

**ESTIMATING REGIONAL POWER CONSUMPTION BY
SERVERS: A TECHNICAL NOTE**

Jonathan G. Koomey, Ph.D.

Project Scientist, Lawrence Berkeley National Laboratory and
Consulting Professor, Stanford University

Contact: JGKoomey@stanford.edu, <http://www.koomey.com>

December 5, 2007

Final report

ESTIMATING REGIONAL POWER CONSUMPTION BY SERVERS: A TECHNICAL NOTE

Jonathan G. Koomey, Ph.D.

Project Scientist, Lawrence Berkeley National Laboratory and
Consulting Professor, Stanford University

INTRODUCTION

This technical note builds on previous analysis of total electricity used by servers in the U.S. and the world (Koomey 2007) to estimate the regional distribution of electricity used by servers.¹ The key findings of that earlier study are summarized in **Figure 1**. Total world electricity used by servers and the associated cooling and infrastructure equipment roughly doubled from 2000 to 2005, to about 123 billion kWh. The U.S. comprised about 40% of that total, but the earlier work was unable to split the non-US electricity use into its associated regions. This technical note accomplishes that task.

DATA AND METHODOLOGY

The main task for this analysis was to distribute server electricity use outside the U.S. into its associated regions, which required information about the installed base of servers in those regions. The earlier work upon which this analysis is based (Koomey 2007) relied on data from International Data Corporation (IDC) on shipments and installed base for the U.S. and the World (the installed base figures for individual non-US regions, which are defined in Appendix A, are not available from IDC). IDC does have *shipments* data for individual non-US regions, and this technical note describes how I converted those shipments data into estimates of installed base for each non-US region.

The first step was to subtract the US installed base and shipments data from the World installed base and shipments data from Koomey (2007) to calculate installed base and shipments for the sum of all non-US regions (**Table 1**). Next, I calculated the ratio of installed base by server class in 2000 for all non-US regions to the sum of non-US shipments over the period 1996 to 2000, and the ratio of installed base by server class in 2005 for all non-US regions to the sum of non-US shipments over the period 1996 to 2005 (**Table 2**). These ratios (or “multipliers”) characterize the relationship between multiple years of shipments and the resulting installed base for all non-US regions added together.

As shown in **Table 3**, IDC reports shipment data by server class from 1996 through 2006 for five major regions: U.S., Western Europe, Japan, Asia/Pacific (excluding Japan), and the rest of the world. I converted shipments data (1996 to 2000 and 1996 to 2005) to

¹ For an expansion of that work that also estimates electricity used by networking equipment and disk drives in U.S. data centers, see EPA 2007.

installed base in each non-US region by using the multipliers for non-US regions from Table 2 (this approach assumes that each non-US region behaves in the same manner as the sum of all non-US regions). I then converted the non-US regional estimates to a percentage of the non-US installed base.

I used these percentages to split the non-US installed base by server class (from Table 1) into regions, as shown in **Tables 4** and **5** (for 2000 and 2005, respectively). I took average power used per server for US and the World in 2000 and 2005 directly from Koomey (2007). Next, I derived average power use per server in 2000 and 2005 for regions outside the US using the differences between total electricity use and total installed base for the US and the World (from Koomey 2007). Finally, I multiplied average power used per server by the installed base by server class and region in 2000 and 2005 to get total direct electricity use (billion kWh) in those years.

As per Koomey (2007), I converted total direct electricity use to total electricity consumption (including cooling and auxiliary equipment) by multiplying by a factor of 2.0. This factor is the ratio of typical total data center load to the information technology equipment plug load, and it includes both cooling electricity use and losses in the power delivery infrastructure. Future work should investigate how this multiplier might vary across data center types and geographic/climatic regions.

RESULTS

Figures 2 and **3** show the results of these calculations. Electricity used by servers in the US and Europe comprise about two thirds of the total, with Japan, Asia Pacific (excluding Japan), and the rest of the world each falling at between 10 and 15% of the total. Europe alone accounts for more than one quarter of the world's server electricity. In 2005, Asia Pacific (excluding Japan) jumped from about 10% of the total to over 13%, reflecting the significant growth during that period in China, India, and other Asian economies.

Figure 4 summarizes the annual percentage growth rates in server electricity use by region from 2000 to 2005. Server electricity use in the Asia Pacific region (excluding Japan) grew at a 23% annual rate, as compared to a world average of 16%/year, making this major region the only one with server electricity use growing at a rate significantly greater than the world average. Europe also grew slightly faster than the world average over this period.

Koomey (2007) came to the following conclusions about future growth in server power from 2005 to 2010:

It is particularly difficult to forecast trends in the IT industry. If the current IDC worldwide forecast holds true, installed base for volume servers will grow by more than 50% from 2005 levels by 2010, while mid-range and high-end installed base will decline 20-30%. If power per server remains constant, those trends would imply an increase in electricity used by servers worldwide of about 40% by 2010. If in addition the average power use per unit goes up at the same rate for

each class as our analysis indicates that it did from 2000 to 2005, total electricity used by servers by 2010 would be 76% higher than it was in 2005.

The IDC forecast by region was not available for this analysis. Assuming that the IDC forecast of worldwide installed base is correct, and that trends in power use per server continue to 2010 as they did from 2000 to 2005, the average annual world growth rate in server electricity use for 2005 to 2010 would be 12% ($=1.76^{0.2} - 1$) compared to the 16% per year growth that prevailed from 2000 to 2005. If we scale growth rates in each region (2000 to 2005) by the ratio 12%/16% we can roughly estimate potential growth by region to 2010, yielding total projected electricity use by region to 2010 (this approach assumes that the server installed base trends and power use per server trends don't vary much by region over this period).

Those calculations indicate that the U.S. share of world server electricity use will likely decline from 40% in 2000 to 34% by 2010, the Asia Pacific region's share will increase from 10% to 16%, and the other regions (Western Europe, Japan, and the rest of the world) will maintain roughly constant shares over that period. The absolute electricity consumption for servers in the Asia Pacific Region in this scenario would more than double from 2005 to 2010, with growth equivalent (in capacity terms) to two 1000 MW power plants. Growth for the entire world by 2010 (including the Asia Pacific region) would total more than ten 1000 MW power plants in this scenario.

CONCLUSIONS

This analysis splits electricity used by servers outside the US into regions. The results reveal the predominance of the US and Europe in total server electricity use as well as much greater than average annual growth rates in the Asia Pacific region (excluding Japan) over the 2000 to 2005 period.

If current trends continue, the US share of total world server electricity use will likely decline from 40% in 2000 to about one-third by 2010, while the Asia Pacific region (excluding Japan) will increase from 10% to about 16% (other regions will maintain roughly constant shares of the world total). In this scenario, growth from 2005 to 2010 in the Asia Pacific region's server electricity use would be equivalent in capacity terms to two 1000 MW power plants, while world growth from 2005 to 2010 (including the Asia Pacific region) would sum to more than ten 1000 MW power plants.

ACKNOWLEDGMENTS

I am indebted to Larry Vertal of AMD for suggesting this work, to Andrew Fox of AMD for supporting it, and to Sarahjane Sacchetti for helping to make it a reality. I am also grateful to Dan Pickens and Keven Bremer of AMD and Lloyd Cohen and Vernon Turner of IDC for help in obtaining the correct IDC data. The work was funded by a grant from Advanced Micro Devices (AMD) and supported with in-kind technical support from both AMD and IDC. The original work on which the analysis is based relied on a peer review panel including experts from (in alphabetical order by company) AMD, APC, AT&T, Dell, Ecos Consulting, EIA, EPA, EPRI Solutions, HP, IBM, ICF, Intel, NRDC, PG&E,

RMI, Rumsey Engineers, Stanford University, Sun Microsystems, Tiax, the University of Colorado (Boulder), and the Uptime Institute. Reviewers of this technical note included Evan Mills, Eric Masanet, David Fridley, and Bruce Nordman of Lawrence Berkeley National Laboratory, Kenneth Brill of the Uptime Institute, and John Stanley of UC Berkeley. Any errors are solely the responsibility of the author.

REFERENCES

US EPA. 2007. *Report to Congress on Server and Data Center Energy Efficiency, Public Law 109-431*. Prepared for the U.S. Environmental Protection Agency, ENERGY STAR Program, by Lawrence Berkeley National Laboratory. August 2. (<http://www.energystar.gov/datacenters>)

Koomey, Jonathan. 2007. *Estimating total power consumption by servers in the U.S. and the world*. Oakland, CA: Analytics Press. February 15. (<http://enterprise.amd.com/us-en/AMD-Business/Technology-Home/Power-Management.aspx>)

APPENDIX A: DEFINITIONS FOR IDC'S REGIONS

<i>Region</i>	<i>Country</i>	<i>Region</i>	<i>Country</i>
USA	USA	Rest of World	
Japan	Japan	<i>Central/Eastern Europe</i>	Bulgaria
Asia Pacific (ex. Japan)	Australia		Croatia
	Hong Kong		Czech Republic
	India		Hungary
	Indonesia		Poland
	Korea		Rest of Central + Eastern Europe
	Malaysia		Romania
	New Zealand		Russia
	Philippines		Slovakia
	China		Slovenia
	Rest of AP		Ukraine
	Singapore	<i>Latin America</i>	Argentina
	Taiwan		Brazil
	Thailand		Chile
	Vietnam		Colombia
Western Europe	Austria		Mexico
	Belgium		Peru
	Denmark		Rest of Latin America
	Finland		Venezuela
	France	<i>Middle East + Africa</i>	Egypt
	Germany		Israel
	Greece		Rest of Africa
	Ireland		Rest of Middle East
	Italy		Saudi Arabia
	Netherlands		South Africa
	Norway		Turkey
	Portugal		United Arab Emirates
	Spain		Bahrain
	Sweden		Kuwait
	Switzerland		Oman
	UK	<i>North America</i>	Qatar
			Canada

Source: IDC Worldwide Server Tracker, 2Q07. Sent in email from Lloyd Cohen to Jonathan Koomey on 4 Sept 07.

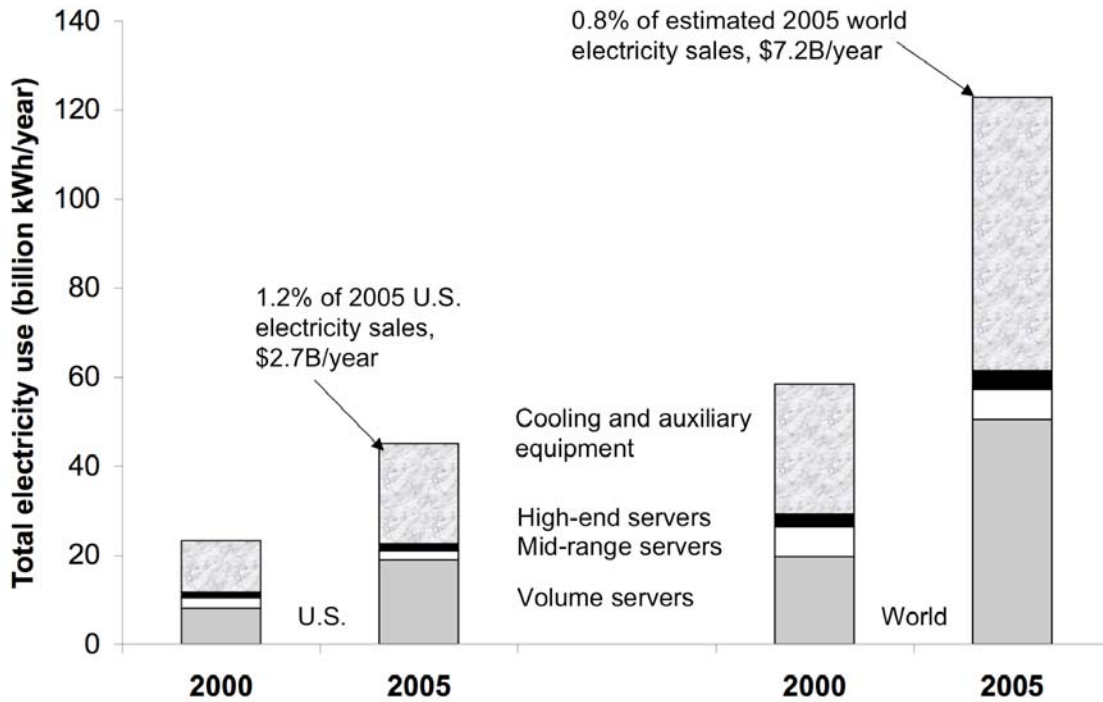


Figure 1: Total electricity use for servers in the U.S. and the world in 2000 and 2005, including the associated cooling and auxiliary equipment (from Koomey 2007)

Sources: IDC data for installed base, shipments, and most popular models, and manufacturer data on power use for individual server models. Total expenditures assume US industrial electricity prices (2006 dollars).

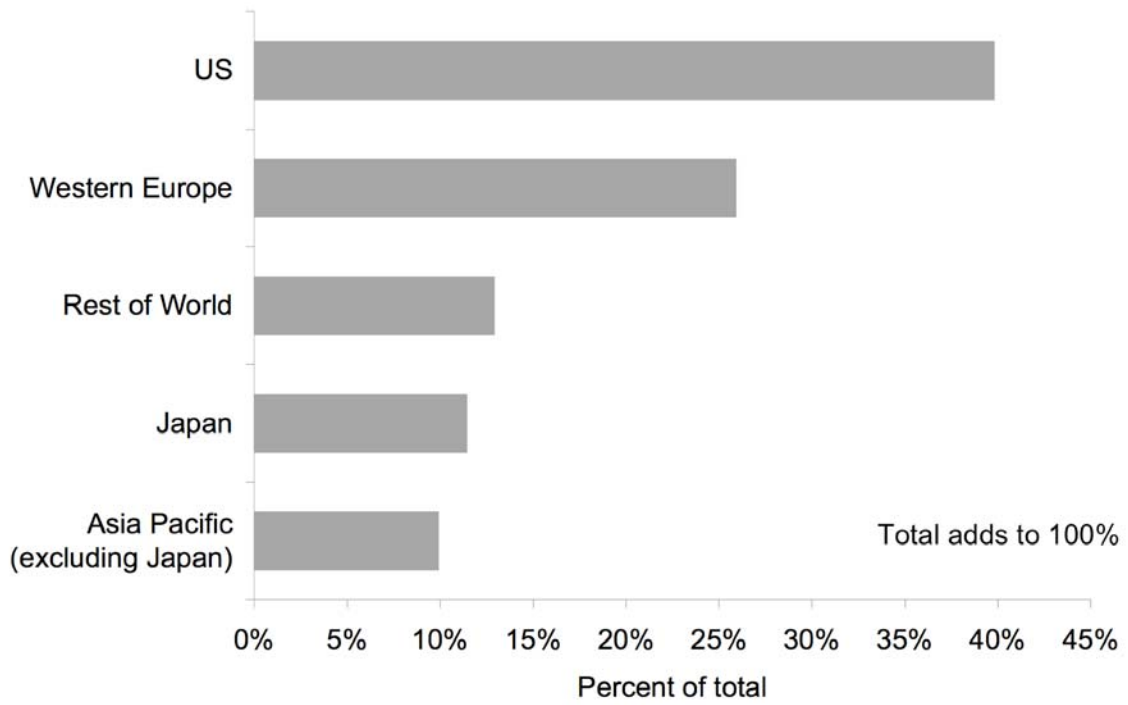


Figure 2: Regional distribution of electricity use for servers in 2000

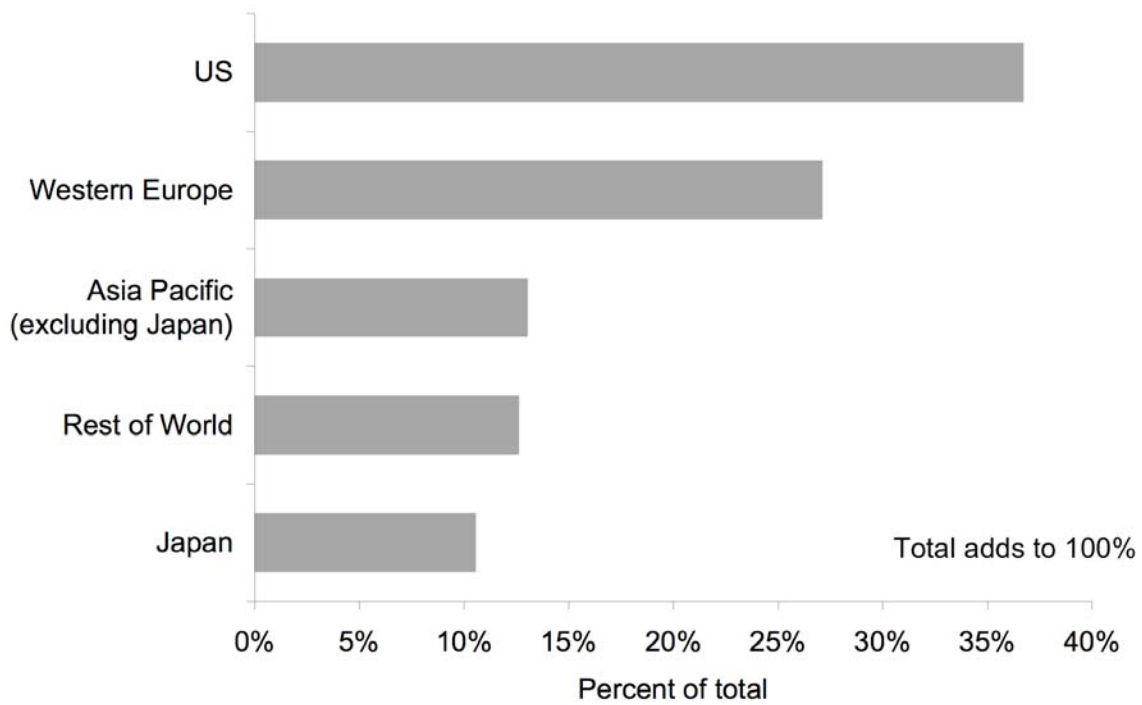


Figure 3: Regional distribution of electricity use for servers in 2005

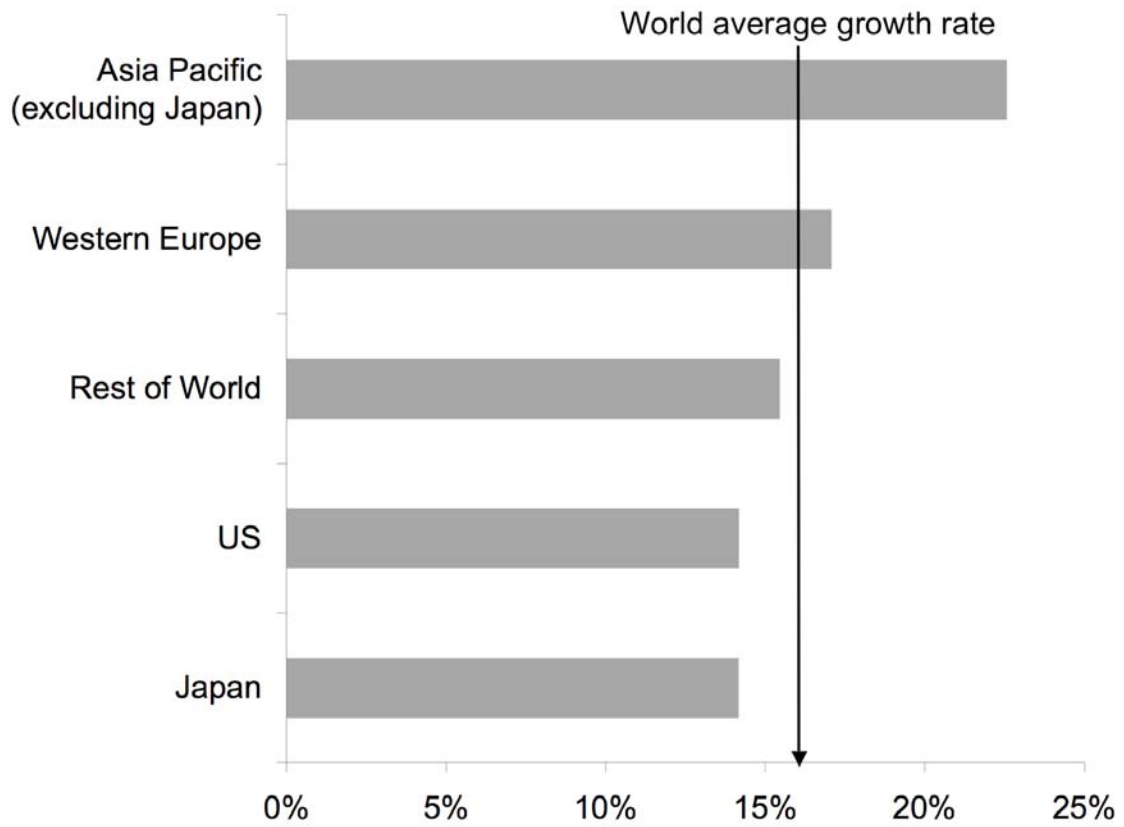


Figure 4: Average annual percentage growth rates in server electricity use by region, 2000 to 2005.

Table 1: Shipments and installed base for servers by class

<i>Shipments (thousands)</i>	<i>1996</i>	<i>1997</i>	<i>1998</i>	<i>1999</i>	<i>2000</i>	<i>2001</i>	<i>2002</i>	<i>2003</i>	<i>2004</i>	<i>2005</i>
<i>US</i>										
Volume Server	442	656	1047	1321	1659	1492	1714	2069	2517	2721
Midrange Enterprise Server	114	149	116	115	111	66	67	76	53	62
High-End Enterprise Server	3	4	4	4	5	4	3	3	3	3
Total	559	809	1167	1440	1774	1562	1784	2148	2572	2786
<i>Rest of World (non-US)</i>										
Volume Server	969	1200	1485	1969	2267	2489	2470	2947	3567	4100
Midrange Enterprise Server	215	239	201	173	173	140	137	135	131	126
High-End Enterprise Server	8	8	9	7	8	7	6	6	6	6
Total	1192	1447	1694	2149	2448	2636	2614	3088	3703	4232
<i>World</i>										
Volume Server	1411	1855	2532	3290	3926	3981	4184	5017	6083	6822
Midrange Enterprise Server	329	389	317	288	283	206	204	211	184	187
High-End Enterprise Server	11	12	13	11	13	10	9	9	9	8
Total	1751	2256	2861	3589	4223	4198	4397	5237	6275	7017
<i>Installed base (thousands)</i>										
<i>US</i>										
Volume Server	1474	1880	2585	3568	4927	5907	6768	7578	8658	9897
Midrange Enterprise Server	591	647	636	668	663	701	574	530	432	387
High-End Enterprise Server	33	26	23	23	23	22	23	21	23	22
Total	2098	2554	3244	4258	5613	6630	7365	8130	9113	10306
<i>Rest of World (non-US)</i>										
Volume Server	2518	3565	5016	6377	7313	9689	9982	10945	14783	16062
Midrange Enterprise Server	981	1096	1094	1122	1146	1189	1109	1009	806	877
High-End Enterprise Server	46	38	47	39	43	47	36	41	43	37
Total	3544	4699	6157	7538	8501	10925	11127	11995	15633	16976
<i>World</i>										
Volume Server	3992	5445	7602	9945	12240	15596	16750	18523	23441	25959
Midrange Enterprise Server	1571	1743	1729	1789	1808	1890	1683	1540	1238	1264
High-End Enterprise Server	78	64	70	62	66	69	59	62	66	59
Total	5642	7253	9401	11796	14114	17555	18492	20125	24746	27282

(1) Source: IDC. Both installed base and shipments data are ISS only (no upgrades). Taken from file IDC_QShare_InstalledBaseForecast2006.xls, sent to Jonathan Koomey by Lloyd Cohen of IDC on 1 February 2007, as presented in Koomey (2007).

(2) Rest of World (non-US) is calculated as the difference between the world data and the US data.

Table 2: Multipliers to estimate installed base from shipments data by region (1)

To apply to 1996 to 2000 shipments for purposes of calculating year 2000 stocks (2)

	<i>US</i>	<i>Non-US</i>	<i>World</i>
Volume	0.96	0.93	0.94
Mid-range	1.10	1.14	1.13
High end	1.16	1.07	1.10

To apply to 1996 to 2005 shipments for purposes of calculating year 2005 stocks (3)

	<i>US</i>	<i>Non-US</i>	<i>World</i>
Volume	0.63	0.68	0.66
Mid-range	0.42	0.52	0.49
High end	0.64	0.53	0.56

(1) The multiplier times the sum of shipments over 1996 to 2000 or 1996 to 2005 will yield an estimate of installed base in 2000 and 2005, respectively.

(2) Multipliers for 2000 are based on US, non-US, and world shipments and stocks for the 1996 to 2000 period (from Table 1)

(3) Multipliers for 2005 are based on US, non-US, and world shipments and stocks for the 1996 to 2005 period (from Table 1).

Table 3: Regional shipments by server class**Volume servers**

	<i>USA</i>	<i>Western Europe</i>	<i>Japan</i>	<i>Asia Pacific (ex. Japan)</i>	<i>Rest of World</i>	<i>Total</i>
1996	442	418	174	171	206	1,411
1997	656	552	216	218	213	1,855
1998	1,047	717	215	262	290	2,532
1999	1,321	918	276	369	406	3,290
2000	1,659	990	348	507	422	3,926
2001	1,492	1,067	423	532	467	3,981
2002	1,714	1,047	369	570	483	4,184
2003	2,069	1,264	406	707	570	5,017
2004	2,517	1,538	477	846	707	6,085
2005	2,721	1,699	546	1,009	858	6,835
2006	2,807	1,764	592	1,163	956	7,282

Mid-range servers

	<i>USA</i>	<i>Western Europe</i>	<i>Japan</i>	<i>Asia Pacific (ex. Japan)</i>	<i>Rest of World</i>	<i>Total</i>
1996	114	87	55	19	55	329
1997	149	86	46	20	88	389
1998	116	83	40	16	62	317
1999	115	70	39	24	41	288
2000	111	65	38	37	32	283
2001	66	59	29	30	22	206
2002	67	56	29	32	21	204
2003	76	58	28	29	19	211
2004	53	58	26	27	20	184
2005	62	55	22	27	21	187
2006	57	56	21	28	21	183

High End servers

	<i>USA</i>	<i>Western Europe</i>	<i>Japan</i>	<i>Asia Pacific (ex. Japan)</i>	<i>Rest of World</i>	<i>Total</i>
1996	3.0	2.3	3.2	0.6	1.5	10.6
1997	4.0	2.5	3.2	0.5	1.7	11.9
1998	4.3	3.8	2.9	0.5	1.7	13.1
1999	3.8	3.0	2.2	0.7	1.2	10.9
2000	4.8	2.8	2.6	1.1	1.7	13.0
2001	3.6	2.7	2.0	1.0	1.2	10.4
2002	3.1	2.9	1.5	1.0	0.9	9.4
2003	2.9	2.6	1.5	0.9	0.8	8.8
2004	2.8	2.6	1.5	0.8	1.0	8.6
2005	2.6	2.3	1.7	0.8	1.0	8.5
2006	2.8	2.2	1.4	0.9	1.1	8.3

(1) Data from IDC via Kevin Bremer at AMD. Filename RegionalServerISSupgradeShipment.xls, sent to Jonathan Koomey on 16 August 2007. Shipment totals are slightly different from those in Table 1 because of minor modifications by IDC in their methodology after the Koomey (2007) report was published.

Table 4: Allocation of server electricity consumption in 2000 to major world regions

	<i>Units</i>	<i>Volume</i>	<i>Mid-range</i>	<i>High-end</i>	<i>Total/Avg</i>
<i>Installed base</i>					
US	Thousands	4927	663	23	5613
Western Europe	Thousands	3332	447	15	3794
Japan	Thousands	1140	250	15	1405
Asia Pacific (ex. Japan)	Thousands	1416	132	4	1552
Rest of World	Thousands	1425	317	8	1750
Total	Thousands	12240	1808	66	14114
<i>Average power used per server</i>					
US	Watts/server	186	424	5,534	236
Western Europe	Watts/server	181	422	4,517	227
Japan	Watts/server	181	422	4,517	271
Asia Pacific (ex. Japan)	Watts/server	181	422	4,517	212
Rest of World	Watts/server	181	422	4,517	246
Total	Watts/server	183	423	4,874	236
<i>Direct electricity consumption</i>					
US	Billion kWh/year	8.0	2.5	1.1	11.6
Western Europe	Billion kWh/year	5.3	1.7	0.6	7.6
Japan	Billion kWh/year	1.8	0.9	0.6	3.3
Asia Pacific (ex. Japan)	Billion kWh/year	2.3	0.5	0.1	2.9
Rest of World	Billion kWh/year	2.3	1.2	0.3	3.8
Total	Billion kWh/year	19.7	6.7	2.8	29.2
<i>Total electricity consumption (including cooling and aux equipment)</i>					
US	Billion kWh/year	16.1	4.9	2.2	23.3
Western Europe	Billion kWh/year	10.6	3.3	1.2	15.1
Japan	Billion kWh/year	3.6	1.8	1.2	6.7
Asia Pacific (ex. Japan)	Billion kWh/year	4.5	1.0	0.3	5.8
Rest of World	Billion kWh/year	4.5	2.3	0.7	7.6
Total	Billion kWh/year	39.4	13.4	5.6	58.4

(1) Installed base for US and World taken from Koomey 2007. Non-US installed base by region was not available from IDC, so it was approximated using IDC shipments data by region (Table 3) and the multipliers (Table 2) characterizing the relationship between installed base and shipments for all non-US regions in the aggregate (Table 1). This approach assumes that installed base for all non-US regions grows in the same manner as does the sum of those regions.

(2) Average power used per server for US and World taken from Koomey 2007. Non-US average power per server calculated for non-US regions using the differences between US and World installed base and direct electricity consumption from Koomey (2007).

(3) Direct electricity consumption for US and World taken from Koomey 2007. Electricity use for non-US regions is calculated by multiplying the installed base by region by the average power used per server of a given class.

4) Direct electricity consumption assumes 8784 hours/year for 2000 and 100% load factor.

5) Total electricity consumption (including cooling and auxiliary equipment) is twice that of the direct server power consumption, based on typical industry practice.

Table 5: Allocation of server electricity consumption in 2005 to major world regions

	<i>Units</i>	<i>Volume</i>	<i>Mid-range</i>	<i>High-end</i>	<i>Total/Avg</i>
<i>Installed base</i>					
US	Thousands	9897	387	22	10306
Western Europe	Thousands	6985	356	15	7355
Japan	Thousands	2361	185	12	2558
Asia Pacific (ex. Japan)	Thousands	3553	137	4	3694
Rest of World	Thousands	3162	199	7	3368
Total	Thousands	25959	1264	59	27282
<i>Average power used per server</i>					
US	Watts/server	219	625	7,651	250
Western Europe	Watts/server	224	598	8,378	258
Japan	Watts/server	224	598	8,378	289
Asia Pacific (ex. Japan)	Watts/server	224	598	8,378	247
Rest of World	Watts/server	224	598	8,378	263
Total	Watts/server	222	607	8,106	257
<i>Direct electricity consumption</i>					
US	Billion kWh/year	18.9	2.1	1.5	22.6
Western Europe	Billion kWh/year	13.7	1.9	1.1	16.6
Japan	Billion kWh/year	4.6	1.0	0.9	6.5
Asia Pacific (ex. Japan)	Billion kWh/year	7.0	0.7	0.3	8.0
Rest of World	Billion kWh/year	6.2	1.0	0.5	7.7
Total	Billion kWh/year	50.5	6.7	4.2	61.4
<i>Total electricity consumption (including cooling and aux equipment)</i>					
US	Billion kWh/year	37.9	4.2	3.0	45.1
Western Europe	Billion kWh/year	27.4	3.7	2.1	33.3
Japan	Billion kWh/year	9.3	1.9	1.7	12.9
Asia Pacific (ex. Japan)	Billion kWh/year	14.0	1.4	0.6	16.0
Rest of World	Billion kWh/year	12.4	2.1	1.0	15.5
Total	Billion kWh/year	101.0	13.4	8.4	122.9

(1) Installed base for US and World taken from Koomey 2007. Non-US installed base by region was not available from IDC, so it was approximated using IDC shipments data by region (Table 3) and the multipliers (Table 2) characterizing the relationship between installed base and shipments for all non-US regions in the aggregate (Table 1). This approach assumes that installed base for all non-US regions grows in the same manner as does the sum of those regions.

(2) Average power used per server for US and World taken from Koomey 2007. Non-US average power per server calculated for non-US regions using the differences between US and World installed base and direct electricity consumption from Koomey (2007).

(3) Direct electricity consumption for US and World taken from Koomey 2007. Electricity use for non-US regions is calculated by multiplying the installed base by region by the average power used per server of a given class.

4) Direct electricity consumption assumes 8760 hours/year for 2005 and 100% load factor.

5) Total electricity consumption (including cooling and auxiliary equipment) is twice that of the direct server power consumption, based on typical industry practice.