Server Supplemental Background Information for the Development of Environmental Performance Criteria

Green Electronics Council

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The International Sustainable Development Foundation (ISDF) commissioned the Golisano Institute for Sustainable Development at Rochester Institute of Technology to undertake background research on the server industry in preparation for future standards development work. The resulting document, *Server Primer: Understanding the Current State of the Industry*, provides background information on server hardware market trends and construction intended to inform the Server Technical Committee and the future working group tasked with developing environmental performance criteria.

In the process of developing its recommendations, the Server Technical Committee (TC) identified additional data needs relative to the composition and construction of servers and to specific environmental performance criteria. This document, *Server Supplemental Background Information*, helps fill this information gap by providing additional data gathered from TC members, as well as a limited number of other experts.

The document poses questions relative to specific environmental performance categories and compiles the aggregate responses of TC members, generally without attribution. The questions and the responses are not intended to be comprehensive.

For the purposes of this document, the definition of servers is the scope the ENERGY STAR draft specification for Computer Servers – Draft 2 Version 2.0, including managed servers and blade servers.

4.1 Environmentally Sensitive Materials

1. **List all types of batteries found in servers, their function, and prevalence (e.g., found in most servers, may be found in servers, or not usually found in servers)?**

Battery Type/Chemistry	Function/Location in Server	Prevalence
Lithium "coin" cell	BIOS, memory, motherboards, "real time clock" (RTC)	All servers
NiMH (Nickel Metal Hydride) battery pack	BBWC/RAID (Battery Backed-Up Write Cache/Redundant Array of Independent Disks) Battery	May be found in servers

2. **LCD screens**
    a. **Are LCD screens found in servers, what function do they serve and if found, how prevalent are these screens in server products?**

LCD screens are not inside the enclosure of individual servers. Some servers and blade arrays may use small LCD screens as a controlling input/output (I/O) device to the server or to communicate identification and diagnostic information.

b. **If present, do the LCD screens typically contain mercury-based light sources or mercury-free technology (e.g., LED)?**

Not applicable.

3. Which of the following chemical substances may be found in servers? For any substances that may be found in servers, what is its purpose/function?

Chemical Substance	Purpose/Function
Mercury	Not found in servers
Hexavalent Chromium	Not found in servers
Lead	Yes, electronic solder and component such as IC chips and connectors. See RoHS exemptions below.
Cadmium	Not found in servers
Please list below any JIG 101 Declarable Substances found in servers. Include their purpose in the right-hand column.	
Antimony trioxide (CAS 1309-64-4) Antimony/Antimony Compounds Arsenic/Arsenic Compounds Beryllium/Beryllium Compounds Bismuth/ Bismuth Compounds Bisphenol A (CAS 80-05-7) Brominated Flame Retardants (other than PBBs or PBDEs) Chlorinated Flame Retardants Di (2-ethylhexyl) phthalate (DEHP) (CAS 117-81-7) Nickel Perchlorate PVC	Specific applications of the substances in the right-hand column were not provided. A general list of applications include: • ceramics • plasticizers • flame retardants • solder • hardware plating • battery coin cells • insulator resins

4. Which substances on the REACH SVHC list are found in servers? For what purpose/function?

Chemical Substance	Purpose/Function
Bis (2-ethyl(hexyl)phthalate) (DEHP) Dibutyl phthalate (DBP) Benzyl butyl phthalate (BBP)	May be found in the coatings of power cables and power distribution units

5. RoHS Exemptions

a. Which RoHS exemptions are applicable to servers?

6(a) Lead as an alloying element in steel for machining purposes and in galvanized steel containing up to 0.35% lead by weight

6(b) Lead as an alloying element in aluminum containing up to 0.4% lead by weight

6(c) Copper alloy containing up to 4% lead by weight

7(a) Lead in high melting temperature type solders (i.e. lead- based alloys containing 85% by weight or more lead)

7(b) Lead in solders for servers, storage and storage array systems, network infrastructure equipment for switching, signaling, transmission, and network management for telecommunications

7(c)-I Electrical and electronic components containing lead in a glass or ceramic other than dielectric ceramic in capacitors, e.g. piezoelectronic devices, or in a glass or ceramic matrix compound

7(c)-II Lead in dielectric ceramic in capacitors for a rated voltage of 125 V AC or 250 V DC or higher

7(c)-III (until 2012/12/31) Lead in dielectric ceramic in capacitors for a rated voltage of less than 125 V AC or 250 V DC

8(b) Cadmium and its compounds in electrical contacts

11 (b) (until 2012/12/31) Lead used in other than C-press compliant pin connector systems

13(a) Lead in white glasses used for optical applications

15 Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit flip chip packages (Tim)

b. Which RoHS exemptions are being claimed by manufacturers for servers?

6(a) Lead as an alloying element in steel for machining purposes and in galvanized steel containing up to 0.35% lead by weight

6(b) Lead as an alloying element in aluminum containing up to 0.4% lead by weight

6(c) Copper alloy containing up to 4% lead by weight

7(a) Lead in high melting temperature type solders (i.e. lead- based alloys containing 85% by weight or more lead)

7(b) Lead in solders for servers, storage and storage array systems, network infrastructure equipment for switching, signaling, transmission, and network management for telecommunications (E.g., Mother board, power supply)

7(c)-I Electrical and electronic components containing lead in a glass or ceramic other than dielectric ceramic in capacitors, e.g. piezoelectronic devices, or in a glass or ceramic matrix compound (E.g., chip resistors)

7(c)-II Lead in dielectric ceramic in capacitors for a rated voltage of 125 V AC or 250 V DC or higher

13(a) Lead in white glasses used for optical applications

15 Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit flip chip packages (E.g., LCI)

- One supplier noted that RoHS exemptions were demonstrated as necessary for servers, commercial equipment, and other data center equipment due to the application and environment these systems needed to operate. As with the case with Pb there have been technical issues with manufacturability (e.g., dual sided reflow and dropped parts), reliability (e.g., 5 yr life assessment through 85/85, or shock/vibe), serviceability (e.g., reduced connector engagement cycling limits serviceability vs. replacement), and performance/interoperability (e.g., degradation of connectors causing increased resistance and thereby impacting performance or data transfer across the interconnect). Though there has been advancements made and may be future technologies addressing these issues, rigorous demonstration of these characteristics and applicability in the data center environments should accompany any recommendation to remove the exemption. Yield loss considerations are part of manufacturability and reliability requirements.

6. Flame Retardants

a. **Are plastic resins used in external parts of any servers? Which parts?**

Server	Plastic Resins in External Parts? (Y/N)	List External Parts Using Plastic Resins
Rack mounted	Yes	For example, slide cover latch, front bezel, rack bezel assembly, chassis, fan covers
Blade	Depends on manufacturer	[None provided]
Pedestal	Depends on manufacturer	For example, front bezel

b. **Do the above external plastic parts of servers contain flame retardants? Which ones?**

Yes, various parts.

c. **Where are flame retardants potentially found in servers?**

PCB laminates, ICs, connectors, cables, plastic clips, mechanical plastic parts such as enclosures, thermo solutions such fans, electrolytic capacitor, essentially any parts with plastics, hard drives, DVD drives, power supplies, ethernet adaptor, enclosure.

4.2 Materials Selection

1. **Approximately how much plastic by weight is in the following types of servers? Note that this is for all plastic in the product. See the verification plastics reporting form used for 1680.1 at http://www.epeat.net/documents/conformity-protocols/annex_1_plastics_materials_form_v1.4.xls.**

Server	Plastic by Weight
Rack mounted	Three server manufacturers provided the following estimates: • Approximately 2KG • Roughly 5% - one example of a rack mount server, including all plastics as a percentage of total weight of server • 10% (without cables, plastic parts on board, e.g., IC, connectors)
Blade	One server manufacturer (also providing bullet 3 above) provided the following estimate: • 5% (without cables, plastic parts on a board)
Pedestal	One server manufacturer (also providing bullet 3 for rack servers above) provided the following estimate: • 15% (without cables, plastic parts on a board)

2. List the top eight to ten (by weight) applications for plastics in servers, the type of resin used, and the amount of resin used in the application. Does this application require a high performance resin that would limit the use of postconsumer recycled content and why?

Manufacturer 1

Application	Resin Type	Plastic Weight	High Performance Resin that would limit use of recycled content? (yes/no) Why?
Slide cover latch	PC/ABS	150 g	Unknown
Fan cover	PC/ABS	150 g	Unknown
Air duct assembly	PC/ABS	600 g	Unknown
Main bezel	PC/ABS	500 g	Unknown
Rack bezel assembly	PC/ABS	300 g	Unknown

Manufacturer 2

Application	Resin Type	Plastic Weight	High Performance Resin that would limit use of recycled content? (yes/no) Why?
Chassis, fan, CPU cover, external shield,	PC/ABS	Largest majority (case and fan)	None known for these parts
Fan case	PBT		None known for these parts
PCB laminate	Glass fiber resins		

Manufacturer 3

Application	Resin Type	Plastic Weight	High Performance Resin that would limit use of recycled content? (yes/no) Why?
Structure part	PP	200g	Yes - Compliance with RoHS
Front bezel	ABS+PC	150g	Yes - Compliance with RoHS

honeycomb in fan box	ABS+PC	150g	Yes - Compliance with RoHS
Dummy blade	ABS+PC	150g	Yes - Compliance with RoHS
Insulation sheet	PC	50g	Yes - Compliance with RoHS
shock absorber	Urethane	50g	Yes - Compliance with RoHS
DIMM/CPU/HDD dummy	PC	30g	Yes - Compliance with RoHS
EMI Gasket	urethane	20g	Yes - Compliance with RoHS

3. Does your company have any experience using postconsumer recycled plastic in servers or similar applications in other products? How does recycled plastic perform in these applications?

One of the 3 server manufacturers providing data has used limited amounts of postconsumer recycled (PCR) PC/ABS in server products. The other 2 manufacturers do not have experience with PCR in servers, but have used PCR in limited applications in desktop computers, monitors, and notebooks. PCR performed adequately according to one of the manufacturers.

4. Is there evidence of environmental benefit from using biobased materials? *(Note: this question was not in the initial questionnaire that was circulated to TC members, but arose later in discussions.)*

A literature review conducted by the Sustainability Consortium found that the bio-based plastic, PLA, is "nominally environmentally advantageous" compared to conventional plastics in laptop housings when considering global warming potential (GWP) from all life cycle stages except EOL. The report goes on to say that the fate and chemical behavior of PLA at EOL are unknown and variable depending on disposition option. The report concludes with a call for additional research before a definitive conclusion can be drawn.[1]

Other LCAs on biobased materials offer additional insights.

- The University of Pittsburgh found that petroleum-based plastics had greater impact in some LCA impact categories while the bioplastics had greater impacts in other categories. For example, the biopolymers were found to be more eco-friendly materials than traditional plastics, due to their biodegradability, low toxicity, and use of renewable resources. Biopolymers, however, were more taxing on the environment in upstream production due to energy use and application of pesticides and fertilizers in farming and chemical processing.[2] This study did not consider material disposition.

[1] Boyd, Sarah, *Bio-Based versus Conventional Plastics for Electronics Housings: LCA Literature Review*, Sustainability Consortium, February 2011.

[2] University of Pittsburgh, "Plant-based plastics not necessarily greener than oil-based relatives, researchers find." *ScienceDaily*, 25 Oct. 2010. Retrieved 25 Jan. 2013 at: http://www.sciencedaily.com/releases/2010/10/101021104741.htm.

- The German Federal Environmental Agency reported that plastic packaging made of renewable resources was not proven to be superior to petroleum-based packaging when evaluating impacts from production through disposal. This conclusion was based on a literature review of 85 LCA studies and professional articles. For example, CO2 emissions and consumption of petroleum were lower for bioplastics. However, bioplastics have greater environmental impacts in other areas, particularly through the use of fertilizers in farming, which causes eutrophication of water and acidification of soil to a greater extent than in the production of common plastics.[3]

According to one TC supplier, a key take away based on these studies is that more research is needed on biobased materials in electronic products.

4.3 Design for End of Life

1. **Is there evidence that Design for EOL requirements in today's standards are having a positive impact?**

   Three electronics recyclers provided their perspectives:

   - Generally speaking, yes. There are many more products with simple fasteners, fewer embedded materials, and modular parts. This is particularly true in the server category. I'm not sure if improved disassembly and recycling opportunities in servers are the result of DFE approaches, but recycling is fairly simple for servers nonetheless. There are other product categories with mixed results on Design for EOL. Namely, mobile products that are glued together.
   - Yes, serviceability and teardown has improved on newer servers vs. older. This is more apparent on some makes and models. The number of screws has been reduced and the number of latches (not requiring tools) has increased. I am not sure this is as a result of EOL design requirements though.
   - We are not seeing a lot of change with regards to design considerations around EOL. Certainly, the swapable nature of drives, power supplies, and modules in servers assists greatly at end of life. However, we consider these changes as design characteristics for repair and upgrade and not specifically for EOL.

2. **Would the removal of the criterion 4.3.2.1- Use of single recyclable plastic type per plastic part - inhibit recovery of plastics from servers? Would it negatively impact the market?**

   Feedback on this question was solicited from TC members as well as additional electronics and plastics recyclers. The responses illustrate a divergence of opinion on this issue.

   Manufacturer Perspective (1 response)

   - Technology exists today that suggest removal of 4.3.2.1 would not inhibit recovery.

[3] German Federal Environmental Agency, "Bioplastics not superior," Press Release, 037:2012. Retrieved 25 Jan 2013 at: http://www.umweltbundesamt.de/uba-info-presse-e/2012/pe12-037_bioplastics_not_superior.htm

Electronics Recycler Perspectives (3 responses)

- The vast majority of plastics are aggregated as a mix and processed for low grade recycling applications. More and more automated shredding processors recover plastic scrap from the end of their line, so all plastics are eventually mixed together and sold as an aggregate. Companies using manual disassembly typically do not have the capacity to sort into various grades of plastic, so recovered plastic is marketed as a mixed aggregate. This is not to say that technology may eventual be developed to enjoy the benefits of separated resins to optimize recovery potential, but such separation processes are not currently commercially available.
- This would definitely affect companies that do manual teardown for plastic recovery more than companies who use shredding or automated sorting. However, metals implanted in plastics and/or plastics that are green in color and /or very reflective can have undesired results when using automated sorting technology. However, the less types of plastic used overall improves the quality and value of the marketed plastic, and reduces the cost of recycling.
- As long as the pieces were separable, it should not have a large negative impact. Servers are typically recovered in a manual disassembly process. If the plastics were not fused, glued, or otherwise difficult to separate, it should still be possible to create clean plastic streams.

Plastics Recycler Perspectives (2 responses)

- Removal of the criteria would challenge the recovery of the plastics to its highest value.
- It wouldn't really negatively impact the plastics recycling market. While we understand the intention, it is unnecessary given how end-of-life electronics are being recycled around the world. We work mostly with large recyclers that use automated recycling approaches and recycle more than one type of product from more than one manufacturer. This criterion wouldn't help them as far as we can see. This criterion would ONLY help if nearly every single IT device from every single OEM used ONLY the same 3 easily separable and recyclable plastics. No electronics recycler we know handles only one product from one time period from one manufacturer. Even within a given manufacturer and given "type" of product from that manufacturer, the types of plastics could vary between products over dates and still meet this criterion. In the real world recyclers handle equipment from many different manufacturers and different product types. Even if all manufacturers met this criterion individually, the recycler could still be face with MANY more than 3 types of plastics. For example, the following list only contains 3 plastic types that could be found in a single product, but they are ALL different from one another and some must absolutely be separated from others: PC/ABS, FR PC/ABS, ABS, FR/ABS, high heat ABS, PP, two different filled PPs (one with talc and one with calcium carbonate). There is also no guarantee that they can be "easily separable" or "recyclable" from one another.

3. **Do servers contain plastic parts >100 g with adhesives, coatings, paints, finishes, or pigments associated with surface coatings? If so, are they incompatible with reuse and recycling? (Criterion 4.3.3.2)**

   There was a divergence of opinion on the "compatibility" of surface coatings with recycling as summarized below.

Manufacturer Perspectives (3 responses)

- Some plastic parts may contain surface coatings, although it is not believed that these coatings would impact recyclability of parts.

Electronics Recycler Perspectives (3 responses)

- There is currently no evidence that downstream plastic processors are significantly limited by the contaminants listed in this question. Large concentrations of adhesives can go up plastic recycling systems, but we are not aware of this being an issue in servers.
- These are contaminants and are generally not compatible with plastic recycling streams. Their use should be avoided or minimized to the extent possible.
- The use of adhesives and coatings can inhibit the recycling of server plastic.

Plastics Recyclers Perspective (1 response)

- We find some coatings and adhesives from EOL electronic plastics are incompatible for reuse in higher value applications. We need to encourage the use of compatible adhesives and coatings where possible.

4. Do any recyclers use plastic type identification markings? Are they likely to in the future?

None of the companies surveyed use the plastic markings for identification and sorting of plastics, although they are aware of companies that do use the plastic markings. Several commenters noted that the plastic markings tend to be unreliable and inefficient for sorting. Further automated sorting is anticipated in the future.

Manufacturer Perspective (1 response)

- Information from major recyclers is that they do not use markings in their process. Use of markings in the future is doubtful.

Electronics Recycler Perspectives (3 responses)

- I am not aware of any automated or manual disassembly recycler that relies on plastic type identification markings to sort plastic at this time. The stamps are not reliable and it is not efficient to read and sort based on these markings. In the future, I would expect plastic to be automatically sorted by optical sorters or spectrometry, which would be more effective at identifying resin type and is used in automated single stream recycling facilities for plastic sorting already.
- We do not. However we have seen hand sorting operations use them.
- These markings are still used, but are less likely to be used in the future as automated separation technologies become more economically viable.

Plastics Recycler Perspectives (2 responses)

- We don't find value in the plastics type identification since our process is not a manual sort. Some manual plastics recyclers use the plastic type identification during sorting. However we have found the identifications not reliable.

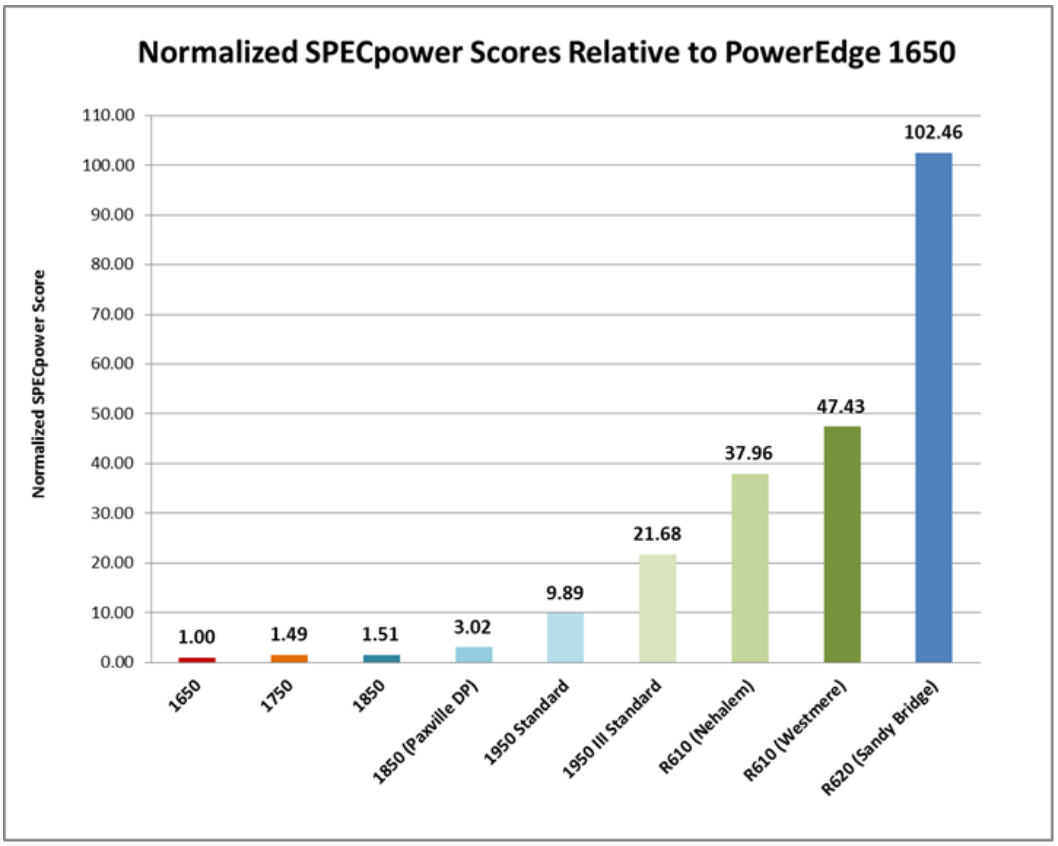
- No recyclers that I know use the plastic markings for sorting. However, I do see recyclers and others from time to time examining parts to learn what they are made from (the marking is not always correct, which is part of the problem – but it usually is). Then the recycler, if he has a lot of parts that look similar might assume that they are all this material. Even if the first marking was correct, this might not be sufficient as OEMs and molders often change materials in the same part (and sometimes also forget to change the material type marking when they do). Molders, particularly in developing countries, might substitute a lower priced material without saying anything. Nevertheless, I see no PROBLEM with having companies mark parts by the type of material (most of our customers do this). There are some small benefits and some small risks with this practice as described above.

4.4 Product Longevity

1. **Is data available that document energy efficiency between generations of servers that make the case for how hard to encourage product life extension?**

   Three server manufacturers provided their perspectives.

   - Server product energy performance as measured by existing performance/power calculations is improving 25 to 90% per product cycle depending on the product and the type of workload supported. In general, a product cycle is 12 to 24 months for servers with 4 processor sockets or less and 24 to 36 months for server products with more than 4 processor sockets. In addition, power management capabilities have generally improved from generation to generation of product so that if these functions are deployed by the system user (which may not happen) the quantity of power used when no workload is present also reduces by 5 to 10% for each generation of product.
   - From IT ECO declarations; conservative energy consumption estimates for determining cooling needs for specific system configurations can be determined using the HP Enterprise Configurator at http://h18004.www1.hp.com/products/solutions/power/index.html.
   - SPECpower is an industry benchmark for measuring a server's performance per watt. The chart below shows SPECpower results for multiple Dell PowerEdge server generations (12th generation through 6th generation) with all scores normalized to a 6th generation server. As evident by the 102x improvement during this time frame, significant improvements have been made in power consumption to complement the performance gains.



One institutional purchaser's perspective:

- For life extension, there may be short terms gains on components such as memory, CPU, and drives but it pushes against Moore's Law. There may be opportunities to look at fairly static components such as the chassis which may be designed for longer multigenerational use, and thereby stretch the product's embedded energy.

2. **Do energy efficiency evaluations of servers include a complete evaluation of upstream energy use (e.g., mining, production of components, etc.)?**

   Note: the Server Primer includes a review of several carbon footprint analyses conducted by server manufacturers.

   - Two studies show the significant contribution (>85%) from the use phase of server equipment.
   - According to one manufacturer, there is no viable and accurate methodology to ascertain the energy inputs required to create and assemble all of the various parts of a server system. A server can consist of hundreds (a one processor socket system) to thousands or tens of thousands (four processor socket systems) of individual parts, sourced from multiple suppliers (in many cases a specific part will be purchased from two or more suppliers to insure continuity of supply and multiple sources). The suppliers who build these parts sell the parts to tens or hundreds of customers and parts for a product may be purchased through supply chains that are 3 to 6 suppliers deep.

An example would be a memory card for a server. You have raw materials (level 1), which are processed into materials and gases to be used in manufacturing (level 2), you then create the semiconductor, package, regulators, capacitors, circuit board, etc. (level 3), you put semiconductors, capacitors and regulators into packages (level 4), and then all of the necessary components from levels 3 and 4 are assembled into a memory card (level 5) and finally are assembled into a server (level 6). Additionally, the processing and manufacturing operations take place around the globe with grid factors ranging from .064 Metric Tonnes of CO2 per MWH in Brazil to .743 MT of CO2 per MWH in China. Then you have 10's of these cards and other components and products in the server and thousands of different ways to combine components and create a configuration for a given server machine type.

The process of estimating, allocating, and calculating an embedded energy use or CO2 emissions has so many permutations and uncertainties that you cannot create a meaningful approximation of this value for the machine type yet alone the actual configuration being purchased. The best you can do is generate a general estimate of the embedded energy for a given product type (one socket server, two socket server, etc. with a "typical" configuration).

In 2010, IBM collaborated with Carnegie Mellon University (CMU) to complete a case study investigating the uncertainty and variability associated with calculation of the greenhouse gas emissions associated with the life cycle of a rack-mount server product. The results of the study verified that greenhouse gas emissions associated with the operation of the server throughout its useful life dominated the full life cycle carbon footprint. This "use phase" of the server accounted for an estimated 94% of the total greenhouse gas emissions associated with the product. However, while the study confirmed the importance of server energy efficiency on the product's overall carbon footprint, it also highlighted the large uncertainties in quantifying the server's carbon footprint. The study estimated the overall uncertainty for the carbon footprint of the selected sever product to be +/- 35%, with uncertainties associated with product use of +/- 50%.

Given the high degree of uncertainty in calculation of supply chain (upstream) carbon footprints and the fact that they represent only a small part of the total carbon footprint of a server, it's not worth investing resources and efforts in this area.

3. **Which components in servers are typically replaced during the product's service life?**

Manufacturer Perspectives (4 responses)

- Parts that are changed (with widely varying degrees of ease and invasiveness) include: hard drives, DRAM memory, power supply, fan, processor, motherboard, and option cards.
- PSUs, fans, HDDs, and memory due to failure, but failure is not typical. Customers may add/upgrade PCIe adapters, memory configuration, or hard drives.
- None.
- Upgrades of installed server systems are possible. Most of our server products provide an upgrade path for new processor, memory, storage or network technologies. Many customers purchase partially populated systems, such as buying a 4 processor socket server with 2 processors installed, to provide expansion capability to support expected future growth or changing requirements. As demand increases or additional workloads are added to the

servers, companies will add processors, memory, storage, and I/O to an existing server system. Some customers will also upgrade technology (install a more capable, compatible processor, or replace an 8 GB DIMM with a 32 GB DIMM to get more memory capacity) to expand system capability. These cases are much less common than the population of space sockets and slots, but do happen in some cases.

While most Server systems are designed to be highly configurable and upgradeable, many users do not upgrade systems due to cost, risk of system incompatibilities, and risk of unplanned downtime. Following are some additional considerations affecting the upgrade and replacement of parts in Servers.

a) Technology is changing at a sufficient pace to complicate upgrade pathways for existing systems. Changes in firmware, component capabilities, etc. can introduce complications for upgrades that can create unforeseen problems and downtime.

b) As a system ages, the likelihood of a component or other type of failure increases making the investment in a new part "risky" as you may end up having a system fail due to a non-upgraded component.

c) Because of items 1 and 2, upgrading an on-line server introduces reliability risks that a data center operator cannot accept where a system is supporting a specific set of applications.

d) The cost of replacing individual parts is prohibitive when compared to the cost of just buying a new server. This is more relevant for one and two socket x86 boxes as opposed to a 4 socket x86 or power box, but in general the risks discussed in items 1 through 3 above plus the higher cost of individual parts outweigh the cost savings associated with upgrading only a portion of the server parts.

Institutional Purchaser Perspective (1 response)

- Although you could make the argument that all FRU's (Field Replaceable Units) could qualify, I have typically seen the following components replaced, roughly in this order: power supplies, fans, drives, memory, and CPUs.

Electronics Recycler Perspectives (3 responses)

- We recovery and resell the following, if functional and if there is market demand (e.g., not obsolete):
    - Memory
    - Hard drives
    - Whole servers (which are G4/G5 or better)
    - RAID card (if not integrated into the board)
    - Processors (though there are limitations due to various slot designs and slot requirements)

  We can recover for repair the following components of servers. We replace damaged parts with harvested parts from cannibalized machines.

    - Memory
    - Fans
    - Power supplies

- During the service life, fans, power supplies, hard drives typically fail in first six months, or not at all before HDD or the server is obsolete. During refurbishment, usually hard drives due to data security.
- Our experience is as follows:
    - Hot swap power supplies. Power supplies can easily be replaced. Many servers also take multiple power supplies. Additional power can be added for back up or additional power. Power supplies are one of the most problematic components in a server
    - Motherboards are the most common failed component in a server.
    - Hard drives often fail during the initial product life and are easily replaced.
    - Processors, memory, and feature cards can also fail, however they are far less likely than the items above.

    Note: A few external factors not related to the servers normal use can also affect the servers longevity. A power surge or a lightning strike to the servers hosting building can affect the longevity of any of the server's components.

4. **Which components in servers can be upgraded to extend the product's service life?**

   Manufacturer Perspectives (4 responses)

- In a server that has a 1-year warranty, very little outside of the basics can be easily upgraded. Processors and memory can be upgraded, but they will not have the best quality sockets, so it easier to damage them during repairs. Power supplies and fans might not be designed for easy repair. This is one reason that I suggested that 3-year warranties be considered as a bonus point in the standard.

  In a server that has a 3-year warranty, processors and memory have easily serviceable sockets. Power supplies and fans are usually hot pluggable. Diagnostic displays inform the owner about what parts have failed.

  Blade servers are a little more complex. The blade enclosures are designed to handle many generations and types of blades, and they must be able to hot plug (add and remove) blades, networking components, fans and power supplies. The blade servers could either be low cost, short warranty, low serviceability or higher cost, longer warranty, better serviceability. The customer is always right, when it comes to economics.
- Customers may add/upgrade PCIe adapters, memory configuration, or hard drives. CPU upgrades are rare but occur. PSUs could be upgraded, but again, I don't think this is typical.
- HDD.
- See answer to question 3 above. Also attached (below) is a product guide for a typical 2-socket server which details configuration and expansion capabilities. As demonstrated, Servers are highly configurable and upgradeable. However, as mentioned above, users may not avail themselves of upgrade possibilities due to a variety of considerations.

Institutional Purchaser Perspective (1 response)

- The chassis could be made to span a greater number of generations. Generally speaking, current chassis typically last 1 generation since they are heavily tied to the power and heat requirements of the CPU. They also tend to be vendor specific and proprietary. The cost per watt savings of the next generation, sometimes along with increasing costs on service contracts to encourage you to move to the next generation, will typically encourage you to opt for replacement. Upgrades are more for short term deficiency fixes. A second tier customer who may not be able to afford the front end capital investments may be interested – even though the energy costs differentials, along with other operations, maintenance, and reliability risk, etc. may more than offset the initial costs.

Electronics Recycler Perspectives (3 responses)

- More memory, larger hard drives. It's difficult to upgrade processors due to design of product enclosure.
- RAM - Often the server is not maxed out on the amount of RAM it can use.

  CPU - often the server has 1 CPU and can be upgraded to 2.

  Hard drive - increases in file size demands have driven capacity requirements up.
- Memory is a common upgraded component of a server. It is commonly added during the units initial product life and as well as during its re-marketing life.

  Hard Drives are also easily upgraded in the same manner as memory. Hard drives can be upgraded in the size of their storage capacity as well as by the speed they process and store data.

  Processors are easily and commonly upgraded like memory and hard drives.

  Motherboards can be upgraded in some servers. However, this is not as common as the items listed above.

  Power supplies. See product longevity response.

  IO or connectivity cards can be replaced and or upgraded to give a server faster through put of data. For example, upgrading from a 2GB HBA card to a 4GB HBA card can enhance the speed of data flowing to and from a server.

  Hard drive controller cards can also be upgraded. They can enhance the speed data is stored and retrieved from hard drives in a server.

4.5 Energy Conservation

1. **What are server mortality rates at higher temperatures?**

- According to one manufacturer, there is increased mortality, as specific components such as hard drives and processors and circuits, experience increased failure rates. ASHRAE has now established temperature and humidity defined as A1, A2 (80°F/27°C), A3, and A4. A2 is currently the standard most often used in enterprise data centers. There are some servers available which can perform reliably at A4 and they are typically found in the Telco space. Companies are bringing more server systems qualified to operate in A3 or A4. However, this standard should not set A4 as a universal requirement as there are significant issues for servers with a high level of Reliability, Availability, and Serviceability requirements which cannot currently run reliably over the A2 standard for extended periods of time. The typical warranty period is 200 to 300 hours of operation above the specified standard before the warranty becomes void.

  The table below provides data published by IBM in their latest Thermal Guideline book for volume servers based on inlet air temperatures. The data was obtained from a large model that x86 guys use in predicting failure rates.

Temperature Impact on Volume Server Hardware Failure Rate			
Dry Bulb Temp (°C)	Failure Rate X-Factor		
	Lower Bound	Average Bound	Upper Bound
15.0	0.72	0.72	0.72
17.5	0.80	0.87	0.95
20.0	0.88	1.00	1.14
22.5	0.96	1.13	1.31
25.0	1.04	1.24	1.43
27.5	1.12	1.34	1.54
30.0	1.19	1.42	1.63
32.5	1.27	1.48	1.69
35.0	1.35	1.55	1.74
37.5	1.43	1.61	1.78
40.0	1.51	1.66	1.81
42.5	1.59	1.71	1.83
45.0	1.67	1.76	1.84
Note: Relative Hardware Failure Rate X-Factor For Volume Servers As A Function Of Continuous Operation			

The minimum required supported range for server inlet temperature should not be increased to ETSI EN 3.1 or the recently announced ASHRAE A4 class. This wider range of environmental support is not required to deliver significant increases in efficiency and carbon emissions reductions. The higher operational range as defined by ETSI EN 3.1 or ASHRAE A4 has potential to increase energy efficiency for data centers located in the very hot regions beyond what can be achieved with the ASHRAE A2 standard. However, this is only an incremental improvement on the order of a few percent over what can be achieved with the ASHRAE A2 Standard. Similar energy reductions could be achieved in hotter regions through better site selection for new data centers.

Accelerated introduction of ETSI EN 3.1 would have both a technical and cost impact on the majority of clients we work with, with very limited benefit in energy and emissions reduction. Only a small proportion of IT equipment is supported and warranted to the ETSI EN 3.1 standard and products are limited in performance compared to volume product ranges and incur a price premium. This greatly restricts user choice and imposes additional equipment acquisition costs on customers in a given product specification scheme.

In our opinion, the IT technology evolution should deliver improvements in equipment support for higher environmental ranges in the short to medium term. We expect some equipment conforming to the ASHRAE A3 guidelines (10 to 40C) operation to be available beginning late in 2012 or early 2013 and that within two to three years a majority of the products available will support this range. As ASHRAE A3 capable equipment becomes more universally available, the standards development team should consider modifying the requirements recognizing that the change will primarily offer benefits to data centers located in warmer climates and that many legacy data centers that can operate to the A2 standard may not be able to easily adapt to the A3 standard.

Institutional Purchaser Perspectives (2 responses)

- See The Green Grid (TGG) presentation (by Steve Strutt of IBM) at http://www.thegreengrid.org/~/media/Presentations/2011EMEATechForum_TheEffectofDataCentreEnvironmentonITandEnergyConsumption.pdf?lang=en

  Essentially, there are other factors at play than just failure rate, when the operating temperature in the data centre goes up. My interpretation of the paper is that although the failure rate of servers increases, even then you are probably within acceptable limits even with occasional ambient temperatures up to 35 degrees C.

- Our engineers haven't found mortality from heat-related failures to be a big problem.

4.6 End of Life Management

1. **What typically happens to servers, their components and materials at the end of their service life? Who handles/processes? Which components/materials are reused vs. recycling?**

   Institutional Purchaser Perspectives (2 responses)

   - Organizations may first decide to move equipment from the production environment into a test/development environment or may retain a certain amount for legacy support. The immediate need for equipment may overshadow longer-term costs. Next they may scavenge servers for reusable parts (memory, drives, fans, CPU, redundant power supplies), remove drives for data destruction, and then transfer the remaining material, along with unneeded collected material), in either a functional or nonfunctional state.

   - Our company has an entire process for hardware; servers are redeployed based on our performance engineering team's recommendations. We also donate to universities and schools if the gear has been retired from our company but is still valuable to the schools. If the equipment is not redeployed or donated it is sent to our global contracted recyclers.

Electronics Recycler Perspectives (3 responses)

- There is an active secondary market to resell whole servers, harvest and recover parts from servers, or disassemble servers for recycling. Virtually all components of a server contain positive recovery value, making it economically attractive for the market to recover these items and keep them out of the waste stream. Servers are reused in whole or part by OEMs, VARs, equipment maintenance organizations and brokers (look at www.processor.com for an active secondary market), or recyclers. It is more likely to reuse memory and hard drives, though processors, fans, and expansion cards also have some reuse value.
- In terms of reuse, and depending on age, functionality and components, they are sold as whole working units or harvested for parts including RAM, CPU, HDDs, accessory cards, case and cosmetic parts. However, these components are harvested for reuse more often due to their relatively small size. Whole servers are expensive to transport.

  If recycled, servers are shredded and sorted into steel, plastic, circuit boards, zorba/aluminum, and wire.
- For the most part, these units are handled by asset management companies to maximize the reuse/resale potential. The units are then demanufactured by that processor or a downstream scrap processor selected by the asset management vendor.

2. What is the extent of aftermarket for servers and components? What limits redeployment in the aftermarket?

Institutional Purchaser Perspective (1 response)

- Redeployment is limited by quality of performance during first deployment, and power consumption. If initial deployment was good often servers are upgraded with larger drives and more RAM and redeployed if the business case supports the cost.

Electronics Recycler Perspectives (3 responses)

- There is a very active aftermarket for servers and server components. They are some of the most valuable items in the reuse stream on a per item value basis.
- There is a robust aftermarket for servers and components (see www.processor.com). One limitation on the server aftermarket is that servers are typically seen as mission critical devices that require high levels of performance. Buyers are at risk when purchasing used servers without a warranty. We often see people purchase used servers and parts as hot swappable backups to bridge gaps when their primary hardware fails OR we see organizations with low budgets that are looking for a better value on server equipment to purchase used.
- IT professionals prefer using new or late model equipment. These have service warranties and are less likely to go down, effecting network functionality. Some companies provide service warranties for used model equipment but late model equipment is in greater demand. Some earlier model equipment can be used for noncritical applications and in developing markets.

3. **What are optimal end of life practices for servers? For example, recovery of critical minerals, etc.**

   Manufacturer Perspectives (2 responses)

   - Most servers are disassembled and materials are recycled. Most server components are readily recyclable in most geographic regions.
   - Gold, rare metals are recovered.

   Institutional Purchaser Perspective (1 response)

   - Optimally if our company deems the equipment to have no value it will be donated or resold and continue the life cycle.

   Electronics Recycler Perspectives (3 responses)

   - Servers should follow the "reuse before recycling" process. There are good reuse options. For recycling, since servers have such high metal content, the end of life goal should be for maximum material recovery in a safe manner. There is less of an issue with hazardous material concentrations in these devices (compared to TVs and laptops).
   - Data destruction as part of recycling and prior to reuse. Recycling should be standard product breakdown into primary commodity streams—steel, plastic, aluminum, copper, precious metals. Batteries must be segregated and recycled separately within the developed world. Precious metal streams are primarily circuit boards, CPUs, RAM. These streams should be sent to recycling within the developed world due to lead, cadmium, and other hazards in these streams.
   - Servers have good material recovery potential, but do require manual disassembly to remove on board lithium batteries prior to any shredding for recovery.

4.7 Corporate Performance

1. **Have any full LCAs on servers been conducted that are, or could be made, available?**

   The *Server Primer* summarizes several carbon footprint analyses on servers. No publically available full LCAs, covering multiple impact categories, were identified.

2. **Are any LCAs on servers available that include the impact of energy versus materials? Comparative analysis of chemical reductions achieved from meeting an energy reduction criterion versus a chemical reduction criterion?**

   No studies were identified.

4.8 Packaging

1. **How are servers typically packaged for delivery to installers (e.g., VARs)? To end-use customers?**

   Packaging depends on a number of factors, including the number of units shipped and whether the servers are purchased pre-assembled.

Manufacturer Perspectives (2 responses)

- Typically, servers are individually packed in a corrugated paper box with enough cushioning material to sufficiently minimize the risk of shipping damage. Large orders will be palletized with stretch wrap and banding.

  There are multi-packs available for some servers like 1 and 1U products. The large pallet sized box requires mechanical handling.

- If we are installing the servers typically 6. To end-use customers it varies. Small companies may take one while large customers will take thousands.

  Dell provided a slide deck that shows some of the typical packaging for a single server, and an attachment that covers their "multi-pack" program.


Dell server packaging info.pptx

Multipk_SS_11.pdf

- How the Server is packaged will depend on whether the unit is installed in a rack cabinet for the customer, or whether it is purchased as an uninstalled Server node. For customers that purchase uninstalled server nodes, they will typically come single packed. However, for customers that purchase nodes installed in rack cabinets, the packaging is for the cabinet itself.

- Single units packaged in corrugated boxes with padding, piled on a crate. Populated rack of servers may be shipped in a custom crate (with padding) on a pallet.

Institutional Purchaser Perspectives (2 responses)

- It can depend on the scale of the purchase, the server, level of customization, and level of pre-configuration. I typically have seen servers and their options and subcomponents delivered to the customer site in many separate boxes for assembly there *unless* the customer has purchased, at additional cost, to have it preassembled. The boxes still are generated but are disposed of before they hit the customer site. Another layer of packaging is then typically generated as the assembled servers are then repackaged again for final delivery to the site.

- One purchaser noted the differences in packaging from two manufacturers:
    - Manufacturer 1 - multipack with 10 servers per cardboard/pallet, minimal foam.
    - Manufacturer 2 – some multipack, 4 servers per cardboard/pallet, some single pack, lots of internal boxes for accessories, lots of foam.

2. What types of packaging and materials are used for servers (e.g., corrugated boxes, HDPE plastic bags, wooden pallets)?

Typical packaging materials include corrugated boxes, some type of foam for padding, and plastic bags, plus wooden pallets for pre-assembled racks.

Manufacturer Perspectives (4 responses)

- Most all products ship in a corrugated paper box with a polyethylene bag and some sort of cushioning. Our company uses low density polyethylene foam, urethane foam, high density polyethylene thermoforms, PET thermoform, and EPS blended materials for cushioning. Wooden pallets are utilized to consolidate shipping containers for ease of handling larger products and-or orders.
- Mainly corrugated boxes and LDPE foam. Most of the industry uses 2.2 PCF but we try to use the 1.7 PCF. Some heavy products use wood bases. We try to use corrugated bases even though this material is subject to more damage.
- Packaging for Servers typically will involve a combination of the following materials. Corrugated cartons and cushions, LDPE bags, EPS, EPP or EPE foam cushions (1 of these) or RHDPE Thermoformed cushions, wooden pallets for consolidation and moving large products, LDPE Stretch Wrap, Polyester Banding, Polypropylene Tape, Corrugated Clips (these are molded plastic fastening devices) and ESD Bags (when necessary).
- Corrugated boxes, HDPE plastic bags, Expanded PE, wooden pallets.

Institutional Purchaser Perspectives (2 responses)

- Many separate boxes for assembly at customer site *unless* the customer has purchased, at additional cost, to have it preassembled) and more (e.g. Styrofoam, other types of plastic bags, ties, electrostatic bags, bubble wrap, straps (metal and plastic).
- Wooden pallets, cardboard, and foam (black, white, pink).

3. Are any packaging materials typically recovered and reused by the manufacturer? Shipment to VAR vs. VAR delivery to end-use customer?

Manufacturer Perspectives (3 responses)

- All packaging materials utilized by our company are considered recyclable. Our main campus along with other campuses, do recycle corrugated and foam packaging materials. Our customers may recycle in their area.
- The LDPE can be turned back into bead form but there are only about 20 places in the US. There is little to no recover in our shipments.
- Typically, no. Exceptions apply for a specific client in a limited geographic area. The common situation is that the same packaging is used for VARs and end customers. Our customer base is worldwide. It is neither environmentally beneficial, nor economically feasible, to return bulky packaging on a global scale for reuse. In addition, our clients require the packaging to be pristine looking and new, and do not react favorably to cosmetically imperfect packaging that has been previously used.

We are working to pilot a packaging reuse project with our nestable thermoformed cushions (which are made from high levels of PCRC, up to 100%), since they are an internal packaging component, not subject to cosmetic appearance issues and because they can be nested (up to 10:1 ratio) for return shipments for less emissions. However, these cannot be used for the entire weight range typical of 1-4 socket servers.

Institutional Purchaser Perspectives (2 responses)

- Due to high value of components and the top priority of maintaining functionality, packing materials are typically not recovered or reused since they are intended to take the brunt of any shipping trauma in order to protect the item(s) within. Just as you would not want to reuse a bike helmet, people may be leery of reusing packing materials. It may be useful to look at overall reduction and/or to improve cradle-to cradle recyclability and make packaging materials of more recovery desirable materials, either for reverse logistics or recovery for profit locally. Perhaps we can take an idea from Henry Ford (who saved on costs by reusing packaging materials into the final product's floor boards) and use packing materials as part of the server or for blanking plates?
- No, most packaging materials are recycled by us.

4. Are there industry standards for packaging materials that are applicable to servers?

Manufacturer Perspectives (3 responses)

- There are no industry standards for server packaging materials.
- Yes, our company utilizes ASTM, TAPPI, and ISO standards for testing and marking packaging. In addition, we develop standards for testing packaging and materials. ASTM and TAPPI standards are utilized for compression testing of boxes for stacking strength. ASTM standards are utilized for cushion curves that are published by foam material suppliers. The handling symbols on the outside of the shipping containers are a combination of ASTM 5445 and ISO 780 icons. Our performance packaging test standard for servers and options is a blend of industry standards and knowledge of our distribution system.
- No. Server Packaging is largely dictated by the fragility of the Server product and the expected modes of transportation. Manufacturers of servers determine for themselves what packaged product testing standards (ref. Shock/Vibration, etc.) they want to use. There are some industry standards available but not all manufacturers use them. The resulting product fragility dictates what packaging materials will most economically and technically provide the necessary product protection.

  Most manufacturers use similar materials as described above but with varying designs. Our company requires all servers to go through unpackaged shock and vibration testing to ensure that they meet a specific ruggedness (fragility) target based on the size of the product. The package design (and amount of packaging) is designed around the fragility of the server. In this way we are able to minimize the amount of excess packaging, while ensuring the product is protected. This builds permanent quality into the product, as opposed to temporary protection that is discarded with the packaging. Note: "Sustainable" packaging material choices such as bio-based plastics, high% PCRC, or emerging novel materials such

as bamboo, mushroom, paper pulp, starch, etc. typically find their first uses in low weight, high volume, low fragility applications which may not intersect well with the 1-4 socket server category.

Institutional Purchaser Perspective (1 response)

- Unfortunately no as servers vary in size and weight, and different business units inside of companies have different specs for packaging.