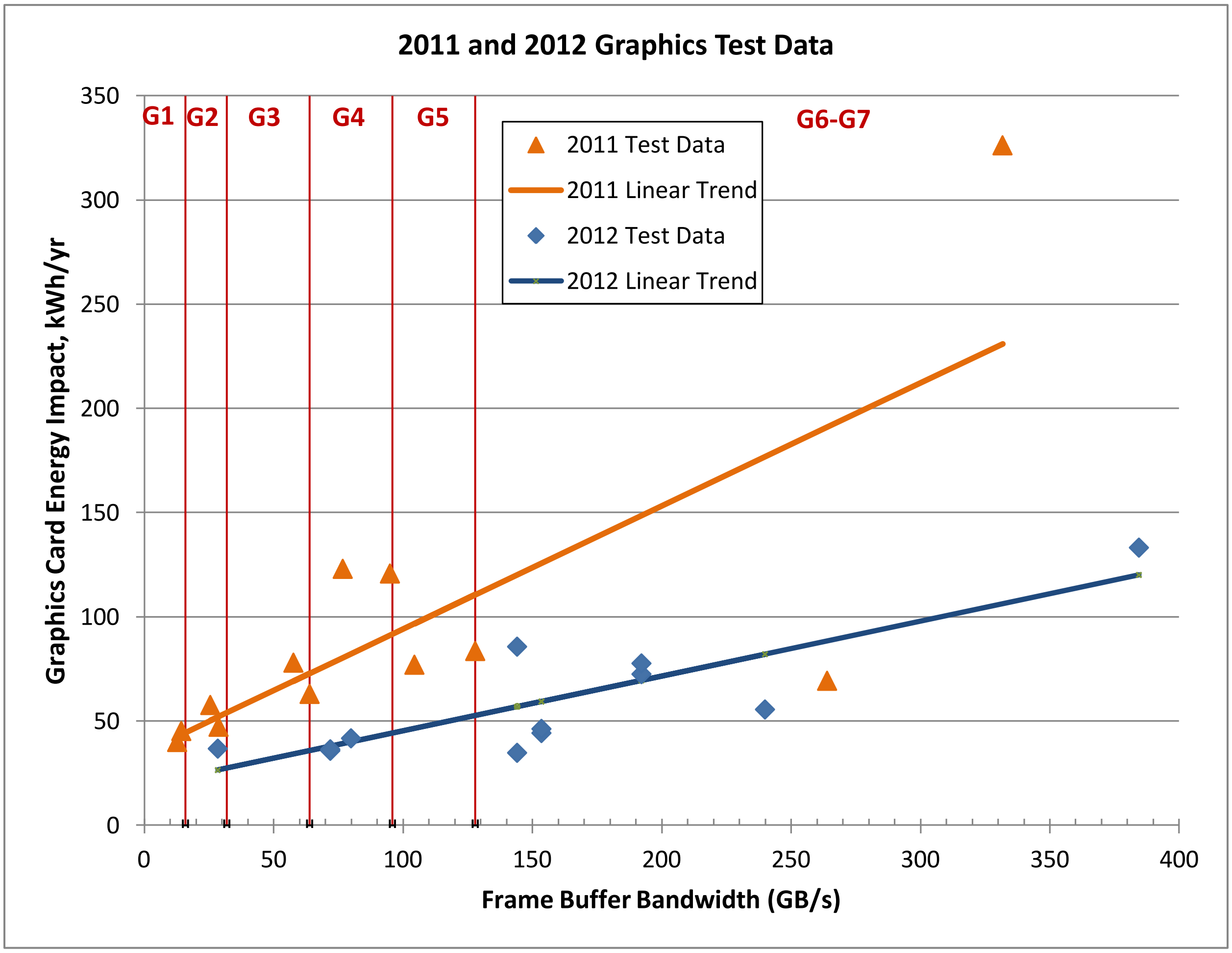
24 discrete graphics cards that were selected from six ECMA-383[v] graphics categories and represent over one-third of the desktop discrete graphics card models introduced on the U.S. market in 2011 and

[1] Hypothetical values to illustrate the concept, not measurements on a particular system and graphics card.

2012. They were tested on six computer systems representing a wide range of market segments, including Mainstream, Performance, High Performance, and Very High-end/Enthusiast segments.

The study found dramatic improvements in discrete graphics card energy efficiency in idle mode between 2011 and 2012, and generally much lower adder levels than those used in efficiency standards designed prior to 2011.

Figure 13: 2011 and 2012 Graphics Test Data



By the end of 2012, most of the high-end graphics card market had already transitioned to the new high-efficiency architectures, and the mainstream and entry markets were beginning to transition. We can expect this transition to be complete by end 2014, making 2012 or later levels a reasonable baseline for graphics adders in CEC standards.

Detailed adder values by category for different stringency levels are available in the attached study reports.

2.1.2 Internal Power Supplies

Inefficient power supplies can waste 30-40% of the AC power drawn from the outlet before it even reaches other components. Higher efficiency 80-PLUS Bronze internal power supplies are now broadly available. Over 1,500 Bronze qualified models are listed on the 80-PLUS website[vi]. The European Ecodesign computer regulation includes internal power supply efficiency requirements equivalent to 80 PLUS Bronze.

Cost of 80 PLUS Bronze Efficiency

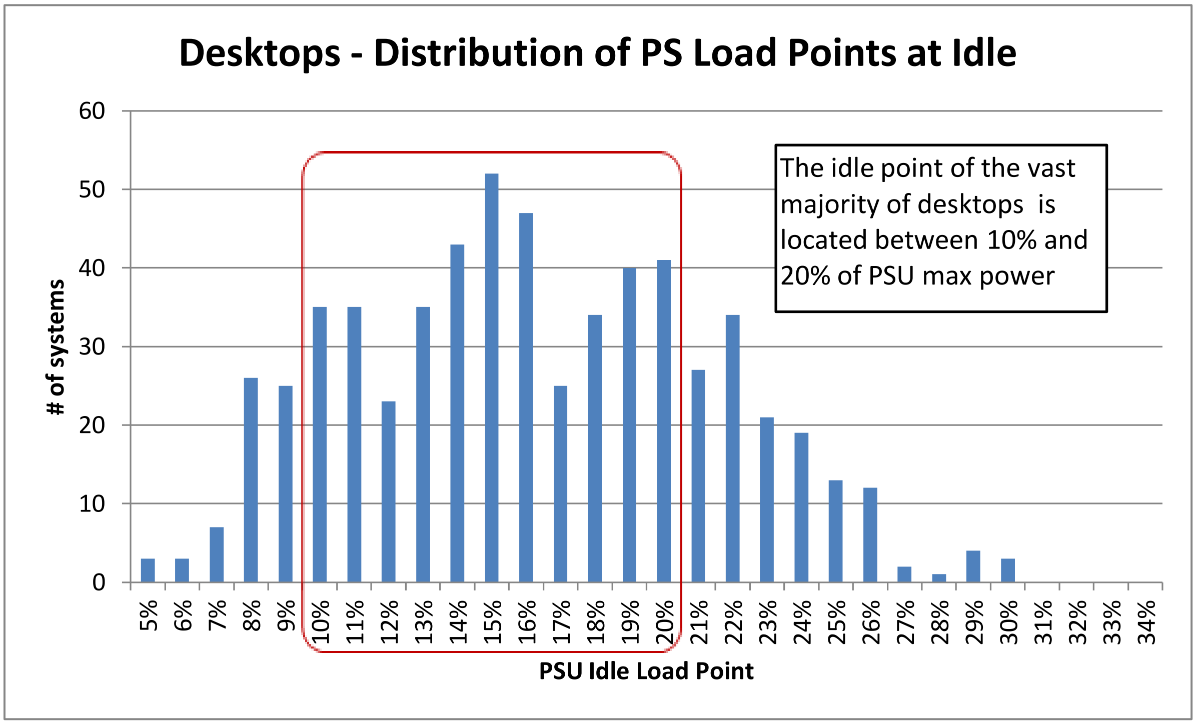
The NEEA 80 PLUS Market Progress Evaluation Report #4[vii] by Navigant estimates the incremental cost to the OEM of an 80 PLUS Bronze power supply over a non 80 PLUS power supply in the range of $5-$13, and used an average of **$7** in its model.

The report also notes that costs appear to continue their downward trend.

Efficiency at 10% load

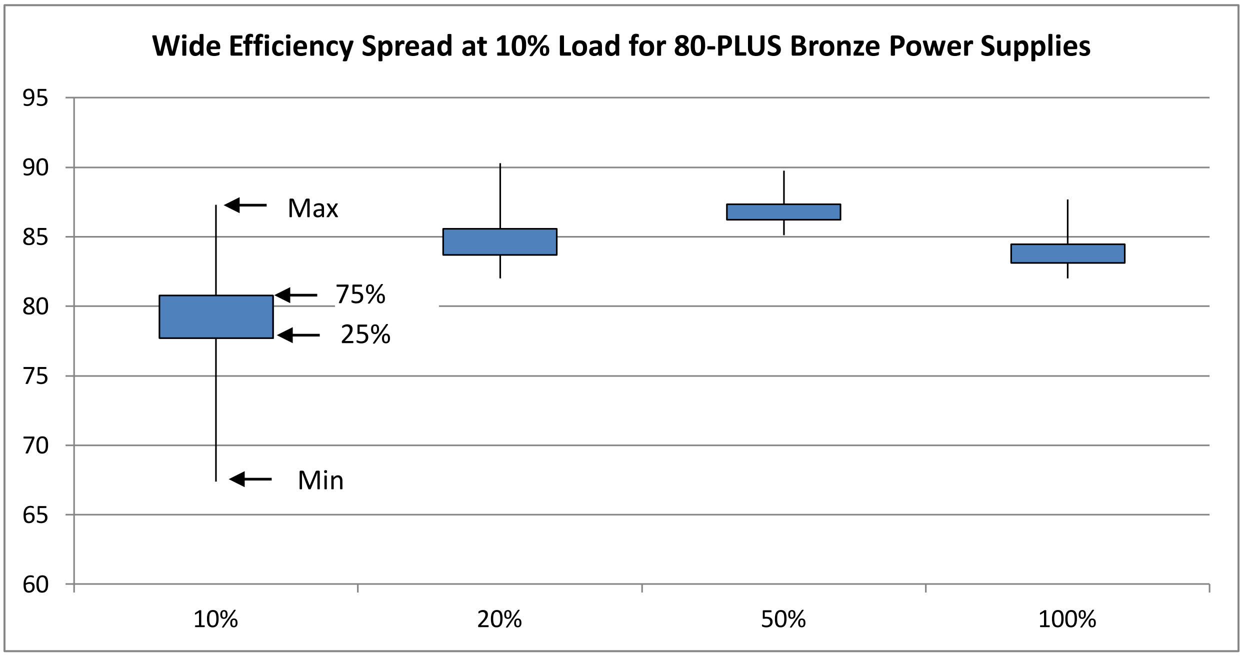
80-PLUS sets efficiency and power factor correction requirements at 20%, 50% and 100% load. In addition to the 80-PLUS efficiency criteria, NRDC strongly recommends specifying a minimum efficiency requirement at 10% load. While 20% load was intended to capture the idle state of computers when 80-PLUS was originally implemented, the increasing ability of computers to scale power down in idle mode or when performing little work, means that many computers today operate in the 10%-15% load range of their power supply and this shift to lower load points is expected to continue as computers continue to improve their power scalability. Setting efficiency requirements at 10% load is important to ensure computer power supplies are designed to be efficient where it matters most.

Figure 14: Distribution of Power Supply Load Points at Idle



Due to the absence of efficiency requirements at 10% load, there is a much wider efficiency spread at 10% load than at 20% or higher load points. While all these power supplies are 80-PLUS Bronze-qualified, the best one is 87% efficient at 10% load, while the worst one is only 67% efficient at 10% load, a spread of 20%! (23% on a relative basis).

Figure 15: Efficiency spread at 10% load vs. other load points



10%-load test method – Testing efficiency at 10% load is exactly the same as testing at 20% and other load points, and can be done using the Generalized Internal Power Supply Efficiency Test Protocol (available at www.efficientpowersupplies.org).

10%-load efficiency data has been available on the 80-PLUS website for all models certified since Jan. 1, 2012. This provides a substantial dataset to help set appropriate efficiency requirements at 10% load.

3. Energy Saving Technologies, Components, and Features

3.1 Power Management Settings

Mandating that all computers be shipped with power management enabled is helpful and necessary, however it is not a silver bullet.

Power management settings have become increasingly sophisticated in the latest operating systems: it now includes options to dim the screen, turn off the storage drive, switch off the display and sleep, as well as more technical options such as throttling the processor and other components.

Power management has the potential to save large amounts of computer energy, however field studies continue to show that this potential remains largely unrealized. For example the Minnesota plug load study[viii] found that 80 percent of desktop computers in U.S. homes do not have sleep enabled, and 75 percent of desktop computer electricity consumption occurs when no one is in front of the computer.

Little of that seems due to power management being disabled on computers out of the factory, our experience indicates that all major manufacturers now do enable power management on all their computers, and have been doing so for several years. The issue comes from the fact that power management rapidly gets disabled when computers are in operation.

We are not aware of any data on the reasons that lead to power management being disabled, but we hypothesize based on anecdotal evidence that this is due to a combination of reasons:

- Many enterprise IT managers install a company "image" of the operating system and its configuration options on enterprise computers. These images rarely enable power management due to a lack of awareness of its benefits or lack of incentive for the IT department to save energy, misconceptions or mistrust about operational issues caused by power management, such as running nightly backups and virus scans with power management enabled;
- Software programs either intentionally disable power management or inadvertently block the operating system's ability to transition to sleep mode;
- User inconvenience and lack of awareness of energy saving benefits: some users also disable power management themselves. They may do it once for a specific need and never go back and re-enable it.

This highlights the fact that mandating that all computers sold in California be shipped with power management enabled is not a silver bullet: it will certainly help as not all manufacturers may ship with power management enabled, either by design or due to manufacturing process issues (we recently found evidence of two major manufacturers unintentionally shipping many of their devices with power management disabled). Standards will increase the rate of power management enablement at the factory by making it a compliance issue rather than a voluntary behavior.

Tightening time settings to make computers go to sleep more rapidly wouldn't help much either and might actually backfire by increasing the annoyance factor and encouraging more users to disable it. NRDC recommends the use of the ENERGY STAR time settings as a good compromise between savings and user convenience.

Fulfilling the true potential of power management to save energy in computers will require a real commitment and collaboration by hardware manufacturers, operating system and application developers to remove the barriers that currently prevent computer power management from working as effectively as it does today on slates.

4. Market Characteristics

4.1 Range of Energy Use within ENERGY STAR Categories

Figures 16 and 17 illustrate the wide range of energy use for computers of similar functionality.

Figure 16: Ranges of Energy Consumption in ENERGY STAR v6.0 Qualified Product List - Desktops

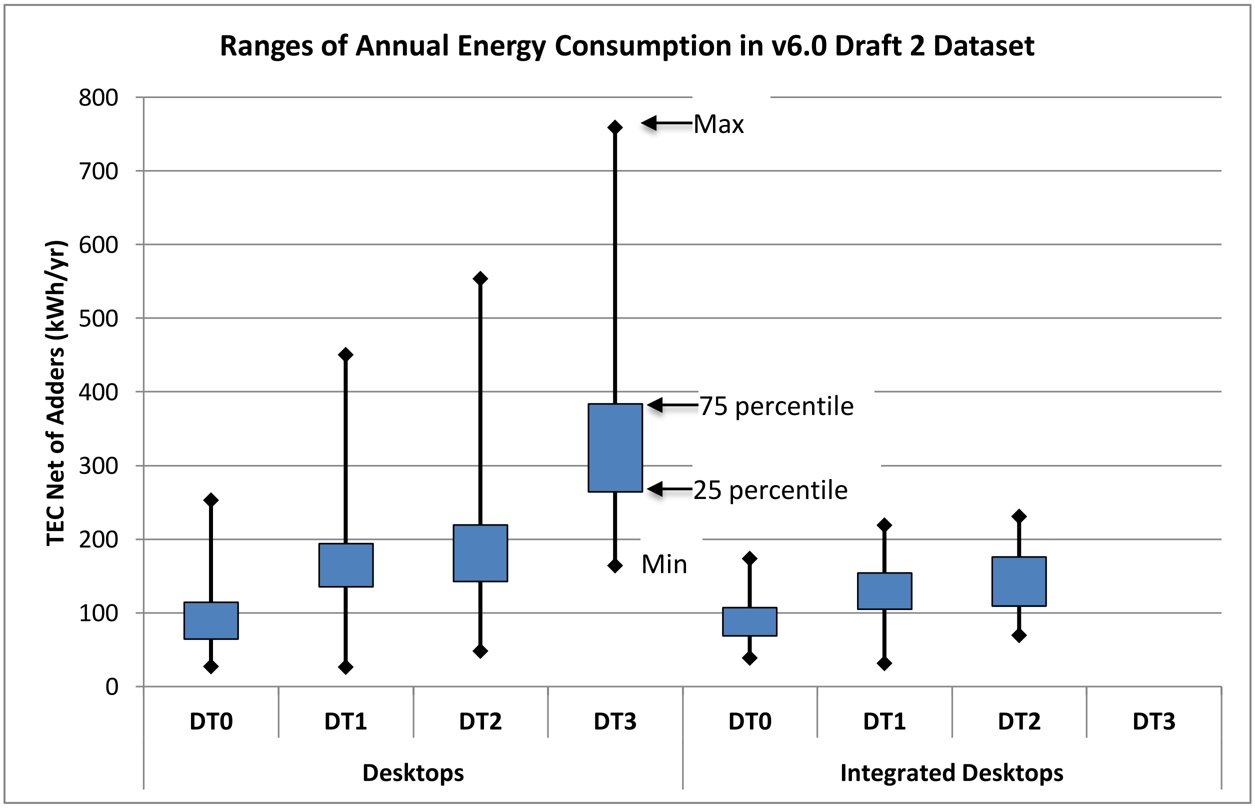
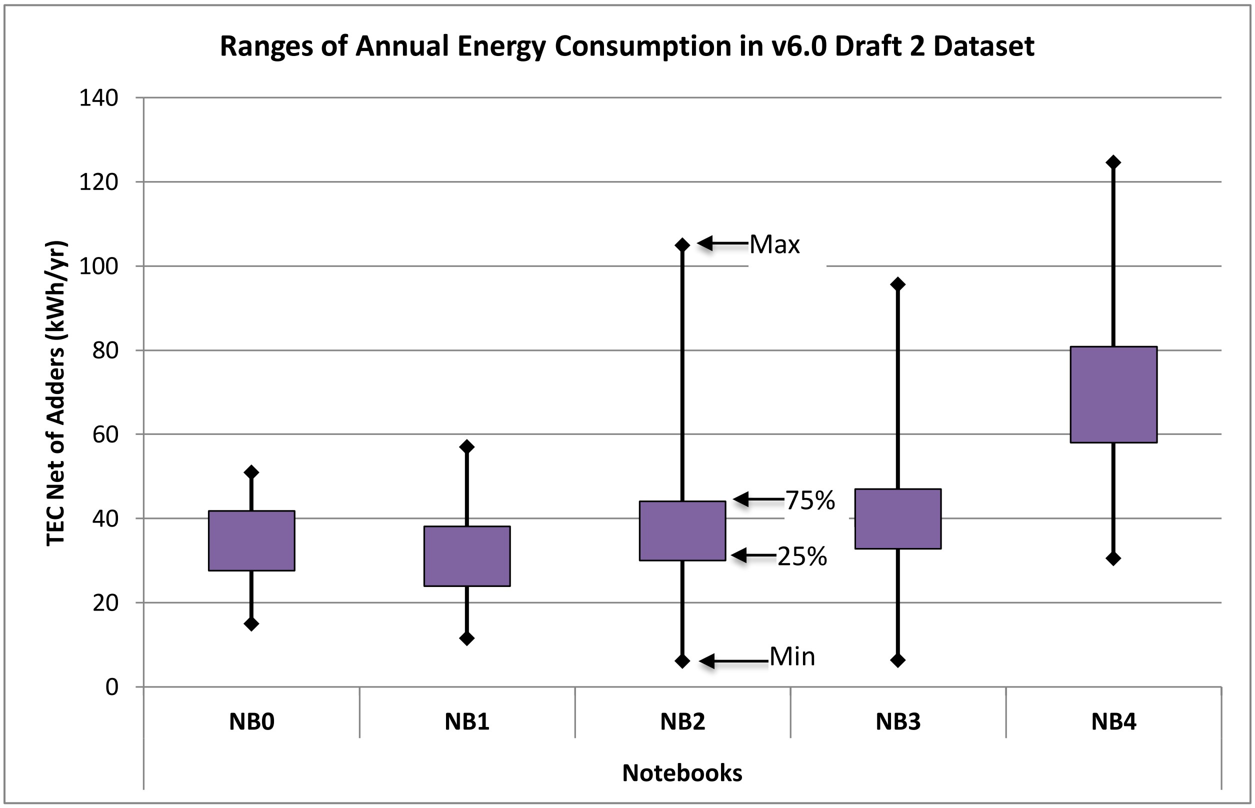


Figure 17: Ranges of Energy Consumption in ENERGY STAR v6.0 Qualified Product List - Notebooks



Notes:

- Figures 16 and 17 plot TEC net of adders, i.e. with graphics and other adders subtracted from measured TEC, in order to compare products of similar functionality (apples to apples comparison). For example, a computer with a discrete graphics card is represented with the graphics allowance for that card subtracted in order to be compared with similar computers without discrete graphics.
- The plot is based on EPA's v6.0 dataset, which uses draft 2 categories.

5. Market Competition for Efficient Products

5.1 Current Market Drivers Toward Improving Computer Efficiency

While some drivers in the computer market are helping improve the energy efficiency of personal computing, others are not or are even having the opposite effect. This means that natural market drivers alone cannot be relied on to reduce the energy use of computers in aggregate, policy intervention is necessary to compensate for misaligned drivers while not hindering or accelerating beneficial ones.

Market drivers aligned with computer energy efficiency

- **Battery life**: devices that operate part or most of the time on battery , such as notebooks and slates, have a strong incentive to be as energy efficient when operating on battery, to provide users with the longest battery life for the least battery cost and weight.
- **Mobility**: competition from slates and smart phones which are capable of switching on and off almost instantly, and are extremely thin and light, is forcing notebooks and to some extent desktops to reduce latency, size and weight in order to stay relevant.
- **Shift from desktops to all-in-ones and notebooks**: changing consumer preferences for more energy efficient devices is helping reduce the average unit energy use. In aggregate, the beneficial energy savings effect is mitigated by the rapid continued growth of computer devices.

Market drivers which are either not helping reduce, or are increasing computer energy use

- **The battery life incentive clearly does not apply to traditional or integrated desktops**, which is a key reason for the difference in energy efficiency between these devices and notebooks. And even notebooks are used mostly plugged in, compared to slates which are used mostly on battery. This leads to different designs with different levels of energy efficiency.
- While external power supplies are regulated by federal efficiency standards, **internal power supplies are not regulated**. The NEEA 80-PLUS Market Progress Evaluation Report #4[ix] reports that the weighted average market share of 80 PLUS internal power supplies in desktops sold in the U.S. in 2011 was slightly less than 50 percent of U.S. desktop PC sales. This means that roughly half of desktops had power supplies that were less than 70% efficient at their average operating point. This contrasts with around 80% efficiency or higher for external power supplies, or a 13% efficiency improvement potential just from power supply efficiency.
- **The desktop computer market, especially on the residential side, is most strongly driven by price and performance**. Energy efficiency does not drive sales, and only reduces profit margins.

This can lead to a race to the bottom on efficiency absent regulation to level set the playing field on efficiency.

- **The size of computer displays is continuing to increase**, especially for desktops. More notebooks are also used with second screens. This results not just in a continued growth in display energy use despite efficiency gains, it also increases the energy use of the computer components (GPUs and associated components).

5.2 How are Consumers and Commercial Purchasers Able to Identify the Most Efficient Products on the Market? The Least Efficient?

The only energy label for computers in the U.S. today is the ENERGY STAR label. As discussed in previous sections, the market share of computers meeting ENERGY STAR energy levels is currently estimated to be over 50% for traditional desktops and over 90% for integrated desktops and notebooks, which does not allow users to identify the most efficient products. This problem should be resolved when the new ENERGY STAR v6.0 goes into effect, provided that EPA sets energy levels and adders to effectively target the top 25% of the market at effective date. NRDC's analysis and public comments to EPA indicate that currently proposed Draft 3 levels would fail to do that and target up to 50% of the 2012 market instead.

There is no easy way for consumers or commercial purchasers to identify the least efficient products on the market. The only supposed comprehensive source of information available may be manufacturer self-reported energy use, e.g.:

- Apple: http://www.apple.com/environment/reports/
- Dell: http://www.dell.com/content/topics/global.aspx/about_dell/values/regulatory_compliance/dec_conform?c=us&l=en&s=corp
- HP:http://www.hp.com/hpinfo/globalcitizenship/environment/productdata/itecodesktop-pc.html
- Lenovo: http://www.lenovo.com/social_responsibility/us/en/datasheets_notebooks.html

However these self-reports do not seem to be available for all manufacturers, and even if they were, the lack of simple comparative report would make it very cumbersome for consumers and purchasers to use this information to identify the least efficient products on the market.

5.3 Current Market Share of Computers that Meet ENERGY STAR's Computer Specification v5.2

The market share for computers that meet ENERGY STAR 5.2 levels reported by EPA for 2011 is low for desktops (17%) and high for notebooks (75%), however these numbers mask a different reality due to a number of factors detailed below. NRDC estimates that the real market share for computers that meet v5.2 energy levels is over 55% for traditional desktops and over 90% for integrated desktops and notebooks.

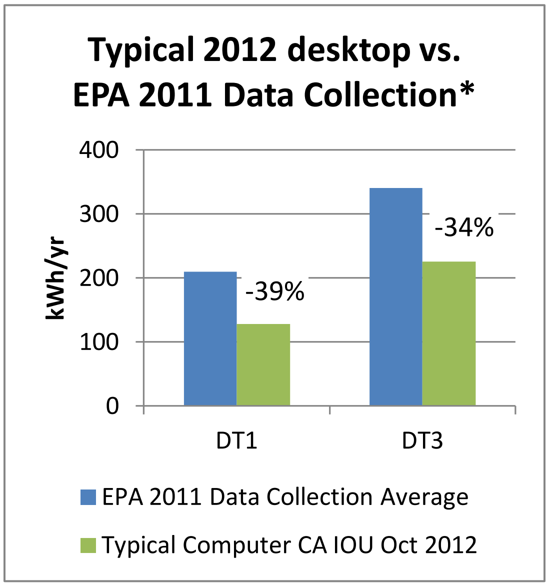
Estimating the real market share of computers that meet ENERGY STAR energy levels as of end of 2012

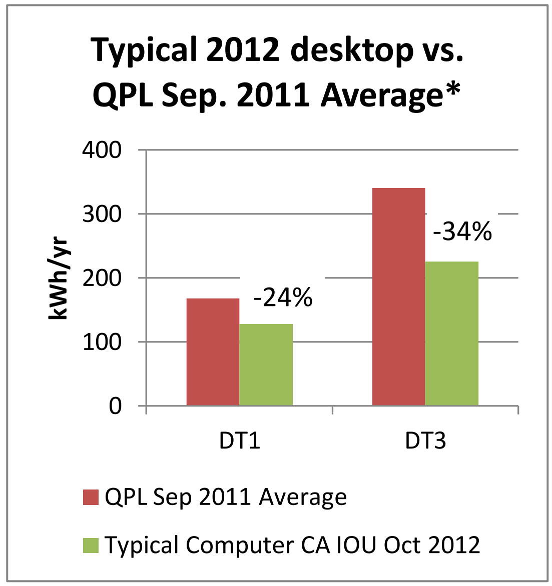
The market share of computers that meet ENERGY STAR's computer specification 5.2 was last reported by EPA in its 2011 Unit Shipment Data (USD) report[x] as 17% for desktops and 75% for notebooks. However the real market share of computers that meet ENERGY STAR energy levels as of end of 2012 is much higher than that because of the following factors:

1. **Market share not reported in Unit Shipment Data Report**
   The 2011 USD response rate was 71%, meaning 71% of partners responded, and EPA states that "no adjustments are made to the totals to account for partners that fail to report their shipments". While the market share of respondents and non-respondents in unknown, it seems fair to adjust reported market shares by extrapolating them to the total number of partners.

2. **Market evolution from 2011 to 2012**
   At the time of writing, the latest available USD report was for 2011. CA IOU market research and testing shows that there has been significant energy reductions between 2011 and 2012.
   The charts below compare 3 desktops (two DT1s and one DT3 per Draft 2 categories) selected to represent the most common configurations on the market in late 2012 (typical 2012 desktops) and tested by the CA IOUs, with the EPA data collection and QPL datasets:

Figures 18 and 19: Typical 2012 Desktop Energy Consumption vs. 2011 Datasets

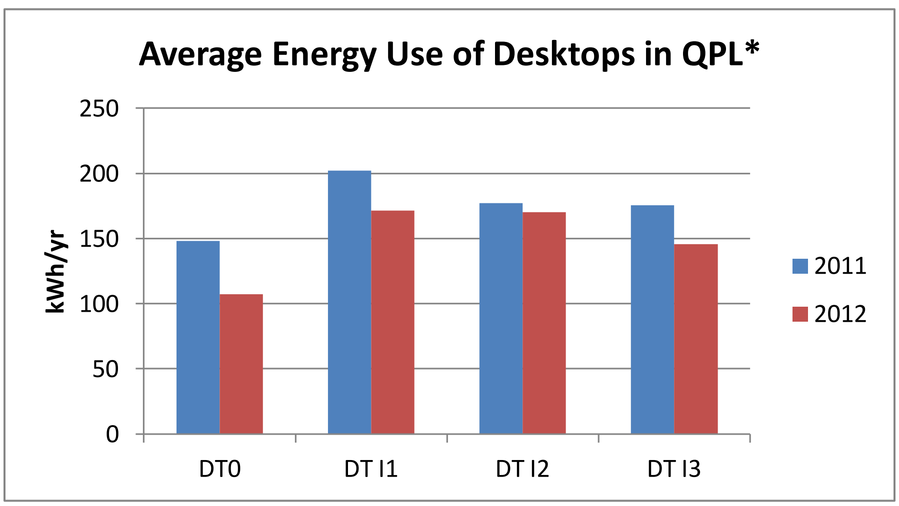




(*) Using v6.0 Draft 2 categories and duty cycle

This large reduction in energy use between 2011 and 2012 models is corroborated by the 14% year on year reduction in average energy use in the QPL:

Figure 20: 2012 vs. 2011Energy Consumption in QPL



(*) Using v6.0 Draft 3 categories and duty cycle

QPL averages are an under-estimate of improvements of the overall market because the market share of ENERGY STAR products also increases, diluting the baseline. Average market energy improvements are higher than indicated by the QPL.

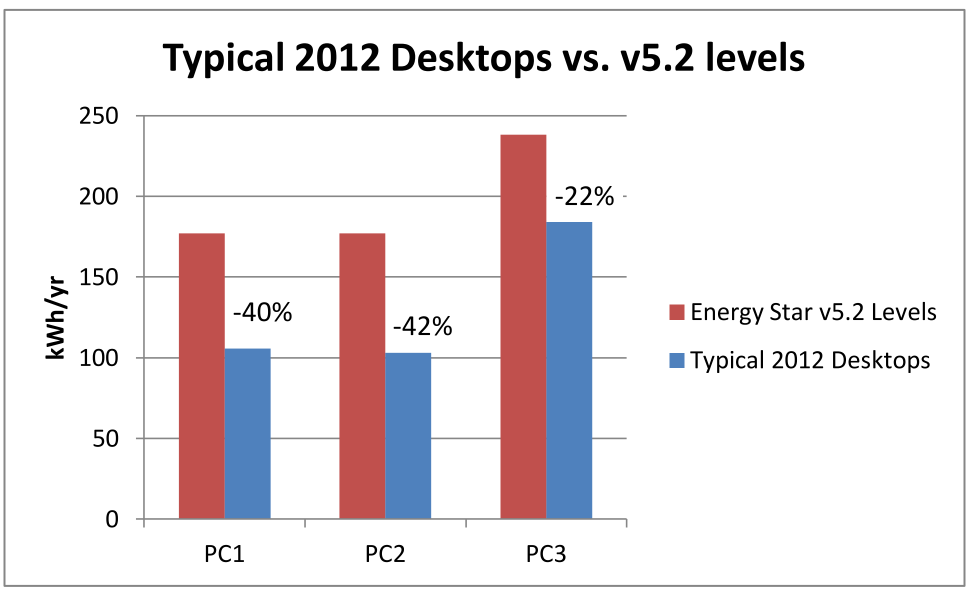
3. **Models that meet energy levels but not power supply requirements**
ENERGY STAR qualification requires models to meet not just energy limits, but also power supply requirements. It is a well-known fact that many models can meet ENERGY STAR limits but do not qualify because of non-compliant power supplies. This is confirmed by the EPA 2011 Data Collection dataset which shows several models meeting energy levels but not power supply requirements. For the purpose of setting standard levels and estimating compliance rates, these models need to be counted as capable of meeting proposed levels.

4. **Models that meet ENERGY STAR v5 requirements but are not submitted for qualification due to manufacturer marketing strategy to avoid qualification costs in certain market segments -** It also appears that some models that meet both energy limits and power supply requirements are not submitted for qualification due to the cost of the EPA's third-party qualification process, leading manufacturers to not submit some products in particular market segments.

This is corroborated by the following sources:

1. **California IOUs** market research and testing[xi] shows that the energy use of typical 2012 desktops was 22% to 42% lower than v5.2 levels and close to v6.0 Draft 3 levels. As v6.0 are designed to represent the top 25% of the market, this infers that the market share of desktops meeting v5.2 energy levels is significantly higher than 50%.

Figure 21: Typical 2012 Desktops vs. ENERGY STAR v5.2 levels



(*) Using v5.2 categories and duty cycle

2. **NEEA** Market Progress Evaluation Report #4 on the 80 PLUS program[xii], estimated the ENERGY STAR market share for desktops in 2011 at **43%**, compared with EPA USD's estimate of 17%.
3. **IDC** reported that **57%** of desktop computers sold in the US in 2011 were ENERGY STAR (IDC 2012, from NEEA Market Progress Evaluation Report #4 on the 80 PLUS program referenced above).

Based on the above research and analysis, we estimate that the 2012 market share of computers meeting ENERGY STAR TEC levels is approximately 56% for traditional desktops and 94% for integrated desktops. This is based on the following estimation model:

	All Desktops	**Traditional Desktops**	**Integrated Desktops**	**Notebooks**
v5.2 market share (2011)	17%	8%	49%	75%
2011 QPL unit ratio	100%	72%	28%	
Adjusted for non-reported market share	24%	18%	45%	80%
Adjusted for Market evolution (2011-2012)	39%	35%	53%	85%
2011 QPL unit ratio	100%	66%	34%	
Adjusted for models that meet energy levels but PSU does not meet requirements	59%	47%	82%	90%
Adjusted for models that meet ENERGY STAR v5 TEC limits but not submitted for qualification due to qualification cost or other marketing strategy reasons	69%	56%	94%	95%
Estimated market share for 2012 computers that meet v5.2 levels	**69%**	**56%**	**94%**	**95%**

In conclusion, while these estimates are based on best-judgment assumptions, they are aligned with market research and testing results. These estimates represent the market share of computers that meet v5.2 energy levels, which is different from being ENERGY STAR-qualified, due to ENERGY STAR's non-energy requirements such as power supply efficiency requirements. For the purpose of setting energy standards levels, it is appropriate to focus on products meeting energy levels rather than actual qualification.

6. Other Information

6.1 Factors Affecting Energy Consumption – Active Mode and Accessories

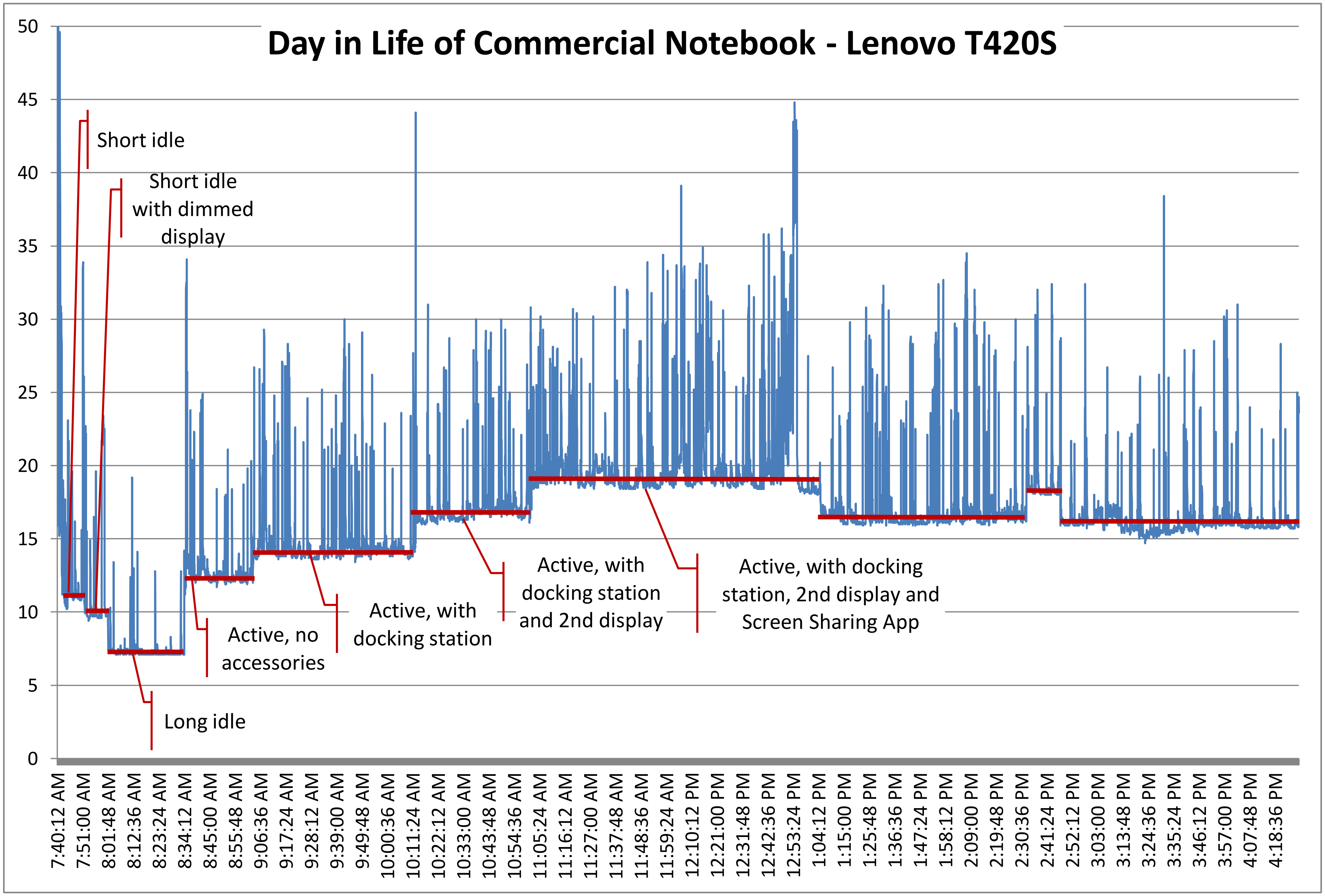
The annual energy consumption of computers is estimated using the ENERGY STAR Typical Energy Consumption (TEC) formula, which uses idle mode (short and long as defined in the ENERGY STAR v6.0 Draft specification[xiii]) as a proxy for active mode power. While this proxy worked well in computers until recently, better power scalability in modern computers is increasing the difference between idle and active power. NRDC's anecdotal testing suggests that a notebook's daily active energy use (including all active and idle time during a day's use) can be 20% to 50% higher than ENERGY STAR's weighted idle energy. We are not suggesting to include active mode in a CEC standard due to the lack of test method, however **we recommend that CEC includes an active mode correction factor when estimating computer energy use and savings potential.**

The ENERGY STAR duty cycle is based on a profile study performed for the Ecma-383/IEC-62623 standard on 500 enterprise users from large high tech companies in 2010. A subset of 17 computers in this study found a "TEC error" (difference between ENERGY STAR v5 idle and actual energy use) of 1.2%, validating the use of idle as a proxy for active in ENERGY STAR v5. However a number of things have changed since then:

(1) The v6.0 duty cycle include Long Idle, which encourages energy savings in extended periods of idle time, but also lower ENERGY STAR's estimate of a computer's idle time
(2) Computers have increased their ability to scale power up and down depending on the work performed, which increases the power difference between idle and active.

To investigate the difference, NRDC measured power use with a logging meter over several days of typical use on a modern notebook (Lenovo T420S).

Figure 22: Power Use of a Modern Notebook Over a Day's Work



While this is anecdotal and not meant to be representative of all computers, it suggests that ENERGY STAR's v6.0 idle is no longer a valid proxy for a computer's energy use, and that the difference can be as high as 20% to 60% depending on use and what accessories are connected to the computer.

Figure 23: Incremental Power by Mode

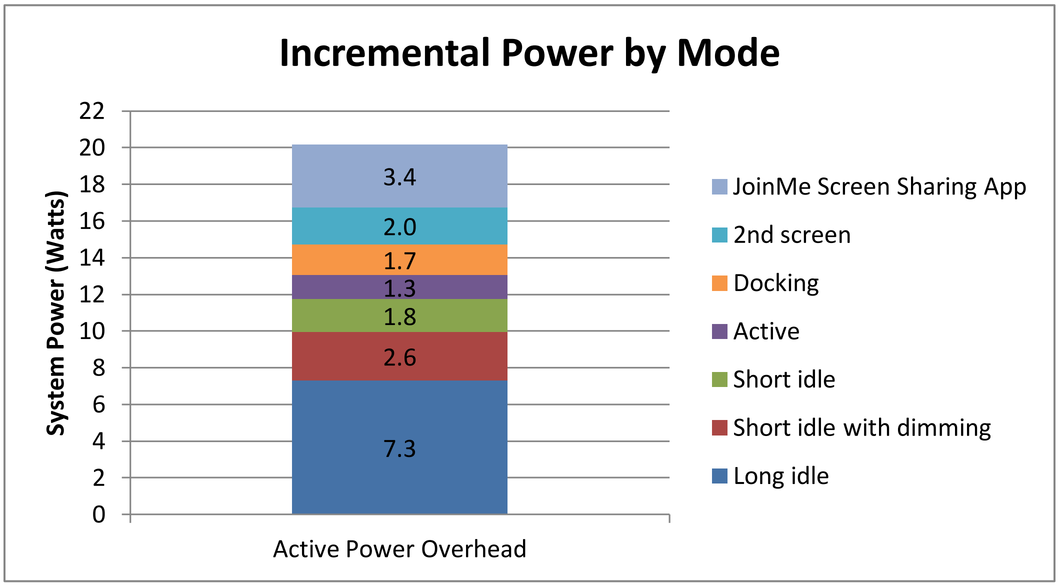
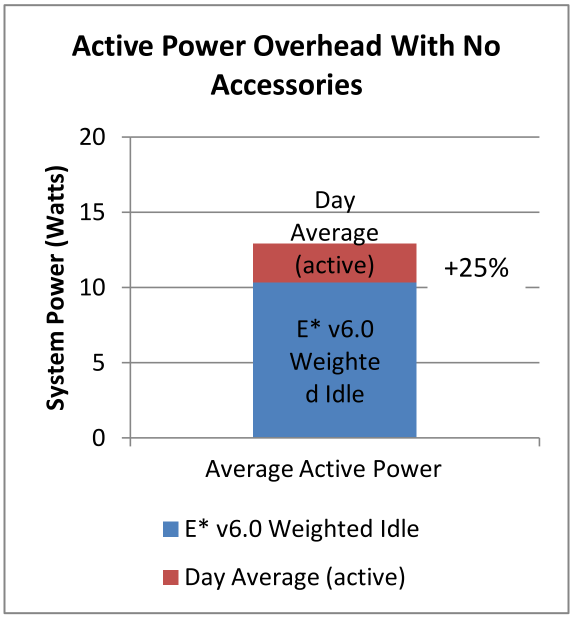
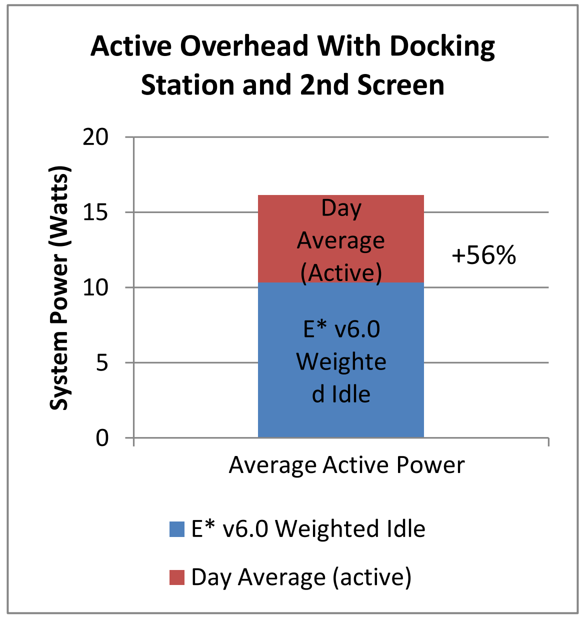


Figure 23 shows that active mode adds approximately 2 watts (20%) above ENERGY STAR v6.0's weighted idle, and a docking stations and a 2nd screen add another 20% each. It is important to note that this does not include the power used by the docking station and second screen themselves, it is only the additional power used by the notebook when connected to these accessories.

Figures 24 and 25 represent the same data by contrasting ENERGY STAR's v6.0 weighted idle power with the average active daily power as measured:

Figures 24 and 25: Active Power Overhead





Docking stations and second screens are used by a significant number of users, especially in commercial settings and also in residential settings for second screens. Docking station and second screen are just being used here as examples of commonly used accessories, other wire-connected accessories such as external hard drives, speakers, scanners and printers etc would likely have similar effects. This suggests that the typical energy use of computers is significantly higher than reported by the ENERGY STAR v6.0 TEC formula.

Accounting for active use, and depending on how many accessories users typically use with their computers, and the percentage of time these accessories are connected, the aggregate energy use of computers could be anywhere between 20 to 50 percent higher than estimated by the ENERGY STAR duty cycle. **NRDC proposes to use a 30 percent factor as a starting point estimate until further data is available.**

6.2 Certification/Registration Approach for Configurations

One of the challenges with computer efficiency standards lies in the high number of configurations available for each product family. A typical desktop computer may have a dozen different components with a handful configurations available for each. For example, a given computer model may offer a choice of CPUs, memory, graphics cards, hard drives, etc. These options can lead to over a million possible permutations.

The ENERGY STAR program has addressed this issue by requiring manufacturers to test and report “product configurations that represent the worst-case power consumption for each product category within the family are considered Representative Models”.

This approach limits the testing and reporting burden for manufacturers. NRDC believes this approach is suitable for Title 20, provides a sufficient assurance that all other configurations meet the standard, and has the merit to be consistent with ENERGY STAR.

Conclusion

NRDC thanks the Energy Commission for its leadership in establishing cost-effective appliance efficiency standards that reduce electricity bills as well as climate and other harmful emissions for all Californians.

NRDC strongly encourages the Commission to move forward with minimum efficiency standards for computers.

Thank you for your consideration of NRDC's input.

Respectfully submitted,

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1. ENERGY STAR v5.2 Qualified Product List May 1, 2013
2. ENERGY STAR v6.0 Dataset v2
3. NRDC Dataset – Desktops
4. NRDC Dataset – Notebooks
5. NRDC Power Supply Data and Analysis
6. NRDC Active Load Test Data
7. CLASP-NRDC 2011 Graphics Cards Test Report
8. NRDC Stock and Energy Use Estimate

End Notes

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[i] See Attachment #8. Stock and Energy Use

[ii] Intel's Haswell architecture: http://www.anandtech.com/show/6355/intels-haswell-architecture/3

[iii] ENERGY STAR v6.0 Development Webpage: https://www.energystar.gov/products/specs/node/143

[iv] CLASP/NRDC 2011 cards: http://www.clasponline.org/Resources/Resources/StandardsLabelingResourceLibrary/2012/Impact-of-Graphics-Cards-on-Desktop-Computer-Energy-Consumption and PG&E 2012 cards: http://www.energystar.gov/products/specs/sites/products/files/California%20IOU%20%20NEEA%20Comments_Public.pdf

[v] International standard for measuring the energy consumption of personal computing products - http://www.ecma-international.org/publications/standards/Ecma-383.htm

[vi] 80-PLUS qualified internal power supplies: http://www.plugloadsolutions.com/80PlusPowerSupplies.aspx
[vii] NEEA 80 PLUS Market Progress Evaluation Report #4: http://neea.org/docs/reports/80-plus-mper-4-final-06-11-12.pdf

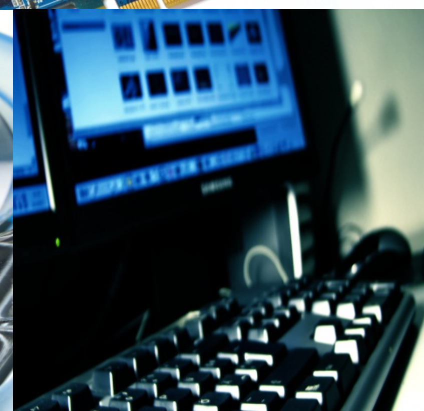
[viii] Pigg & Bensch 2010, Minnesota Plug Load Study, http://www.ecw.org/ecwresults/257-1.pdf

[ix] NEEA 80 PLUS Market Progress Evaluation Report #4: http://neea.org/docs/reports/80-plus-mper-4-final-06-11-12.pdf

[x] ENERGY STAR Unit Shipment Data Report: http://www.energystar.gov/index.cfm?c=partners.unit_shipment_data

[xi] California IOUs market research and testing: http://www.etcc-ca.com/reports/cost-effective-computer-efficiency
[xii] NEEA 80 PLUS Market Progress Evaluation Report #4: http://neea.org/docs/reports/80-plus-mper-4-final-06-11-12.pdf

[xiii] ENERGY STAR v6.0 Draft specification http://www.energystar.gov/products/specs/sites/products/files/Draft%203%20Version%206%200%20Specification%20for%20Computers.pdf



The Impact of Graphics Cards on Desktop Computer Energy Consumption

September 2012

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Contents

Executive Summary

In 2012, the Collaborative Labeling and Appliance Standards Program (CLASP) and the Natural Resources Defense Council (NRDC), in collaboration with Ecova, initiated an innovative study designed to provide policy makers with data on discrete graphics card energy consumption in desktop computers. This data was gathered to support the establishment of effective energy consumption allowances (or "adders") for graphics cards in the Version 6.0 ENERGY STAR computer specification, as well as in other labeling initiatives and mandatory standards that use the ENERGY STAR computer specification as a framework.

Graphics card adders impact energy saving. Overly lenient graphics card adders can provide a significant excess allowance of energy consumption for the rest of the computer system, which enables less energy efficient computers to meet efficiency requirements for standards and labeling programs. On the other hand, overly stringent graphics card adders may restrict market access for efficient computers that require cards for graphics-intensive applications (e.g. computer gaming). Setting graphics card adders at appropriate levels will ensure that standards and labeling programs support the market for energy efficient computers while excluding inefficient models.

Stand-alone graphics cards are typically measured and evaluated independently from the computer systems in which they are used; system-level power demand impacts are then derived by applying a power conversion factor. This traditional approach does not account for the impact of the graphics card on other components in the computer system, which may be significant in some cases.

This study employed a novel approach for measuring the power impact of discrete graphics cards; the net power impact of the cards was determined by measuring the difference in system-level power demand between a computer with the card and the same computer without the card, using integrated graphics. This approach provides a more accurate assessment of the net power impact of a discrete graphics card on a computer system.

Ecova tested 12 discrete graphics cards that were selected from six ECMA-383[1] graphics categories and represent over one-third of the desktop discrete graphics card models introduced on the U.S. market in 2011. The six computer systems in which the cards were tested represented a wide range of market segments, including Mainstream, Performance, High Performance, and Very High-end/Enthusiast[2] segments. While it was not in the scope of this study to evaluate the impact of the cards on all computer configurations on the market, the selected configurations were chosen to represent a range of performance levels across a representative sample of the primary desktop computer market segments.

Key findings from the study are as follows:

1. **The power impact of each discrete graphics card varied significantly from computer to computer**, indicating that a number of system-specific factors other than the card itself impact system power demand when a discrete graphics card is installed;

[1] International standard for measuring the energy consumption of personal computing products - http://www.ecma-international.org/publications/standards/Ecma-383.htm
[2] Information Technology Industry Council Comments on Energy Star Computers Version 6, March 10 2011 Kickoff Meeting. Available at: http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/computer/ITI_Comments_4.pdf

2. **Power demand in idle mode generally increased as discrete graphics card frame buffer bandwidth increased;** however, there were large differences between cards;
3. **A new technology called ZeroCore Power Technology, which was featured in one high-end card, dramatically reduced power demand** when the computer was in idle mode; and,
4. **The additional power needed to operate a second discrete graphics card was approximately 25 percent less** than that required for the first card in a particular host computer.

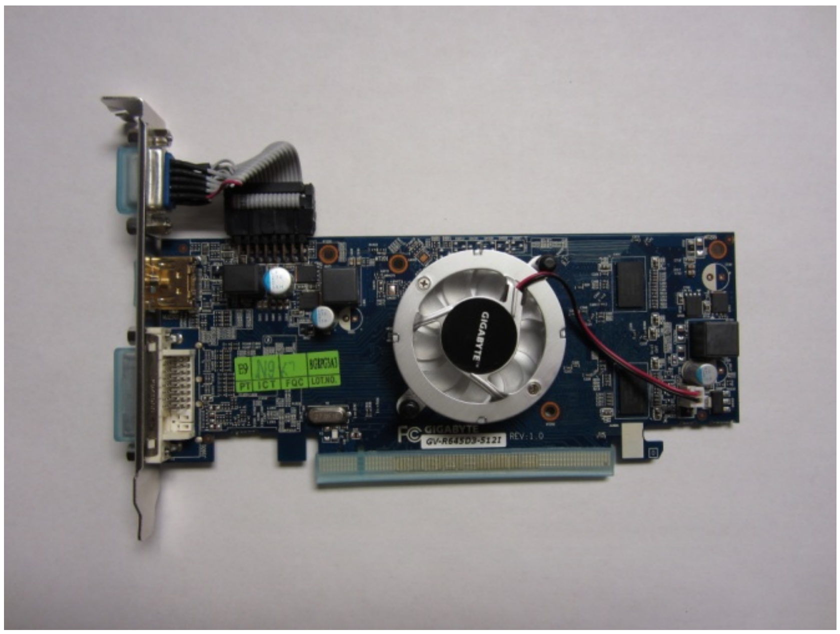
Based on the findings listed above, we recommend the following modifications to the process of determining effective adders for discrete graphics cards:

1. **Graphics card adders should be set using system-level test data** rather than individual card-level power;
2. **A linear regression across all data points allows adders to be determined more accurately than a category-by-category approach**, given the limited number of data points available in each category;
3. **Innovative technology can significantly reduce discrete graphics power demand in idle mode** in the near-future; thus, adder levels should be regularly updated to adapt to the current deployment of new low-power idle technology; and,
4. **Additional and ongoing testing using a methodology similar to the one presented in this study** should be employed to assess graphics cards newly introduced on the market.

1. Introduction

Discrete graphics cards (dGfx) are add-in graphics-processing cards that interface with a computer's motherboard through an expansion slot (typically a PCI bus) and differ from integrated graphics (iGfx), which are assimilated into the motherboard or processor (CPU). Discrete graphics cards include specialized graphics processing units (GPUs) that are designed to accelerate the display of graphical images on computer screens. They are often used for graphics-intensive applications such as computer gaming, video editing, and computer-aided design.

Photo 1: A discrete graphics card, photo taken by Ecova



The addition of a discrete graphics card to a computer often results in a large increase in the energy consumed by the overall system. As such, additional energy consumption allowances (or "adders") for discrete graphics cards are a critical component of computer energy efficiency specifications. Adders aim to make energy efficiency specifications performance-neutral by providing power or energy allowances for specific capabilities. Overly lenient graphics card adders can provide a significant excess allowance of energy consumption for the rest of the computer system, which enables less energy efficient computers to meet efficiency requirements for standards and labeling programs. On the other hand, overly stringent graphics card adders may restrict market access for efficient computers that require cards for graphics-intensive applications (e.g. computer gaming). Setting graphics card adders at appropriate levels will ensure that standards and labeling programs support the market for energy efficient computers while excluding inefficient models.

A representative sample of graphics card energy consumption is needed to set appropriate graphics card adders. The Version 6.0 ENERGY STAR computers dataset contains a limited number of configurations equipped with recent discrete graphics cards, and, in most cases, does not include data from a baseline configuration (i.e., the exact same system without the card), which is necessary to evaluate the additional power required for the graphics card to function.

This study provides a representative dataset demonstrating the impact of discrete graphics cards on the power demand of desktop computers while in idle mode, to support the process of setting effective graphics adders in the Version 6.0 ENERGY STAR computers specification. This data can also be used by other labeling initiatives or mandatory standards programs that use the ENERGY STAR computer specification as a framework.

2. Background

2.1 Scope

This study applies to discrete graphics cards for desktop computers; notebook computers require a different test approach due to their higher levels of integration and customization. Notebook graphics are also much more efficient than desktop graphics due to battery life considerations. The study therefore focuses solely on desktop computers, which offer the greatest opportunity for energy savings from discrete graphics among various types of computers.

Some desktops have more than one discrete graphics card to increase performance. To help set adders for additional discrete graphics cards beyond the first, the study also includes testing of configurations with multiple discrete graphics cards in the same system.

Finally, this study focuses on consumer-grade graphics cards (e.g. for computer gaming) as opposed to professional-grade graphics cards. The latter are designed primarily for workstations and represent a small share of the market relative to graphics cards on personal computers.

2.2 Computer Energy Use

Although 2011 sales of desktop computers were about half those of notebooks in mature markets, and their unit sales are projected to marginally decline over the next four years, desktops still use over three times as much energy as notebooks on a per unit basis. As a result, aggregate desktop energy use is projected to remain higher than that of notebooks through the year 2016, as illustrated in Figures 1 and 2.

Figures 1: Computers Sales[3]

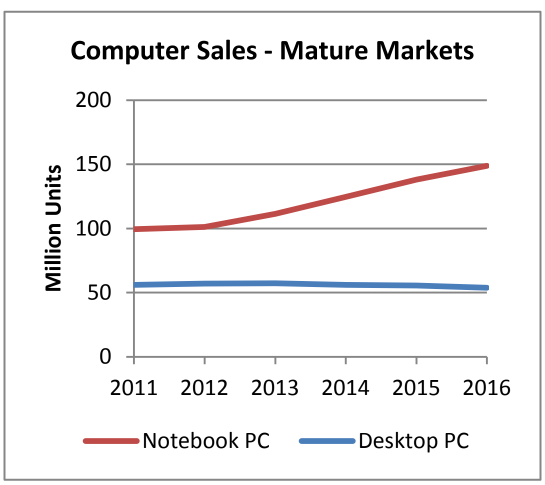
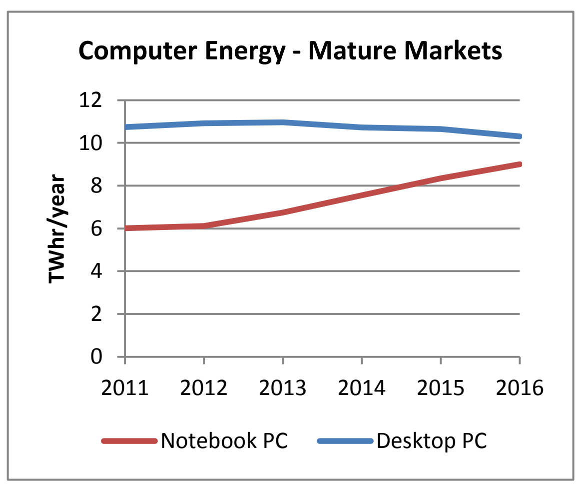


Figure 2: Computer Energy[4]



[3] IDC June 2012: http://www.idc.com/getdoc.jsp?containerId=prUS23549112

[4] Annual energy use of new computers sold each year, based on ENERGY STAR Computers v5 energy limits and duty cycle. This includes all computers sold, whether ENERGY STAR-qualified or not.

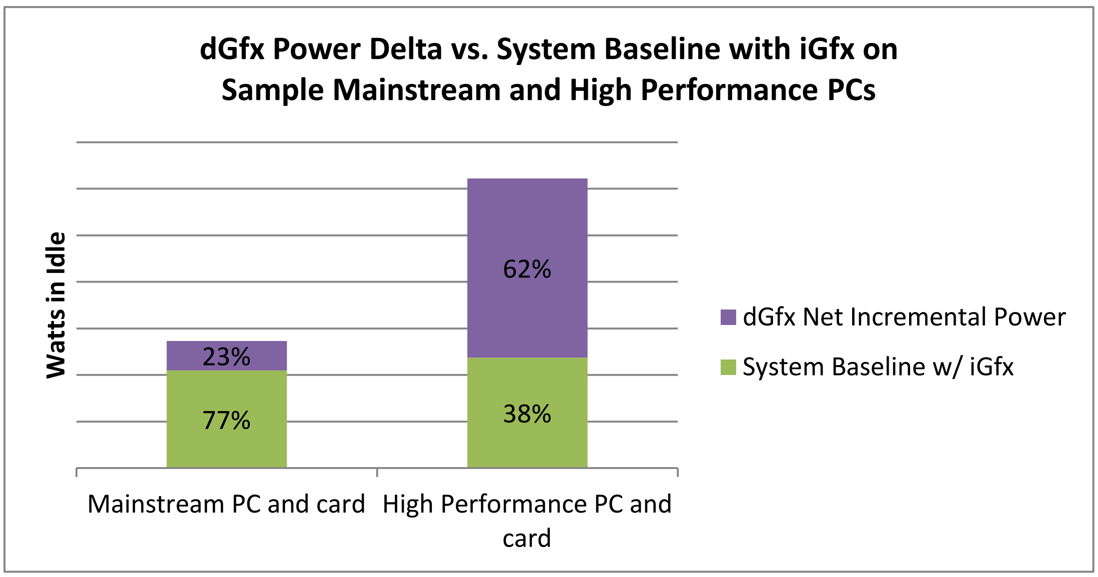
International Data Corporation (IDC) also forecasts that desktop computer unit sales will continue to grow in emerging markets over the period from 2012-2016. The high energy use of desktop computers suggests that a continued focus on desktop computer energy efficiency is necessary to reduce the global energy use of computers.

2.3 Discrete Graphics Energy Use

Desktop computers are the second highest source of electricity consumption among electronic equipment in U.S. homes, after televisions.[5] When present, discrete graphics cards can be responsible for a significant share of the host computer's energy use. Figure 3 illustrates the share of discrete graphics idle[6] power on two sample systems from the study's test data:

- A mainstream desktop computer with a low-end discrete graphics card[7];
- A high performance desktop computer with a high-end discrete graphics card[8].

Figure 3: Net Power Delta of Sample Discrete Graphics Cards on Low-End and High-End Systems



Note: Figure 3 uses data from two sample configurations. It is not meant to represent an average, but to illustrate the relative impact of discrete graphics.

In 2010, discrete graphics cards were found in between one third and one half of desktop computers on the market;[9] therefore, reducing the power demand of discrete graphics cards in idle mode is a key strategy for the reduction of the overall energy use of desktop computers.

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[5] International Energy Agency. Gadgets and Gigawatts (2009)
[6] Weighted average of Short and Long idle per Energy Star v6 draft 2 mode weightings
[7] Mainstream configuration: PC1 with GPU1 (AMD Radeon HD 6450), as described in Appendix III
[8] High-performance configuration: PC5 with GPU12 (NVIDIA GeForce GTX 590)
[9] 65-70 million desktop discrete GPUs shipped worldwide in 2010 (Mercury Research: http://www.xbitlabs.com/news/graphics/display/20101027211059_ATI_Maintains_Lead_on_Discrete_GPU_Market_Mercury_Research.html) for 145 million desktop PCs (IDC: http://www.idc.com/getdoc.jsp?containerId=prUS22861211).

3. Methodology

3.1 Overview

This study was designed to provide results that can be compared directly with (and used for the definition of) discrete graphics adders in ENERGY STAR-based specifications. The key objective was to calculate the net power impact of a discrete graphics card as the difference in power between a computer with the card and the same computer without the card. This net power impact was then converted to energy impact using the ENERGY STAR duty cycle.[10]

Laboratory testing was performed on 12 cards, featuring one GPU from each of the two main manufacturers (AMD and NVIDIA) in six of the seven ECMA-383 categories.[11] Each card was tested in six different computers selected to represent a broad range of desktop computers.[12] Each test was performed initially three times in order to identify potential testing variability. Testing was then reduced to two tests per configuration after variability was determined to be insignificant in the initial tests. The results were then analyzed. The findings are presented in Section 4.

The following sections cover the key aspects of the methodology.

3.2 System Level Testing

The study measured alternating current (AC) power of the entire computer system "at the wall."[13] This measurement provides a more accurate assessment of the impact discrete graphics cards have on the power consumption of the computer system than measuring direct current (DC) power at the component level inside the system and converting it into AC power.

Computers are integrated systems; therefore adding a discrete graphics card to a computer affects system power in more ways than just adding power used by the discrete graphics card itself. For example, plugging a discrete graphics card into a system also results in the following:

- Integrated graphics are automatically switched off in the majority of computers;
- System components, such as the CPU, motherboard and memory, consume more power in response to new demands from the discrete graphics card. This increase in power is partially compensated by the cessation of power demands from the integrated graphics card;
- Power supply load point and efficiency change in response to the difference in net DC power; and,
- In some cases, upsizing the power supply (replacing it with a unit rated at a higher maximum wattage) in order to accommodate peak power demands when the discrete graphics card is active. This impacts the efficiency curve of the power supply as well as its loading point at idle.

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[10] http://www.energystar.gov/index.cfm?c=revisions.computer_spec

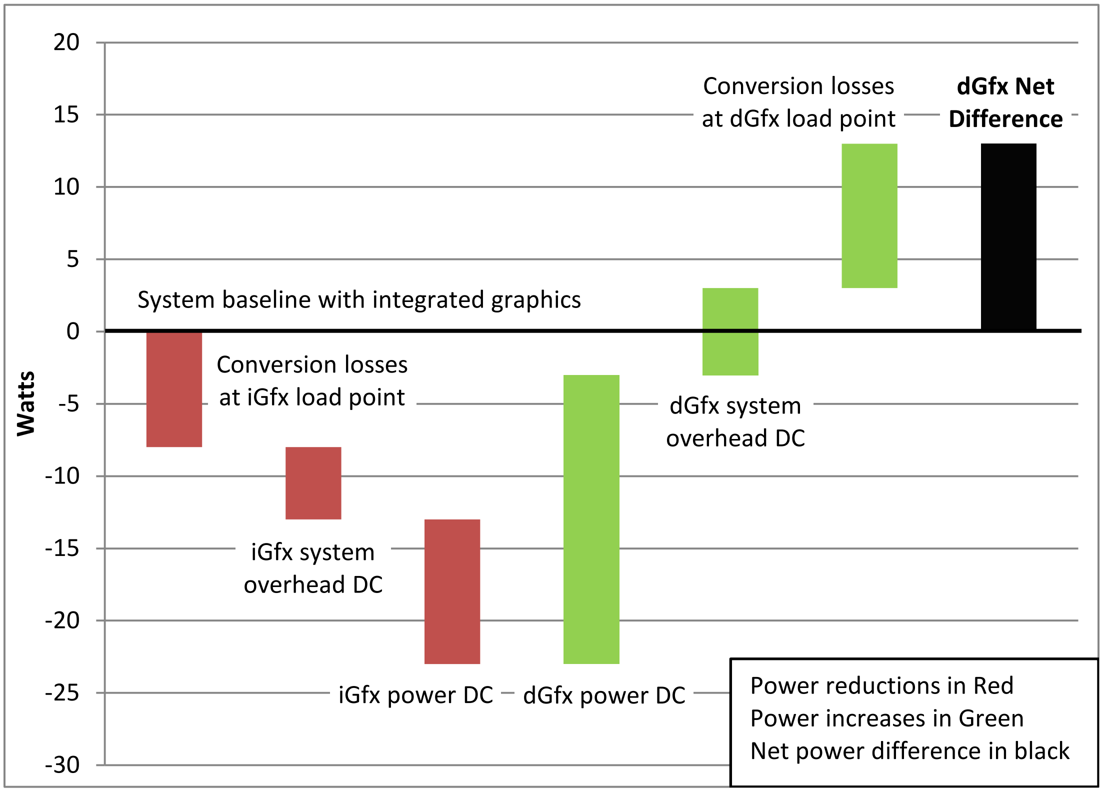
[11] ECMA-383 Standard: Measuring the Energy Consumption of Personal Computing Products - http://www.ecma-international.org/publications/standards/Ecma-383.htm. The G6 category was excluded from the study because there were very few cards of this type on the market at the time of testing.

[12] GPU12 was exempt, as it would only operate in three of the test computers.

[13] Power consumption of the computer measured at the wall electrical outlet.

The changes in net power described above are illustrated in Figure 4. This study evaluates the net impact of these effects by calculating the difference of AC power demand between a computer with the dGfx card and the same computer without the card.

Figure 4: Changes in System Power When Adding a Discrete Graphics Card[14]



3.3 Idle Mode Testing

In keeping with the ENERGY STAR Computers Version 5.2 and Version 6.0 Draft 2 specifications and test protocols, power measurements were taken in idle mode only, not active mode. The discrete graphics card net energy impacts presented throughout this study correspond to the energy requirements of the card in idle mode, when graphics processing needs are very limited and could be handled by integrated graphics.

Computer power in Off and Sleep modes was measured for Baseline configurations (computers without a discrete graphics card) for reference purposes. The power demand in Off and Sleep modes was verified not to vary between configurations with and without a discrete graphics card. Therefore power demand in Off and Sleep modes does not impact the net energy impact of discrete graphics cards.

The power impact was measured in both short idle (computer display on) and long idle (computer display in low-power mode), per the ENERGY STAR Computers revised test method dated July 21,

[14] Figure 4 shows hypothetical values to illustrate the concept, not measurements on a particular system and graphics card.

2011[15]. The net energy impact was then calculated using the mode weightings proposed in the ENERGY STAR v6.0 draft 1 and 2[16].

3.4 Test Protocol

The test approach is consistent with the ENERGY STAR computer specification test methodology[17]. Unless otherwise specified, all terms used in the test methodology are consistent with the definitions in the ENERGY STAR specification for computers. The study uses ENERGY STAR definitions for all operating modes: off, sleep and idle (short and long).

Although the ENERGY STAR test methodology requires only one test run per sample, each computer system was tested with each discrete graphics card two to three times in idle mode. Up to 3 test runs were performed for each configuration to ensure that any significant variability was detected, and tests were repeated until 2 consistent runs were obtained. Variability between test runs turned out to be marginal, and additional runs due to unexpected variability were only necessary for one configuration.

Additional details on the test methodology can be found in Appendix I.

3.5 Discrete Graphics Card Selection

Selection Criteria and Rationale

The study's objective was to select two recent cards in each of the six most common ECMA-383 graphics categories[18], with a balanced representation of the two major GPU manufacturers, AMD and NVIDIA.

A survey of discrete graphics cards offered in the desktop computer lines in four of the major original equipment manufacturers (OEMs) of desktop computers: HP, Dell, Apple and Acer, was performed. Graphics cards were categorized based on frame buffer bandwidth (GB/s) and associated ECMA-383 classification. Frame buffer bandwidth is a performance proxy for graphics cards defined by ECMA-383 for the purpose of categorization. The study's selection included the most recently-released cards identified in a market survey from both NVIDIA and AMD for each ECMA-383 category. In addition, graphics cards capable of NVIDIA® SLI™ and AMD CrossFireX™ configurations for each ECMA-383 category were selected where possible. To fill in gaps in certain performance categories in the study's OEM market survey, popular graphics cards based on third-party web sites such as Tom's Hardware and GPU Review[19] were selected. Within each ECMA-383 category cards that were most recently released and most commonly used by OEMs were selected when possible.

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15 http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/computer/Computers_Test_Method_Rev_July_2011_Draft.pdf?abd9-54e8

16 http://www.energystar.gov/index.cfm?c=revisions.computer_spec

17 ENERGY STAR Computer Test Method, July 21, 2011, http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/computer/Computers_Test_Method_Rev_July_2011_Draft.pdf

18 ECMA graphics categories are defined at http://www.ecma-international.org/publications/standards/Categories_to_be_used_with_Ecma-383.htm

19 See http://www.tomshardware.com/reviews/fastest-graphics-card-radeon-geforce,3085.html and http://www.gpureview.com

NVIDIA's current lineup of discrete graphics cards does not include an NVIDIA® SLI™ capable card for every ECMA-383 category. As a result, no NVIDIA® SLI™ capable cards were tested in the G1 and G2 categories. AMD/ATI offers single and CrossFireX™ configuration cards for each ECMA-383 category other than G6.

Selected Graphics Card Models

Selected graphics card are detailed in Appendix II.

The cards selected for the study cover approximately 36% of discrete desktop graphics card models released by AMD and NVIDIA in 2011. See Appendix II for the list of cards released by AMD and NVIDIA in 2011.

3.6 Test Computer Configurations

As discussed in section 3.2 System Level Testing, graphics card power demand depends not just on the card itself but also on the system it is operating in. Therefore, selecting a representative set of test computers was important to ensure the validity of the study's test results.

Tests were conducted on 6 test computers in order to represent various segments of the market, covering both the consumer and commercial markets, and a range of performance levels including Mainstream, Performance, High Performance, and Very High-end/Enthusiast. While it is not possible to accurately represent all configurations on the market, 6 configurations carefully chosen to represent different technologies and performance levels provided a representative sample of the main desktop computer market segments.

The 6 test computers included different types of technologies and efficiencies for key components including CPUs, motherboards and power supplies. Different models of these components were intentionally used across all 6 computers. Although using the same components would have enabled better control for the impact of graphics cards vs. other variables, it would not have been representative of market configurations. For adders to be meaningful it is essential that test data is as representative of the market as possible.

A more detailed explanation of the study's computer configuration process and list of detailed hardware configurations is provided in Appendix III.

Power supply configurations are not included in Appendix III, instead they are covered separately in the following section because of special requirements imposed by the study's test methodology.

3.7 Power Supply Configurations

The choice of power supply units (PSUs) required special consideration. Contrary to other components, PSUs could not be held constant for a given computer, they had to be changed depending on which graphics card was being tested. As discrete graphics can represent a significant share of a computer's active mode peak power, the PSUs used in the baseline configurations are generally not capable of supporting the higher performance cards' peak power requirements. For each test, the PSU was sized appropriately for the peak power requirements of the card being tested and its host system by following card manufacturer minimum PSU size recommendations.

The PSU could have been held constant for each computer by using a single PSU capable of supporting the highest powered card, but this would not have been representative of typical market configurations for smaller cards. Upsizing the PSU depending on the graphics card represents real design decisions made by manufacturers in the market.

The same selection principles utilized in the selection of CPUs and motherboards were applied to the selection of PSUs: a range of PSU efficiencies representative of current PSUs in the market were selected. These PSUs were matched to the computer system, so that the combination of computer system and PSU power rating and efficiency represents configurations commonly found in the market. To account for the need to upsize PSUs for the highest powered cards, a set of PSUs of comparable efficiency were selected for each test computer. Detailed PSU models and efficiencies can be found in Appendix IV.

Using a different PSU in the baseline and in the discrete graphics card test is legitimate and representative of design practices in the market. However, it raises two questions regarding the accuracy of the test results in this study:

1. Are differences in power supply conversion losses a significant factor in the reported discrete graphics card net impact values?
2. Did upsizing certain PSUs result in significant differences in power compared to using the Baseline PSUs?

A detailed analysis of these two questions is presented in Appendix IV. In summary, changes in power supply conversion losses were responsible for less than one fifth of the incremental discrete graphics card power. The increase in power supply losses is nearly proportional to the increase in DC power demand by the system. The power supply efficiency increases slightly as load increases, but this effect is relatively minor compared to the increased losses due to higher load.

The other four fifths of the AC power impacts result from system power changes due to the discrete graphics card, not to differences in PSU conversion losses. Moreover this ratio was very consistent across cards, varying between 15 and 19 percent, indicating that power supplies did not introduce significant variability in test results.

Regarding the impact of PSU upsizing, the study's analysis shows that the incremental power due to PSU upsizing is on average only 2% of the discrete graphics card net power impact. This means that PSU upsizing introduced negligible variability on the discrete graphics card net impacts reported in the project results.

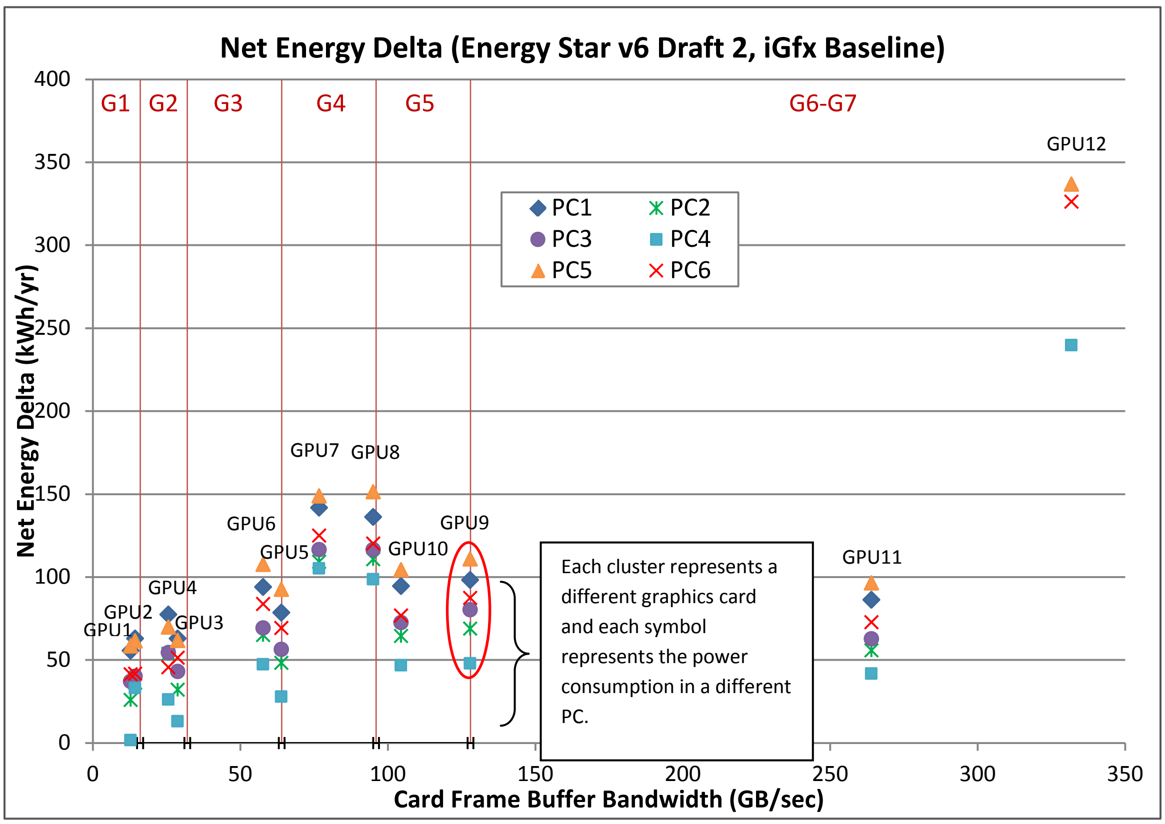
4. Data Analysis & Key Findings

This section presents an analysis of the net annual energy impacts for each card[20]. Policy recommendations follow in Section 5.

4.1 Single Card Test Results

Figure 5 shows the net energy impacts of single card configurations per card and per test computer. The x-axis represents the card frame buffer bandwidth, with higher values generally corresponding to higher graphics performance[21]. The y-axis represents the difference in idle power between the system using the discrete graphics card, and the baseline system using integrated graphics.

Figure 5: Net Energy Delta (Version 6.0 ENERGY STAR Computers Draft 2, iGfx Baseline)



Notes:

1. GPU12 (NVIDIA GeForce GTX 590) has only 3 data points because it would only run in 3 of the 6 test computers due to its high power requirements.
2. GPU1 on PC4 uses only 1.6 kWh/yr. This reflects the fact that increased power demand from adding GPU1 is almost completely compensated by the reduction in power from switching off PC4 integrated graphics.

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[20] The study's test data and analysis is available at http://www.clasponline.org/ResourcesTools/Resources/StandardsLabelingResourceLibrary/2012/Impact-of-Graphics-Cards-on-Desktop-Computer-Energy-Consumption

[21] There are other factors to graphics performance, but frame buffer bandwidth is a simple and generally accepted proxy for the purpose of graphics card categorization.

Figure 5 illustrates the following facts:

1. **Power demand of individual graphics cards varies from computer to computer**

   Differences in energy consumption across test computers for a given card are represented by the vertical spread in clusters on the chart. The spread of energy consumption across test computers is generally consistent for all cards, meaning each card generally increased computer power demand by the same amount across each of the computer systems tested. This confirms that the net energy delta for a system with a discrete graphics card is due to power changes in the system in addition to power consumed by the card itself. Table 1 below provides more analysis on this point.

2. **Computer power demand generally increases with graphics card frame buffer bandwidth**

   As discrete graphics card frame buffer bandwidth increases, so does the computer's energy consumption. However this is not always the case, as shown by the two G5-category cards, which require less additional power than the G4-category cards, even though they have a greater frame buffer bandwidth as shown on Figure 5;

3. **One of the cards tested (GPU11) delivers a dramatically better idle power to performance ratio than the others**

   GPU11 and GPU12 are both G7 cards. The difference in energy consumption may be explained by new technology used by GPU11. GPU11 is an AMD Radeon HD 7970, the first card on the market to feature ZeroCore Power Technology designed to radically reduce card power demand in idle mode. This suggests that new energy efficiency technology may substantially decrease graphics card power demand in idle mode once this technology is rolled out to a large number of cards. Recent NRDC market research indicated that AMD and NVIDIA had already rolled out low-power idle technology to 11 new cards across 4 ECMA categories in the first half of 2012[22].

Table 1 below presents the same data as Figure 5 in table format with color coding to highlight high and low values. It shows that some computer systems, such as PC5, consistently used more additional energy to run the discrete graphics cards than other computers. This is likely due to the fact that PC5's integrated graphics are highly efficient in idle mode, resulting in lower baseline power and therefore a higher power difference when using discrete graphics.

By the same token, some computers consistently used less additional energy to run the discrete graphics cards than other computers. PC4 in particular consumed significantly less additional energy. This appears to be due to high integrated graphics power demand in idle mode compared to the other computers. This limits the energy reduction from switching off the integrated graphics when the discrete graphics card is added. PCs 2, 3, and 6 appear closer to the average and may be more representative of the average computer.

[22] Radeon HD 7970, Radeon HD 7950, Radeon HD 7870, Radeon HD 7850, Radeon HD 7770, Radeon HD 7750, GeForce GTX 680, GeForce GTX 690, GeForce GTX 670, GeForce GTX 630, GeForce GTX 640,

Table 1: Net Energy Delta (ENERGY STAR v6.0 Draft 2 duty cycle, iGfx Baseline)

kWh/yr	PC1	PC2	PC3	PC4	PC5	PC6	Average
iGfx	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
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 scales indicate comparative energy use change among the computers tested for a given graphics card (GPU) compared to baseline integrated graphics; red indicates the highest change in energy consumption, followed by orange, yellow, light green, and green indicated the lowest.

4.2 Average by Card

To facilitate the use of test results for policy purposes, the average of the net energy impacts on the computer system across test computers was calculated to derive a single value per card. The average was calculated across the 4 median PCs, excluding the systems yielding the lowest (PC4) and highest (PC5) values overall. While PC4 is a valid market configuration, including it in the average could have penalized computers with effective integrated graphics power management. PC5 yielded the highest power impacts overall and was excluded to balance out the exclusion of PC4 and ensure that the average is representative of the median of the test sample. Table 2 gives average results per card, for both ENERGY STAR v6.0 Draft 2 and ENERGY STAR v5 mode weightings.

Table 2: Average Test Results for Each Graphics Card

Card	GPU	Card Frame Buffer Bandwidth[1] (GB/s)	ECMA-383 (v3)[2]	Energy Delta E* v6 Draft 2[3] (kWh/yr)	Energy Delta E* v5[4] (kWh/yr)
GPU1	AMD Radeon HD 6450	12.8	G1	40.0	33.1
GPU2	NVIDIA GeForce GT 520	14.4	G1	45.3	35.8
GPU3	AMD Radeon HD 6570	28.8	G2	47.3	39.0
GPU4	NVIDIA GeForce GT 440	25.6	G2	57.8	45.5
GPU5	AMD Radeon HD 6670	64.0	G3	63.1	51.6
GPU6	NVIDIA GeForce GTS 450	57.7	G3	78.1	63.4
GPU7	AMD Radeon HD 6770	76.8	G4	123.1	102.3
GPU8	NVIDIA GeForce GTX 460	95.0	G4	120.8	99.5
GPU9	AMD Radeon HD 6850	128.0	G5	83.7	68.7
GPU10	NVIDIA GeForce GTX 550	104.5	G5	77.1	62.6
GPU11	AMD Radeon HD 7970	264.0	G7	69.4	69.0
GPU12	NVIDIA GeForce GTX 590	331.8	G7	326.3	278.5

Notes:

1. Card Frame Buffer Bandwidth: a proxy for graphics card performance as defined by ECMA-383 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. Energy Delta E* v6 Draft 2: average difference across the 5 test computers between system Typical Energy Consumption (TEC) with the card and Baseline 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 v6.0 draft 2 (45% Off, 5% Sleep, 15% Long Idle, 35% Short Idle).
4. Energy Delta E* 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 report.

4.3 Average by ECMA Category

Table 3 provides the average net energy consumption increases by ECMA category. It averages values for the 2 cards tested in each computer and category.

Table 3: Average Test Results by ECMA Category

ECMA-383 (v6)	Energy Star v6 draft2 kWh/yr	Energy Star v5 kWh/yr
G1	42.6	34.4
G2	52.5	42.3
G3	70.6	57.5
G4	122.0	100.9
G5	80.4	65.7
G7 (GPU11)	69.4	69.0
G7 (GPU12)	326.3	278.5

Note that category average values do not necessarily represent a recommended adder value for that category. Depending on the policy program, more stringent values may be warranted. Chapter 6 proposes policy approaches using lower values than the averages in Table 3.

Energy Star v5 values are different from Energy Star v6.0 because of different mode weightings in the two versions of the specification. For programs based on the ENERGY STAR v5 framework, program managers should use the ENERGY STAR v5 values.

4.4 Dual Card Test Results

Dual-card configurations, and more generally multi-card configurations, refer to computers that use more than one discrete graphics card. These configurations are used to increase graphics performance: either by providing higher performance than a single card could, or by providing equivalent performance at a potentially lower price than that of a single card.

Discrete graphics cards capable of operating in multi-card configuration 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 than for single card configurations, because not all cards and test computers supported multi-card configurations. Dual card tests were only performed in PCs 4 and 6 and on ten cards (excluding GPU2 and GPU4) as other cards and computers did not support dual-card configurations. A summary of the additional energy required to run a second discrete graphics card is summarized in Table 4.

Table 4: Dual Graphics Card Energy Deltas: 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): Energy delta between single card and integrated graphics
2. Dual Card d(single card): Energy delta between the second card and the first one
3. Dual Card d(iGfx): Energy delta between the second card and integrated graphics

As illustrated by GPU1 in PC4 (Table 4), dual graphic card adders for PC4 are skewed by the fact that there is little difference between PC4's power demand with integrated graphics versus a single graphics card, because its integrated graphics card consumes a large amount of power in idle mode. 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 for a second card abnormally high and not representative of the average computer.

PC6 is more representative of an average computer. The additional power needed to run a second graphics card is lower than that required for the first card. Second cards require on average 73% of the power of the first card on PC6.

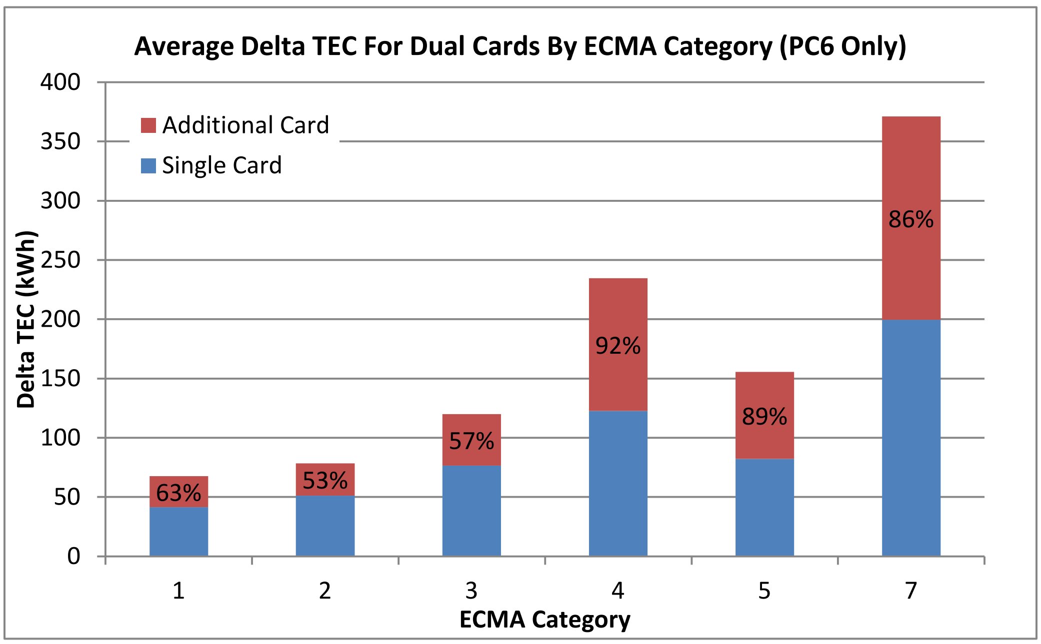
Some cards recently released in the market are capable of powering down the second card almost completely in dual card mode[23], however none of the cards tested in this study had that capability.

[23] http://blogs.amd.com/play/2012/01/30/power-efficiency-is-making-a-difference/

Table 5: Energy Delta (kWh/yr) for Dual Cards by ECMA Category for PC6

ECMA Category	Average Single Card d(iGfx)	Average Dual Card d(single card)	Second card as % of first card
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 6: Average Energy Delta for Dual Cards by ECMA Category for PC6



Note: Table 5 and Figure 6 use ENERGY STAR v6.0 Draft 1 formulae. ENERGY STAR v5 shows similar ratios with different absolute values.

5. Recommendations

5.1 Setting Adders for Discrete Desktop Graphics Cards

The methodology of the study was designed so that test results are directly comparable to, and usable for the definition of, ENERGY STAR graphics adders.

Considerations for Setting Adders

Allowance Leakage: The annual typical energy consumption approach enables flexibility to implement the most cost-effective way to meet a standard. However, when adders represent a significant share of typical energy consumption (TEC), as is the case with graphics and display adders, rapid technology evolution can result in a large unwarranted allowance for the rest of the system, which could result in the qualification of relatively inefficient computers. We refer to this situation as "allowance leakage". It is an unintended consequence of the flexibility that the TEC approach provides, and can reduce the effectiveness of TEC-based standards if not managed appropriately.

Market Bias: Base TEC limits are set at the level that achieves a certain pass-rate in a given category after applying adders. When categories contain both systems with and without discrete graphics (as in ENERGY STAR v5.0 and v6.0 draft 2), setting adders too high will give systems that use discrete graphics an advantage over those that don't, resulting in a potential bias towards systems that benefit from the overly high adders. The reverse is also true for adders that are set too low.

Market bias can be avoided or minimized by separating systems that use discrete graphics from those that don't, and/or by ensuring that adders are set at an appropriate level.

Stringency of Adders

Making specific adder recommendations is not the purpose of this study. Adder levels will need to be set by programs based on independent analysis and assessment of test data. We provide here general guidance to standards and labeling program managers on how the results of this study can be utilized.

Recommendations are based on the following guiding principles:

- The stringency of adders depends on the objectives and the type of program being considered;
- Adders should be set at a certain percentile of the test dataset, including this study and any other complementary data source that uses a methodology consistent with this study;
- Adders should be no less stringent than the median of the test dataset, in order to minimize allowance leakage and market bias;
- The energy efficiency of discrete graphics is evolving rapidly as evidenced by the ZeroCore Power technology used by the AMD Radeon HD 7970 card. Program managers should take that evolution into account by setting adders slightly lower than their program qualification target rate to ensure the standards meet their objectives when in effect.

Table 6 below puts forth target percentile ranges for adder levels based on the study's test data and the guiding principles listed above.

Table 6 - Target Percentile of Dataset for Adder Setting

Program Type	Program Qualification Target	Set Adders in Following Percentile Range of Dataset
	Top 10% of market	**5th-15th**
	Top 25% of market	**20th-30th**
	Top half of market	**40th-Median**
	Top 75% of market	**Median**

Use a linear regression based on frame buffer bandwidth to set adders

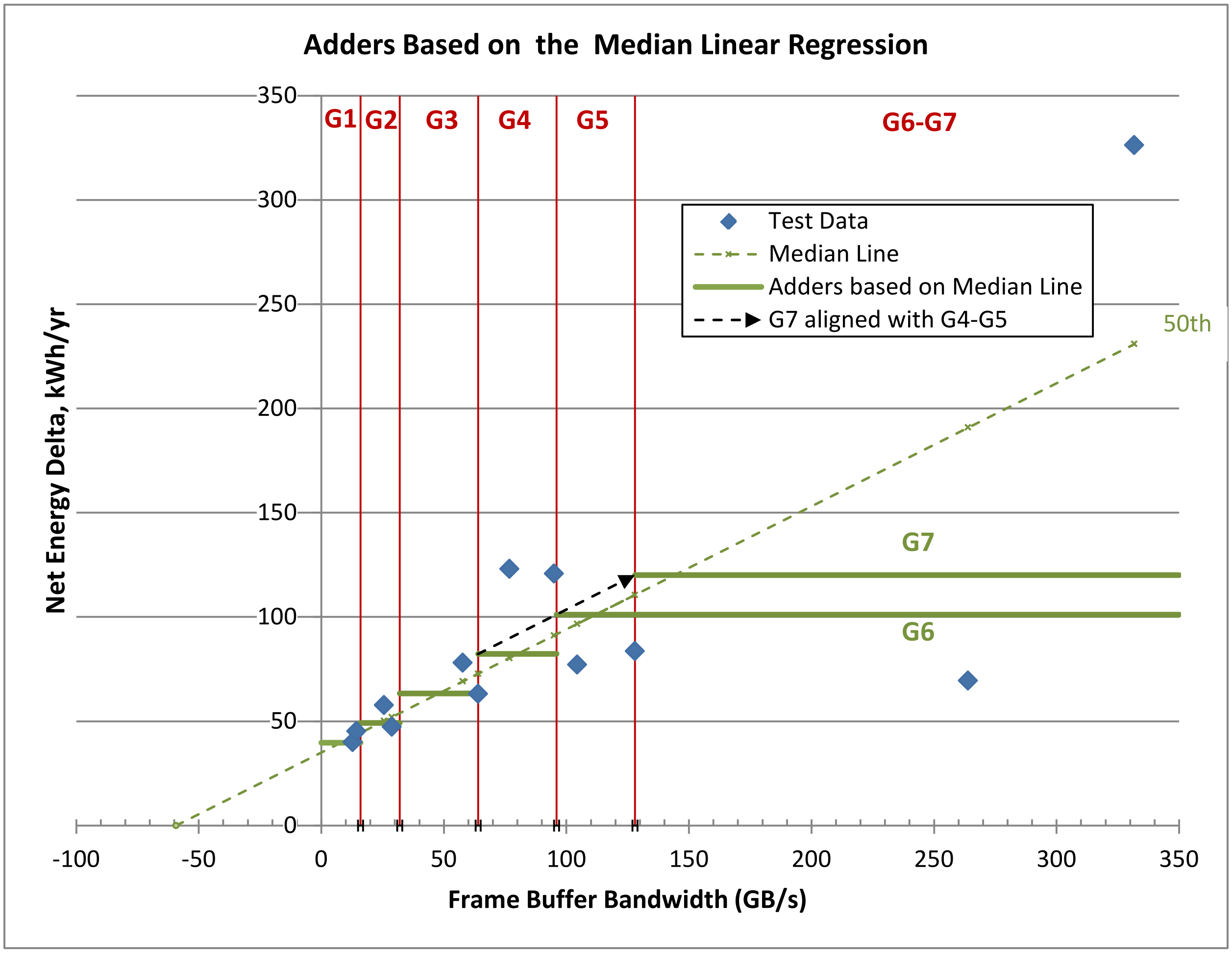
The approach of setting graphics card adders by taking the average or a target percentile of data points within each graphics category has limitations: the number of data points in each category is limited not just by testing costs and time, but also by the limited number of products available on the market in each category at any given time. As a result the target percentile for each category is very sensitive to the data available, which increases the risk of setting adders at inappropriate levels.

The alternative "linear regression" approach uses test data points across all graphics categories to establish the median and other percentile lines for the entire data set. The benefits of using a linear regression is that the adder levels are based on more test data, making the levels less vulnerable to outliers. Adders based on linear regression are illustrated in Figure 7 below.

Category adders are then calculated as follows:

- G1 through G5 are set at the mid-way point of the linear regression in each category;
- G6 is set equal to the G5 adder, following the approach by EPA in ENERGY STAR Version 6.0 Draft 2; and,
- G7 is aligned with the G4 and G5 adders, so that the difference between the G4 and G5 adder is equal to the difference between the G5 and G7 adder.

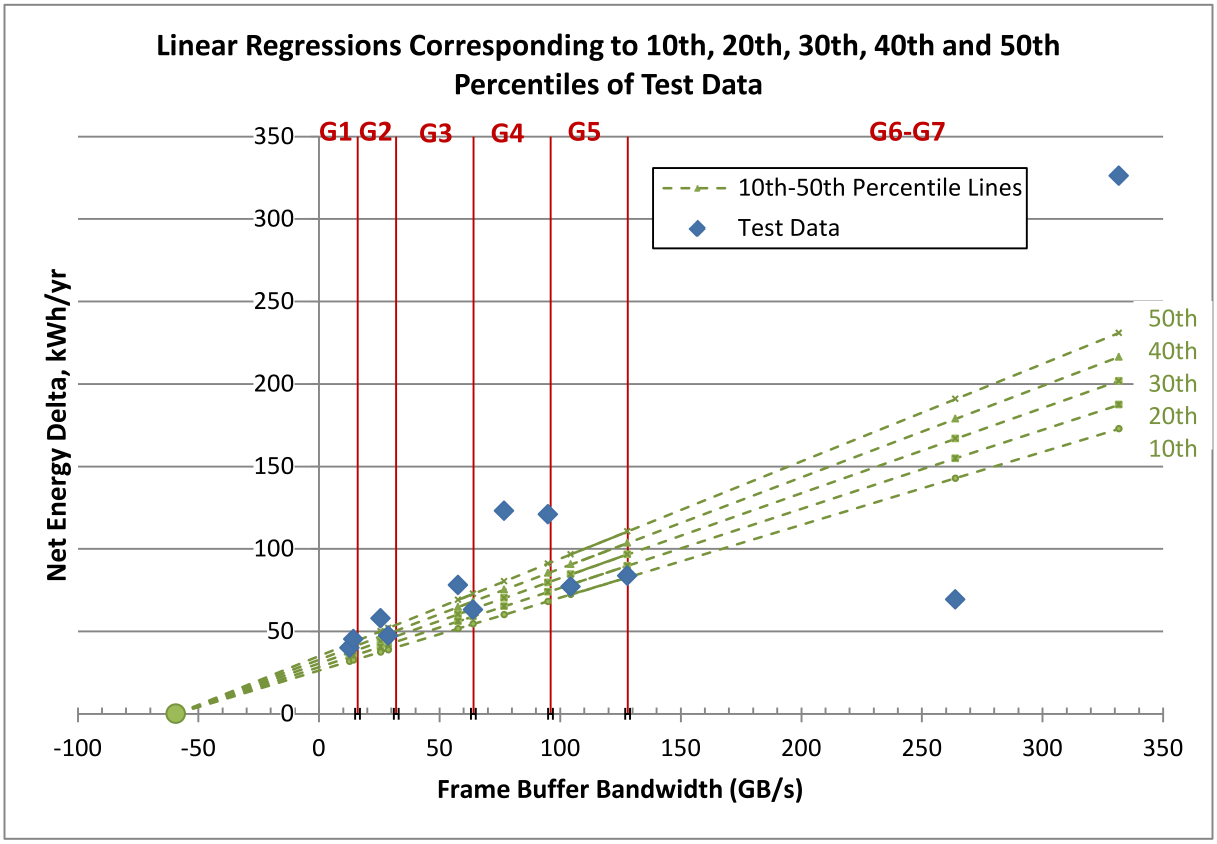
Figure 7: Adders Based on the Median Linear Regression



Setting adders by ECMA category creates a “stair-step” pattern. This can create incentives for higher frame buffer bandwidths, e.g., movement to the right on the graph from each category to utilize the higher adders at higher bandwidths. Note that we are not proposing to set graphics adder as a linear function of frame buffer bandwidth. While this would have the benefit of avoiding the discontinuities implicit in stair-steps, it would provide no absolute upper limit at high frame buffer bandwidths, and it could unfairly disadvantage some graphics card designs over others. Frame buffer bandwidth is an accepted performance proxy for the purpose of categorization, however it is not meant to be used as a pure performance metric.

To set adders based on lower percentiles, a similar approach can be followed using lower percentile lines such as those illustrated in Figure 8 below. These percentile lines are calculated by pivoting the median line around its x-intercept point so that only a given percentage of test data points is below or on the line. For example, the 25th percentile line is such that 25 percent of the data points are below or on it, and 75 percent above it. The median, 40th, 30th, 20th and 10th percentile lines are shown in Figure 8.

Figure 8: Linear regressions corresponding to 10th, 20th, 30th, 40th and 50th Percentiles of Test Data



Adders for each category can then be calculated in the same manner as illustrated for the median line above.

The line equations and corresponding adder values for each percentile line are given in Tables 7 and 8 below:

Table 7: Target Adder Levels (kWh/yr) Per Target Percentile – Energy Star v6.0

Percentile	Line Equation	G1	G2	G3	G4	G5	G6	G7
50th	y = 0.5905x + 35.0	40	49	63	82	101	101	120
40th	y = 0.5533x + 32.8	37	46	59	77	95	95	112
30th	y = 0.5162x + 30.6	35	43	55	72	88	88	105
20th	y = 0.4791x + 28.4	32	40	51	67	82	82	97
10th	y = 0.4420x + 26.2	30	37	47	62	76	76	90

Table 8: Target Adder Levels (kWh/yr) Per Target Percentile – Energy Star v5.0

Percentile	Line Equation	G1	G2	G3	G4	G5	G6	G7
50th	y = 0.5270x + 27.2	31	40	52	69	86	86	103
40th	y = 0.4921x + 25.4	29	37	49	65	81	81	96
30th	y = 0.4572x + 23.6	27	35	46	60	75	75	89
20th	y = 0.4224x + 21.8	25	32	42	56	69	69	83
10th	y = 0.3875x + 20.0	23	29	39	51	63	63	76

Managing the Impact of Breakthrough Innovation in Low-Power Graphics Technology

One of the two G7 cards tested shows dramatically lower energy use in idle mode than the other one (70 kWh vs. 326 kWh). This card, the AMD Radeon HD 7970, was the first card on the market to feature AMD's "ZeroCore Power" technology, which radically reduces idle power. This is very promising for the energy efficiency of computers using discrete graphics, however it creates a significant risk for the effectiveness of the ENERGY STAR Computer Specification.

The magnitude of the power reduction in idle mode enabled by AMD's ZeroCore Power technology makes the allowance leakage issue much more acute than with other cards in the test sample: any computer featuring the Radeon HD 7970 card could get a very large free allowance, enabling less efficient machines to qualify. ZeroCore Power and other similar technologies will likely become much more prevalent over the next 12-18 months, creating an increasingly large loophole in specifications based on legacy cards, and rendering them potentially ineffective once the majority of the discrete graphics market has adopted the technology. Ten other cards with low-power idle capability had been released by June 2012. This suggests that the market is rapidly adopting this type of technology.

This is an issue not just because overly high adders fail to encourage more efficient discrete graphics, but because they make the overall standard ineffective for computers with discrete graphics (fortunately this issue does not affect computers with integrated graphics).

In order to address this issue, program managers may consider using the following approach:

1. In the short-term, set adders based on the latest cards released in the market.
2. Closely monitor the market for the deployment of low-power idle technology, and conduct additional testing as necessary;
3. Revise adders as soon as there are multiple cards utilizing this technology in each category.

5.2 Setting Adders for Additional Graphics Cards (Beyond the First Card)

The study's dual card test results presented in section 4.4 indicate that additional discrete graphics cards do not use as much incremental power as the first card. Additional cards have different effects on system power demand from the first card: for example the card may not create as much incremental activity in CPU and memory as the first card. On the other hand, the energy use of integrated graphics is only avoided once by the first card. Test results indicate that the net effect of these two factors is that the second card uses less additional power than the first one by approximately 25%, as illustrated by Table 5 and Figure 6 in section 4.4.

This 25% ratio is based on testing on a single computer. This limited test data attaches a significant level of uncertainty to this ratio. Additional testing of dual-card configurations would be ideal. Alternatively, additional data from industry on this issue would also help strengthen this study's findings on this point.

The study did not test configurations with more than two discrete cards; therefore the incremental energy use of additional cards beyond the second card was not assessed. However, configurations with more than 2 cards are rare and in the absence of specific data, it seems reasonable to assume that their incremental power demand in idle is similar to that of the second card, for the same reasons.

5.3 Setting Adders for Discrete Notebook Graphics Cards

Notebook discrete graphics cards were not tested; therefore no recommendations are made on graphics adder values for notebooks, however interested readers are referred to the methodology proposed by EPA in ENERGY STAR v6.0 draft 2 to convert desktops graphics adders into notebook graphics adders by applying a ratio of 38%.[24]

[24] Slide 8 of EPA's presentation at the May 23, 2012 stakeholder meeting: http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/computer/V6_D2_EPA_Presentation.pdf?7506-3135

6. Conclusion

This study used a unique approach to determining the system-level power impacts of computer discrete graphics cards. The traditional approach is based upon the internal DC power of the card and applies a power conversion factor to derive the AC power of the card. Instead the impact of a card was measured at the system level on a sample of host computer systems and the results were averaged out.

The study shows that incremental power demand due to the card varies significantly between host computers. This indicates that there are a number of factors other than the card itself that lead to increases in net system power demand. As a result, adders should be set on the basis of the net effect of all these factors.

The test sample of 12 cards and 6 test computers is representative of the 6 main graphics categories and of both major GPU manufacturers. It covers over a third of the desktop discrete graphics cards introduced on the market in 2011. Target adder values are provided based on the study's test results.

The study also identified the emergence of a new technology with radically lower power demand in idle mode. This technology is very promising for the efficiency of desktop computers with discrete graphics. It also means that programs using adders based on legacy technology may quickly become obsolete due to allowance leakage. To address this issue interested parties are encouraged to conduct additional and ongoing testing using this study's methodology to assess cards newly introduced on the market, and policy makers should rapidly adjust their programs to adapt to the deployment of new low-power idle technology.

This study's methodology provides robust values from which to set graphics adders. As a result, standards and labeling program managers are encouraged to consider the recommendations made in this report when setting graphics adders.

7. Appendices

Appendix I – Test Methodology

Test Equipment

Testing was performed at an EPA-recognized, accredited test laboratory at Ecova, Inc.[25]. Equipment used for the testing phase of this study consists of high precision laboratory grade instruments. Ecova's measurement equipment is calibrated by an ISO/IEC 17025 accredited calibration laboratory. Equipment includes the following:

- Chroma Programmable AC Power Source 61602
- Yokogawa WT1600 Digital Power Meter

Testing complied with ENERGY STAR's instrumentation measurement accuracy requirements:

1. Power measurements with a value greater than or equal to 0.5 W shall be made with an uncertainty of less than or equal to 2% at the 95% confidence level.
2. Power measurements with a value less than 0.5 W shall be made with an uncertainty of less than or equal to 0.01 W at the 95% confidence level.

The Yokagawa WT1600 digital power meter exceeds ENERGY STAR instrumentation measurement accuracy requirements for computer testing. With power measurements at 115 volts, 60Hz in the 50 to 500 watt range (where most of the idle power measurements for desktop computers fell) the WT1600 has a measurement uncertainty of less than 0.3%. The propagated measurement uncertainty associated with calculating differences in power demand (which requires two measurements) can range between 0.5 W if idle power measures are near 70 W and 1.1 W if idle power measurements are near 200 W.

Energy Star Idle Mode Test Procedure

The standard ENERGY STAR Computers Test Procedure[26] was adjusted as follows:

1. Prior to testing, configure power management to trigger long-idle behavior (e.g. shutting down the screen and hard drives) at approximately 12 minutes.
2. Switch on the computer and begin recording elapsed time, starting either when the computer is initially switched on, or immediately after completing any log in activity necessary to fully boot the system.
3. Once logged in with the operating system fully loaded and ready, close any open windows so that the standard operational desktop screen or equivalent ready screen is displayed.
4. After 5 minutes or less after the initial boot or log in, set the meter to begin accumulating true power values at a frequency greater than or equal to 1 reading per second for approximately 12 minutes. This constitutes the short-idle measurement.
5. Accumulate power values for 8 to 10 additional minutes to capture long-idle measurements. (Note: both short and long-idle power measurements were captured in a single run.)

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[25] For accreditation 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

[26] http://www.energystar.gov/ia/partners/product_specs/program_reqs/Computers_Program_Requirements.pdf?1bf5-bee9

Multi-Card Test Methodology

Multi-capable cards were tested in both single and multi-card configurations. There were 10 multi-capable cards and 2 systems capable of utilizing these NVIDIA® SLI™ and AMD CrossFireX™ configurations. Each unique configuration was tested three times. Multi-card testing also used the ENERGY STAR July 21st, 2011 test method[27] for measuring short and long idle mode:

Idle Mode testing

1. Prior to testing, configure power management to trigger long-idle behavior (e.g. shutting down the screen and hard drives) at approximately 12 minutes.
2. Switch on the computer and begin recording elapsed time, starting either when the computer is initially switched on, or immediately after completing any log in activity necessary to fully boot the system.
3. Once logged in with the operating system fully loaded and ready, close any open windows so that the standard operational desktop screen or equivalent ready screen is displayed.
4. After 5 minutes or less after the initial boot or log in, set the meter to begin accumulating true power values at a frequency greater than or equal to 1 reading per second for approximately 12 minutes. This constitutes the short-idle measurement.
5. Accumulate power values for 8 to 10 additional minutes to capture long-idle measurements. (Note: both short and long-idle performance will be captured in a single run.)

Other Test Conditions and Documentation

Each of the following comes directly from the ENERGY STAR test method unless otherwise noted.

- Desktop computers shall be configured with a standard mouse, keyboard and external display.
- Primary hard drives shall not be power managed ("spun-down") during short-idle testing unless containing non-volatile cache integral to the drive (e.g. "hybrid" hard drives or similar non-removable disk caching architectures). For long idle testing, set the hard drive to spin down after 12 minutes of testing.[28]
- The computer display power management settings shall be set to prevent the display from powering down to ensure it stays on for the full length of short-idle testing. For long idle testing, set the display to shut down after 12 minutes of testing [28]
- All tests will be conducted with an active Ethernet network connection with full network connectivity.[29]
- All component drivers will be updated via the manufacturer's website prior to testing.[30] The laboratory technician will install NVidia and AMD/ATI's control panel software and record graphics card settings for each test. The laboratory technician will check the control panel

[27] http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/computer/Computers_Test_Method_Rev_July_2011_Draft.pdf?abd9-54e8

[28] This requirement does not come directly from the ENERGY STAR test method. We have specifically selected the 12 minute point for spinning down the hard drive as an ideal time to start long idle behavior.

[29] If there is significant variability in the instantaneous power measurements during the test runs the project team may disable the Ethernet connection to reduce variability.

[30] This requirement does not come directly from the ENERGY STAR test method. We have added this since we will utilize custom-built machines that will need certain software updates prior to testing.

software to ensure no settings have been automatically changed when installing a new card, and will confirm that default settings are chosen.

- Computers will be tested with Wake-on-LAN (WOL) enabled for all tests.
- Default (as shipped) Windows 7 operating system settings shall be used unless otherwise specified.[30] Windows 7 power management settings are as follows:

Table 9: Proposed power management settings

Windows 7 Option	Proposed Settings
Turn off display	12 min
Put computer to sleep	30 min
Turn off hard disk	12 min
Wireless Adapter settings *(options include: max performance, low power saving, med power saving, and max power saving)*	max performance
Allow hybrid sleep	on
Hibernate after	never
Allow wake timers	enabled
USB selective suspend setting	enabled
PCI Express Link State Power Management *(specifies the Active State Power Management (ASPM) policy to use for capable links when the link is idle. Other options include 'off' and 'max power saving')*	moderate power savings
Put GPU to sleep	never[31]
Min processor state	5%
System cooling policy	active
Max processor state	100%
JavaScript Timer Frequency	max performance
When sharing media	prevent idling to sleep
When playing video	optimize video quality

[31] Certain GPU's may be tested in a setting that allows for the graphics card to be powered down in idle state (e.g. the AMD HD7970)

Appendix II – Graphics Card Models

Table 10. Discrete Graphics Card Models and Characteristics

ECMA-383 (v6)	Manu.	GPU Model	Date of Release	Card FBB (GB/s)	Max GPU Power (W)	Manufacturer Recommended PSU Power (W)	SLI/CrossFire X Capability	Price ($)	Graphics Card and Product Link	Quantity
G1	ATI/AMD	Radeon HD 6450	Apr '11	12.8	18	400 (500 for dual)	2-way	47	Gigabyte GV-R645D3-512I	2
G1	NVIDIA	GeForce GT 520	Apr '11	14.4	29	300	none	55	MSI N520GT	1
G2	ATI/AMD	Radeon HD 6570	Apr '11	28.8	44	400 (500 for dual)	2-way	70	Sapphire 100323L	2
G2	NVIDIA	GeForce GT 440	Feb '11	25.6	65	300	none	80	EVGA 01G-P3-1441-KR	1
G3	ATI/AMD	Radeon HD 6670	Apr '11	64.0	66	400 (500 for dual)	2-way	97	Sapphire 100326L	2
G3	NVIDIA	GeForce GTS 450	Sep '10 /Mar'11	57.7	106	400	2-way	120	Gigabyte GV-N450-1GI	2
G4	ATI/AMD	Radeon HD 6770	Jun '11	76.8	108	not listed	2-way	107	PowerColor AX6770 1GBD5-H	2
G4	NVIDIA	GeForce GTX 460	Jul '10	95.0	160	450	2-way	79	Galaxy 60XMH6HS3HMW GeForce GTX 460 GC Edition	2
G5	ATI/AMD	Radeon HD 6850	Oct '10	128.0	127	500	2-way	145	HIS H685FN1GD Radeon HD 6850	2
G5	NVIDIA	GeForce GTX 550	Mar '11	104.5	116	400	2-way	145	EVGA 01G-P3-1556-KR	2
G7	ATI/AMD	Radeon HD 7970	Jan '12	264.0	250	500	2-way	550	DIAMOND 7970PE53G Radeon HD 7970	2
G7	NVIDIA	GeForce GTX 590	Mar '11	165.9	365	700	4-way	750	EVGA 03G-P3-1596-AR	2
									Total:	**22**

The test sample represents 36% of AMD and NVIDIA cards released in 2011 (not including configuration variations such as different memory configurations). This ratio does not include the two 2010 cards and the 2012 card. The 2010 cards were chosen because there were no 2011 models meeting the category requirements. The 2012 card was chosen in order to evaluate the potential of AMD's "ZeroCore Power" technology.

Model	Date Released	In Study	
Radeon HD 6850	22-Oct-10	Y	
GeForce GTX 460	15-Nov-10	Y	
…			
Radeon HD 6290	7-Jan-11		
Radeon HD 6750	21-Jan-11		
Radeon HD 6350	7-Feb-11		
Radeon HD 6450	7-Feb-11	Y	
Radeon HD 6570	7-Feb-11	Y	
Radeon HD 6670	7-Feb-11	Y	
Radeon HD 6990	8-Mar-11		
Radeon HD 6790	4-Apr-11		
Radeon HD 6770	28-Apr-11	Y	
Radeon HD 6410	20-Jun-11		
Radeon HD 6530	20-Jun-11		
Radeon HD 6550	20-Jun-11		
Radeon HD 6320	15-Aug-11		
Radeon HD 6370	1-Nov-11		
Radeon HD 6930	Dec-11		
GeForce GTX 560	25-Jan-11		
GeForce GT 440	1-Feb-11	Y	
GeForce GTX 550	15-Mar-11	Y	
GeForce GTX 590	24-Mar-11	Y	
GeForce GT 520	12-Apr-11	Y	
GeForce GT 530	14-May-11		
GeForce GT 545	14-May-11		
GeForce GTX 560	17-May-11		
GeForce GTS 450	1-Sep-11	Y	
GeForce 510	29-Sep-11		
Radeon HD 7970	9-Jan-12	Y	
	2011	9	36%

Appendix III – Test Computer Configurations

Overview

Six computer configurations were built, each with a unique central processing unit (CPU) and motherboard pairing. These six configurations were combined with a set of secondary computer components including storage drive, system memory, computer case, power supply unit (PSU), optical drive, and operating system to create six different computers identified as 'PC1', 'PC2', 'PC3', 'PC4', 'PC5', 'PC6' for testing.

The following goals and criteria were used to develop the CPU and motherboard pairings for the computers in which the discrete graphics cards were to be tested. Secondary components are also defined.

Goal

The project was tasked with the following:

> *Determine the change in idle-mode power demand when replacing integrated graphics on a computer with a discrete graphics card solution across a representative but constrained set of contemporary computers and discrete cards.*

Given the wide variation in computer components and discrete graphics cards, a comprehensive test of every possible configuration is logistically impossible, so careful selection of components becomes critical.

Requirements for Meeting the Goal

Before selecting specific components, the project first developed the following requirements to achieve the goal (presented in order of importance):

1. Include major market components for CPU and integrated graphics
    a. Include both Intel and Advanced Micro Devices (AMD) processors.
    b. Include integrated graphic solutions on CPU and on motherboard.
    c. Include single card and multiple card configurations.

2. Capture a range of low to high performance computers available in late 2011.
    a. Develop computers that approximately parallel the mainstream, performance, enthusiast and very high-end enthusiast computers as defined by industry proposed ENERGY STAR 6.0 performance categories for desktop computers (See Table 11).[32]
    b. Select motherboards and CPUs that reflect most recent technology at price points that match the four categories above.

[32] Information Technology Industry Council Comments on Energy Star Computers Version 6, March 10 2011 Kickoff Meeting. Avalable: http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/computer/ITI_Comments_4.pdf

General Hardware Design

Based on the goals and requirements for the project, Ecova developed motherboard and CPU pairings presented in this document. This includes discussion of:

- Computer Construction – General plans for building computers specifically for this testing.
- CPU – Plans and considerations for selection of CPU manufacturers and performance levels.
- Integrated Graphics – Plans and considerations for whether integrated graphics will be provided on the motherboard or CPU.
- Motherboards – Plans and considerations for motherboard selection.

Computer Construction

As noted earlier, due to the nature of the project the test approach utilizes 'build-your-own' desktop computers rather than unique original equipment manufacturer (OEM) computer models. This approach allowed us to:

1. Easily swap out discrete graphics card quickly in a laboratory setting.
2. Preserve the option to control or vary different secondary components, such as hard disk drive (HDD) and power supply unit (PSU), as needed.

CPU

Desktop CPUs from the world's two largest manufacturers, Intel and AMD, were utilized. To better reflect market share, the tests covered four Intel and two AMD CPUs.[33] CPU performance capabilities and number of internal cores were chosen to fit appropriately into one of the targeted computer market segments that parallel the ENERGY STAR 6.0 categories for desktops proposed by industry. These market segments have their own hardware and performance requirements (Table 11). These segments are: Entry, Mainstream, Performance, High Performance, Very High-end/Enthusiast. An entry level desktop configuration was excluded from this project because this low performance category is becoming less common in today's market, particularly for configurations with discrete graphics. Given the project's timing and funding constraints, this category was considered the lowest priority and was excluded from scope.

As the project scope is limited to only six computers, only two categories will include multiple computers. To support multiple card testing (SLI and CrossFireX cards), the tests required at least two computers at the High-Performance or Enthusiast category. This leaves one other computer category that could contain multiple computers. Selecting this category first requires considering the CPU capabilities available to consumers.

As of December of 2011, Intel was shipping CPUs that span the range of low performance to high performance. These appear in all-in-one systems and in both reduced-size and full tower form factors. In these systems, on-die graphics are available for both low and high end computing solutions, although high-end systems are generally paired with discrete cards.

[33] As of Q2 2011, Intel's overall worldwide CPU share is approximately 79.3 percent, while AMD's is 20.4 percent. From http://www.engadget.com/2011/08/02/amds-market-share-tiptoes-higher-intel-still-ruler-of-the-roos/

In contrast, a survey of performance reviews and major vendors shows that AMD is less present as an Enthusiast / Very High End solution. On comparative benchmarks, the AMD Phenom II x4 (which is not the latest AMD CPU) remains the most commonly recommend performance AMD solution, and in OEM configurations, the Phenom II x4 also appears to be performance choice for AMD. However, the Phenom chip does not provide on-die graphics; in fact AMD only provides on-die solutions to the All-in-one, Laptop, and Mainstream markets (via the Fusion). To include an AMD CPU with an on-die solution means that the test configurations must include an AMD Fusion, which logically fits in the Mainstream category.

Beyond this, the test suite still requires an AMD-based computer with multiple graphics card support to compare multiple card performance across Intel/AMD. Without a true AMD competitor to Intel's i7, this last computer uses AMD's fastest solution, the Phenom II x4: placing this computer in the High Performance category.

Table 11. Proposed ENERGY STAR 6.0 Draft 2 Desktop Categories

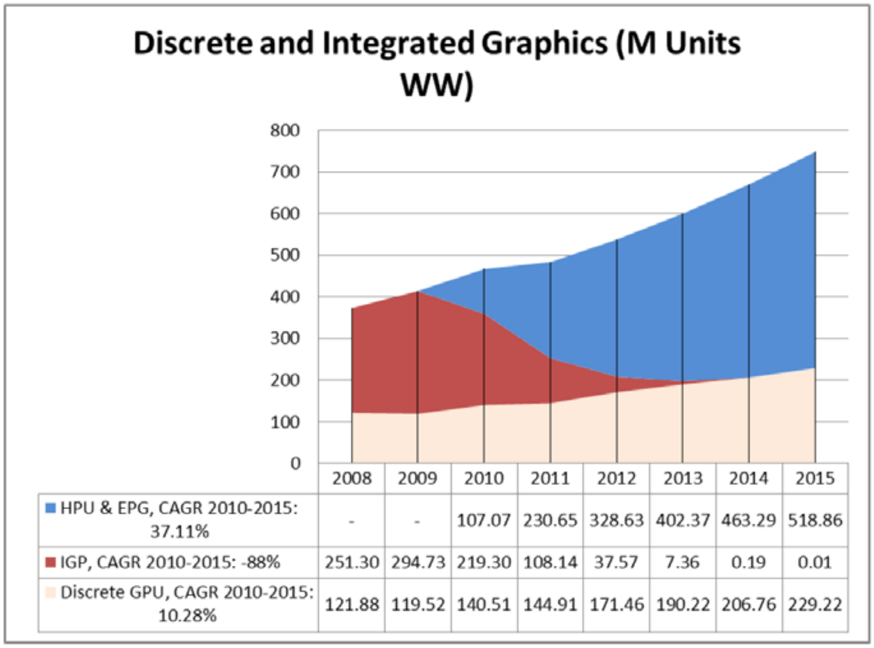
Category	DT 0	DT 1	DT 2	DT 3	DT 4
Market *	Entry	Mainstream	Performance	High Performance	Very High-end/Enthusiast
Cores	N/A	cores ≤ 2 (less than or equal to 2 cores)	≥3 cores (greater than or equal to 3 cores)	≥4 Cores (greater than or equal to 4 cores)	≥4 Cores (greater than or equal to 4 cores)
Channels of memory	Ch mem = 1 (1 Channel of memory)	Ch mem = 2 (2 Channels of memory)	≥ 2 channels (more than or equal to 2 channels of memory)	≥2 Channels (more than or equal to 2 channels of memory)	≥2 Channels (more than or equal to 2 channels of memory)
Base memory (min)	1GB	2GB	2GB	≥4 GB	≥4 GB
Base Graphics	iGfx (integrated graphics)	iGfx (integrated graphics)	iGfx (integrated graphics)	dGfx ≥ G5 based on 7-class dGfx classes (any additional dGfx allowed)	dGfx ≥ G5 based on 7-class dGfx classes (any additional dGfx allowed)
Graphics Adders	dGfx ≤ G7 (less than or equal to G7)	dGfx ≤ G7 (less than or equal to G7)	dGfx ≤ G7 (less than or equal to G7)	≥G6 (greater than or equal to G6)	≥G6 (greater than or equal to G6)
PCIe					≥2 PCIe slots/end points of x8 or x16 configuration
PSU Rating					≥500W
Form Factor	Both Traditional & Integrated DT	Both Traditional & Integrated DT	Both Traditional & Integrated DT	Both Traditional & Integrated DT	Traditional (with expansion slots)

Source: Information Technology Industry Council Comments on Energy Star Computers Version 6, March 10 2011 Kickoff Meeting. Available at: http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/computer/ITI_Comments_4.pdf

Integrated Graphics

Each of the six computer configurations contained an integrated graphics processing (IGP) solution, either integrated on the motherboard or on the CPU die (often called embedded processor graphics, or EPG). Jon Peddie Research suggests that EPG devices will almost entirely replace the IGP market by 2014 (Figure 9). Because of this trend, four computer configurations were selected with graphics integrated directly into the CPU die and the remaining two with graphics integrated on the motherboard. *Only systems that have some form of integrated graphics were tested.* The nature of the study's testing requires an integrated graphics option to serve as the baseline for each of the six computer configurations.

Figure 9. Embedded processor graphics (EPG) overtakes integrated graphics processors (IGPs) by 2014.



	2008	2009	2010	2011	2012	2013	2014	2015
HPU & EPG, CAGR 2010-2015: 37.11%	-	-	107.07	230.65	328.63	402.37	463.29	518.86
IGP, CAGR 2010-2015: -88%	251.30	294.73	219.30	108.14	37.57	7.36	0.19	0.01
Discrete GPU, CAGR 2010-2015: 10.28%	121.88	119.52	140.51	144.91	171.46	190.22	206.76	229.22

Source: Jon Peddie; http://jonpeddie.com/media/presentations/an-analysis-of-the-gpu-market/

Motherboard

For computer configurations sharing the same ENERGY STAR performance category, motherboards were chosen from the same manufacturer to eliminate any ambiguity in the data that could be manufacturer specific. However, motherboard from different manufacturer were used across different tiers of performance (i.e. proposed ENERGY STAR category) to allow for an appropriate mix of manufacturers and associated energy use implications (if any).

Motherboard chipsets correspond to the CPU manufacturer (i.e., Intel CPUs were paired with motherboards equipped with Intel chipsets) and were selected relative to the performance of the CPU. This ensured that the key components of each computer were fairly representative of the market.

Of the six motherboards, two were also capable of utilizing multiple (two or more) discrete graphics cards from either AMD or NVIDIA. These multiple-card technologies are commonly known as 'SLI' when referring to NVIDIA based graphics options and 'CrossFireX' when referring to AMD/ATI based graphics options. These two motherboards will be paired with an EPG integrated graphics option.

Other features:

- All motherboards support dual channels of memory.
- All motherboards selected are equipped with common features such as integrated audio and networking.
- Additional motherboard features (such as SATA and USB communication interfaces as well as memory capacity) do not dictate motherboard selection as these features tend to correspond with the motherboard chipset.

Secondary Components

Ecova built six computer configurations with unique central processing unit (CPU) and motherboard pairings as previously defined. These six configurations were combined with a set of secondary computer components including power supply unit (PSU), memory, storage, optical drive and computer case to create six different computers. The following criteria were used to develop secondary component selections for the computers in which the discrete graphics cards will be tested.

Power supply unit (PSU)

See separate discussion in section 4.7 of the main report.

Memory

Memory varies for each of the six computer configurations. In general, as computer performance increases so does memory size and speed. Memory latency also decreases as P computer performance increases. In addition, motherboard specifications also dictates the size and speed of memory that was utilized for each computer configuration.

Storage

For each of the six computer configurations, the same storage (hard disk drive) make and model were used. We believe that the choice of storage drive had no significant impact on the graphics card idle power demand.

Optical drive

For each of the six computer configurations, the same optical drive make and model was used. We believe that the choice of optical drive type and speed had no a significant impact on the graphics card idle power demand. This device should not be active during short and long idle mode testing.

Computer Case

For each of the six computer configurations, the same computer case make and model and associated cooling system was used.[34] We believe that the choice of computer case had no significant impact on the graphics card idle power demand.

Detailed Test Computer Configurations

The specific test computer configurations are detailed in Table 12 on the following page.

[34] Each computer was tested in the same room under ENERGY STAR required temperature and humidity conditions.

Table 12: Test Computer Configurations

Test PC	PC1	PC2	PC3	PC4	PC5	PC6
Market Class	Entry	Slim	Basic Commercial	Budget Gaming	Performance	Enthusiast Gaming
Proposed ENERGY STAR Category	DT1 Mainstream	DT2 Performance	DT2 Performance	DT3 High Performance	DT3 High Performance	DT4 Enthusiast
CPU Manufacturer	Intel	AMD	Intel	AMD	Intel	Intel
CPU Performance	Intel Core 2 Duo E7600 Wolfdale 3.06GHz (Dual-Core)	AMD A8-3850 Llano 2.9GHz (Quad-Core)	Intel Core i5-2300 Sandy Bridge 2.8GHz (Quad-Core)	AMD Phenom II X4 960T Zosma 3.0GHz (Quad-Core)	Intel Core i5-2500K Sandy Bridge 3.3GHz (Quad-Core)	Intel Core i7-2600K Sandy Bridge 3.4GHz (Quad-Core)
Type of Integrated Graphics	integrated on motherboard (IGP)	integrated into CPU die (EPG)	integrated into CPU die (EPG)	integrated on motherboard (IGP)	integrated into CPU die (EPG)	integrated into CPU die (EPG)
Motherboard	GIGABYTE GA-G41MT-S2P LGA 775 Intel G41	MSI A75A-G35	MSI P67A-C43 (B3) LGA 1155 Intel P67	ASUS Sabertooth 990FX Socket AM3+	ASUS P8Z68-V PRO/GEN3 LGA 1155 Intel Z68	ASRock Z68 Extreme7 Gen3 LGA 1155 Intel Z68
Power Supply Unit 1	Non-80+ 300W Athena Power AT30	80+ Bronze 300W SeaSonic SS-300ES	80+ Gold 300W TBD	Non-80+ 300W Athena Power AT30	80+ 300W FSP Group FSP300-60GHS-R	80+ 300W FSP Group FSP300-60GHS-R
Power Supply Unit 2 (as needed)	Non-80+ 450W Coolmax CX-450B	80+ Bronze 450W COOLER MASTER GX 450W RS450-ACAAD3	80+ Gold 450W Rosewill CAPSTONE Series CAPSTONE-450	Non-80+ 550W Ultra LSP550 550-Watt	80+ 550W OCZ Fatal1ty 550W	80+ 650W Sunbeam PSU-ECO650
Power Supply Unit 3 (dual-card only)	None	None	None	80+ 1000W Thermaltake TR2 RX TRX-1000M	None	80+ 1000W Thermaltake TR2 RX TRX-1000M
Channels of Memory	2	2	2	2	2	2
Base Memory	2GB	2GB	2GB	4GB	4GB	8GB
Memory Model	Crucial 2GB DDR3 SDRAM DDR3 1066 (PC3 8500)	G.SKILL NS 2GB DDR3 SDRAM DDR3 1333 (PC3 10600)	Kingston HyperX 2GB DDR3 1333 (PC3 10600)	G.SKILL Ripjaws Series 4GB (2 x 2GB) DDR3 SDRAM DDR3 1600 (PC3 12800)	CORSAIR DOMINATOR GT 4GB (2 x 2GB) DDR3 DDR3 1866 (PC3 14900)	G.SKILL Ripjaws X Series 8GB (2 x 4GB) DDR3 SDRAM DDR3 2133 (PC3 17000)
Storage	Western Digital Caviar Blue 500GB HDD	Western Digital Caviar Blue 500GB HDD	Western Digital Caviar Blue 500GB HDD	Western Digital Caviar Blue 500GB HDD	Western Digital Caviar Blue 500GB HDD	Western Digital Caviar Blue 500GB HDD
Optical Drive	ASUS 24X DVD Burner	ASUS 24X DVD Burner	ASUS 24X DVD Burner	ASUS 24X DVD Burner	ASUS 24X DVD Burner	ASUS 24X DVD Burner
Computer Case	Antec Nine Hundred Two V3	Antec Nine Hundred Two V3	Antec Nine Hundred Two V3	Antec Nine Hundred Two V3	Antec Nine Hundred Two V3	Antec Nine Hundred Two V3
Multi-Card Capable	No	No	No	Yes	No*	Yes
Operating System	Windows 7	Windows 7	Windows 7	Windows 7	Windows 7	Windows 7

Appendix IV – Power Supply Configurations and Efficiencies

Power Supply Models

Table 13: Power Supply Models

PSU ID	Mfr / Model	80-PLUS Category	Power Rating (W)
PSU1	COOLMAX CA-300 300W ATX	Non-80+	300
PSU2	SeaSonic SS-300ES	80+ Bronze	300
PSU3	FSP AURUM GOLD 400	80+ Gold	400
PSU4	COOLMAX CA-300 300W ATX	Non-80+	300
PSU5	FSP Group FSP300-60GHS-R	80+	300
PSU6	FSP Group FSP300-60GHS-R	80+	300
PSU7	Coolmax CX-450B	Non-80+	450
PSU8	COOLER MASTER GX 450W RS450-ACAAD3	80+ Bronze	450
PSU9	Rosewill CAPSTONE Series CAPSTONE-450	80+ Gold	450
PSU10	Ultra LSP550 550-Watt	Non-80+	550
PSU11	OCZ Fatal1ty 550W	80+	550
PSU12	Sunbeam PSU-ECO650	80+	650
PSU13	Antec CP-1000 1000W	80+	1000
PSU14	Antec CP-1000 1000W	80+	1000

PSU1 and PSU 4, PSU5 and PSU6, and PSU13 and PSU 14 are the same and were purchased in duplicate in order to enable parallel testing to reduce testing time.

Computer - Power Supply Combinations

Table 14: Computer-Power Supply Combinations

		PSU Tier A			PSU Tier B			PSU Tier C		
PC ID	**PC Market Class**	**ID**	**Power rating (W)**	**Efficiency Rating**	**ID**	**Power rating (W)**	**Efficiency Rating**	**ID**	**Power rating (W)**	**Efficiency Rating**
PC1	Entry	PSU1	300	Non-80+	PSU7	450	Non-80+			
PC2	Slim	PSU2	300	80+ Bronze	PSU8	450	80+ Bronze			
PC3	Basic Commercial	PSU3	400	80+ Gold	PSU9	450	80+ Gold			
PC4	Budget Gaming	PSU4	300	Non-80+	PSU10	550	Non-80+	PSU13	1000	80+
PC5	Performance	PSU5	300	80+	PSU11	550	80+	PSU13	1000	80+
PC6	Enthusiast Gaming	PSU6	300	80+	PSU12	650	80+	PSU14	1000	80+

PSUs 1-6 were used for baseline tests and low-power discrete graphics cards. PSUs 7-12 were used for higher power cards and dual-card tests. PSU13 and 14 were used for GPU 12 due to its high peak power requirements.

Detailed computer-GPU-PSU combinations are available in the study spreadsheet.

Influence of Power Supply Efficiency on Test Results

The changes in power supply conversion losses between configurations with and without the discrete graphics card is legitimate and representative of market reality, however it raises two questions regarding the accuracy of the test results in this study:

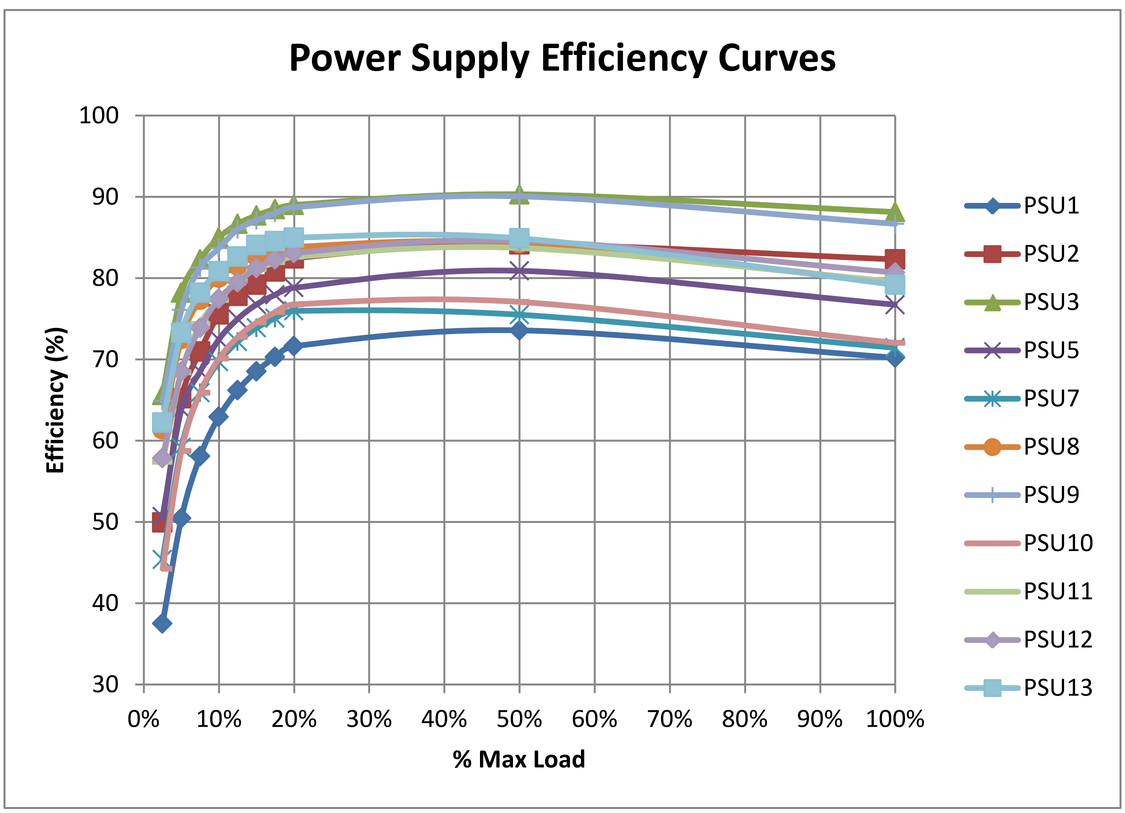
1. Are the power supply effects a significant factor in the reported discrete graphics card net impact values? If they were, power supply choices could introduce significant variability in the measurements, independently from the discrete graphics card.
2. While upsized PSUs of comparable efficiency with baseline PSUs were selected, did upsizing the PSU introduce significant variability in the net TEC impact results?

To answer these questions, with Intel's, Ecova and EPRI's help, the power supplies used for the project were benchmarked to determine their efficiency profile. This data was used to back-calculate the following quantities:

1. System DC power for both baseline systems (with iGfx) and with the discrete graphics card;
2. Hypothetical discrete graphics card AC power using the baseline PSU. This is hypothetical because such a computer may not be able to operate the discrete graphics card at peak load. It is only calculated to allow the comparison between the baseline operating load point and that of the upsized PSUs.

Figure 10 shows power supply efficiencies as measured by Intel and EPRI:

Figure 10: Power Supply Efficiency Curves



Figures 11 and 12 illustrate the changes in load point of the PSUs, and the corresponding PSU efficiencies. The charts below cover only GPU1 for clarity. Charts showing all GPUs are available in the project data file[35].

Figure 11: PSU Load Points for GPU1[36]

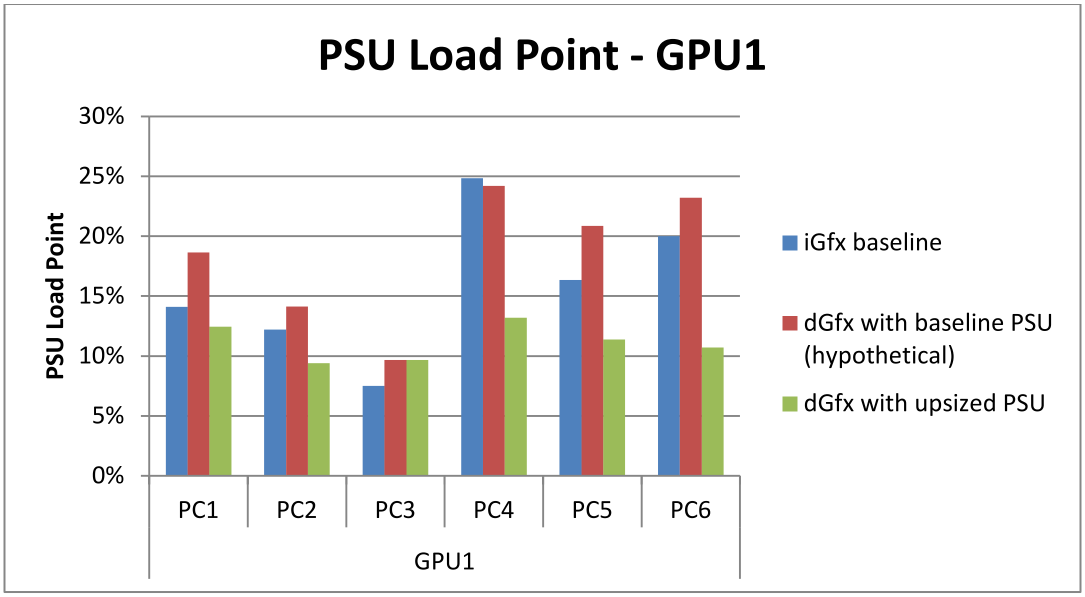
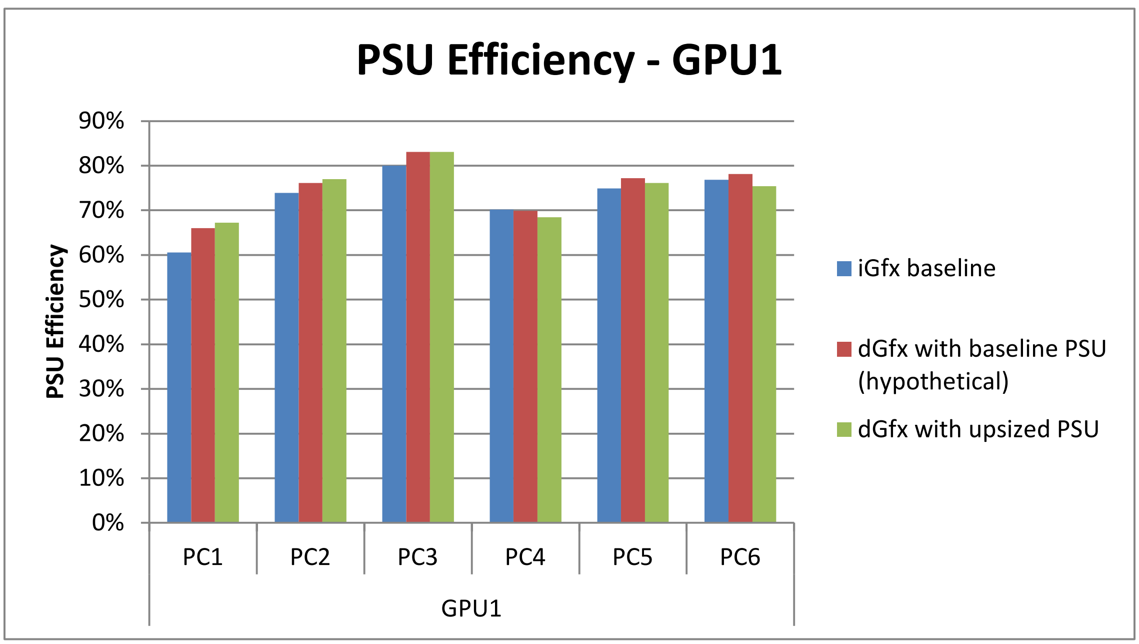


Figure 12: PSU Efficiencies for GPU1



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[35] http://www.clasponline.org/ResourcesTools/Resources/StandardsLabelingResourceLibrary/2012/Impact-of-Graphics-Cards-on-Desktop-Computer-Energy-Consumption

[36] Note that the PSU on PC3 was not upgraded because the baseline PSU was able to support the discrete graphics card at peak power. All other PCs had their PSU upgraded.

Figure 12 shows that PSU upsizing had a relatively minor and mixed impact on PSU efficiencies: the efficiency of upsized PSUs at discrete graphics card idle load point were slightly higher or slightly lower than the efficiency of the baseline PSU, depending on each computer-discrete graphics card-PSU configuration. Overall, the chart does not indicate outsized impacts from PSU upsizing.

The impact of overall PSU conversion losses and of PSU upsizing, averaged across all 5 test computers (excluding PC4), are shown on Figures 11 and 12:

Figure 13: Contribution of PSU conversion losses to discrete graphics card adders

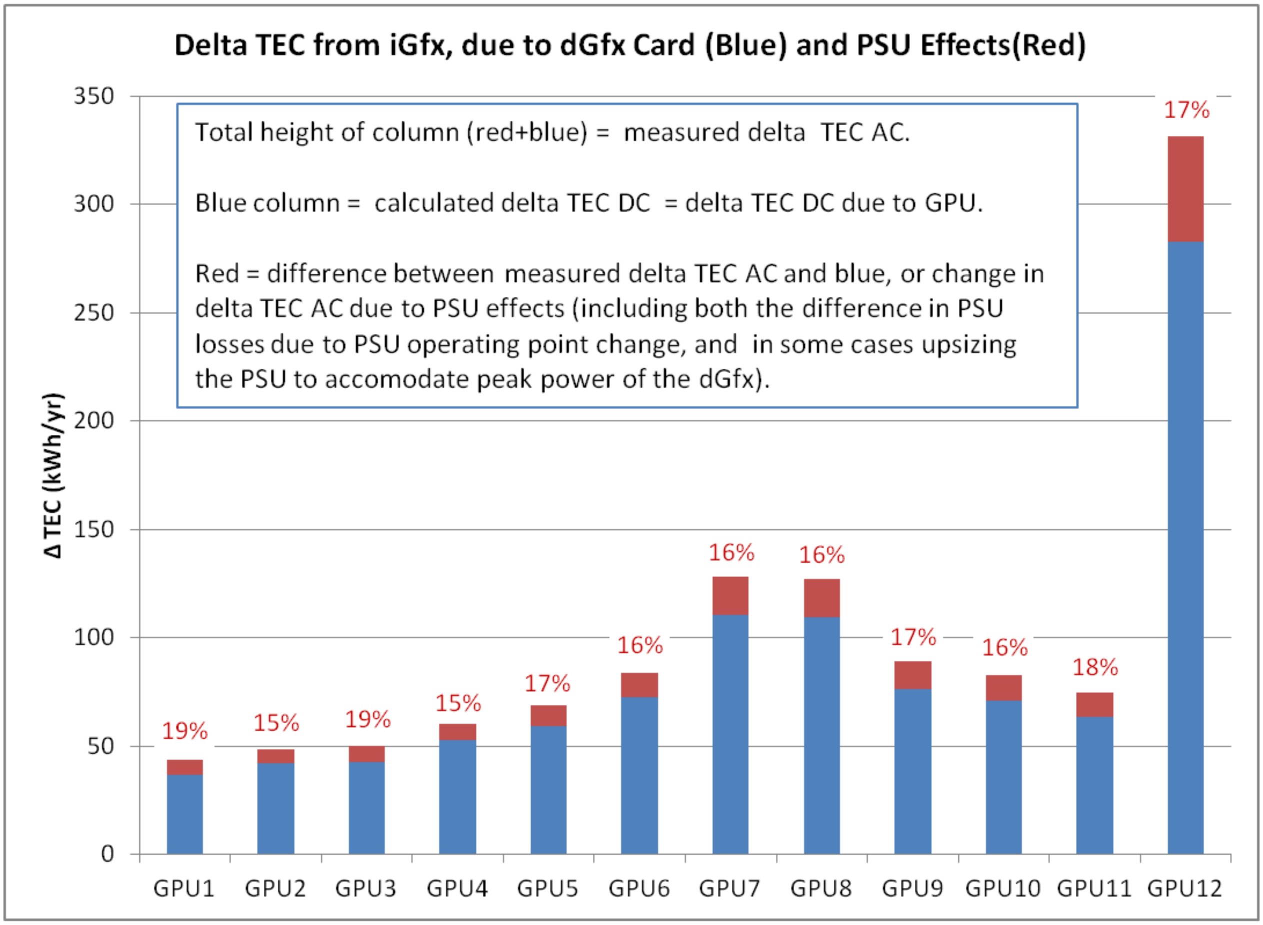

Figure 13 shows that on average, 17% of the net discrete graphics card impact is due to changes in conversion losses in the PSU when adding a discrete graphics card. The vast majority of the TEC delta comes from internal power changes due to the discrete graphics card, not to differences in conversion efficiency.

Figure 14: Effect of PSU Upsizing Alone (Excluding Changes in DC Power and PSU Operating Point)

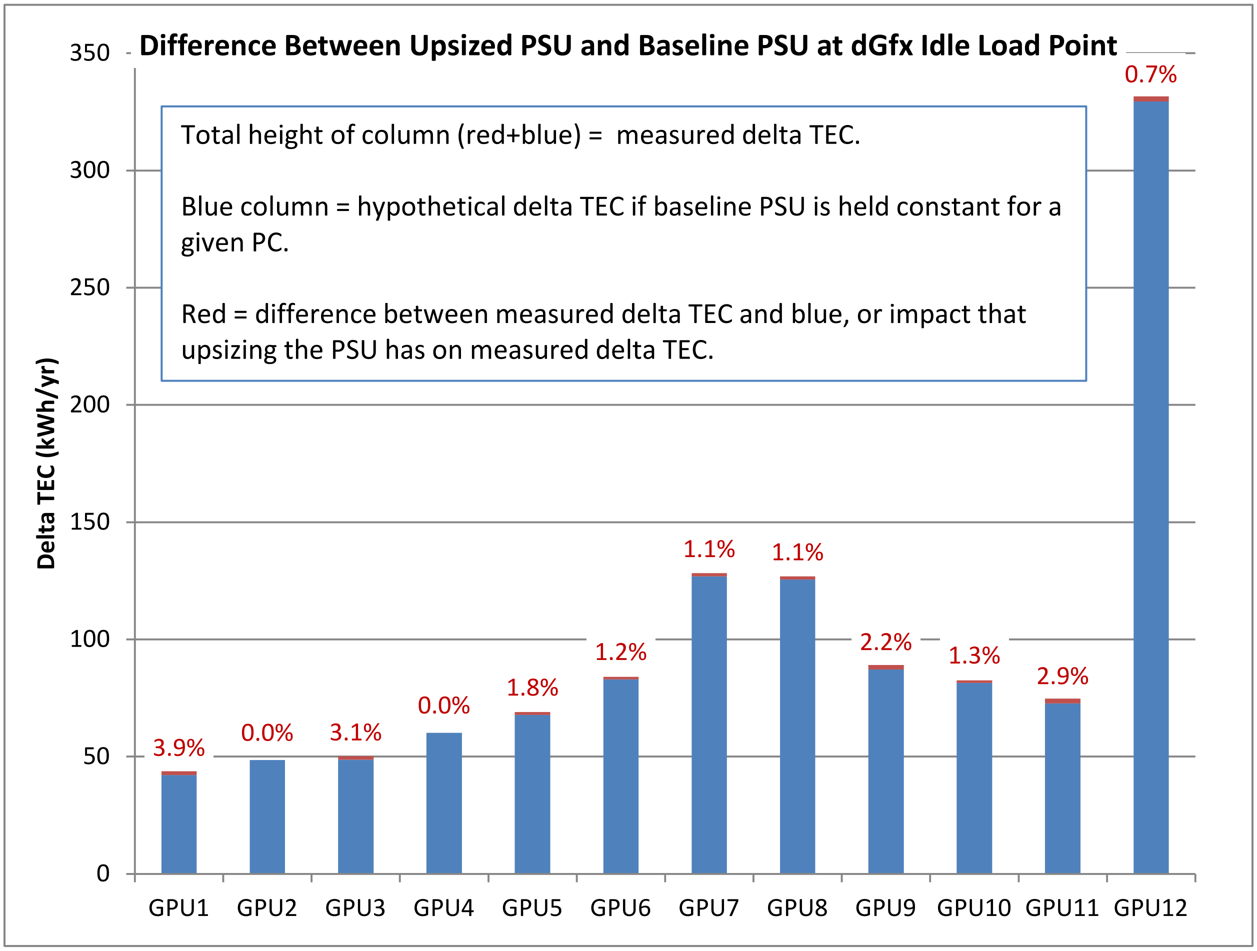

Figure 14 shows that the variability of delta energy due to PSU upsizing is on average 2%. As seen previously on Figure 12, the variability is higher with a mix of positive and negative impacts at the computer-GPU configuration level, but the 2% average means that PSU upsizing introduced negligible variability on the discrete graphics card net impact values reported in the project results.

Appendix V – Detailed Test Data and Analysis

A spreadsheet containing detailed test data and analysis can be found at http://www.clasponline.org/ResourcesTools/Resources/StandardsLabelingResourceLibrary/2012/Impact-of-Graphics-Cards-on-Desktop-Computer-Energy-Consumption

NRDC's Response to CEC's Invitation to Participate in the Development of Appliance Energy Efficiency Measures

2013 Appliance Efficiency Pre-Rulemaking on Appliance Efficiency Regulations: Docket Number 12-AAER-2A - Consumer Electronics – Displays

May 9, 2013

Submitted by:
Pierre Delforge, Natural Resources Defense Council

On behalf of the Natural Resources Defense Council and our more than 250,000 members and online activists in California, we respectfully submit this response to the Energy Commission's Invitation to Participate in the Development of Appliance Energy Efficiency Measures, posted on March 25, 2013. This response addresses the Commission's questions on displays.

NRDC has reviewed the submission made by the California Investor Owned Utilities (IOUs) and is in agreement with their data and analysis. Rather than repeat much of their content, NRDC provides below supplemental answers to selected topics listed in the Commission's Invitation to Participate (ITP).

Energy use - Displays, including computer monitors, digital picture frames and signage displays, are pervasive in California households and businesses, with one display per capita on average (including residential and commercial displays). The CA IOUs calculated, based on published U.S. studies, that displays could be responsible for as much as 5 TWh of electricity consumption annually in California. This is equivalent to the electricity use of all the households in the city of San Diego and San Jose, and costs Californians over $600 million in annual electricity bills.

Existing standards and data sources - Electronic displays have been covered by the ENERGY STAR program for over a decade. They benefit from a mature specification and test method, as well as an extensive product database featuring both qualified and non-qualified products. This information will greatly facilitate standard development by the Commission.

Enhanced-Performance Displays (EPDs) - The v6.0 ENERGY STAR specification covers Enhanced-Performance Displays through an adder. EPDs are a rapidly growing and high-energy consuming segment of the display market, they could represent a significant share of display energy use over the next few years. As such NRDC believes it is important to include EPDs in the CEC standard. This can be done by leveraging ENERGY STAR's adder approach so that EPDs are designed to use the most cost-effective technologies available without constraining their performance. Some EPD power data is already available in the ENERGY STAR Qualified Product List (11 EPD models qualified as of May 1, 2013) and this number is expected to increase significantly over the next few weeks as the specification goes into effect on June 1, 2013.

Range of power use – The ENERGY STAR dataset shows a wide range of power use for displays of similar size as evidenced by the charts in section 2.7 of the CA IOU ITP response. This indicates a significant opportunity for energy savings from minimum efficiency standards.

Efficiency opportunities – Display technology and energy efficiency have been evolving rapidly over recent years as evidenced by the rapid increase in ENERGY STAR v5 market share. There continues to be significant opportunities for efficiency with increasing LED efficiency, panel transmittance and optical film efficiency, electronic component efficiency such as power supplies, as well as promising emerging technologies such as OLED. These technologies have a potential for significant energy efficiency improvements over the next few years. Appropriate policy intervention will be key to ensure that this potential is effectively realized.

Conclusion

NRDC thanks the Energy Commission for its leadership in establishing cost-effective appliance efficiency standards that reduce electricity bills as well as climate and other harmful emissions for all Californians.

NRDC strongly encourages the Commission to move forward with minimum efficiency standards for displays.

Thank you for your consideration of NRDC's input.

Respectfully submitted,

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NRDC's Response to CEC's Invitation to Participate in the Development of Appliance Energy Efficiency Measures

2013 Appliance Efficiency Pre-Rulemaking on Appliance Efficiency Regulations: Docket Number 12-AAER-2A - Consumer Electronics – Game Consoles

May 9, 2013

Submitted by:
Pierre Delforge, Natural Resources Defense Council

On behalf of the Natural Resources Defense Council and our more than 250,000 members and online activists in California, we respectfully submit this response to the Energy Commission's Invitation to Participate in the Development of Appliance Energy Efficiency Measures, posted on March 25, 2013. This response addresses the Commission's questions on game consoles.

I. Market Characteristics

Video game consoles have become a staple in the majority of California homes with an average of one console per household in the state. Sales are expected to increase over the next few years as the introduction of next generation consoles in 2013 triggers a refresh of existing stock. Some of the most common game consoles on the market today consume a similar amount of annual energy to a mainstream desktop computer. In aggregate, California game consoles consume roughly 1,100 GWh annually, equivalent to half the output of a medium-sized 500 MW power plant, and as much electricity as is consumed annually by all the households in the city of Oakland.

II. Basic Information

Existing programs - The only existing energy efficiency standard for game consoles in the US is the newly announced EPA recognition program, which is voluntary. As of today, none of the game consoles on the market have sought recognition under this program although the Nintendo Wii U appears to meet the program's requirements. The EPA program is voluntary, providing no guarantee that manufacturers will produce qualifying products or participate. A mandatory standard will ensure that game consoles meet minimal efficiency requirements whether they participate or not in the EPA program.

EPA's specification includes power limits for the following modes of operation: Active Navigation Menu, Active Streaming Media and Standby. It does not include limits for Active Game Play.

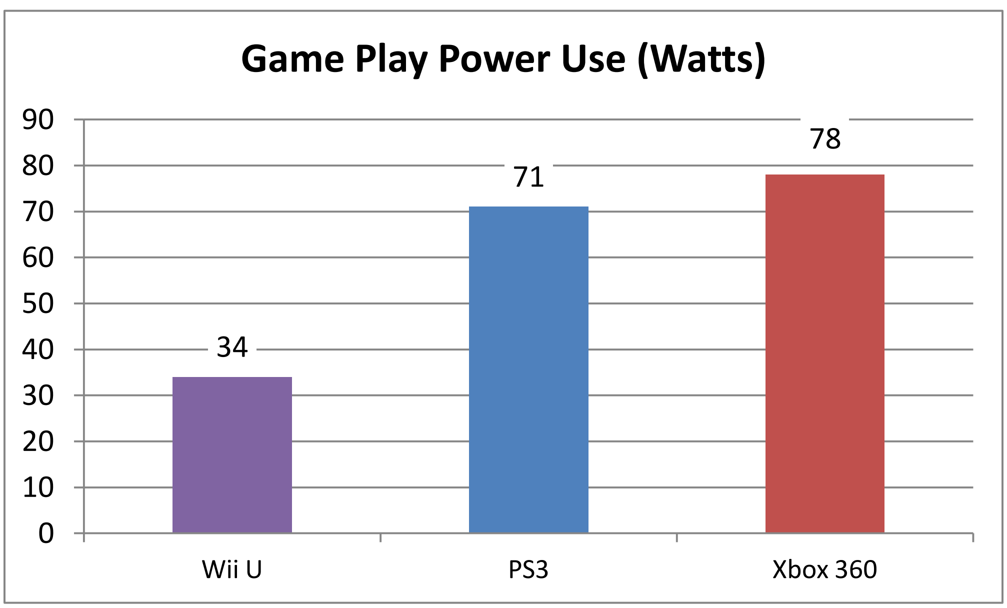
Test methods - The EPA program provides a test method for all key operating modes except for Game Play. NRDC proposes a test method for active Game Play in Appendix 1. A Game Play test method is important in order to 1) inform users of the power draw of their console in active gaming mode, 2) enable CEC and stakeholders to monitor Game Play power use and reassess the energy use of consoles in that mode and the opportunity for policy intervention, and 3) encourage manufacturers to voluntarily reduce active gaming power use.

Standard framework - The ENERGY STAR program provides a robust framework for a CEC standard, which does not limit power use in Game Play, the primary function of game consoles. The program only sets power limits for secondary modes such as Streaming Media Play, Navigation Menu and Standby. CEC can use a similar framework with standard levels adjusted to account for the mandatory nature of Title 20 standards. This will not limit console performance when playing games, and will ensure that consoles are designed to use energy efficiency best-practices to perform secondary functions where higher efficiency alternatives are available.

III. Operations, Functions and Modes

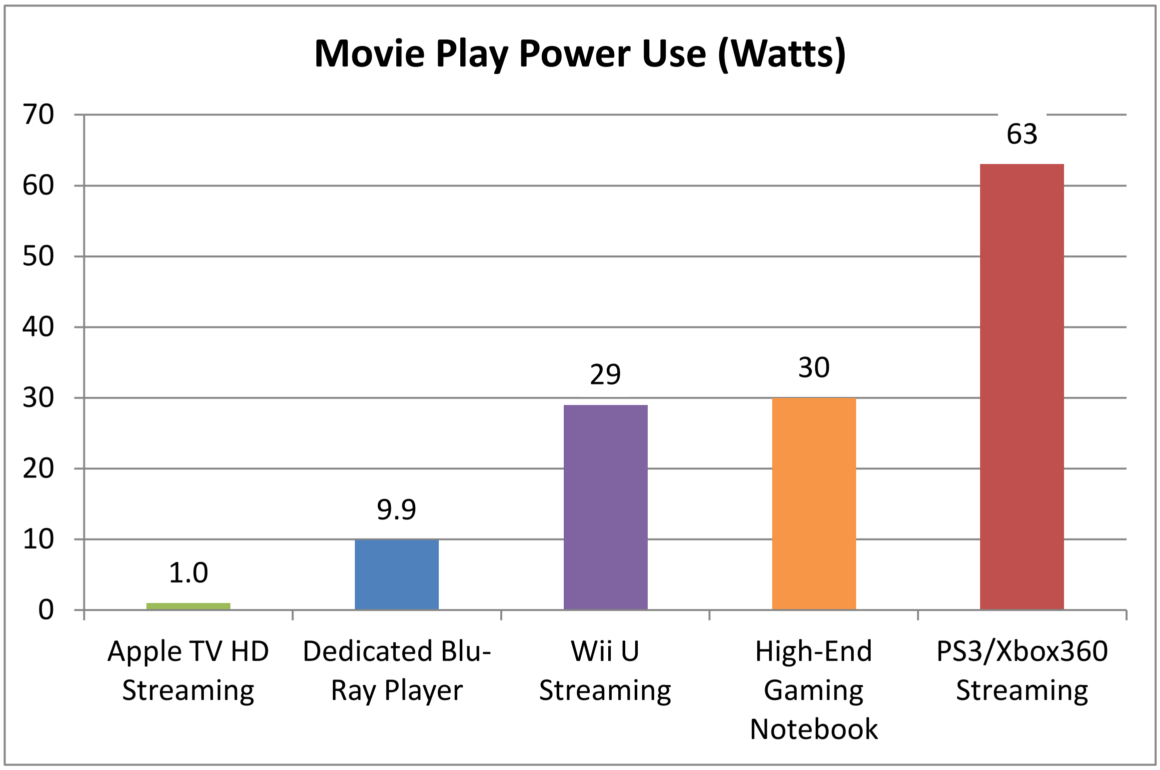
Range of power use – There is a wide range of power use among consoles on the market to perform similar tasks. For example, the PS3 and Xbox 360 draw twice as much power as the Wii U to play a typical game in HD:

Figure 1: Range of Power use to Play a Game in High Definition



Game consoles are also being used increasingly for non-gaming functions such as watching streaming media. Microsoft claims that "Xbox users now spend more time consuming media than playing games"[1]. Unfortunately game consoles draw much higher power than other devices to play the same video with the same resolution. There is a very large range of energy use between different types of devices to play the same video with the same resolution. This reflects different architectures and capabilities as integrated game consoles are designed to play games which dedicated steaming players cannot, however there are significant differences even between multi-function devices of equivalent capabilities such as between the higher-consuming consoles and high-end gaming notebooks. As playing movies and videos becomes one of the most popular uses of game consoles, the energy used in media play could increase substantially when much more efficient alternatives are available.

Figure 2: Comparison of HD Movie Play Power Use on a Range of Devices



[1] http://allthingsd.com/20130104/game-on-xbox-bosses-mehdi-tellem-come-to-dive-into-media/

Power data - The power use of game consoles in key operating modes is easily measured. NRDC tested recent models of the 4 main consoles on the market and obtained the following data:

Power use of recent consoles (all measurements in watts)

	Standby	Networked Standby	Active Navigation Menu	Active Streaming Media	Active Game Play
Microsoft Xbox 360 (2013)	0.4	N/A	65	63	78
Nintendo Wii (2010)	1.3	10 (6 in 2012)	12	14	14
Nintendo Wii U (2012)	0.5	0.5/11[2]	32	29	35
Sony PS3 (2013)	0.3	11	68	63	71

Modes are defined as follows:

- Standby: Off, cannot be reactivated from the network, per EU Ecodesign definition.
- Networked Standby: Off with active network link, the console can be reactivated from the network, per EU Ecodesign definition.
- Active Navigation Menu: Home menu, equivalent to Idle on a computer.
- Active Streaming Media: Actively playing a movie or video.
- Active Game Play: Actively playing a game.

There are a number of new consoles announced for introduction in the coming months, including next generations of existing consoles such as the PlayStation 4, and new market entrants such as the Ouya[3] and Xi3 Piston[4] consoles. Preliminary reports indicate power use in game play of the order of 5W for the Ouya console[5] and 40W for the Piston console[6]. We will refine these numbers as soon as possible based on each console's launch schedule. This should be in time for consideration as part of subsequent phases of the rulemaking for some of the new consoles. Microsoft is also expected to make announcements this Spring on the successor to the Xbox 360.

[2] Per an April 2013 system update, the Wii U is now capable of downloading content while in standby and uses 11 watts to do so. However the Wii U appears to go back to a low-power standby mode once it has completed the download. We are investigating this behavior further.

[3] http://www.ouya.tv/

[4] http://xi3.com/buy_now-piston.php

[5] http://www.engadget.com/2013/04/03/ouya-review-founding-backer-edition/

[6] http://www.eurogamer.net/articles/df-hardware-what-is-inside-piston

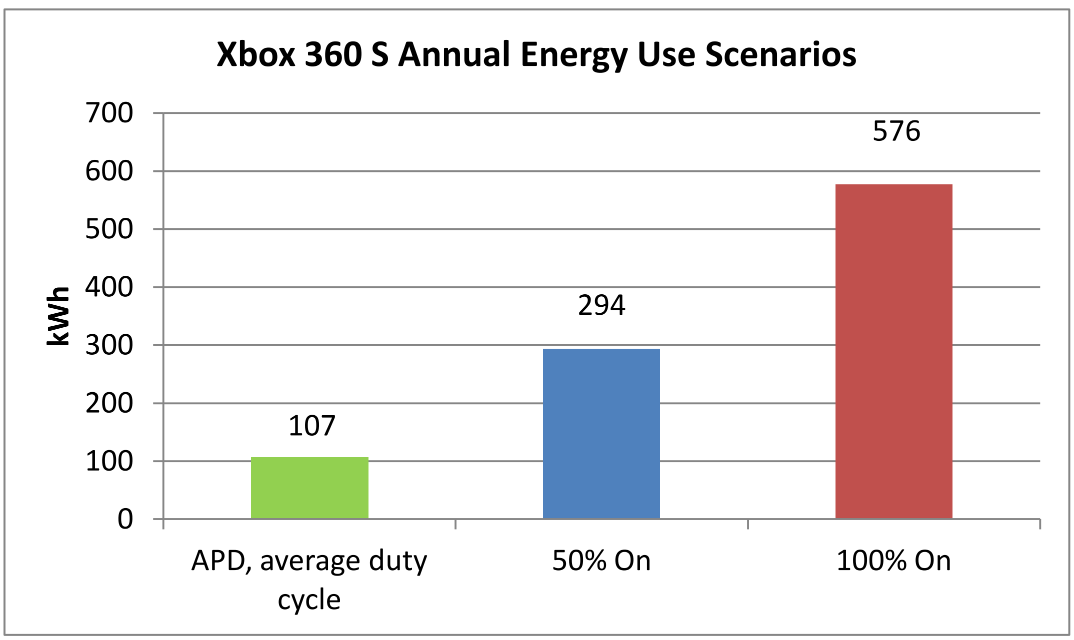
Duty cycle data - There is little publicly available data on the average time spent by users in the various modes of the console, however manufacturers have data on the usage patterns of their own consoles and have shared some of it informally with advocates. We provide below our best-estimate duty cycle derived from discussions with industry and non-publicly available surveys and data shared by manufacturers.

% of Time	PS3	Wii	Wii U	Xbox 360
Game Play	7.0%	7.0%	7.0%	7.0%
Media	5.0%	5.0%	5.0%	5.0%
Navigation	5.0%	5.0%	5.0%	5.0%
Standby	78%	41.5%	83%	83%
Networked Standby	5%[7]	41.5%[8]	0%[9]	0%

These are average numbers across the entire stock, including some consoles which are left on all/most of the time, some which are switched off manually or use auto-power down (APD), and some which are rarely or never used.

The energy use of game consoles is highly dependent on how much time they are used and whether they are switched off when not in use. Figure 3 illustrates the annual energy consumption of an Xbox 360 under three scenarios.

Figure 3: Annual Energy Consumption of the Xbox 360 Under Three Usage Scenarios



[7] In the absence of publicly available data, and based on manufacturer feedback supported by anecdotal evidence that the Remote Play mode is not commonly used, we provide this number as an assumption.
[8] In the absence of more specific data, we propose to use the assumption that Wii standby mode is evenly divided between passive and networked standby
[9] The Wii U has just released a system update enabling software download in standby mode, and has announced a future update to extend this functionality to applications under the "SpotPass" name. It is too early to estimate the percent of time spent in this mode. We will use 0 and will update this assumption as soon as possible.

Figure 3 shows the importance of auto-power down in reducing annual energy use. To be effective, APD needs to remain enabled in the vast majority of consoles over their life. The challenge of keeping APD enabled is illustrated by a 2010 study on residential desktops which found that 80 percent of desktop computers in US homes do not have sleep/hibernate enabled[10].

IV. Hardware Technology

Power supply efficiency – NRDC commissioned Ecova to measure the efficiency of power supplies used in PS3 and Xbox 360 models purchased in March 2013.

PS3 - The PS3 uses an internal power supply, which was tested using the Generalized Internal Power Supply Efficiency Test Protocol[11].

Load	20%	50%	100%	Average
PS3-CECH 4001B	74.82%	81.58%	80.98%	**79.13%**

This corresponds to the following load point and efficiency in active game play:

Game play power use (PS input)	71 W
Game play power supply load point	37%
Power supply efficiency at game play (interpolation)	**78.5%**

A power supply with an efficiency equivalent to 80 PLUS Bronze (82% at 20% load, 85% at 50% load) would save over 5% of game play power.

Xbox 360 - The Xbox 360 uses an external multi-voltage power supply, which was tested using DOE's test procedure for EPS (June 2011):

Load	25%	50%	75%	100%	Average
Xbox 360 - Model 1439	81.61%	83.50%	81.20%	83.87%	**82.55%**

This corresponds to the following load point and efficiency in active game play:

Game play power use (PS input)	78 W
Game play power supply load point	56%
Power supply efficiency at game play (interpolation)	**83%**

A power supply with a 87% efficiency (DOE proposed 86% <u>average</u> efficiency in its March 2012 proposal) would save 4.6% of game play power.

[10] Pigg and Bensch, Minnesota plug load study, 2010
[11] Tested with power supply removed from the console, with cooling from a fan powered by a source other than the power supply unit

V. Conclusion

NRDC thanks the Energy Commission for its leadership in establishing cost effective appliance efficiency standards that reduce electricity bills as well as climate and other harmful emissions for all Californians.

NRDC strongly encourages the Commission to move forward with minimum efficiency standards for game consoles.

Thank you for your consideration of NRDC's input.

Respectfully submitted,

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Appendix I - Active Gaming Test Method for Video Game Consoles

By Pierre Delforge, NRDC

Date: May 2013

I. Purpose

Active gaming continues to represent one of the highest energy uses in game consoles despite the increased use of video playback and other non-gaming uses. While NRDC does not advocate for limits on active gaming energy use in order not to interfere with console performance in gaming mode, we believe it is important to be able to measure and report average power use of video consoles in gaming mode. This will help inform users of the power draw of their console in active gaming mode, it will support potential energy labeling programs such as FTC's Energy Guide, and will encourage manufacturers to reduce active gaming power use voluntarily.

The purpose of this paper is to investigate the feasibility of a test method for video game consoles active gaming mode, and propose a draft of this test method.

The investigation attempts to address the following key challenges with active gaming power measurement:

1. **Reproducibility**: How to ensure that measurements can be reproduced consistently, despite the fact that active gaming power use varies depending on user actions during a gaming session and across gaming sessions and users.

2. **Representativeness**: How to ensure that the test method yields a reasonable proxy for active gaming energy use in the field. Active gaming power varies across game titles for a given console.

3. **Identify any other factors** that need to be taken into account by the test method, such as use of pause mode, idle time, and cut scenes.

Note that Mexico already requires reporting of console Game Play power use, but without defining a test procedure. This proposal has the benefit to enable such reporting in a reproducible and representative manner.

II. Summary of Findings

NRDC's testing shows that while instantaneous power use in game play mode is highly variable depending on place in the game and user behavior, most of this variability averages out over time. When measurements are taken over a sufficiently long period of time (such as 20 minutes or longer) and selecting a test game or test sequence that does not include cut scenes, the variability between different measurement sessions for a given game and user is less than 2%.

User variability can be minimized by ensuring that the person playing the game during testing has minimal familiarity with the game controls and principles. If the tester is not familiar with the game, for example in a 3rd-party test lab, we suggest the user familiarizes him or herself with the game for at least 1 hr prior to testing, which should be sufficient to minimize variability with novice users.

Power use varies by game title, with the majority of game title average power use in a narrow 5% band, with a few outliers outside that band. We suggest a pre-test benchmarking process to select a reference test title close to the median of that band, and using that reference test title in the rest of the test method for a given console model, as representative of typical game play power use for that model.

The largest variability we identified came from different units of the same console model, likely due to component variations and manufacturing variability in IC components. We suggest an approach of selecting a unit that is typical of the highest power consuming unit among the key component combinations, or alternatively an approach reporting a range of the highest and lowest power consuming units among key component combinations.

Other factors can influence test results including console temperature driving variable fan activity, cut scenes which introduce non-negligible variability in natural game play, and the use of Pause or Idle in game play. We suggest a test method that avoid or minimizes variability from these factors.

We conclude that it is feasible to define a test method that yields reasonably reproducible results (within a 5-10% range depending on testing conditions), is representative of actual game play power use in the field and does not impose an undue testing burden and therefore cost on manufacturers.

This analysis is based on Sony PlayStation 3 platform only. Its findings need to be validated on the Microsoft Xbox 360 and the Nintendo Wii platforms.

III. Study Approach

The objectives of this study were to identify the main factors that contribute to the variability of power use in game play, and to determine the feasibility of measuring game play power use in a reproducible and representative manner. To this effect, extensive measurements were performed across a variety of PS3 models, units, game titles and users. We selected 12 PS3 game titles covering different types of games (1st/3rd person shooter, fighting, driving, Sports, Action adventure, Casual). We metered console power use while players were actively playing these game titles. Game play was natural, not scripted. We then downloaded and analyzed the data, and present the results in this paper.

Console models and meters summary:

Tester	Meter	PS3 model	PS3 Release Date
Sony	Xitron 2802 Xitron 2801	CECH-3001A	Aug-11
Sony	Xitron 2802	CECH-2101A	May-10
NRDC	Watts Up Pro – NRDC Xitron 2801	CECH-3001A	Aug-11
Ecova	Yokagawa Watts Up Pro - Ecova	CECH-2101A	May-10

Summary of Testing Performed:

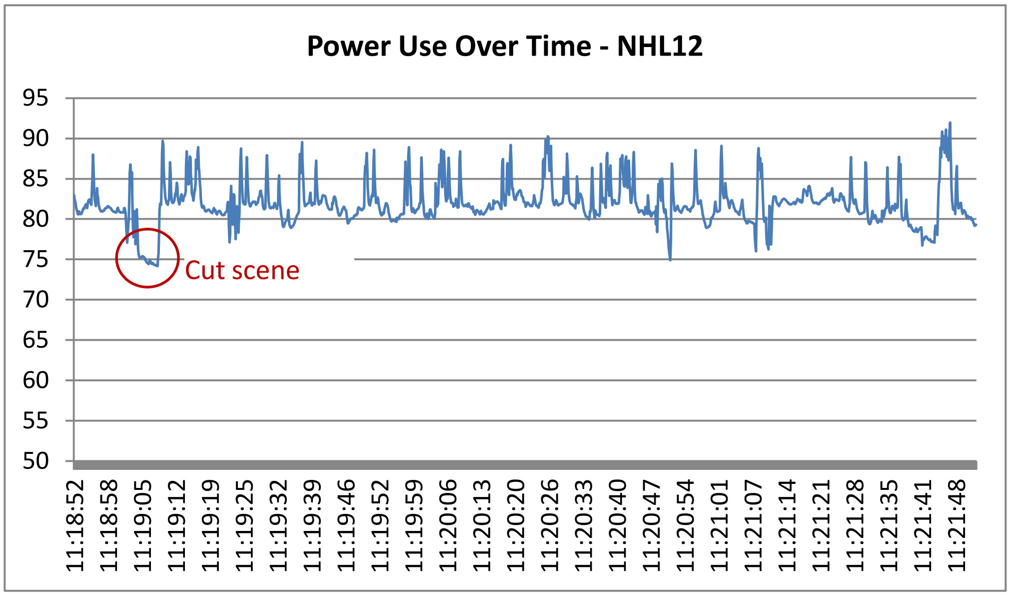
PS3 Model	Unit	Game Title	Sessions	Total Time (hh:mm)
CECH-3001	Sony1	Call of Duty, Modern Warfare 3	2	0:06
		God of War	2	0:06
		NHL12	2	0:05
		Tekken Hybrid	2	0:06
	Sony2	Call of Duty, Modern Warfare 3	3	1:42
		NHL12	2	1:01
	CF413676151-Sony3	Sonic Generations	3	0:20
		God of War III	1	0:10
		Lord of the Rings: War in the North	1	0:10
		Call of Duty, Modern Warfare 3	1	0:06
	CF414506426-Sony4	Call of Duty, Modern Warfare 3	1	0:19
		God of War	1	0:10
		Sonic Generations	1	0:09
	CF416803486-	Saint's Row	3	3:42

PS3 Model	Unit	Game Title	Sessions	Total Time (hh:mm)
	NRDC	Lord of the Rings: War in the North	2	2:18
		Sonic Generations	3	1:57
		Lego - Harry Potter	2	1:03
		God of War	2	0:39
		NHL12	3	0:39
		Jimmy Johnson's - Anything with an Engine	1	0:21
		Call of Duty, Modern Warfare 3	1	0:10
		Bejeweled - Fish Frenzy	1	0:20
		Motor Storm - Pacific Rift	1	0:14
		Back to the Future	1	0:09
CECH-2101	Ecova	God of War	1	0:10
		NHL12	1	0:10
	Sony	NHL12	2	0:20
		God of War III	2	0:20
Grand Total			**48**	**17:12**

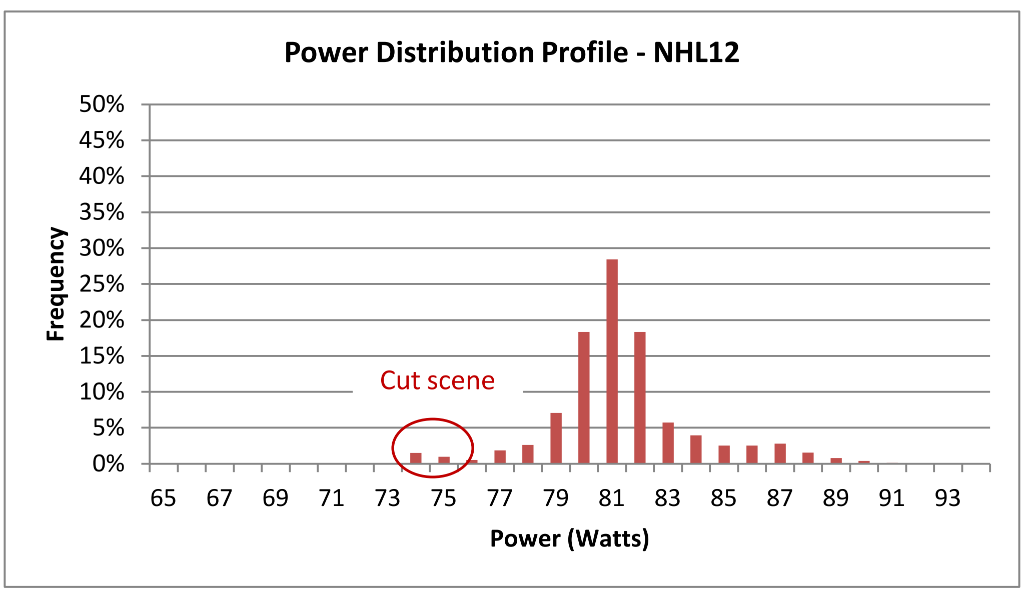
IV. Results Overview

The following data is for one specific game and measurement session, but is typical of other measurements, albeit with different averages and power signatures.

Instantaneous console power during active gaming is highly variable, as illustrated by the following chart:



Active gaming power use follows a fairly normal distribution:

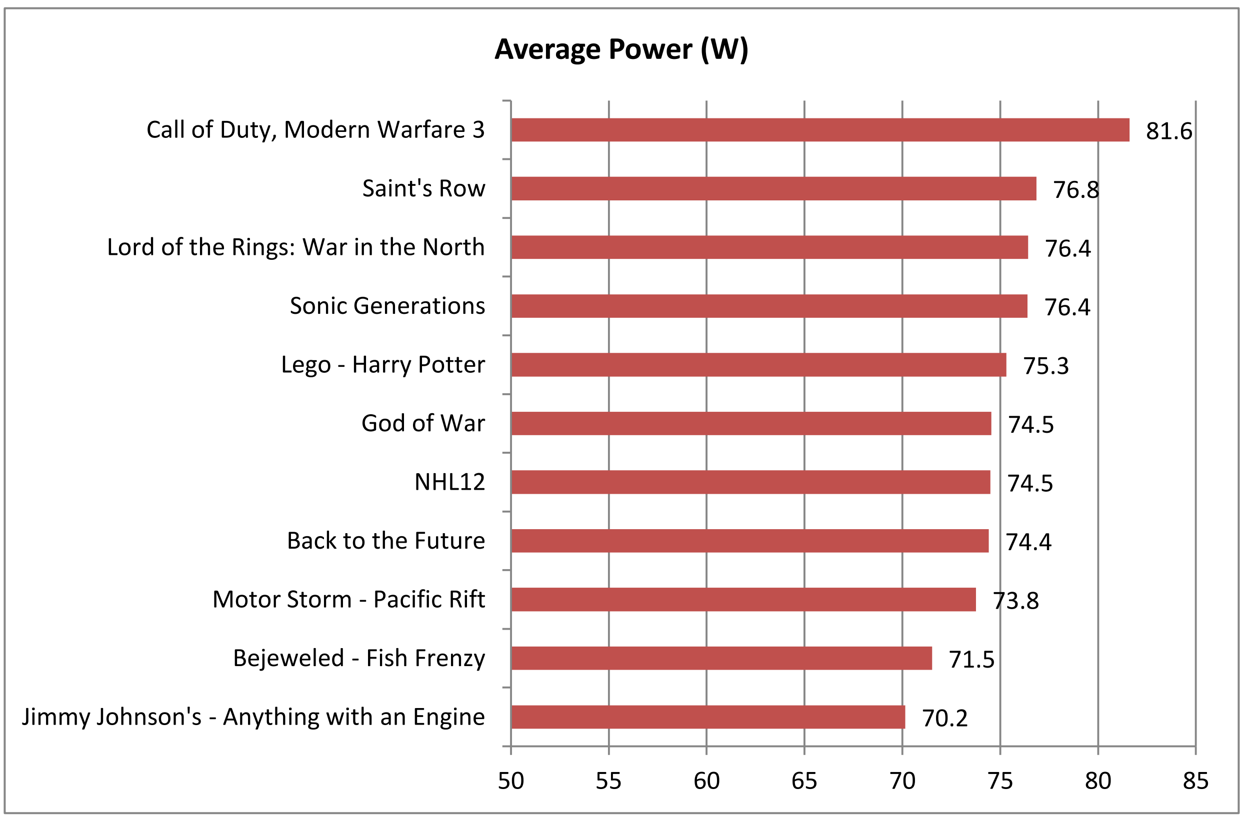


Power profile - NHL12:

Min	74.2 W
25%	80.7 W
50%	81.7 W
75%	82.7 W
Max	91.9 W
Average	81.9 W
Std Dev	2.6 W
Range	17.8 W

Average power use by game title:

The following chart shows average power use by game title for one of the PS3 units tested:



The difference between the lowest and highest consuming game is 16%, with most of the titles in a 5% band around the median.

V. Analysis

We analyzed the following sources of variability in the results, in order to determine which sources were significant and how to address them in the test method:

1. Session variability (variability within a test session and between test sessions, everything else being the same)
2. User Variability (variability due to user behavior)
3. Game title variability
4. Unit variability (differences between several units of the same console model)
5. Other factors

1. Session Variability

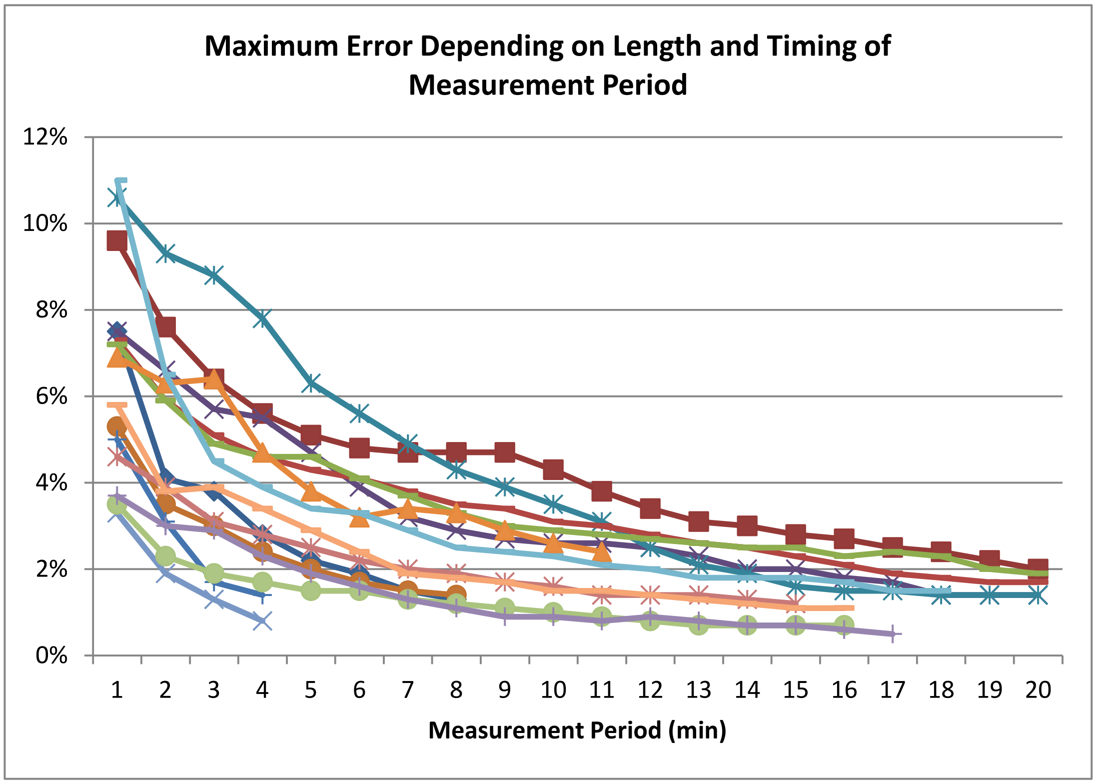
One of the main issues raised by EPA and DOE regarding a test method for active gaming was that active gaming power use varies depending on user actions, such as what the gamer is shooting at, what moves they do, where they go etc. The concern is that measurements would be inconsistent between testing sessions, either due to the high variability of power use over time, or to the differences in user behavior.

Automated Scripting

One approach to address this concern would be scripting. However this would require a degree of scripting minutia which is essentially impossible to conduct manually. For example, it would be impossible to specify the timing and target of shots, or the trajectory and speed of a vehicle in a repeatable manner. This might be possible through recording of inputs and automated playback, although this would require not just automated playback of user inputs, but also predictability of the environment response to user actions (e.g. behavior of other drivers in car race). The feasibility of game play automation remains questionable and was not pursued in this study.

Natural Game Play

Instead, we explored an approach based on natural game play, where console power use is recorded while the tester plays the game normally over a certain period of time. Our testing indicates that the variability of average power measurements reduces as the measurement period increases. In other words, variations get smoothed out over a sufficiently long measurement period. The following chart shows how variability reduces over time for a number of testing sessions (multiple users, titles and consoles):



Maximum error in the above chart is defined as the difference between the highest and the lowest average over a measurement period. For example, given a 30-minute test, the maximum error for 5-minute measurement periods is the highest minus the lowest 5-minute interval average over that 30-minute test period. It indicates how variable the test result would be depending on how long the measurement period is, and when it starts. We suggest a 20-min measurement period in order to minimize variability to less than 2%. Note that this time-dependent variability can be further reduced by avoiding or eliminating cut scenes and pause periods in the measurement period, as described further down.

2. User Variability

The previous section addresses variability over time for the same user. This section addresses the differences in user behaviors for a given game. The table below shows differences in average power use between different users of the same game title and on the same hardware unit:

Variability across users (session averages):

Game	Unit	Users	Min	Max	Difference
Saint's Row	CECH-3001-CF416803486-NRDC	2	75.7	76.1	0.5%
Call of Duty, Modern Warfare 3		3	86.5	87.2	0.7%
NHL12 (CECH-3001)	CECH-3001-CF416803486-NRDC	2	80.7	81.6	1.1%
Lego - Harry Potter	CECH-3001-CF416803486-NRDC	2	74.0	75.2	1.6%

NHL12	CECH-2101-Ecova	2	82.9	84.3	1.7%
Sonic Generations	CECH-3001-CF416803486-NRDC	2	74.9	77.4	3.3%
NHL12 (CECH-3001)	CECH-3001-CF416803486-NRDC	2	72.3	76.4	5.5%

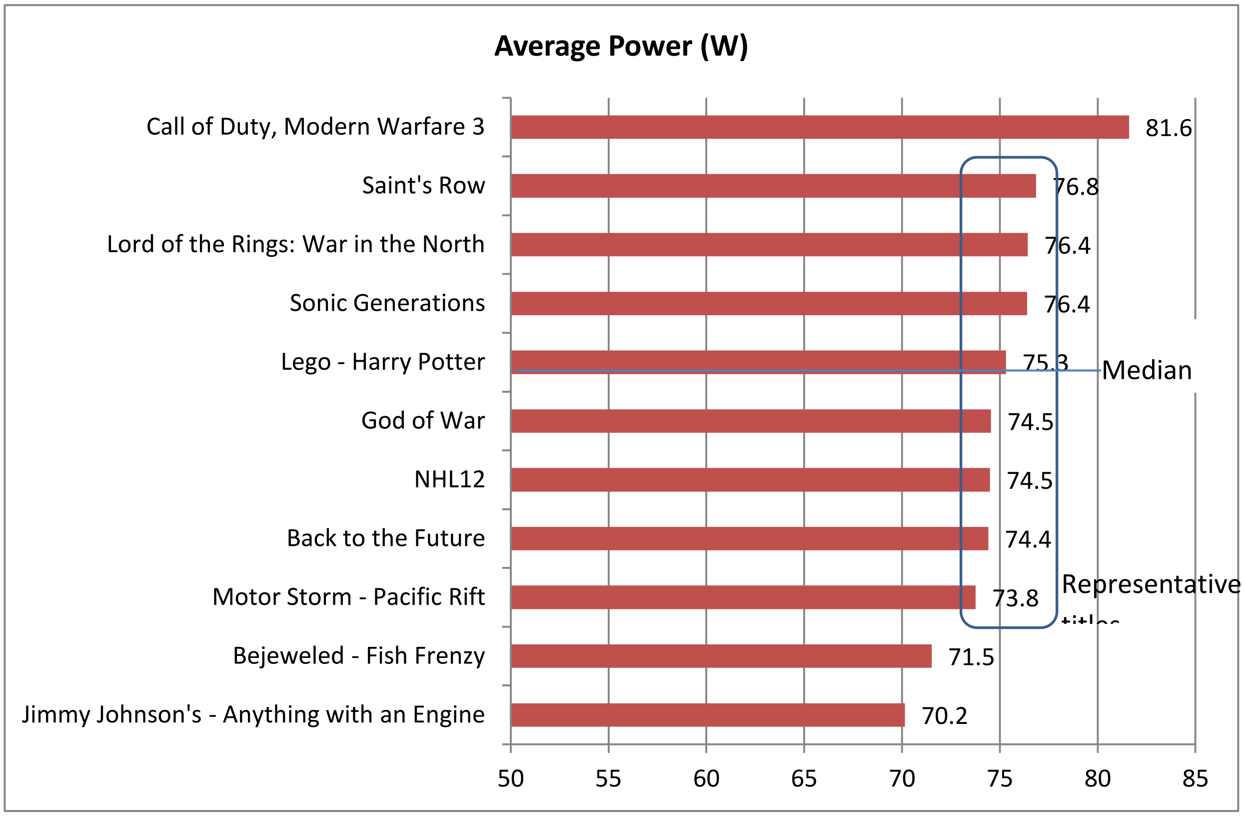
The last 2 rows show differences between minimum and maximum power draw in excess of 3%. In contrast to the other samples, these two points both represent the difference between a novice user discovering the game and therefore playing at a relatively slow pace, and an experienced user playing at a normal pace. This suggests that it is possible to minimize user variability by ensuring that tester has sufficient familiarity with the game controls and principles in order to play at a pace typical of that of average gamers.

The difference in game power use is most significant when a novice user does not know which controls to use, and does not understand the basic principles of the game. In most games, this can be learnt in just a few minutes. We believe that asking testers who are not familiar with the game to play it for at least 1 hour before the test would resolve that problem.

When users have sufficient familiarity with the game, user variability is less than 2%, which is within the range of timing variability discussed above and could be caused as much by timing variability as by user variability.

3. Game Title Variability

The graph below shows the variability of average power use by game title for one of the units tested:



The game titles in the rectangle are within 1% of the median of the dataset and would be appropriate candidates to provide representative measurements of the console's active power use.

Reference Game Title Selection

We suggest the following process for selecting a reference game title in an objective and transparent manner:

1. Perform a benchmark of active gaming power use on the top 10 best-selling titles for the console over the past 12 months (Frequency to be determined: could be as required by manufacturer depending on new model releases).
2. Select the game title that is the closest to the median of the sample.
3. Share benchmark results and selected reference game title with energy efficiency stakeholders to ensure an objective and transparent process.

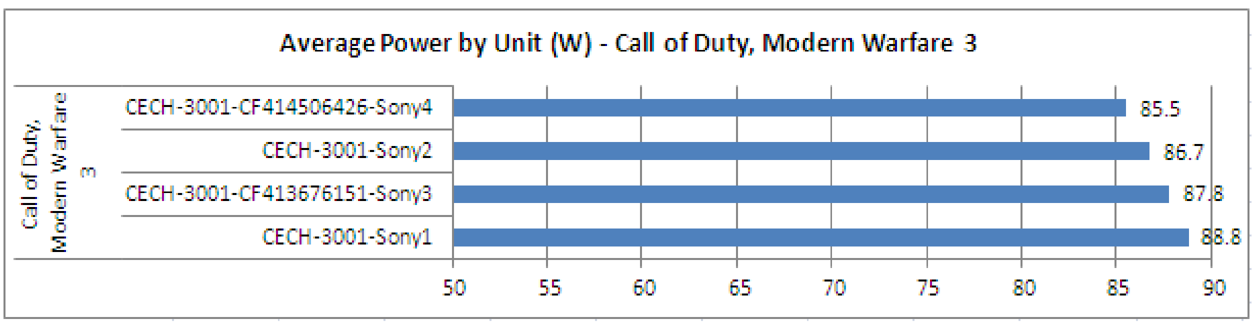
Note that the reference test game may be different for different consoles, but we think that the different games will support a fair active power test method if the same selection process is followed.

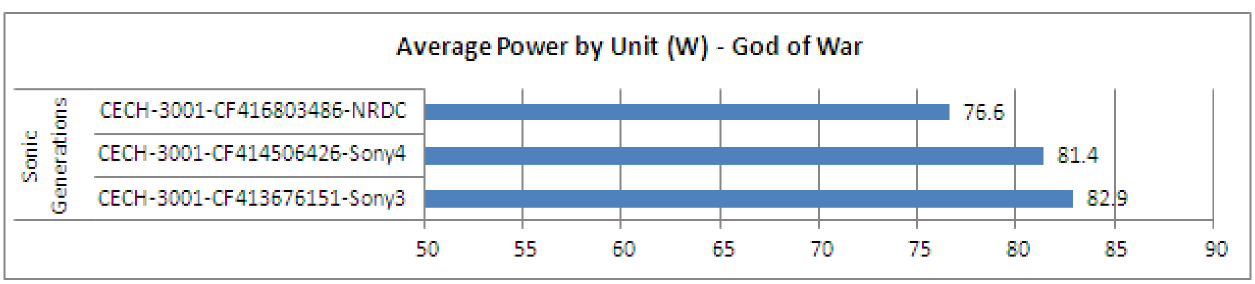
Technology Evolution

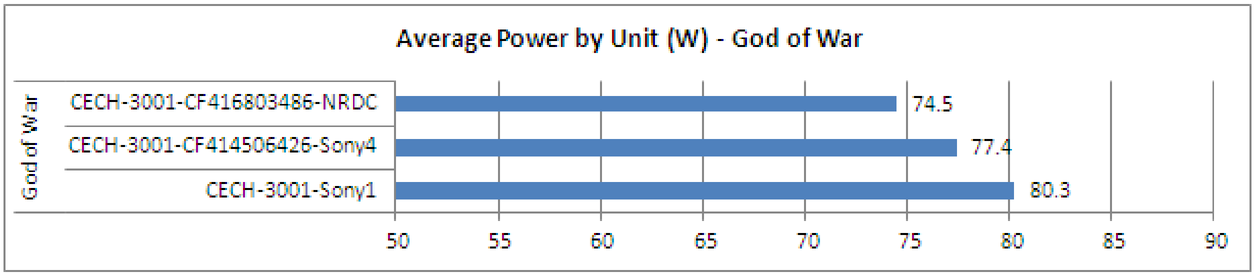
It is possible that technology evolution changes a console power profile, and that a game title that is representative for a console model is no longer as representative for a new model. In that case, the manufacturer could choose to perform a new benchmark of 10 titles and select a new reference title that is more representative of active power use for the new model.

4. Unit Variability

We found significant variations between different units of the same PS3 model. We tested 4 units of the CECH-3001A model of the PS3 and found the following variations in average active gaming power use for given game titles:







The lowest consuming CECH-3001A unit gives results up to 9% lower than the highest consuming one. As this difference is larger than we expected, we double-checked other potential factors (meter calibration, game title versions) and validated this difference. We hypothesize that this difference is due to both manufacturing variability on chips, and probably more significantly to component variations within console models, such as power supply, hard drive, fan assembly etc. Sony-PlayStation confirmed the use of 2 different power supplies, hard drives and fan assemblies for the PS3 CECH-3001A model.

Unit variability is a concern because measurements taken with one console may not be representative of many of the consoles in use in the field, or available to consumers to purchase. We suggest the following possible approach for addressing unit variability and are open to other suggestions.

Method to Deal With Variability Across Units of a Given Console Model

Assuming manufacturers know which components are sourced from multiple suppliers for a given model, and can identify units that represent variations in the components most likely to affect power use in game play, such as the power supply and fan assembly (assuming there is no variation in CPU and GPU), we suggest one of the following approaches:

1. **Highest power unit**: select the test unit that has the highest game play power use in a sample of manufacturing variations. The objective is not to identify the absolute highest power console which could require testing an unnecessarily large sample. A simple method would be to select a the 2 or 3 component combinations that get shipped the most, measure their average game play power use per this test method, and retain the highest power one.
2. **High-Low range**: similar approach with selecting and reporting both the highest and lowest power use in the component combinations sample, as a High-Low range.

5. Other Factors

Console power use in active gaming can vary depending on a number of other factors. This section identifies a number of factors and proposes ways to minimize variability for these factors.

6. Fans

Fans seem to come on or off, or vary their speed, depending on the temperature in the console. Console temperature depends on lab temperature conditions, as well as console usage prior to the testing period: a console which has already been subject to a series of tests will be warmer than a console starting cold.

In order to reduce fan power variability due to fan power, we propose the following test conditions:

1. Energy Star recommended temperature conditions in lab
2. Leave the console idle in Navigation mode for 10 minutes prior to the start of each test run, to allow the console to warm up from cold or cool down from active gaming.

7. Cut Scenes

Cut scenes occur at varying times during games. Power use during cut scenes tends to be significantly lower than active gaming power. In order to minimize variability due to cut scenes, we propose that cut scenes are either avoided if possible, e.g. by selecting a game, or a sequence in the game without cut scenes, or edited out of the test data if they cannot be avoided in the reference test game title.

8. Pause Mode and Gaming Inactive

Gaming Pause mode, or Gaming Inactive (leaving the game in active mode without actively playing it) introduce non-typical power signatures and can yield atypical power measurements. We recommended that Pause and Gaming Inactive are not used during testing.

9. Meter Variability

Tests were performed in different labs using different meters depending on local equipment availability. Most meters were Energy Star certified (Xitron, Yokagawa), the 2 Watts Up Pro meters were not. In order to ensure that differences in calibration between meters did not affect the results, we validated the accuracy of the Watts Up Pro meters by putting them in series with the certified meters for some tests and found that while they had a lower resolution (ability to capture rapid swings in power use), they reported the correct average. One of the Watts Up Pro meters had a systematic error of 1 Watt which was corrected in the data.

VI. Test Method Outline

1. **Test game title selection**:
    - Stakeholders (NRDC is willing to lead this effort) perform benchmark of top 10 selling titles over previous year. Select title that is close to median (within 2%) and has no or few cut scenes or offers the ability to by-pass them, and has a fairly stable power signature over different phases of play.
    - Stakeholders provide test data to CEC and recommend representative test game.
    - CEC selects test title for Game Play test procedure.

2. **Console test unit(s) selection**: Manufacturers identify key manufacturing configurations, select the unit(s) that have the highest (and optionally lowest if reporting a range) power consumption in active game play per the test method below.

3. **Lab equipment and conditions**
    - Per testing conditions in EPA's test method.
    - Sampling frequency: 1 second. This seems to be sufficient from an accuracy perspective while minimizing the burden of editing out cut scenes if necessary.
    - Tester needs to have minimal familiarity with the game title, in order to avoid prolonged inactivity or over weighted learning situations. If the tester is not familiar with the game, tester needs to play the game for at least 1 hour prior to the test session in order to learn the basic controls and principles of the game.

4. **Measurements**:
    1. Let console warm up/cool down in navigation mode for 10 minutes.
    2. Launch game.
    3. Start metering after game loading and initial cut scenes are finished.
    4. Play game normally (with the objective to advance in the game).
    5. Skip all cut scenes (when possible), or edit them out of measurements.
    6. Do not pause game, or leave it inactive during measurement period.
    7. Measure active gaming for 20 minutes, not including cut scenes.

5. **Results analysis and reporting**
    - Calculation methodology: Calculate the average of sample power readings. The average allows editing out of cut scenes if necessary, which is not possible with a cumulative measurement.

NRDC Responses to CEC Invitation to Participate – Set Top Boxes and Small Network Equipment

Consumer Electronics Docket -Number 12-AAER-2A

Submitted By:
Noah Horowitz
Senior Scientist
Natural Resources Defense Council (NRDC)

May 9, 2013

On behalf of the Natural Resources Defense Council (NRDC) and our more than 250,000 California members and electronic activists, we respectfully submit responses to the California Energy Commission's (CEC's) Invitation to Participate (ITP) for set top boxes (STBs) and small network equipment (SNE).

NRDC has worked closely with the California Investor Owned (IOU) utilities during their development of a response to the CEC's ITP for these devices and we are aligned with the IOUs submission for STBs and SNE. Below we provide a shorter response that provides answers to selected questions from the ITP rather than a more complete duplicative one.

BACKGROUND

NRDC completed the first in depth study of the energy use of STBs deployed by cable and satellite providers that enable consumers to receive and view pay TV in 2005 and performed a follow-up study in 2012 that included field measurements of more than 40 STB models. The 2011 study showed that nationally STBs consumed an estimated $3 billion and 9 large 500MW power plants worth of electricity per year. In addition, these devices continued to consume near full power when the user was not watching or recording a show, even when "turned off". While there have been some recent improvements to the energy efficiency of these devices since our study, significant incremental energy savings opportunities remain.

In addition NRDC and its consultant Ecova have just completed a study on the energy use of self-standing SNE devices like modems and routers and found they consume more than a $1 billion per year to operate and that more efficient models consume at least 30% less energy to operate.

I. BASIC INFORMATION

<u>*1 and 2. Product Definition and Scope/ STB Types*</u> – Until recently there was general consensus regarding what constitutes a STB provided by the cable, satellite or telephone company. Two emerging developments in the industry have since complicated the nomenclature tied to STBs and there is currently an inconsistency on how ENERGY STAR defines some new types of STBs and how DOE and the Consumer Electronics Association (CEA) treat them within their respective proposed test methods. The two new types of STBs are:

Headless gateways – Historically the main STB in the home provided video directly to the main TV in the home via a video output. In the near future, the industry has announced that they will be introducing so called "headless" gateways which distribute the content throughout the home via wired or wireless network. In its draft test method, DOE has excluded STBs that do NOT provide video output directly to a TV. This is an arbitrary distinction that would exclude STBs with this design from being covered by the test method and by a potential future DOE minimum efficiency standard.

Multifunction STB (gateways) – the cable industry is developing whole home STBs that will also include one or more of the following additional functions: hi speed internet/data (modem), digital telephony (VOIP) and/or router. Rather than having a self-standing box for each function, all these functions would be integrated into the main STB for distribution throughout the home. The test methods and policies under development either exclude these "converged" products or do not adequately account for the incremental energy these new features use.

Regarding scope NRDC recommends:

- CEC include self-standing small network equipment devices such as modems, routers, or telephony devices, or boxes that combine these services within the scope of its regulation.
- CEC include all types of STBs within its regulations including basic/standard set top boxes, DVRs, whole home DVRs, thin clients, and digital transport adapter (DTAs). (Note per a May 7 2013 presentation by Dish Network at a workshop at UC Irvine's Cal Plug Center, there are an estimated 33 million installed cable DTAs and this may grow as Comcast, the biggest cable service provider is requiring its existing customers that receive pay TV directly through a co-axial cable to now install a DTA. Go to: http://www.engadget.com/2013/04/15/comcast-encrypt-basic-cable/). STBs that include one or more SNE functions should also be covered by the scope of potential CEC policies.
- CEC should work with the industry to develop a consensus nomenclature that adequately defines gateway and headless gateway devices and includes both of the types of STBs described above within the scope of its regulations. Energy adders could be developed for minimum energy efficiency standards for STBs that also include additional functionality such as modems or routers.

3. Existing Test Procedures – There are three test procedures in play in the United States for STBs. They are DOE's most recent draft, the version in the soon to be finalized ENERGY STAR Version 4.1 specification, and the test method developed by the Consumer Electronics Association - CEA 2043. These three test methods are essentially 90% identical and have slight differences on how to treat additional features like built in modems, and headless gateways. We expect DOE to finalize its test method shortly. To the extent DOE left something out, such as headless gateways, we believe ENERGY STAR will include them in their final specification, including additional language for the test method, and CEC could supplement the DOE test method with the ENERGY STAR text or text of its own if necessary.

EPA has a draft test method for self-standing SNE devices which is due to be finalized as part of ENERGY STAR's final SNE specification within the next few weeks. In addition to using the EPA's test method for self-standing SNE, CEC could add the relevant sections to its STB standards for those STBs that include built-in SNE functionality such as modems or VOIP telephony. For example, a whole home DVR that includes a built in modem would require the tester to follow the ENERGY STAR test procedure regarding how to set up the modem (e.g., connect to a live internet connection with a speed of at least X, and leave the connection idle during the test. Do not however perform active data transfer such as sending email, or streaming a movie during the test.)

4. Sources of Test Data

STBs - NRDC measured the on and standby power use of STBs installed in the field in 2010 and published this data in our report which can be downloaded at: http://www.nrdc.org/energy/files/settopboxes.pdf

In Attachment 1 we provide the raw data from our field measurements from our study. This data includes make and model number as well as the features contained within each box. Attached at the end of our comments are the raw field data from this study.

For more up to date information on the more efficient models on the market today, go to the ENERGY STAR website's qualified product list for models that meet Version 3 at: http://downloads.energystar.gov/bi/qplist/Set_Top_Boxes_Product_List.xls

SNE – NRDC retained Ecova to measure the power use of various SNE equipment and we will publish the results of this study shortly. In Attachment 2 we provide the results of our field and laboratory measurements made in 2012. These results do include the make and model number of the samples that we tested.

In addition EPA has collected extensive manufacturer reported data for SNE equipment and it is available at the ENERGY STAR website in a masked version (i.e without listing manufacturer or model number).

7. Product Development Trends

The main trends within the STB and SNE categories are:

Whole home DVRs/gateways and deployment of thin clients – a growing number of homes now have a DVR and the satellite industry is quickly moving to whole home DVRs that provide the user the ability to access a DVR and the stored content on any TV in the home without the need to have a DVR for each TV. The second and third TVs in the home could receive content via a low power thin client, which has the potential to use very low power levels when not in use as it is not connected directly to the service provider. (Note, while today's thin clients use almost the same amount of power when on or in sleep mode, future models should be able to attain sleep power levels of 1 to 2 Watts, as they are not connected to the service provider). Instead of using thin clients, cable may instead choose to use hybrid STBs that consume roughly twice as much energy as a thin client since they may be required to maintain a connection to the service provider, thereby significantly driving up sleep mode energy use.

Headless gateways – allows the service provider to locate the main STB anywhere in the home and to potentially distribute this content around the home via a wired or wireless network, avoiding the need for running coaxial cable throughout the home. We understand these are about to be launched in Europe and similar devices will enter the US market shortly thereafter.

Multifunction gateways – the cable industry in particular is looking to create an all in one box whole home STB that would not only deliver video content throughout the home but also voice, data and/or routing capabilities. This makes installation simpler, eliminates the need for multiple boxes in the home and could potentially reduce overall energy use if implement properly. These products would support so called "triple play" offers where the consumer receives all three services – video, data and voice -- for one low monthly price.

Cloud based services – some of the program guides may be distributed from the cloud and received via the internet. This could result in lower levels of standby power. Over time, content may reside in the cloud and this would eliminate the need for manufacturers to include a hard drive and associated hardware within their DVRs. This could reduce the complexity and cost of future DVRs, and the power to operate them.

Additional features – the industry may elect to receive and display signals that include 3D and/or ultra-high definition (UHD) video. While no content is currently distributed in UHD, the TV industry is heavily promoting this and it is likely to be added to some new STB models in the future. As UHD signals contain roughly 4 times more data, it will require additional processing power.

III. Market Competition for Efficiency Products

4. How are consumers able to identify the most efficient products on the market? - Today consumers have little to no choice[1] regarding the STB they receive from their service provider. In almost all cases, the STB is supplied by the service provider to the consumer for free or via some contractual arrangement (e.g. monthly rental fee or it is part of the overall monthly rate). The transaction between the customer and service provider falls into two parts: a) do you sign up with cable, satellite or telco?, and then b) do you want a DVR or not and how many TVs do you want to hook up to the pay TV service. The consumer typically has very little if any say of the actual STB they receive at that point. The energy use or cost of operation is not discussed during this transaction. In fact, the service provider websites do not include energy use disclosures on their website for interested consumers.

Bottom line, STB energy efficiency has not received sufficient attention due to the fact that the consumer and not the service provider pay the electric bill. This has started to change with the evolution of ENERGY STAR specifications for STBs and the threat of future regulation at the state and/ or federal levels.

There is also some market confusion regarding ENERGY STAR qualified products. The author has personally experienced the situation where he requested an ENERGY STAR qualified STB and was told all our STBs are ENERGY STAR. What they really meant was most of their STBs met ENERGY STAR Version 2, an outdated version of ENERGY STAR where qualifying products use 30% or more energy per year to operate than those that meet Version 3, the version in effect at the time. My only choice at the cable service provider's store was an ENERGY STAR Version 2 box and not the more efficient Version 3 box. Note, ENERGY STAR does not require posting the Version # on the product label.

While consumers can access the qualified product list (QPL) at energystar.gov, most don't even know about this website and in most cases this data is not sufficiently actionable by the consumer as their choice is often limited to the STB the installer has on its truck that day.

Regarding SNE, the market is split between products purchased by consumers at retail and those provided by the service provider. Today almost none of the SNE products report their energy use on the package nor does the manufacturer or service provider websites provide this information. In the near future, ENERGY STAR will add SNE to their program which will allow motivated consumers the means to select the more efficient model when shopping for a new device.

[1] TiVo sells DVR STBs that consumers can purchase directly at retail. TiVo stand-alone STBs represent a very small fraction of the overall market.

Power Measurements of Cable, Satellite and IPTV Set-Top Boxes

Service Provider Type	Service Provider Name	Make	Model Name	Product Class	MultiRoom Capability	Additional Tuners	Active Power Use (W)	Standby Power Use (W)
Cable	Comcast	Motorola	DCH70	SD	No	No	11	10
Cable	Comcast	Motorola	DCH70	SD	No	No	10	10
Cable	Verizon FiOS	Motorola	QIP2500	SD	No	No	13	12
Cable	Time Warner	Motorola	DCT2224	SD	No	No	14	14
Cable	Verizon FiOS	Motorola	QIP2500	SD	No	No	14	14
Cable	Verizon FiOS	Motorola	QIP2500	SD	No	No	14	14
Cable	Verizon FiOS	Motorola	QIP2500	SD	No	No	14	14
Cable	Verizon FiOS	Motorola	QIP2500	SD	No	No	14	14
Cable	Time Warner	Scientific Atlanta	Explorer 2100	SD	No	No	17	16
Cable	Comcast	Motorola	DCT2000	SD	No	No	17	16
Cable	Comcast	Motorola	DCT2000	SD	No	No	18	18
Cable	Comcast	Motorola	StarfoneSFT2	SD	No	No	19	19
Cable	Charter	Motorola	StarfoneSFT2	SD	No	No	20	19
Cable	Comcast	Pace	RNG110	HD	No	No	13	12
Cable	Bresnan	Pace	DC700X	HD	No	Yes	14	14
Cable	Time Warner	Cisco	Explorer 4250HDC	HD	No	No	19	18
Cable	Time Warner	Cisco	Explorer 4250HDC	HD	No	No	19	18
Cable	Comcast	Motorola	DCX3200	HD	No	No	20	20
Cable	Time Warner	Scientific Atlanta	Explorer 3250HD	HD	No	No	20	19
Cable	Cox	Scientific Atlanta	Explorer 3250HD	HD	No	No	19	19
Cable	Verizon FiOS	Motorola	QIP7100	HD	Yes	Yes	21	21
Cable	Time Warner	Cisco	Explorer 8300HD	HD	No	No	23	23
Cable	Comcast	Motorola	DCH3200	HD	No	No	26	25
Cable	Bresnan	Motorola	DCH6200	HD	No	No	35	35
Cable	Comcast	Pace	TDC577X	SD/DVR	No	Yes	26	24
Cable	Comcast	Pace	TDC575D	SD/DVR	No	Yes	26	25
Cable	Time Warner	Cisco	Explorer 8300HDC	HD/DVR	No	Yes	26	25
Cable	Cox	Cisco	Explorer 8240HDC	HD/DVR	No	Yes	25	25
Cable	Time Warner	Cisco	Explorer 8300HDC	HD/DVR	No	Yes	29	26
Cable	Verizon FiOS	Motorola	QIP7216	HD/DVR	Yes	Yes	29	28
Cable	Comcast	Motorola	DCX3400	HD/DVR	No	Yes	29	28
Cable	Comcast	Motorola	DCT3416	HD/DVR	No	Yes	30	30
Cable	Comcast	Motorola	DCT3412	HD/DVR	No	Yes	31	30
Cable	Verizon FiOS	Motorola	QIP6416	HD/DVR	No	Yes	31	31
Cable	Comcast	Motorola	DCH3416	HD/DVR	No	Yes	34	32
Cable	Verizon FiOS	Motorola	QIP6416	HD/DVR	No	Yes	36	35
Cable	Bresnan	Pace	TDC779X	HD/DVR	No	Yes	41	41
Cable	Bresnan	Motorola	DCH6416	HD/DVR	No	Yes	47	46
Satellite	DirecTV	DirecTV	D11	SD	No	No	12	9
Satellite	DirecTV	DirecTV	H24	HD	No	No	16	15
Satellite	DirecTV	DirecTV	H23-600	HD	No	No	19	18
Satellite	Dish Network	Dish Network	625	SD/DVR	Yes	Yes	30	29
Satellite	DirecTV	DirecTV	HR24	HD/DVR	Yes	Yes	31	31
Satellite	DirecTV	DirecTV	HR22-100	HD/DVR	Yes	Yes	33	30
Satellite	DirecTV	DirecTV	HR21-100	HD/DVR	Yes	Yes	33	32
Satellite	DirecTV	DirecTV	HR22-100	HD/DVR	Yes	Yes	37	35
Satellite	DirecTV	DirecTV	HR22-100	HD/DVR	Yes	Yes	37	36
Satellite	DirecTV	DirecTV	HR20-700	HD/DVR	Yes	Yes	38	37
Satellite	DirecTV	DirecTV	HR20-700	HD/DVR	Yes	Yes	38	38
Satellite	Dish Network	Dish Network	ViP922	HD/DVR	Yes	Yes	43	40
Satellite	Dish Network	Dish Network	ViP612	HD/DVR	Yes	Yes	44	42
Satellite	Dish Network	Dish Network	ViP622	HD/DVR	Yes	Yes	52	49
Satellite	Dish Network	Dish Network	ViP722	HD/DVR	Yes	Yes	55	52
IPTV	AT&T U-Verse	Motorola	VIP1200	HD	No	No	10	9
IPTV	AT&T U-Verse	Motorola	VIP1200	HD	No	No	10	10
IPTV	AT&T U-Verse	Motorola	ViP1225	HD/DVR	Yes	Yes	19	12
IPTV	AT&T U-Verse	Motorola	VIP1216	HD/DVR	Yes	Yes	18	17
Streaming Device	N/A	Apple	MC572LL/A	Internet	No	No	3	0.5
Streaming Device	N/A	Roku	XR-HD	Internet	No	No	7	7

Ecos took these measurements in the field in the summer of 2010, using a Watts up? PRO ES power meter, from set-top boxes connected to service from a cable, satellite or IPTV service provider.

59 total set-top boxes measured
44 unique set-top box models

Attachment 2 – Summary Data of NRDC-Ecova Measurements of SNE Devices

Below we provide a description of the testing that was done and how it was performed, followed by a table of the results.

MODELS TESTED

Before selecting which devices to test, we conducted a market survey of small network products offered in retail stores and distributed by service providers in the U.S. Our goal was to select products commonly purchased by consumers or distributed by service providers. Within this group of products, we made our best effort to select devices that represented a wide range of energy efficiency and features such as maximum data transfer speed. Table 1 shows how many products we tested in each category by test location, Ecova's lab or in situ in a subscriber's household:

Table 1: Summary of small network equipment tested by Ecova

Product Category	# tested in-home	# tested in-lab	total tested
Modem	7	9	16
Gateway	2	12	14
Optical Network Terminal	2	-	2
Router	-	9	9
Switches	-	11	11
Access Points	-	4	4
Outdoor Units	4		4
Total	**15**	**45**	**60**

TESTING METHODOLOGY

We tested network devices in the lab where possible in order to ensure accuracy levels consistent with those required by the ENERGY STAR test method. For lab tests, we measured average power (P_{avg}) using a modified version of the ENERGY STAR Test Method for Small Network Equipment. The key difference between our test procedure and the ENERGY STAR test procedure is that we did not use a shielded box for wireless testing. We merely ensured that a nearby wireless client was connected over Wi-Fi.

For those devices, such as Verizon FiOS ONTs, for which we could not test in the lab, we conducted in-home tests without a calibrated power source or meter; therefore, the accuracy of these test results is lower.

Our ODU test method depended on how the ODU was powered. There are two ways that ODUs are typically powered:

- Set top box provides power to the ODU, sending power up the signal coaxial cable. In this arrangement, the connected STBs power only the portions of the ODU electronics that are required for the channels that are being received
- An external power supply (EPS) provides power to the ODU, usually through a device that inserts the power on the coax at some point between the STB and the ODU. In this arrangement all of the electronics in the ODU is powered at all times

As a result of these differences, we tested these two types of ODUs differently.

- For EPS powered ODUs, a Kill-a-watt meter was installed between the outlet and the EPS, and then power observed in the following modes
  - No STBs connected
  - STBs connected but turned off
  - 1,2,3,4 or more STBs connected and turned on, tuned to first to ESPN HD then Discovery HD, recording power consumed in each configuration
- For STB powered ODUs, Ecova made a DC power measurement in each of the coax cables supplying a 5LNB ODU powered via 4 coax cables

- The total power delivered to the ODU via coax was measured with a channel selection such that:
    - 1 LNB was active
    - 2 LNBs were active
    - 3 LNBs were active
    - 5 LNBs were active

Small Network Equipment Energy Consumption in U.S. Homes

Connecting devices with less energy

NRDC Issue Paper
May 2013

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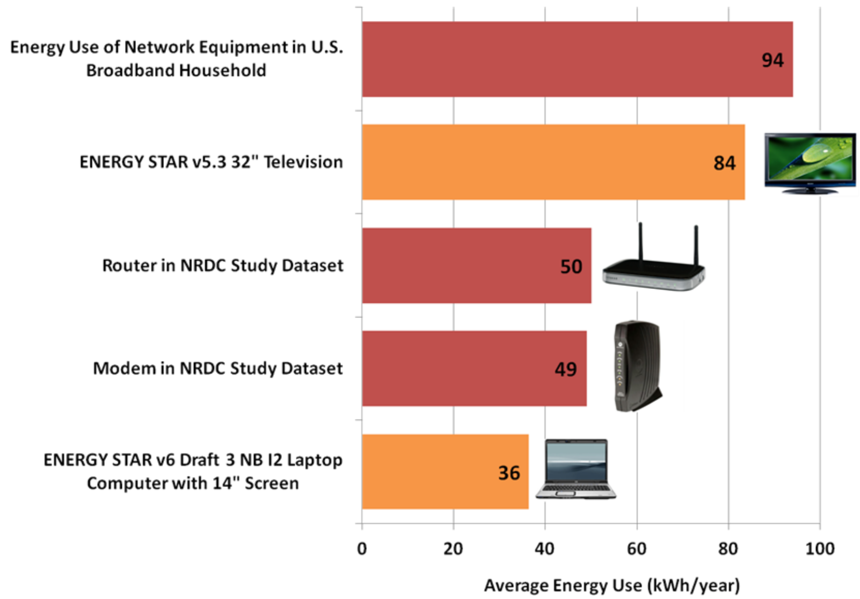
TABLE OF CONTENTS

EXECUTIVE SUMMARY

Most discussions about the energy consumption of home electronic products focus on the large devices like televisions, computers and video game consoles that operate at the edge of today's digital networks. The purpose of this research is to examine the myriad small in-home devices that enable these and other edge devices to communicate with each other and with Internet service providers. In the U.S. today, there are approximately 145 million residential small network devices used to access the Internet and move digital content around our homes. While many of the same or similar small network devices are used in commercial settings, this report focuses on the devices used in U.S. households, the most common of which are a) modems, which connect a household to its service provider, b) wireless routers, which connect computers, printers, tablets and other connected devices within the household, and c) integrated devices called gateways or Internet access devices (IADs), which perform both of these functions and often provide telephone service as well. Little is known about the energy consumption of small network equipment, so NRDC retained Ecova to build on a foundational study by Lawrence Berkeley National Laboratory by measuring the power consumption of residential small network equipment in common use cases, estimating the national energy consumption of these devices, and assessing the energy savings potential of more efficient network technologies.

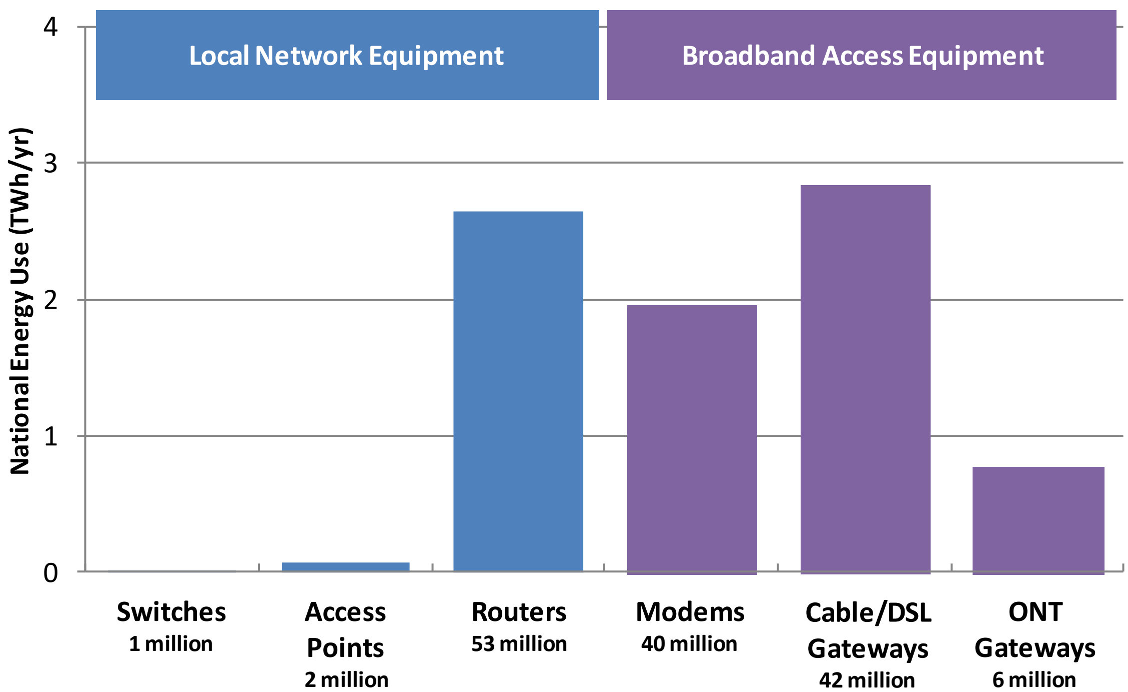
Approximately 88 million households subscribe to high-speed Internet service U.S. On average, each household operates two small network devices that collectively consume 94 kilowatt-hours (kWh) of electricity annually. To put that into perspective, these small, innocuous boxes use nearly the same amount of energy annually as a flat screen television that has earned the ENERGY STAR®—or more than twice the annual consumption of an ENERGY STAR certified notebook.

Energy use of network equipment compared to other consumer electronics appliances



Modems, routers and gateways are the most common in-home network devices and account for most of the energy used by small network equipment in U.S. homes. U.S. households use few stand-alone switches, which enable consumers to add additional wired devices to their network, or wireless access points, which add wireless access to a wired network or extend the range of a wireless network. Therefore, their contribution to total national energy consumption is low. A growing number of consumers connect to their service provider through Optical Network Terminals (ONTs), devices typically attached to the outside of the home which translate optical signals to electronic signals and vice versa for subscribers who have high speed fiber optic service (e.g., Verizon FiOS).

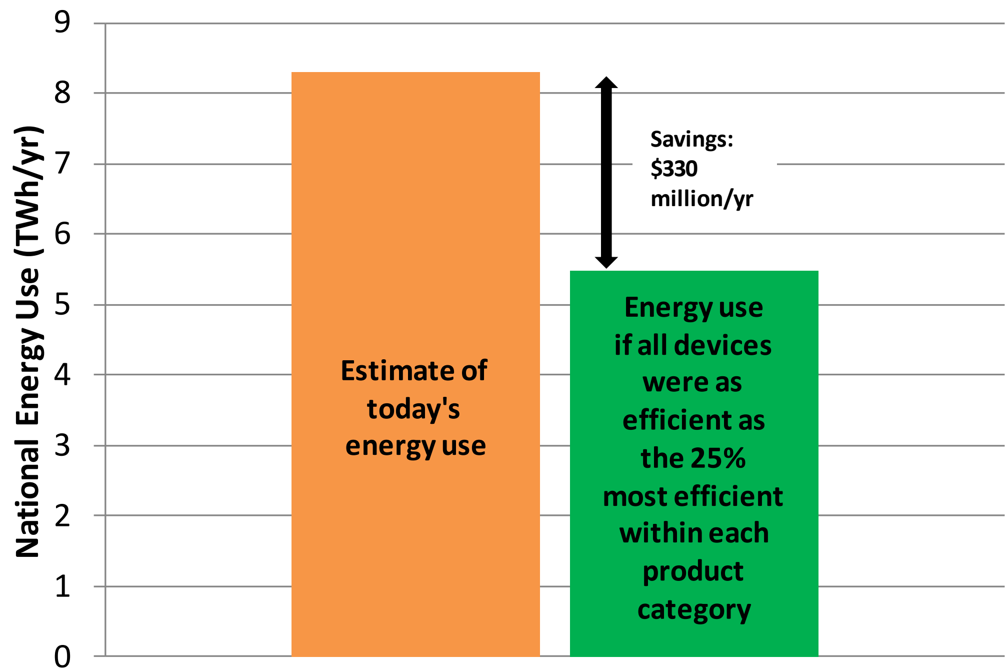
U.S. residential small network equipment energy use



The energy consumption of these small devices adds up. In 2012, small network equipment in U.S. homes consumed approximately 8.3 billion kWh of electricity, nearly equivalent to the annual output of three average (500 MW) coal-fired power plants. This resulted in 5 million metric tons of carbon dioxide emissions, or the equivalent annual tailpipe emissions of 1.1 million cars. U.S. consumers spend about $1 billion per year to power their small network equipment. The annual national electricity use of today's small network equipment is nearly equal to the total annual electricity use of all of the households in Silicon Valley. While this study does not quantify the energy consumption of commercial small network equipment, commercial equipment consumes a significant amount of energy and adds to the savings potential realized through the introduction of technologies and standards that increase the energy efficiency of network equipment.

Fortunately, the 25 percent most efficient small network devices on the market today use less than two thirds of the energy consumed by models with average efficiency levels and similar features. Replacing today's stock of inefficient residential small network equipment with efficient models could save 2.8 billion kWh of electricity or about $330 million worth of consumer energy bills per year. Some of the most efficient devices we tested save energy because they operate at lower power than other products with similar features regardless of the throughput rate. Other devices made the most efficient list because they scale power downward effectively when there is little network traffic.

U.S. residential small network equipment energy use and savings potential

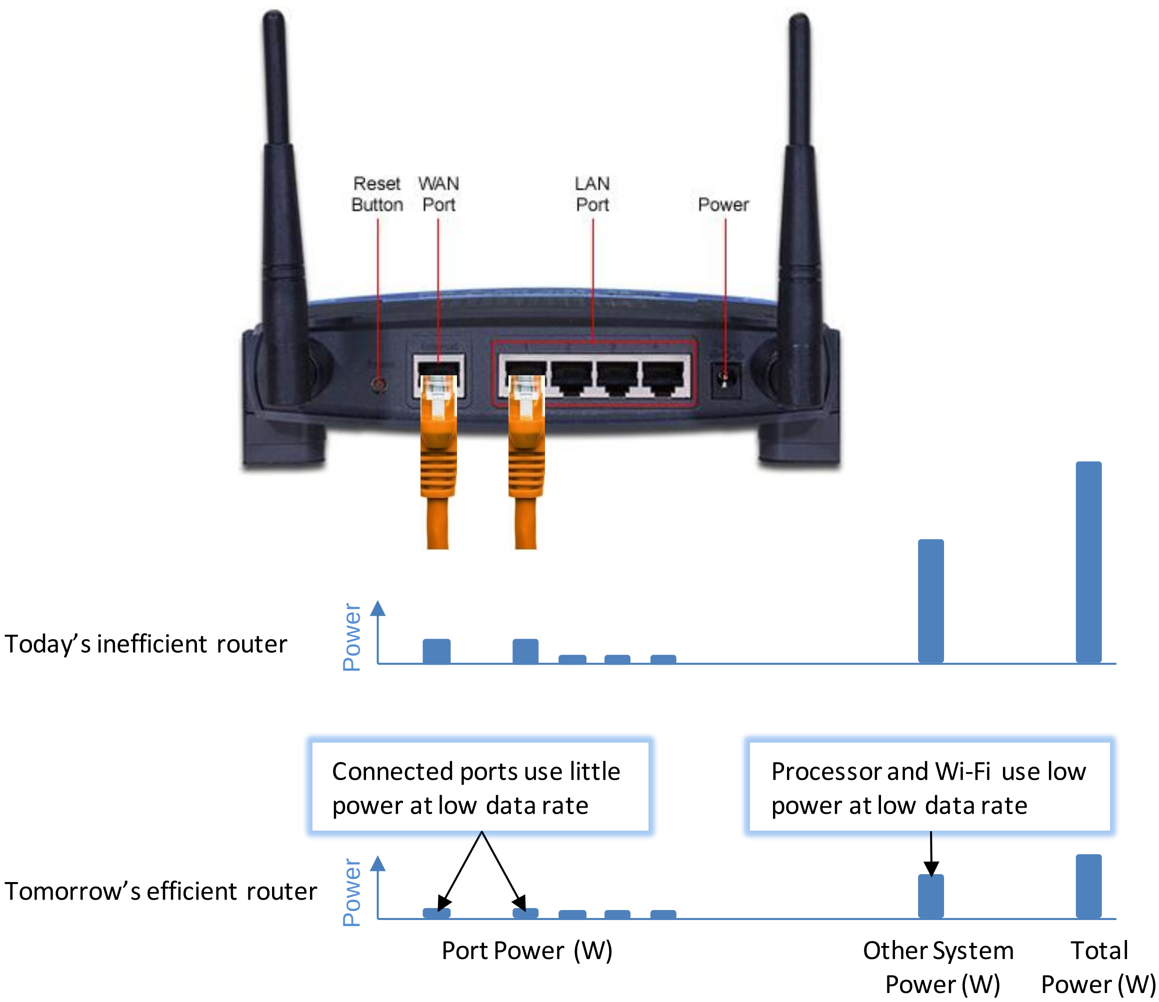


Better yet, more savings are possible in the future given that industry has only started to develop and deploy products with sophisticated power scaling capabilities. The two primary standards in play for home network equipment are IEEE 802.3az Energy Efficient Ethernet (EEE) for Ethernet ports and IEEE 802.11e automatic power save delivery (APSD). Ratified in 2010, EEE enables Ethernet ports and system components to enter a sleep mode called Low Power Idle (LPI) in between data packets when transmitting at less than maximum data rate and both ends of the network link support have EEE enabled. EEE does this without impacting the performance of consumer computing applications. Industry expects near term savings from first generation EEE devices to be 5 to 20 percent of system power at low data rate. Next generation network silicon, designed with power islands, voltage scaling and other power saving approaches, is expected to save up to 80 percent of system power according to a white paper by Intel and Cisco. These savings may more than offset the increase in power draw resulting from the market shift to faster, gigabit per second Ethernet devices.

Wi-Fi power scaling technologies are emerging as well. One manufacturer, Trendnet, has introduced a suite of energy saving features, labeled Green Wi-Fi, that can reportedly save energy by enabling Wi-Fi routers to a) operate at reduced power when no Wi-Fi clients are connected, b) reduce their signal strength when connected clients are in close range, and c) enter a low power states between packets without affecting performance. Trendnet reports that their Green Wi-Fi products use 66 percent less power when unassociated with a Wi-Fi client and 53 percent less when connected but not transferring data.

The figure below illustrates the power break-down when comparing an inefficient router to a future router with similar functionality that incorporates next generation EEE with Wi-Fi power scaling. We assume a typical use case where the router is on and connected to a broadband modem through the Wide Area Network (WAN) Ethernet port, to one idle Ethernet client, perhaps a printer, through the Local Area Network (LAN) port, and to one or more Wi-Fi clients that are not actively transferring content. In other words the home network is ready to use but not actively doing anything at the moment.

Conceptual savings example



Few of the network devices that comprise the stock of residential network equipment have EEE or other energy efficiency technologies. None of the modems or ONTs we tested supported EEE. Of the 23 routers and gateways we tested, introduced in the 2009 to 2012 timeframe, only two supported EEE and only one supported Trendnet's Wi-Fi power scaling technology, so the opportunity to capture additional savings by increasing market penetration of these capabilities appears to be large. Market actors report that EEE will be ubiquitous in the next few years.

A range of policies can accelerate the adoption rate of efficient models. The ENERGY STAR program can identify efficient devices for consumers and for service provider procurement staff. State and federal minimum efficiency standards can eliminate the least efficient models from the market. Utility programs promoting ENERGY STAR products can explore incentive programs. However, small network equipment has challenging program economics compared to CFL programs. A $3 CFL provides about 60 kWh of lifetime savings compared to an $80 router that offers about 20 kWh of lifetime savings. Finally, committed consumers can save energy by powering down small network devices with timers overnight or during other times when they are regularly not used.

I. INTRODUCTION

In the U.S. today, there are approximately 145 million residential small network devices used to access the Internet and move content around our homes.[12] While many of the same or similar small network devices are used in commercial settings, this report focuses on the devices used in U.S. households, the most common of which are a) modems, which connect a household to its service provider, b) wireless routers, which connect computers, printers, tablets and other devices within the household, and c) integrated devices called gateways or Internet access devices (IADs), which perform both of these functions and often provide telephone service as well. Little is known about the energy consumption of these devices, so NRDC retained Ecova to build on the work of Lawrence Berkeley National Laboratory[3] by answering the following questions about small network equipment:

1. How much energy do the major types of products such as modems and routers consume?
2. Is there a significant spread in the power draw of models with similar features? Do some models provide the same function more efficiently than others?
3. What is the national energy use of these devices?
4. What savings opportunities exist and how do we take advantage of them?
5. Although not typically considered small network equipment, how does the energy use of Satellite outdoor units (ODUs) compare to broadband modems, which perform a similar function?

Our goal was to understand the energy use of small network equipment, and identify savings opportunities and policy approaches to reduce consumption associated with this product category.

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[1] Estimated number of small network devices in U.S. homes in 2012 based on an analysis of market data presented in: Urban, Bryan, Verena Tiefenbeck, & Kurt Roth. 2011. Energy Consumption of Consumer Electronics in U.S. Homes in 2010. Fraunhofer Center for Sustainable Energy Systems. Final Report to the Consumer Electronics Association.

[2] We use the terms *small network devices* and *small network equipment* interchangeably to refer to equipment used to perform the networking function as opposed to the edge devices like tablets and notebooks that enable user interaction with the network.

[3] LBNL scientists completed a study of network equipment energy use, including case field studies of networks in a campus, a medium commercial building, and a typical home: Lanzisera, Steven, Bruce Nordman, & Richard E. Brown. 2010. Data Network Equipment Energy Use and Savings Potential in Buildings. In *2010 ACEEE Summer Study on Energy Efficiency in Buildings*.

II. SMALL NETWORK EQUIPMENT 101

Residential small network devices enable consumers to access high-speed (i.e. broadband) Internet services and to transmit data between devices within the home. ENERGY STAR divides network devices into two main categories: broadband access equipment and local network equipment.[4]

Broadband Access Equipment allows consumers to access high-speed Internet from a service provider such as their cable, satellite or phone company.

Figure 1: Examples of Broadband Access Equipment

Modem

Receives a broadband signal from a cable or telephone service provider via a coax, telephone or fiber optic cable. Typically delivers the broadband signal to a single computer or router via an Ethernet cable.

Gateway

A modem with one or more additional functions such Ethernet or Wi-Fi routing. A gateway that receives a broadband signal over a fiber optic cable is called an optical network terminal (ONT). We exclude gateway devices with set-top box functionality in our discussion of network gateways. If a gateway has set-top box functionality, then we consider it a set-top box gateway.

A gateway or modem connects a household to the service provider via a coax, telephone or fiber optic cable.[5] Modems and gateways are often configured to work with a specific service provider. The two most common types of broadband access equipment are cable or digital subscriber line (DSL). Sometimes telecommunications companies (Telcos) run fiber optic cable to the home and use an optical network terminal (ONT) to convert light pulses into electronic signals that devices within the home can understand and vice versa. Most, if not all, residential ONTs have multiple functions, such as providing data, phone and TV signals to devices in the home network, and therefore are classified as gateways. Although consumers usually acquire modems and gateways from their service provider, some models can be purchased directly at retail outlets such as Best Buy and Radio Shack.

[4] Per ENERGY STAR Program Requirements for Small Network Equipment: EPA, Environmental Protection Agency. 2012. *ENERGY STAR® Program Requirements for Small Network Equipment, Draft 2 Version 1.0*. http://energystar.gov/products/specs/sites/products/files/ES_SNE_Draft_2%20_V1_Specification_Nov2012.pdf.

[5] We did not test any set-top box gateways. These gateways provide set-top box functionality and are capable of outputting audio and video signals.

Local Network Equipment enables consumers to set up home networks consisting of multiple, connected "edge" devices, like computers, printers, game consoles, tablets, smart TVs, et cetera. The most common local network devices are routers. Few homes have switches, which are used in additional to a router to add more Ethernet edge devices than the router supports. Wireless access points are primarily used in commercial settings like airports to provide Wi-Fi access to wired networks. Most consumer access points serve as Wi-Fi range extenders. They receive a Wi-Fi signal and rebroadcast an amplified signal to extend the range of a Wi-Fi network. Customers usually purchase local network devices through retail channels, but they sometimes lease equipment from service providers. While categorized as broadband access equipment in this report, gateways also perform functions offered by local network equipment. We use the following definitions for local network equipment:

Figure 2: Examples of Local Network Equipment

Router

Assigns an Internet Protocol (IP) address, a unique numerical label, to each device within a local network. The router then directs Internet traffic to these devices, such as computers and printers, and may send and receive data over an Ethernet cable or wireless connection.

Switch

Links multiple edge devices in the home and directs Internet traffic to their specific IP addresses. Generally used to extend a network's range or increase the number of devices that can connect with each other in the network.

Access Point

Provides wireless network connectivity to multiple clients as its primary function and does not include routing capability.

Small network equipment typically connects to other in-home devices via wireless antennae or Ethernet ports and cables:

Figure 3: Examples of Ethernet Ports and Cables

Ethernet Port

Enable Ethernet cable connection.

Ethernet Cable

Connects networked devices using the Ethernet protocol.

We define small network equipment as network devices with 11 or fewer ports.[6] Typically, modems, ONTs and access points have one Ethernet port. Gateways, routers and switches usually have multiple Ethernet ports.

[6] Per ENERGY STAR Program Requirements for Small Network Equipment: EPA, Environmental Protection Agency. 2012. *ENERGY STAR® Program Requirements for Small Network Equipment, Draft 2 Version 1.0*. http://energystar.gov/products/specs/sites/products/files/ES_SNE_Draft_2%20_V1_Specification_Nov2012.pdf.

III. POWER MEASUREMENT OF NETWORK DEVICES

TEST METHOD

To understand the power use of small network devices, NRDC worked with Ecova to measure the power draw of 60 network devices using a simplified version of the ENERGY STAR test method.[7] We tested equipment from all product classes, representing a wide range of energy efficiency levels, maximum data transfer rates and features. We tested devices purchased in retail stores and distributed by service providers. Where possible, we tested network devices in Ecova's research laboratory. In some cases we conducted field measurements. For example, we could not replicate Verizon's optical signal in our lab, so we tested these devices in situ where Verizon's service was available.

Ecova also tested a limited number of outdoor units (ODUs), the electronics and dish that enable a satellite TV provider to send pay-TV signals to a customer's premises. We did so by using by using the test method outlined in Appendix A.

Figure 4: Satellite TV Outdoor Unit (ODU)

RESULTS

Test data are listed in Appendix B and summarized in Figure 5 and Figure 6.

[7] EPA, Environmental Protection Agency. 2012. *ENERGY STAR® Test Method for Small Network Equipment, Final Draft, Rev. November 2012*. http://energystar.gov/products/specs/sites/products/files/ES_SNE_Final_Draft_Test_Method_Nov2012.pdf.

Figure 5: Power draw of small network equipment measured in this study

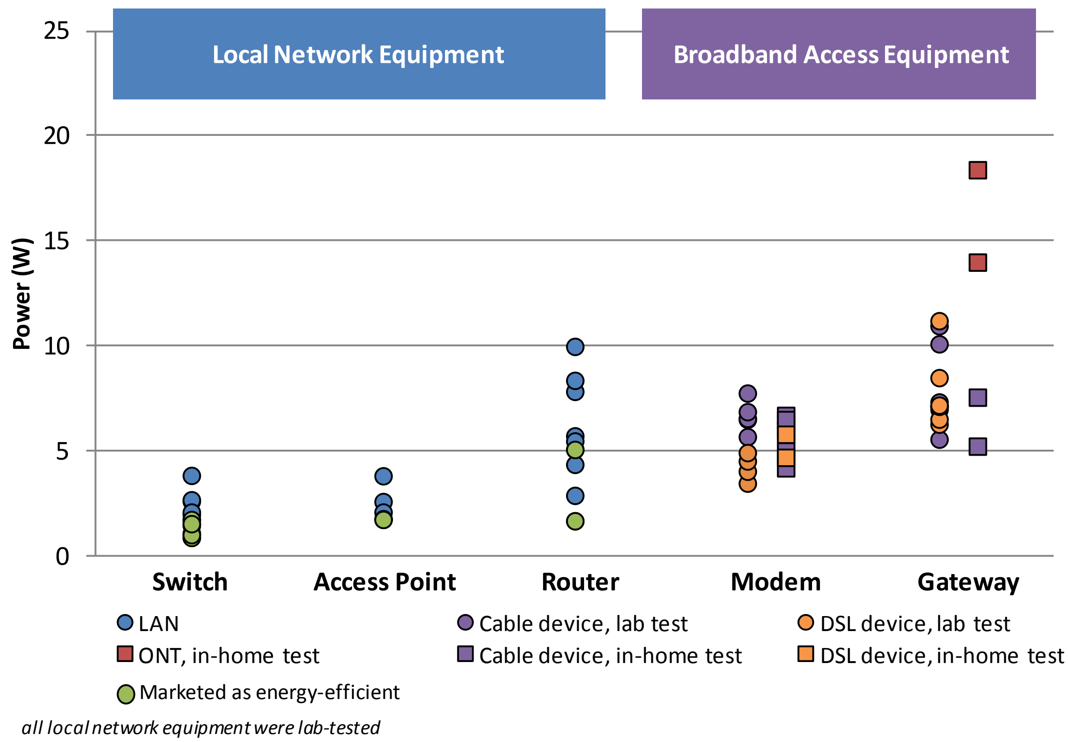
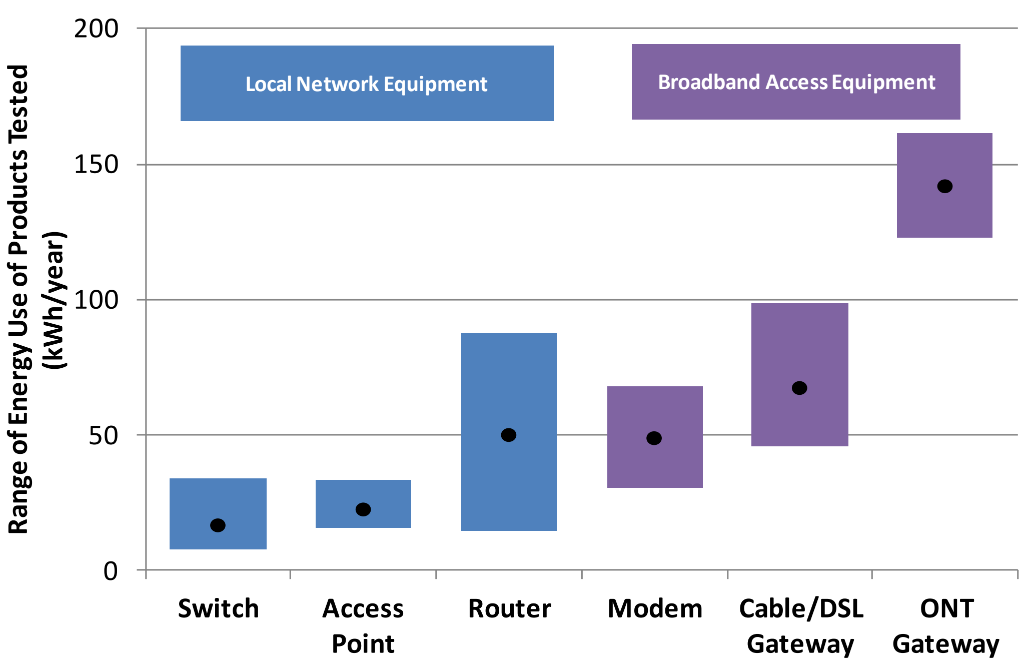


Figure 6: Range of energy use and average (shown as black dot) of each product group tested



Results and interpretation:

- Local network devices marketed as energy efficient generally draw the least power (Figure 5, green symbols). Some of these products adhere to the EEE standard, while others offered proprietary solutions, D-Link Green and TRENDnet GREENnet, discussed in Section IV.

- In most, but not all cases, it is more efficient to use a gateway with combined modem and routing functionality rather than use separate modem and router devices (Figure 5).

- There are no significant differences between average power draw of models purchased in retail compared to similar models leased by service providers.

- Differences in power between two service providers who use the same broadband device are insignificant (~0.2 watts, Appendix B). However, the energy consumption of a given set-top box model can differ by service provider because of the difference in software build. We recommend additional testing to assertively rule out this possibility in broadband equipment. Market actors indicate that in the future there could be differences in energy use between service providers who use the same model gateway devices based on how they configure power management.

- Limited observations suggest that ODUs powered by an external power supply draw a constant 5 to 9 watts throughout the day resulting in energy consumption of 43 to 79 kWh/yr in addition to the energy consumed by the set-top boxes.

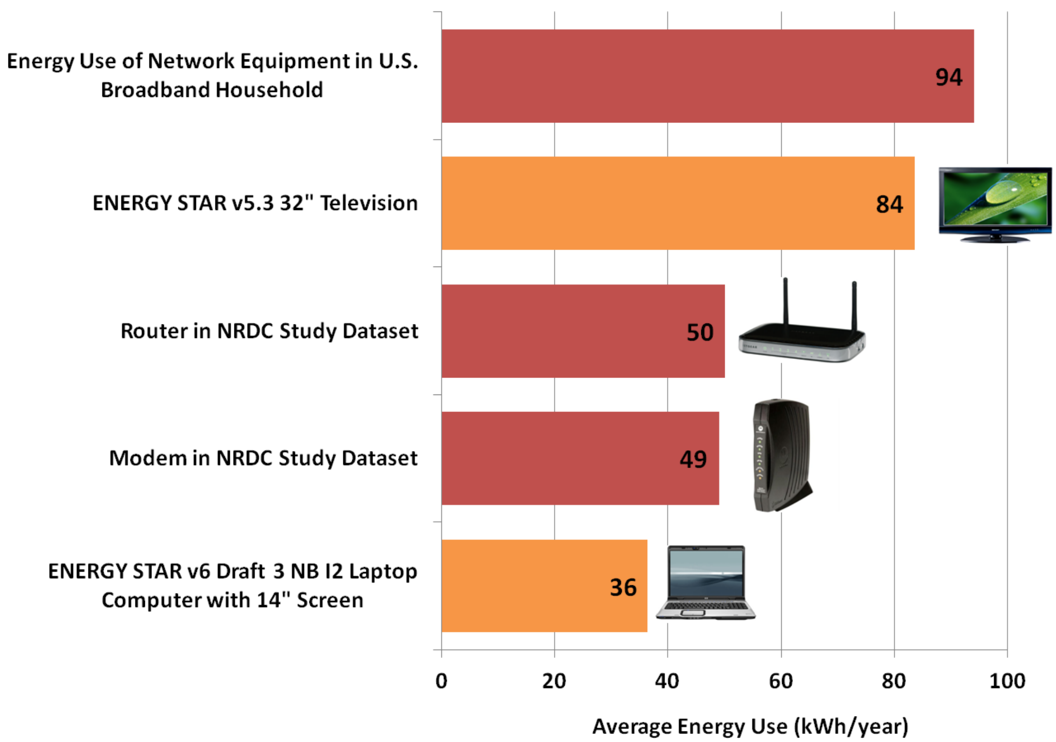
- ODUs powered by a household's set-top boxes via coax cable scale power as the number of active LNBs within the ODU increases. Each LNB within the ODU serves a distinct group of channels, so increasing the number of different channels tuned will increase the number of active LNBs until all LNBs are active. Limited observations of this type of ODU showed that a 5 LNB set-top box powered ODU drew about 1.25 watt when only one channel was tuned to a maximum of 6.25 watts once all LNBs were active.

- Of the device categories we tested, ONTs draw the most power at 14 to 18 watts, resulting in an annual energy consumption of 123 to 161 kWh/yr (Figure 6). In addition to providing Internet and phone service, some of these devices receive video information for watching TV. They do not, however, replace the set-top box at each TV in the home. Like ODUs, subscribers often leave these devices connected to the exterior of the house even after they discontinue service. Consequently, the consumer could be paying almost $20 a year for wasted electricity.

- Most small network devices draw the same amount of power when sitting idle as they do when transmitting large amounts of data at high data rate.

- Approximately 88 million households subscribe to high-speed Internet service in the U.S. On average, each household operates two small network devices that collectively consume 94 kilowatt-hours (kWh) of electricity annually (Figure 7).

Figure 7: Energy use of network equipment compared to other consumer electronics appliances



IV. NATIONAL ENERGY CONSUMPTION & SAVINGS OPPORTUNITIES

NATIONAL ENERGY CONSUMPTION

The energy consumption of small network devices adds up. In 2012, small network equipment in U.S. homes consumed approximately 8.3 billion kWh of electricity[8], equivalent to the annual output of three average (500 MW) coal-fired power plants.[9] This resulted in 5 million metric tons of carbon dioxide emissions, or the equivalent annual tailpipe emissions of 1.1 million cars.[10-11] U.S. consumers spend $1 billion per year to power their small network equipment.[12] The annual national electricity use of today's small network equipment is nearly equal to the total annual electricity use of all of the households in Silicon Valley.[13] While this study does not quantify the energy consumption of commercial small network equipment, this equipment consumes a significant amount of energy and adds to the savings potential realized through the introduction of technologies and standards that increase the energy efficiency of network equipment.

We calculated the national energy consumption of residential small network equipment by:

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[8] ODU energy consumption is not included in our estimates of national energy consumption or savings potential.

[9] Coal-fired power plant based on a Rosenfeld. A Rosenfeld is the equivalent of displacing a 500 MW existing coal plant operating at a 70% capacity factor with 7% T&D losses. Displacing such a plant for one year would save 3 billion kWh/year at the meter and reduce emissions by 3 million metric tons of CO2 per year as described in: Koomey, J., et al., Defining a standard metric for electricity savings. Environmental Research Letters, 2010. 5(1): p. 014017. http://iopscience.iop.org/1748-9326/5/1/014017/.

[10] Estimated CO_2 emissions from electricity consumption based on 0.6 metric ton of CO_2 per MWh. Energy Information Administration. Table 1. 2010 Summary Statistics (United States). http://www.eia.doe.gov/cneaf/electricity/st_profiles/us.html. Note we use this emissions factor for electricity consumption, taking into account both baseload and non-baseload generation. We use a different emissions factor to estimate potential emissions reductions resulting from savings strategies.

[11] Estimated number of equivalent cars based on 135,207 passenger vehicles per 1 billion kWh of electricity use. U.S. EPA Greenhouse Gas Equivalencies Calculator. http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results.

[12] Assumes national residential electricity rate of 11.72 cents per kWh. U.S. Energy Information Administration. 2011. Table 5A. Residential average monthly bill by Census Division, and State 2011. http://www.eia.gov/electricity/data.cfm#sales.

[13] Total residential electricity use for San Mateo, Santa Clara, Santa Cruz and Alameda counties was 9.3 billion kWh in 2011. California Energy Commission. 2012. Energy Consumption Data Management System (ECDMS), Electricity Consumption by County. http://ecdms.energy.ca.gov/elecbycounty.aspx.

- converting power measurements to annual energy consumption values by assuming these devices spend 100 percent of their time as tested in idle mode;
- multiplying the average unit energy consumption times the estimated stock for each category of network device as shown in Table 1 and Figure 8 below; and
- summing the energy consumption across all six categories as shown in Table 1.

Table 1: Estimated national energy consumption of U.S. residential small network equipment stock

Product Type	Average Power (W)	Average Unit Energy Consumption (kWh)	Units (millions)	National Energy Use (TWh)	Power Plants
Modems	5.6	49	40	2.0	0.7
Gateways	7.7	67	42	2.8	0.9
Routers	5.7	50	53	2.6	0.9
Switches	1.9	17	1	0.0	0.0
Access Points	3.9	34	2	0.1	0.0
ONTs	14.9	130	6	0.8	0.3
		Total	**144**	**8.3**	**2.8**

Modems, routers and gateways are the most common in-home network devices and account for most of the energy used by small network equipment in U.S. homes (Figure 8). U.S. households use few stand-alone switches, which enable consumers to add additional wired devices to their network, or wireless access points, which add wireless access to a wired network or extend the range of a wireless network. Therefore, their contribution to total national energy consumption is low. A growing number of consumers connect to their service provider through ONTs, devices typically attached to the outside of the home which translate optical signals to electronic signals and vice versa for subscribers who have high speed fiber optic service (e.g., Verizon FiOS).

Figure 8: U.S. residential small network equipment energy use. U.S. residential stock is noted below each product category.

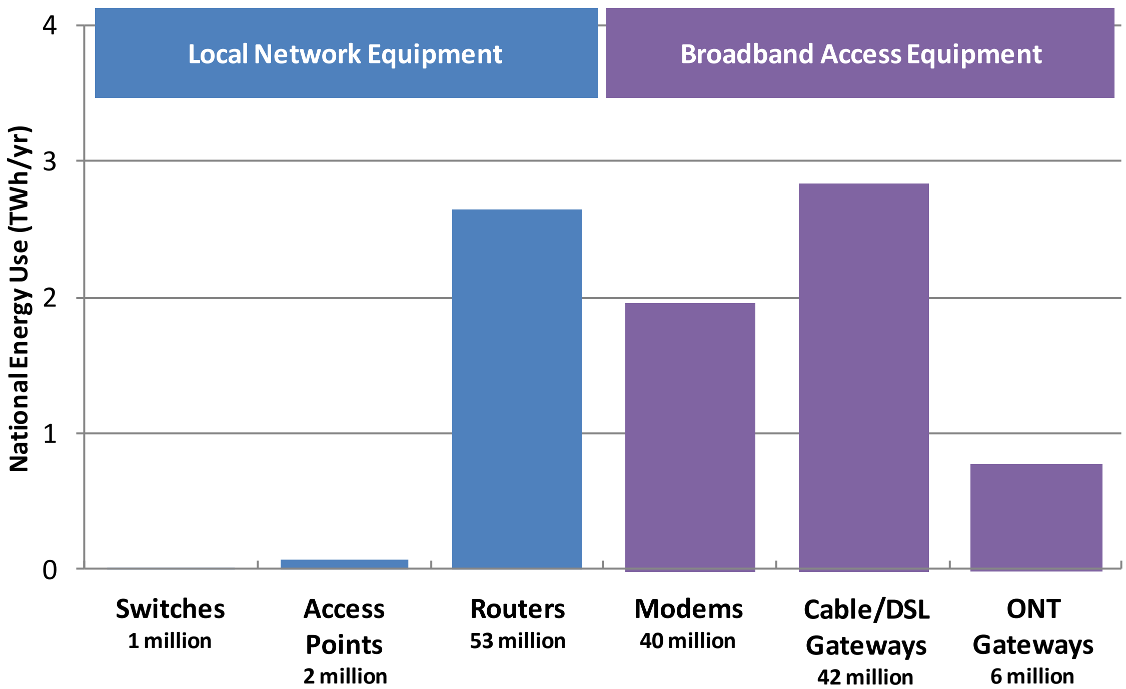


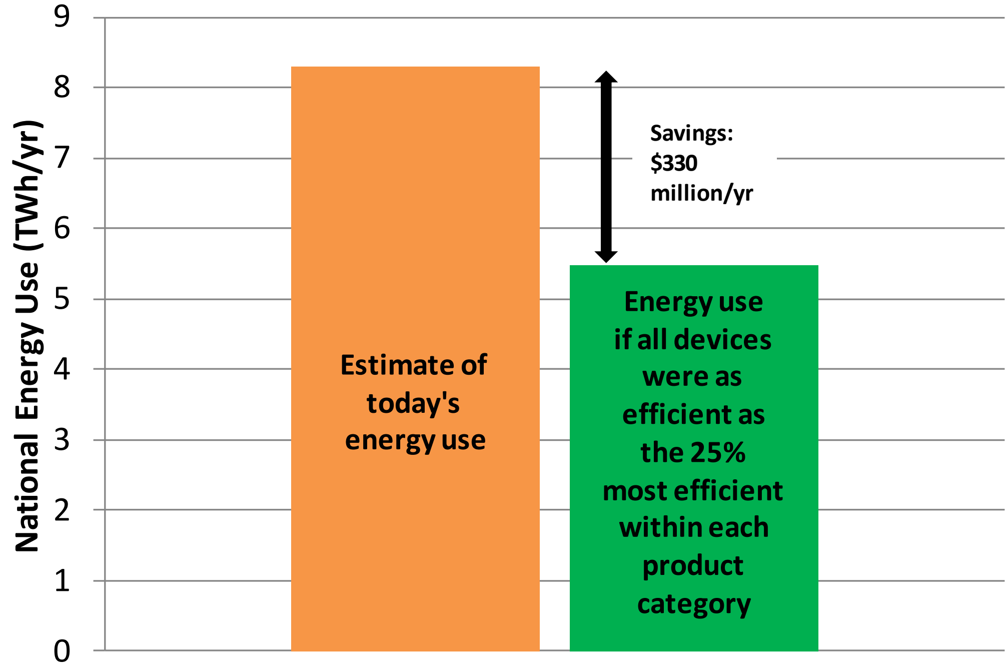
Figure Note: Estimated number of small network devices in U.S. homes in 2012 based on an analysis of market data presented in: Urban, Bryan, Verena Tiefenbeck, & Kurt Roth. 2011. Energy Consumption of Consumer Electronics in U.S. Homes in 2010. Fraunhofer Center for Sustainable Energy Systems. Final Report to the Consumer Electronics Association.

ENERGY SAVINGS POTENTIAL

It is evident from the test measurements that much of the variation in measured power levels within each of the six product categories we used is due to variation in capabilities as opposed to efficiency levels. For example, gigabit per second network devices generally use more energy than their 100 megabit per second counterparts, and cable modems require more power than their Asymmetric Digital Subscriber Line (ADSL) counterparts.

To compensate for feature differences in our analysis, we use ENERGY STAR functional adders and base allowances to feature-normalize power levels. This approach reveals that the 25 percent most efficient small network devices within each product category use less than two thirds of the energy of average models with similar features. Replacing today's stock of inefficient residential small network equipment with efficient models could save 2.8 billion kWh of electricity or about $330 million worth of consumer energy bills per year (Figure 9).

Figure 9: Estimated national energy consumption and savings associated with a shift to the 25 percent most efficient devices within each U.S. residential small network equipment product category



More savings are possible given that industry is in the early phases of development and deployment of power scaling devices. The two primary standards that enable network equipment power scaling are IEEE 802.3az Energy Efficient Ethernet (EEE) and IEEE 802.11e Automatic Power Save Delivery (APDS) for Wi-Fi devices. Few of the network devices that comprise today's stock of residential network equipment have EEE or other energy efficiency technologies. None of the modems or ONTs we tested supported EEE. Of the 23 routers and gateways we tested, introduced in the 2009 to 2012 timeframe, only two supported EEE and only one supported Trendnet's Wi-Fi power scaling technology, so the opportunity to capture additional savings by increasing market penetration of these capabilities appears to be large. Market actors report that EEE will be ubiquitous in the next few years. Furthermore, next generation products with EEE should save even more than today's efficient models, by scaling power in the whole device instead of just in individual ports.

ENERGY-SAVING TECHNIQUES

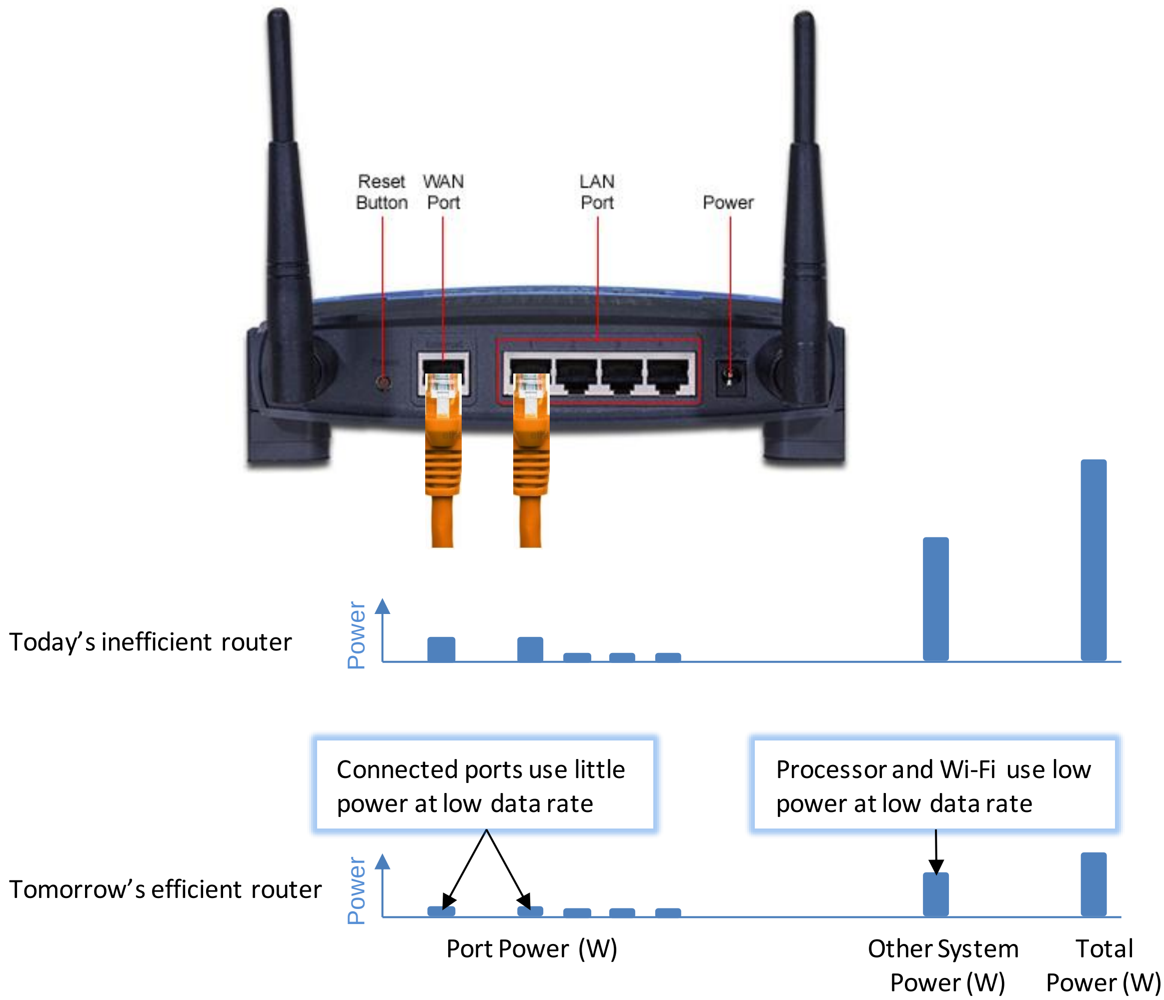
Some of the most efficient devices we tested save energy because they operate at lower power than other products with similar features regardless of the throughput rate. Other devices made the most efficient list because they scale power downward effectively when there is little network traffic. As mentioned above, power scaling methods include IEEE 802.3az Energy Efficient Ethernet (EEE) for Ethernet ports and IEEE 802.11e automatic power save delivery (APSD). Ratified in 2010, EEE enables Ethernet ports and system components to enter a sleep mode called Low Power Idle (LPI) in between data packets when transmitting at less than maximum data rate and both ends of the network link support have EEE enabled. EEE does this without impacting the performance of consumer computing applications. Industry expects near term savings from first generation EEE devices to be 5 to 20 percent of system power at low data rate. Next generation network silicon, designed with power islands, voltage scaling and other power saving approaches, is expected to save up to 80 percent of system power.[14] These savings may more than offset the increase in power draw resulting from the market shift to gigabit per second Ethernet devices.

Wi-Fi power scaling technologies are emerging as well. One manufacturer, Trendnet, has introduced a suite of energy saving features, labeled Green Wi-Fi, that can reportedly save energy by enabling Wi-Fi routers to a) operate at reduced power when no Wi-Fi clients are connected, b) reduce their signal strength when connected clients are in close range, and c) enter a low power states between packets without affecting performance. Trendnet reports that their Green Wi-Fi products use 66 percent less power when unassociated with a Wi-Fi client and 53 percent less when connected but not transferring data.[15]

Figure 10 illustrates the power break-down when comparing an inefficient router to a future router with similar functionality that incorporates next generation EEE with Wi-Fi power scaling. We assume a typical use case where the router is on and connected to a broadband modem through the Wide Area Network (WAN) Ethernet port, to one idle Ethernet client, perhaps a printer, through the Local Area Network (LAN) port, and to one or more Wi-Fi clients that are not actively transferring content. In other words the home network is ready to use but not actively doing anything at the moment.

[14] Cisco. 2011. IEEE 802.3az Energy Efficient Ethernet: Build Greener Networks. http://www.cisco.com/en/US/prod/collateral/switches/ps5718/ps4324/white_paper_c11-676336.pdf.
[15] TRENDnet. 2011. TRENDnet Green Initiatives. http://www.trendnet.com/downloads/GREENnet_Initiatives.pdf.

Figure 10: Conceptual savings example



To benefit from EEE, the devices on both ends of an Ethernet connection, for example a router and a computer, must have EEE enabled. If an EEE-capable router is connected to one EEE-capable computer and another computer without EEE enabled, the router port connected to the EEE computer will scale power to use, and the port connected to the other PC will not scale power to use. Manufacturers enable EEE by default on most compliant network devices. However, EEE was not default-enabled on half of the EEE-capable computers we tested.[16] Moreover, it is difficult to find the software setting to enable it. We confirmed in our lab that network devices that had EEE drew less power

[16] None of these computers were ENERGY STAR qualified.

when transferring data with EEE enabled and more power when transferring data with EEE disabled.

V. POLICY & CONSUMER BEHAVIOR RECOMMENDATIONS

VOLUNTARY LABELING PROGRAMS AND MANDATORY STANDARDS

The ENERGY STAR specification for small network devices will help consumers identify efficient devices and choose service providers that offer efficient home network equipment as part of their subscription packages. The ENERGY STAR program should require EEE in both network equipment and edge devices such as computers and printers. It should also ensure that its test procedure and program requirements reward Wi-Fi power scaling technologies.

State and federal policy makers should consider mandatory energy efficiency standards for small network equipment in order to eliminate the least efficient products from the market. These standards should require EEE on both network equipment and Ethernet edge devices.

International policymakers recognize small network equipment as an important energy savings opportunity. The European Union's (EU) Code of Conduct encourages broadband equipment with Ethernet interfaces to implement EEE and enable the technology by default.[17]

UTILITY INCENTIVE PROGRAMS

Electric utilities should explore ways to provide financial incentives to accelerate the adoption of energy efficient small network equipment. Rebate programs for retail devices (i.e., most local network and some broadband access equipment) might involve lower attribution risk than rebate programs for service provider-deployed devices (i.e., most broadband access equipment). In other words, it may be easier for a utility to prove that its program has influenced consumer purchase decisions than it is for the

[17] EC, European Commission. 2013. *Code of Conduct on Energy Consumption of Broadband Equipment, Version 4.1*. Institute for Energy and Transport, Renewable Energy Unit. http://www.telecom.pt/NR/rdonlyres/523BB1DB-55C9-4929-BA8C-839648106B2D/1463116/CodeofConductBroadbandEquipmentV4_1final.pdf

utility to prove that its program has influenced service provider procurement plans. However, small network equipment has challenging program economics compared to CFL programs. A $3 CFL provides about 60 kWh of lifetime savings compared to an $80 router that offers about 20 kWh of lifetime savings (Table 2).

Table 2: Comparison of CFL vs. small network equipment sample program data[18]

	13 watt ENERGY STAR Qualified Light Bulb	60 watt Incandescent Light Bulb
Purchase Price	$3.00	$0.50
Lifetime	6,000 hours	1000 hours
Number of Replacements in 5 years	0	5
Cost of Replacement Light Bulbs	$0.00	$2.50
Electricity Use (kWh/yr)	15.6	72
Operation Cost (Electricity Cost)	$9	$40
Total Cost	$12	$43

	4.6 watt Efficient Router	7.9 watt Average Router
Purchase Price	$80.00	$80.00
Lifetime	5 years (24 x 7)	5 years (24 x 7)
Annual Electricity Use (kWh/yr)	40	69
5 Year Operation Cost (Electricity Cost)	$22	$38
Total Cost	$102	$118

CONSUMER BEHAVIOR

Until EEE becomes an ENERGY STAR qualifications requirement, consumers should look for devices that are both ENERGY STAR qualified and EEE-enabled to ensure their devices are efficient and support edge device energy savings. Devices with EEE have 802.3az on the box or in online specifications. Manufacturers such as TRENDnet and D-Link have EEE products on the market today (Figure 11).

[18] CFL program data and retail price of electricity (11.09 cents/kWh) from http://www.energystar.gov/ia/products/downloads/CFL_PRG.pdf?6a0f-582a. Router purchase price based on Amazon's top 5 most popular N600 routers. Limited pricing analysis suggests little to no incremental cost for EEE.

Figure 11: Examples of low power, EEE-enabled devices currently on the market. Left: TRENDnet REW-711BR router. Right: D-Link DGS-108 switch.

Consumers can also reduce Wi-Fi transmit power on some wireless devices, can schedule times of day when Wi-Fi turns off, and can use timers to power down network devices overnight or during other periods of regular inactivity. Network devices that support phone service tend to include battery backup to preserve phone service during power outages, most importantly the ability to dial 911, so they should not be powered down without careful consideration.

APPENDIX A: SAMPLING PLAN AND TEST METHOD

MODELS TESTED

Before selecting which devices to test, we conducted a market survey of small network products offered in retail stores and distributed by service providers in the U.S. Our goal was to select products commonly purchased by consumers or distributed by service providers. Within this group of products, we made our best effort to select devices that represented a wide range of energy efficiency and features such as maximum data transfer speed. Table 3 shows how many products we tested in each category by test location, Ecova's lab or in situ in a subscriber's household:

Table 3: Summary of small network equipment tested by Ecova

Product Category	**# tested in-home**	**# tested in-lab**	**total tested**
Modem	7	9	16
Gateway	2	12	14
Optical Network Terminal	2	-	2
Router	-	9	9
Switches	-	11	11
Access Points	-	4	4
Outdoor Units	4		4
Total	**15**	**45**	**60**

TESTING METHODOLOGY

We network devices in the lab where possible in order to ensure accuracy levels consistent with those required by the ENERGY STAR test method. For lab tests, we measured average power (P_{avg}) using a modified version of the ENERGY STAR Test

Method for Small Network Equipment. The key difference between our test procedure and the ENERGY STAR test procedure is that we did not use a shielded box for wireless testing. We merely ensured that a nearby wireless client was connected over Wi-Fi.

For those devices, such as Verizon FiOS ONTs, for which we could not test in the lab, we conducted in-home tests without a calibrated power source or meter; therefore, the accuracy of these test results is lower.

Our ODU test method depended on how the ODU was powered. There are two ways that ODUs are typically powered:

- Set top box provides power to the ODU, sending power up the signal coaxial cable. In this arrangement, the connected STBs power only the portions of the ODU electronics that are required for the channels that are being received
- An external power supply (EPS) provides power to the ODU, usually through a device that inserts the power on the coax at some point between the STB and the ODU. In this arrangement all of the electronics in the ODU is powered at all times

As a result of these differences, we tested these two types of ODUs differently.

- For EPS powered ODUs, a Kill-a-watt meter was installed between the outlet and the EPS, and then power observed in the following modes
    - No STBs connected
    - STBs connected but turned off
    - 1,2,3,4 or more STBs connected and turned on, tuned to first to ESPN HD then Discovery HD, recording power consumed in each configuration
- For STB powered ODUs, Ecova made a DC power measurement in each of the coax cables supplying a 5LNB ODU powered via 4 coax cables
    - The total power delivered to the ODU via coax was measured with a channel selection such that:
        - 1 LNB was active
        - 2 LNBs were active
        - 3 LNBs were active
        - 5 LNBs were active

APPENDIX B: TEST RESULTS

Notes:

1. The products sampled for this study represent a subset of popular models available on the market in mid-2011. We use simple average power values by product category to estimate the national energy consumption of SNE stock, a method that introduces significant uncertainty into our estimates.
2. Products highlighted in green represent products with marketed energy-efficient features.

Product Class	Manufacturer	Model Number	Location of Test	Service Type	Service Provider	Power (W)			
						WAN Test	LAN Test	Wireless Test	ENERGY STAR average power
Router	Cisco	Linksys WRT54GL	Lab	-	-	-	4.6	4.2	4.4
Router	Mediabridge	Medialink MWN-WAPR150N	Lab	-	-	-	2.9	2.9	2.9
Router	TRENDnet	TEW-711BR	Lab	-	-	-	1.8	1.6	1.7
Router	D-Link	DIR-655	Lab	-	-	-	5.7	4.4	5.1
Router	Apple	Airport Extreme (5TH Gen)	Lab	-	-	-	9.0	7.7	8.4
Router	Apple	Airport Extreme A1354	Lab	-	-	-	8.4	7.3	7.8
Router	Netgear	R6300-100NAS	Lab	-	-	-	10.4	9.6	10.0
Router	D-Link	DIR-665	Lab	-	-	-	6.4	5.0	5.7
Router	Netgear	WNDR3400	Lab	-	-	-	5.7	5.3	5.5
Switch	LevelOne	GSW-0807	Lab	-	-	-	0.9	-	0.9
Switch	TRENDnet	TE100-S50g	Lab	-	-	-	1.7	-	1.7

Product Class	Manufacturer	Model Number	Location of Test	Service Type	Service Provider	Power (W)			
						WAN Test	LAN Test	Wireless Test	ENERGY STAR average power
Switch	D-Link	DGS-108	Lab	-	-	-	1.0	-	1.0
Switch	TRENDnet	TPE-S44	Lab	-	-	-	3.8	-	3.8
Switch	TRENDnet	TE100-S5	Lab	-	-	-	2.1	-	2.1
Switch	NetGear	FS605	Lab	-	-	-	2.0	-	2.0
Switch	Cisco	Linksys SE1500	Lab	-	-	-	1.1	-	1.1
Switch	Cisco	Linksys SE2500	Lab	-	-	-	2.6	-	2.6
Switch	D-Link	DSS-8+	Lab	-	-	-	2.7	-	2.7
Switch	TRENDnet	TEG-S80G	Lab	-	-	-	1.5	-	1.5
Switch	D-Link	DGS-1008G	Lab	-	-	-	1.5	-	1.5
Access Point	NetGear	WN3000RP	Lab	-	-	-	-	2.6	2.6
Access Point	Apple Airport Express	MB321LL/A	Lab	-	-	-	-	3.8	3.8
Access Point	Diamond	WR300N	Lab	-	-	-	-	2.1	2.1
Access Point	Uspeed	AK-66UPWNWR-WU	Lab	-	-	-	-	1.8	1.8
Modem	Motorola	SB6121	Lab	Cable	-	6.5	-	-	6.5
Modem	Arris	WBM760A	Lab	Cable	-	5.7	-	-	5.7
Modem	Zoom	5241	Lab	Cable	-	7.8	-	-	7.8
Modem	Motorola	SB5100	Lab	Cable	-	6.6	-	-	6.6
Modem	Cisco	DPC3000	Lab	Cable	-	6.9	-	-	6.9
Modem	Zoom	ADSL 5715	Lab	DSL	-	4.0	-	-	4.0
Modem	ZyXEL	Prestiqe 660M	Lab	DSL	-	3.5	-	-	3.5
Modem	NETGEAR	DM111P	Lab	DSL	-	4.5	-	-	4.5
Modem	D-Link	DSL-2320B	Lab	DSL	-	4.9	-	-	4.9

Product Class	Manufacturer	Model Number	Location of Test	Service Type	Service Provider	Power (W)			
						WAN Test	LAN Test	Wireless Test	ENERGY STAR average power
Modem	Cisco	DPC3008	In-home	Cable	Comcast	6.7	-	-	6.7
Modem	uBee	U10C018.80	In-home	Cable	Charter Communications	5.0	-	-	5.0
Modem	uBee	DOM3513	In-home	Cable	Comcast	6.5	-	-	6.5
Modem	RCA Digital Broadband	DCM425	In-home	Cable	Time Warner	4.2	-	-	4.2
Modem	uBee	U10C035	In-home	Cable	Comcast	6.0	-	-	6.0
Modem	Westell	6100	In-home	DSL	Verizon	4.7	-	-	4.7
Modem	Netopia	Cayman 3300 Series	In-home	DSL	CenturyTel	5.8	-	-	5.8
Gateway	NetGear	CG3000D	Lab	Cable	-	10.1	10.6	9.6	10.1
Gateway	Motorola	SBG6580	Lab	Cable	-	11.0	11.4	10.5	11.0
Gateway	ARRIS	TG862G/GT	Lab	Cable	-	7.0	7.3	6.6	7.0
Gateway	NetGear	CG814WG	Lab	Cable	-	7.4	7.4	7.2	7.3
Gateway	Cisco	DPR2320	Lab	Cable	-	5.5	-	5.7	5.6
Gateway	UBEE	DDW2600	Lab	Cable	-	7.1	7.5	6.8	7.1
Gateway	Actiontec	Q2000	Lab	DSL	-	11.4	11.5	10.8	11.2
Gateway	Westell	VersaLink 7500	Lab	DSL	-	7.1	7.4	6.8	7.1
Gateway	CenturyLink	C1000A	Lab	DSL	-	8.4	8.9	8.1	8.5
Gateway	Actiontec	M1000, W1000	Lab	DSL	-	5.6	-	6.9	6.3
Gateway	2Wire	2Wire 2700HG-B	Lab	DSL	-	7.2	7.4	7.0	7.2
Gateway	Motorola	3347	Lab	DSL	-	6.4	6.7	6.4	6.5
Gateway	Arris	TM302G	In-home	Cable	RCN	5.3	5.4	5.0	5.2
Gateway	Netgear	CG814WG V2	In-home	Cable	Time Warner	7.6	7.8	7.3	7.6

Product Class	Manufacturer	Model Number	Location of Test	Service Type	Service Provider	Power (W)			
						WAN Test	LAN Test	Wireless Test	ENERGY STAR average power
ONT	Tellabs	ONT611	In-home	Fiber	Verizon/Frontier FiOS	14.0	-	-	14.0
ONT	Motorola	ONT1000GJ2	In-home	Fiber	Verizon	18.4	-	-	18.4