Summary of Assumptions for EPA ENERGY STAR® Savings Estimates
ENERGY STAR Preliminary Draft Computer Specification (Version 4.0)

Introduction
The purpose of this document is to share the assumptions used to create the energy savings estimates shared at the ENERGY STAR computer stakeholder meeting on March 15, 2005. EPA is open to revising these assumptions as new data and/or comments on existing data are received. EPA will continue to refine these savings estimates throughout the specification development process. Questions regarding the content of this document should be directed to Andrew Fanara, EPA, at (202) 343-9019 or fanara.andrew@epa.gov.

The first part of this document provides the basic assumptions that went into creating the estimate and presents the resulting energy savings that match what was presented during the stakeholder meeting. Appendix A contains additional details and rationale associated with the creation of the basic assumptions provided below. ***NOTE: All of these estimates assume that the specification would not cause the current power management (PM) enabling rates in homes (10%) or businesses (6%) to increase or decrease.***

Assumptions Summary
In order to create an energy savings estimate, a baseline energy consumption of today's computers must be compared to the expected energy consumption of computers once the ENERGY STAR specification takes effect. In order to simplify this calculation, the energy consumption of one computer is calculated by multiplying the power (watts) consumed in an operational mode by the time (hours) spent over the course of a year in that mode. Then, this annual energy consumption per computer (kilowatt hours or kWh) is scaled up to a national level based on available computer sales data. Tables 1 and 2 give the power and duty cycle assumptions used. The duty cycle was calculated based on an average of different user scenarios, and so therefore cannot be compared to one user's experience.

Table 1 – Power Level Assumptions

	Off Mode Power	Sleep Mode Power	Active Mode: Idle State Power	Active Mode: High Performance State Power
Current Desktop Computer	2.9 W	11.2 W	Commercial: 55.0 W Residential: 70.0 W	Commercial: 80.0 W Residential: 126.0 W
Version 4.0 ENERGY STAR Desktop Computer	2.0 W	5.0 W	Commercial: 42.0 W Residential: 52.0 W	Commercial: 70.0 W Residential: 101.0 W
Current Laptop Computer	2.4 W	7.0 W	21.0 W	30.0 W
Version 4.0 ENERGY STAR Laptop Computer	0.50 W	5.0 W	21.0 W	30.0 W
Current Server	Not Applicable	Not Applicable	172.0 W	246.0 W
Version 4.0 ENERGY STAR Server	Not Applicable	Not Applicable	140.0 W	200.0 W

Table 2 – Duty Cycle Assumptions
(Assumes current low rates of PM enabling)

	Hours per Day				Hours per Year			
			Active Mode				Active Mode	
	Off Mode	Sleep Mode	Idle State	High Performance State	Off Mode	Sleep Mode	Idle State	High Performance State
Commercial Desktop/Laptop	6.4 hrs	0.8 hrs	16.1 hrs	0.7 hrs	2344 hrs	280 hrs	5886 hrs	250 hrs
Residential Desktop/Laptop	14.3 hrs	0.3 hrs	8.0 hrs	1.4 hrs	5233 hrs	93 hrs	2927 hrs	507 hrs
Server	0.0 hrs	0.0 hrs	19.0 hrs	5.0 hrs	0 hrs	0 hrs	6935 hrs	1825 hrs

Results

The energy savings per unit that was calculated using these assumptions are given in Table 3 below.

Table 3 – Per Unit Energy Savings

Product	Annual Unit Savings (kWh per year)
Commercial Desktop	83
Residential Desktop	71
Commercial Laptop	5
Residential Laptop	10
Server	306

Using an IDC report indicating 53 million computers were sold in 2004 and other sources detailed in Appendix A, assuming constant sales for the next three years, and assuming an ENERGY STAR market penetration rate of 25%, it is possible to calculate the 3-year cumulative energy savings and associated environmental benefits of the ENERGY STAR Preliminary Draft V4.0 specification (Table 4). Three years was picked as the typical computer life for use in the cumulative savings estimates.

Table 4 – Energy and Environmental Benefits of ENERGY STAR Specification at 25% Market Penetration

Total 3 year Cumulative National Energy Savings (millions kWh)	Total 3 year Cumulative National Carbon Dioxide Savings (million tons CO_2)	Total 3 year Cumulative National Value of Electricity Saved per Year (millions of dollars)	Equivalent Number of American Households Powered for One Year
5098	4.2	372.1	498,844

Note: the 3-year cumulative CO_2 savings number has changed from 3.5, as presented during the stakeholder meeting, to 4.2 based on new information regarding DOE estimates for $CO_{2\ per}$ kWh generated.

Next Steps

Over the next few months EPA will continue to refine these assumptions to further improve the energy savings analysis. Specifically, the following revisions to the analysis are under consideration:

- Develop a more detailed sales model that takes into account future changes in sales based on recent trends and projections.
- Create multiple duty cycle scenarios to understand the implications of higher enabling rates on total savings. This would require adopting different duty cycles for enabled and non enabled computer models.
- Evaluate the specific savings associated with each initiative, including: off, sleep, idle, power supply, and increased enabling. Preliminary estimates indicate that if 50% of future ENERGY STAR qualified computers were enabled, then in the commercial sector, an additional 76kWh per year per computer could be saved on average (Appendix A).
- Collect usage and performance data from ENERGY STAR counterparts in other countries to determine if it is possible to calculate potential "global" savings.

Appendix A
Detailed Analysis and Rationale for Assumptions

Energy Savings Estimate Overview

As mentioned in the summary, a baseline energy consumption of today's computers must be compared to the expected energy consumption of computers once the ENERGY STAR specification takes effect to create an energy savings estimate. In order to simplify this calculation, the energy consumption of one computer is calculated by multiplying the power (watts) consumed in an operational by the time (hours) spent over the course of a year in that mode.[1] Then, this annual energy consumption per computer (kWh) is scaled up based on computer sales data.

Because sales data for workstations and integrated computers are rarely reported in publicly available market reports, and due to the fact that these units are a relatively small market segment compared to other computer form factors, they were not included in the overall savings estimates. **Stakeholders that have access to this type of information are encouraged to provide it to EPA so that savings may also be provided for these product categories in the future.** Desktops, laptops and server savings estimates were included and their energy savings contribution is discussed in this document.

The modes used in this analysis are off, sleep, and active.[2] Active is further broken down into two states: idle and high performance. Idle state accounts for any situation where time is being logged in "System Idle Process" under the Windows Task Manager, or where there is no hard drive activity and CPU utilization is less that 10%. A typical example of this scenario is when a user is viewing a document on the computer screen (not making changes) with no email or data transfer occurring. In high performance state, the computer is undertaking some intensive computing operation, such as opening a program, downloading e-mail, manipulating a graphic, finding a web-site, saving a file, or searching a directory. We estimate this activity occurs far less frequently than idle state.

Average Power in Each Mode/State

The key assumptions used to create the current computer power profiles are listed in Table 5 on the next page.

[1] The energy consumed by a computer in one year (UEC) is described by the following equation where *n* is the number of modes or states: $UEC = [\sum_n Watts_n * Hours_n]$.

[2] Definitions for these modes can be found in ENERGY STAR Computer Preliminary Draft V4.0 specification.

Table 5 – Desktop, Laptop, and Server Power Level Assumptions

	Off Mode	Sleep Mode	Active Mode [3]	
			Idle State	High Performance State
Current Desktop Computer	2.9 W [4]	11.2 W [5]	Commercial: 55.0 W Residential: 70.0 W [6]	Commercial: 80.0 W Residential: 126.0 W [7]
Version 4.0 ENERGY STAR Desktop Computer	Proposed Off Level (2.0 W)	Proposed Sleep Level (5.0 W)	Commercial: 42.0 W Residential: 52.0 W [8]	Commercial: 70.0 W Residential: 101.0 W [9]
Current Laptop Computer	2.4 W [10]	7.0 W [11]	21.0 W [12]	30.0 W[13]
Version 4.0 ENERGY STAR Laptop Computer	Proposed Off Level 0.50 W)	Proposed Sleep Level (5.0 W)	21.0 W[14]	30.0 W [15]
Current Server	Not Applicable	Not Applicable	172.0 W [16]	246.0 W [17]
Version 4.0 ENERGY STAR Server	Not Applicable	Not Applicable	140.0 W [18]	200.0 W [19]

[3] We assume that residential desktop computers are more likely to have high performance video cards and larger power supplies, both of which lead to higher power consumption than commercial desktop computers, which we assume are used for basic office tasks such as email, word processing, etc. and therefore have lower power consumption.
[4] Judy Roberson et al. 2002. "Energy Use and Power Levels in New Monitors and Personal Computers" Available online at http://enduse.lbl.gov/Projects/OffEqpt.html. Berkeley, Calif.: Lawrence Berkeley National Laboratory.
[5] Average of current ENERGY STAR sleep data collected from manufacturers.
[6] Assumes input power of a computer with 250 watt power supply loaded between 10% and 20% of output power. Power supply in this scenario meets Intel's required guidelines (60%, 70%, and 70% efficient at 20%, 50%, and 100% of load, respectively).
[7] Assumes input power of a computer with 250 watt power supply loaded between 30% and 50% of output power. Power supply in this scenario meets Intel's required guidelines (60%, 70%, and 70% efficient at 20%, 50%, and 100% of load, respectively).
[8] Assumes input power of a computer with 250 watt power supply loaded between 10% and 20% of output power. Power supply in this scenario meets ENERGY STAR Preliminary Draft Version 4.0 proposal (80%, 80%, and 80% efficient at 20%, 50%, and 100% of load, respectively).
[9] Assumes input power of a computer with 250 watt power supply loaded between 30% and 50% of output power. Power supply in this scenario meets ENERGY STAR Preliminary Draft Version 4.0 proposal (80%, 80%, and 80% efficient at 20%, 50%, and 100% of load, respectively).
[10] Suzanne Foster and Chris Calwell. 2003. "Laptop Computers: How Much Do They Use and How Much Can We Save?." Report produced for the Natural Resources Defense Council. Data available from Project Manager Noah D. Horowitz, Sr. Scientist, nhorowitz@nrdc.org.
[11] Average of current ENERGY STAR sleep data collected from manufacturers.
[12] Foster, 2003.
[13] Foster, 2003.
[14] Because the power supply efficiencies typically found in the market match the efficiencies required by the ENERGY STAR Preliminary Draft Version 4.0 proposed levels, this active power is the same as the typical scenario.
[15] Because the power supply efficiencies typically found in the market match the efficiencies required by the ENERGY STAR Preliminary Draft Version 4.0 proposed levels, this active power is the same as the typical scenario.
[16] Measurements conducted with California Energy Commission PIER research by LBNL and Ecos Consulting. Report to be completed June 2005. See http://hightech.lbl.gov.
[17] Measurements conducted with California Energy Commission PIER research by LBNL and Ecos Consulting. Report to be completed June 2005. See http://hightech.lbl.gov.
[18] Assumes input power of a computer with 425 watt power supply loaded between 20% and 30% of output power. Power supply in this scenario meets ENERGY STAR Preliminary Draft Version 4.0 proposal (80%, 80%, and 80% efficient at 20%, 50%, and 100% of load, respectively).
[19] Assumes input power of a computer with 425 watt power supply loaded between 30% and 40% of output power. Power supply in this scenario meets ENERGY STAR Preliminary Draft Version 4.0 proposal (80%, 80%, and 80% efficient at 20%, 50%, and 100% of load, respectively).

Hours of Use Per Year (Duty Cycle)

Because there is no concrete data on the hours of use per year of computers (also called the duty cycle), energy estimates are based on three relevant scenarios: commercial desktop/laptop computer average user profile, residential desktop/laptop computer average user profile, and average server user profile.

The commercial profile was built using Lawrence Berkeley National Laboratory's 2004 commercial building night audit report, which found that 36% of users turn their computer off at the end of the day, and 6% of computers were power managed.[20] The following factors were also taken into account when determining commercial duty cycle:

- Commercial computers are almost always connected to an internal network and IT administrators often disable sleep mode features in order to have instantaneous access to all computers on the network.
- The majority of commercial computers tends to have lower functionality and is more often used to perform basic office tasks, like drafting letters, creating presentations, and charting data.
- There are 250 workdays per year and 115 weekends/holidays.

The weighted average duty cycle created from these factors was built using four basic 24-hour workday scenarios:

- Power management (PM) enabled, user turns computer off at end of day
- Power management disabled, user turns off computer at end of day
- Power management enabled, user leaves computer on at end of day
- Power management disabled, user leaves computer on at end of day

An example of two of these scenarios can be found in Table 6, below. In addition, the computer is used differently on a weekend/holiday than during the week. So, for each of these users, a typical weekend/holiday profile was also created, for a total of 8 scenarios.

Table 6 – Example of Two User Scenarios Used to Create Average Duty Cycle for Commercial Computer

	Hours per Day			
			Active Mode	
	Off Mode	Sleep Mode	Idle State	High Performance State
Commercial user with PM disabled, turns computer off	15 hrs	0 hrs	8 hrs	1 hr
Commercial user with PM enabled, turns computer off	15 hrs	2 hrs	6 hrs	1 hr

[20] Judy A. Roberson et all, After-hours Power Status of Office Equipment and Energy Use of Miscellaneous Plug-Load Equipment. LBNL Report number LBNL-53729. 2004. pg. 15. Available at http://enduse.lbl.gov/Projects/OffEqpt.html

The residential profile was built in a similar way, using market data on the number of homes that have cable, LAN, or wireless LAN broadband connections (26.5 million)[21] and comparing that to the number homes with computers (68.2 million).[22] It was assumed that 39% of computer households with a broadband connection were likely to leave the computer powered on and connected to the Internet more often, whereas the remaining dial-up users used their computers less frequently, and shut the computer off when it was not needed. The following factors influencing the residential market were also taken into account to determine hours of use in different modes:

- Because residential computers are less likely to be hooked up to a network, the enabling rate was assumed to be slightly higher (10%) than the commercial enabling rate found by LBNL (6%).
- Residential computers are more highly functional than commercial computers, and more often used for computing-intensive activities such as video gaming, photo manipulation, and CD burning.

Similar techniques were used to build the server user profile outlined with the desktop/laptop commercial average profile and the desktop/laptop residential average profile in Table 7, below. Please note that these profiles represent the average user, and cannot be easily compared to one user's experience.

Table 7 – Duty Cycle Assumptions for Desktop, Laptop, and Server Form Factors
(Assumes current low PM enabling rates)

	Hours per Day				**Hours per Year**			
			Active Mode				**Active Mode**	
	Off Mode	**Sleep Mode**	**Idle State**	**High Performance State**	**Off Mode**	**Sleep Mode**	**Idle State**	**High Performance State**
Commercial Desktop/Laptop	6.4 hrs	0.8 hrs	16.1 hrs	0.7 hrs	2344 hrs	280 hrs	5886 hrs	250 hrs
Residential Desktop/Laptop	14.3 hrs	0.3 hrs	8.0 hrs	1.4 hrs	5233 hrs	93 hrs	2927 hrs	507 hrs
Server	0.0 hrs	0.0hrs	19.0 hrs	5.0 hrs	0 hrs	0 hrs	6935 hrs	1825 hrs

Estimates of Unit Energy Savings

The duty cycle profiles employed in these preliminary estimates assume minimal PM is occurring in homes and offices before and after Tier 1 of Version 4.0 specification takes effect (currently proposed for January 1, 2007). Programs that succeed in getting users to manually switch off computers or automatically engage sleep mode in networked or broadband-connected computers could achieve significant reductions in hours ascribed to idle and active modes and their associated energy use. These initiatives are not included in these because PM was not initially proposed as a Tier I requirement.

Tables 8, 9, and 10 give energy consumption estimates of the potential unit energy savings resulting from desktops, laptops, and servers, respectively. Each savings calculation is made by subtracting the energy use of a computer under the proposed specification from the energy use of a typical computer.

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[21] "Rest of the World has Already Become DSL's Backyard, says ABI Research; Will the US Also Join the Party? Questions ABI Research" ABI Research press release. Oyster Bay, New York. 2004. Available at http://www.abiresearch.com/abiprdisplay.jsp?pressid=226

[22] "Computer Ownership and Internet Access: Opportunities for Workforce Development and Job Flexibility" Employment Policy Foundation's Technology Forecast. 2001. pg. 1. Available at http://www.epf.org/pubs/newsletters/2001/tf20010111.pdf

Table 8 – Unit Annual Desktop Energy Savings

Scenario		Mode of Operation					Annual Unit Energy (kWh per year)
		Unplugged	Standby (Off)	Sleep	Idle	High Perf	
Current Commercial Desktop Computer	Power (W)	0	2.9	11.2	55.0	80.0	354
	Time (hrs/yr)	0	2344	280	5886	250	
	Energy (kWh/yr)	0	6.8	3.1	323.8	20.0	
Version 4.0 ENERGY STAR Commercial Desktop Computer	Power (W)	0	2.0	5.0	42.0	70.0	271
	Time (hrs/yr)	0	2344	280	5886	250	
	Energy (kWh/yr)	0	4.7	1.4	247.2	17.5	
Commercial Desktop Unit Energy Savings (kWh per year):							**83**
Current Residential Desktop Computer	Power (W)	0	2.9	11.2	70.0	126.0	285
	Time (hrs/yr)	0	5233	93	2927	507	
	Energy (kWh/yr)	0	15.2	1.0	204.9	63.9	
Version 4.0 ENERGY STAR Residential Desktop Computer	Power (W)	0	2.0	5.0	52.0	101.0	214
	Time (hrs/yr)	0	5233	93	2927	507	
	Energy (kWh/yr)	0	10.5	0.5	152.2	51.2	
Residential Desktop Unit Energy Savings (kWh per year):							**71**

Table 9 – Unit Annual Laptop Energy Savings

Scenario		Mode of Operation					Annual Unit Energy (kWh per year)
		Unplugged	Standby (Off)	Sleep	Idle	High Perf	
Current Commercial Laptop Computer	Power (W)	0	2.4	7.0	21.0	30.0	139
	Time (hrs/yr)	0	2344	280	5886	250	
	Energy (kWh/yr)	0	5.6	2.0	123.6	7.5	
Version 4.0 ENERGY STAR Commercial Laptop Computer	Power (W)	0	0.5	5.0	21.0	30.0	134
	Time (hrs/yr)	0	2344	280	5886	250	
	Energy (kWh/yr)	0	1.2	1.4	123.6	7.5	
Laptop Unit Energy Savings (kWh per year):							**5**
Current Residential Laptop Computer	Power (W)	0	2.4	7.0	21.0	30.0	90
	Time (hrs/yr)	0	5233	93	2927	507	
	Energy (kWh/yr)	0	12.6	0.7	61.5	15.2	
Version 4.0 ENERGY STAR Residential Laptop Computer	Power (W)	0	0.5	5.0	21.0	30.0	80
	Time (hrs/yr)	0	5233	93	2927	507	
	Energy (kWh/yr)	0	2.6	0.5	61.5	15.2	
Laptop Unit Energy Savings (kWh per year):							**10**

Table 10– Unit Annual Server Energy Savings

Scenario		Mode of Operation					Annual Unit Energy (kWh per year)
		Unplugged	Standby (Off)	Sleep	Idle	High Perf	
Current Server	Power (W)	0	2.9	NA	172.0	246.0	1642
	Time (hrs/yr)	0	0	0	6935	1825	
	Energy (kWh/yr)	0	0.0	0.0	1192.8	449.0	
Version 4.0 ENERGY STAR Server	Power (W)	0	1.0	NA	140.0	200.0	1336
	Time (hrs/yr)	0	0	0	6935	1825	
	Energy (kWh/yr)	0	0.0	0.0	970.9	365.0	
Server Unit Energy Savings (kWh per year):							**306**

IDC estimates that 62% of all computers are sold to the commercial sector and 38% are sold to the residential sector[23]. Furthermore, according to IDC roughly 70% of all computers sold are desktops and 30% sold are laptops.[24] Taking the sum of the product of the annual sales for each type of computer,[25] the unit energy savings for each type of computer, and the assumed market penetration rate (25%) gives the total potential annual national energy savings that could be saved as a result from this proposed specification. The three-year cumulative annual national energy savings potential is over 5 billion kWh (Table 11), with the potential to prevent over 4 million tons of carbon dioxide emissions (Table 12).

Table 11 – Total Annual National Energy Savings with 25% ENERGY STAR Market Participation

Computer Type	Annual Energy Savings per Unit (kWh/yr)	Total Number of Units Sold in U.S. per Year (millions of units)	Percent of ENERGY STAR Units Sold Each Year	First Year National Energy Savings (millions of kWh)	Second Year National Energy Savings (millions of kWh)	Third Year National Energy Savings (million of kWh)	Year 1 – 3 Cumulative National Energy Savings (millions kWh)
Commercial Desktop Computers	83	23.2	25%	481	962	1443	2886
Residential Desktop Computers	71	14.2	25%	251	503	754	1508
Commercial Laptop Computers	5	9.5	25%	12	24	36	71
Residential Laptop Computers	10	5.8	25%	15	29	44	88
Servers	306	1.2	25%	91	182	272	545
Totals		53.9		**850**	**1699**	**2549**	**5098**

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[23] "PC Shipments to Reach Record Levels in 2003 and 2004, According to IDC" Dec 11, 2003. Available Online at http://www.idc.com/getdoc.jsp?containerId=pr2003_12_09_171934

[24] IDC Worldwide Quarterly PC Tracker, June 2004. Summary available at http://www.rtoonline.com/Content/Article/Jun04/PCDemandHigh061004.asp

[25] 2003 Sales data from "PC Shipments Reach Record Levels As Battle For Market Leadership Continues, According To IDC" Jan 14, 2004. Available online at http://www.idc.com/getdoc.jsp?containerId=pr2004_01_13_185937.

Table 12 – Environmental Benefits of Proposed ENERGY STAR Computer V4.0 Requirements

Total 3 year Cumulative National Energy Savings (millions kWh)	Total 3 year Cumulative National Carbon Dioxide Savings[26] (million tons CO_2)	Total 3 year Cumulative National Value of Electricity Saved per Year[27] (millions of dollars)	Equivalent Number of American Households Powered for One Year[28]
5098	4.2	372.1	498,844

Preliminary Estimates of Energy Savings with Improved Enabling

The current ENERGY STAR estimate assumes that 6% of commercial and 10% of residential desktop and notebook computers have PM enabled and functioning.[29] In addition, it assumes servers do not use PM, and energy savings from monitor PM are not considered.

The technical potential associated with PM enabling is the absolute difference in energy use between the average duty cycle that assumes 100% of computers are enabled and the average duty cycle that assumes 0% of computers are enabled. Table 13 below shows the commercial desktop computer per unit technical potential (100% of computers enabled) and average per unit commercial desktop computer savings if 50% of commercial desktops are enabled. This energy savings would be above and beyond the energy savings achieved with Tier 1 provisions outlined in this document.

Table 13 - Energy Savings from PM Enabling

	Average per Unit Annual Energy Consumption (kWh per year)			Per Unit Savings From PM Enabling (compared to disabled) (kWh per year)	Average per Unit Savings from Increasing Enabling from Current Rates to 50% Computers PM Enabled (kWh per year)
	PM 0% Enabled	Current Enabling Rates[30]	PM 100% Enabled		
Version 4.0 ENERGY STAR Commercial Desktop Computer	281.2	270.8	108.5	**173**	**76**
Version 4.0 ENERGY STAR Residential Desktop Computer	218.7	214.3	174.9	**44**	**17.5**

It is important to note that increasing the percentage of computers in use that are power management enabled is dependent on the following factors:

[26] Assuming DOE average of 1.64 lbs of CO_2 for every kWh of generation.
[27] This assumes the national average of $0.073 per kWh available on www.eai.doe.gov
[28] This uses 10,219 kWh per household, as reported in "Electricity Consumption and Expenditures in U.S. Households by End Uses and Census Region, 1997."
[29] It is possible for a PC to be enabled but not functioning for some hardware or software reason. The 6% results are based on after-hours observations of PCs and so reflect rates of power management functioning (what we need for energy savings estimates) as opposed to enabling. However, enabling is a more obvious and natural term to use and the difference between the two in practice is not large.
[30] Weighted average based on 6% commercial enabling and 10% residential enabling.

- Enabling of full network connectivity in sleep
- Availability of hardware and software solutions that adequately support sleep transitions
- Ability of manufacturers to incorporate available solutions into computers sold in the marketplace
- A shift in users' and IT staff's current perceptions of sleep enabling

Savings from PM enabling efforts are likely to spread to the 75% of the PC market not initially ENERGY STAR qualified so that total savings could be considerably higher, particularly since the difference between idle and sleep power for the non-ENERGY STAR qualified units will be higher (often much higher) than in the ENERGY STAR qualified units.