EFFICIENCY STANDARDS FOR EXTERNAL POWER SUPPLIES

CUI INC®

The global regulatory environment surrounding the legislation of external power supply efficiency and no-load power draw has rapidly evolved over the past decade since the California Energy Commission (CEC) implemented the first mandatory standard in 2004. With the publication in 2014 of a new set of requirements by the United States Department of Energy (DoE) that went into effect in February 2016, the landscape has changed again as regulators further reduce the amount of energy that may be consumed by external power adapters.

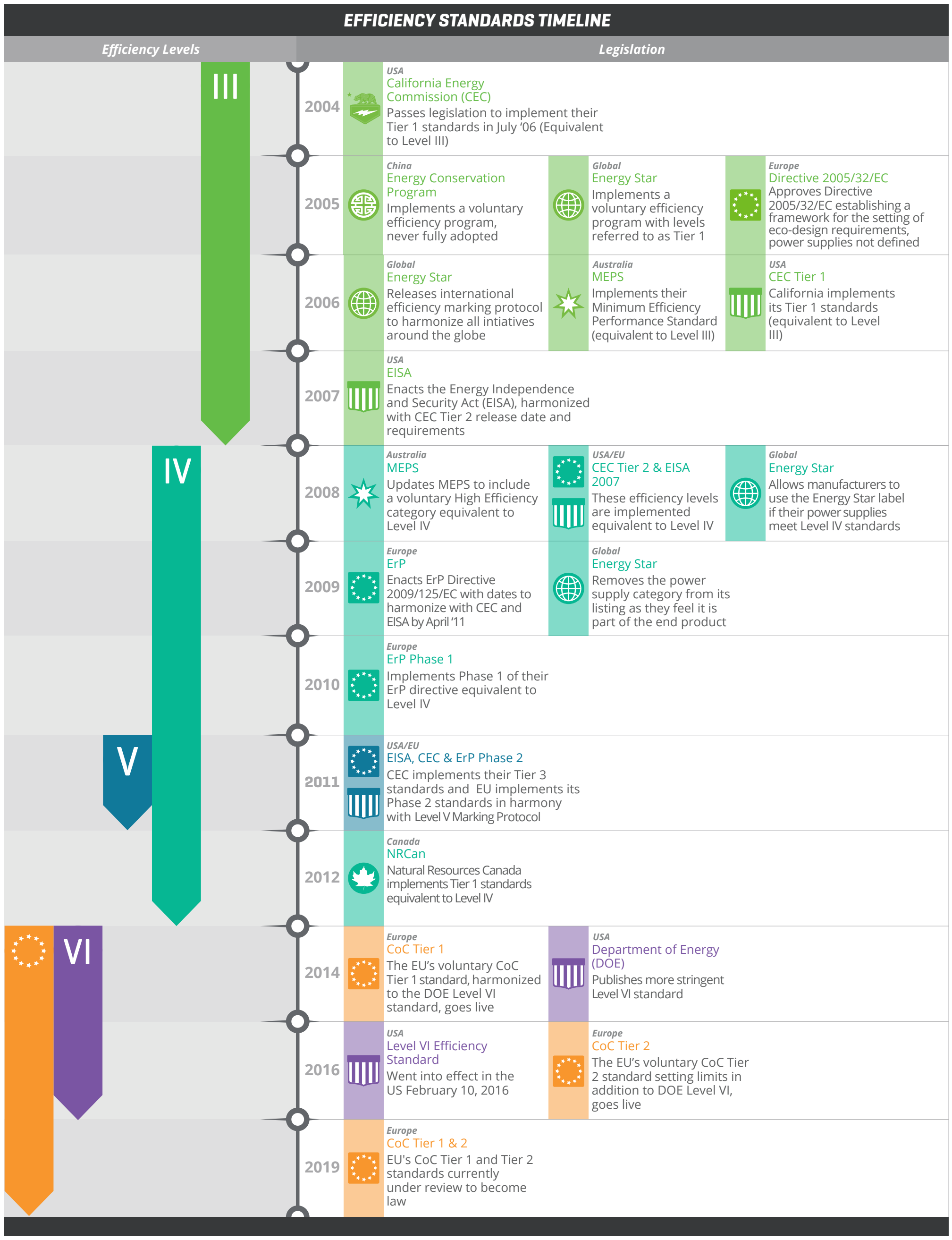
Mandating higher average efficiencies in external power supplies has undoubtedly had a real impact on global power consumption. However, with the benefit of a reduced draw on the power grid come challenges and uncertainties for the electronics industry as it tries to keep up with this dynamic regulatory environment.

The next round of legislation is expected to come from Europe, as the current voluntary Code of Conduct (CoC) Tier 1 and Tier 2 standards are under review by the European Union to become compulsory as Ecodesign rules. Although there is not an official timeline for these voluntary standards becoming law, Original Equipment Manufacturers (OEMs) who design external power supplies into their products would best be served to future-proof their designs to the latest regulations to ensure that they are in compliance in each region where their product is sold. The goal of this paper is to provide an up-to-date summary of the most current regulations worldwide.

A BRIEF HISTORY

In the early 90's, it was estimated that there were more than one billion external power supplies active in the United States alone. The efficiency of these power supplies, mainly utilizing linear technology, could be as low as 50% and still draw power when the application was turned off or not even connected to the power supply (referred to as "no-load" condition). Experts calculated that without efforts to increase efficiencies and reduce "no-load" power consumption, external power supplies would account for around 30% of total energy consumption in less than 20 years. As early as 1992, the US Environmental Protection Agency started a voluntary program to promote energy efficiency and reduce pollution, which eventually became the Energy Star program. However, it was not until 2004 that the first mandatory regulation dictating efficiency and no-load power draw minimums was put in place. Figure 1 demonstrates just how dynamic the regulatory environment has been over the past decade. It also shows the European Union's Code of Conduct standards that are voluntary now, but are currently under review to become Ecodesign requirements in two tiers. The Tier 1 standard, which is broadly equivalent to Level VI, and the tighter Tier 2 standard, both of which are expected to become mandatory sometime in the near future.

Figure 1: This infographic traces the path from the CEC's 2004 regulation up to the latest DoE Level VI standard, which became effective in February 2016, and also shows the EU roadmap for CoC and Ecodesign requirements



THE CURRENT REGULATORY ENVIRONMENT

As different countries and regions enact stricter requirements and move from voluntary to mandatory programs, it has become vital that OEMs continually track the most recent developments to ensure compliance and avoid costly delays or fines. While many countries are establishing voluntary programs harmonized to the international efficiency marking protocol system first established by Energy Star, the following countries and regions now have regulations in place mandating that all external power supplies shipped across their borders meet the specified efficiency level:

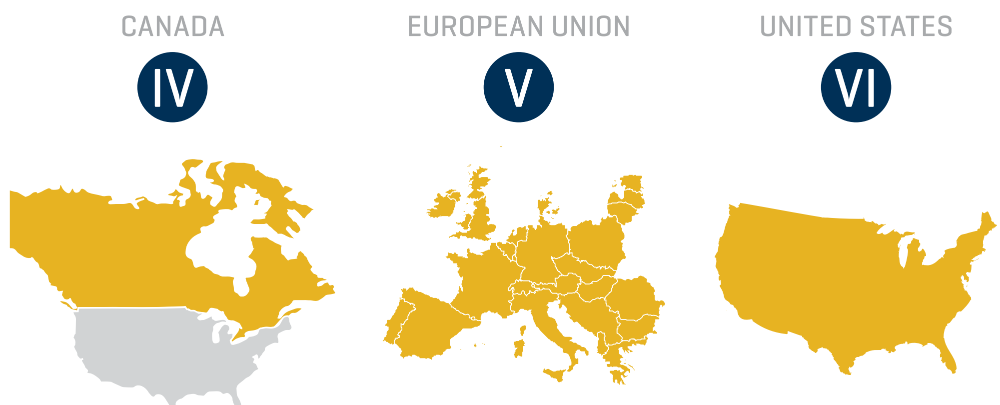


Figure 2: This graphic shows the latest mandatory efficiency standard regulations by region

Power supply manufacturers indicate compliance to these regulations by placing a Roman Numeral on the power supply label as specified by the International Efficiency Marking Protocol for External Power Supplies Version 3.0, updated in September 2013. This latest version of the Protocol provides additional flexibility on where the marking may be placed.

While the US is the only governing body to enforce compliance to the Level VI standard, most external power supply manufacturers have adjusted their product portfolios to meet these requirements. These adjustments are a direct response to the needs of OEM's to have a universally-compliant power supply platform for their products that ship globally. For similar reasons, manufacturers are also taking account of the latest EU CoC requirements to provide compliance ahead of these standards becoming mandatory Ecodesign rules.

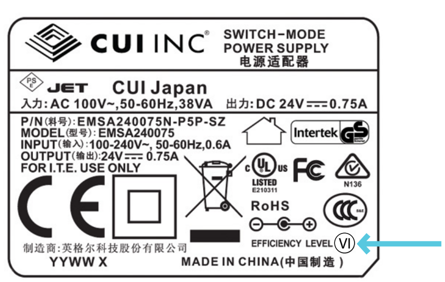


Figure 3: Example of the International Efficiency Marking Protocol on a power supply label

PERFORMANCE THRESHOLDS

Figure 4 summarizes the past performance thresholds established over time up to Level V. The internationally approved test method for determining efficiency has been published by the IEC as AS/NZS 4665 Part 1 and Part 2. The approach taken to establish an efficiency level is to measure the input and output power at 4 defined points: 25%, 50%, 75% and 100% of rated power output. Data for all 4 points are separately reported as well as an arithmetic average active efficiency across all 4 points.

Figure 4: This table summarizes past performance thresholds as they were established over time. The term "power" means the power designated on the label of the power supply

LEVEL	NO-LOAD POWER REQUIREMENT	AVERAGE EFFICIENCY REQUIREMENT
I	Used if you do not meet any of the criteria	
II	No criteria was ever established	No criteria was ever established
III	≤10 Watts: ≤0.5 W of No Load Power 10~250 Watts: ≤0.75 W No Load Power	≤1 Watt: ≥ Power x 0.49 1~49 Watts: ≥[0.09 x Ln(Power)] + 0.49 49~250 Watts: ≥84%
IV	0~250 Watts: ≤0.5 W No Load Power	≤1 Watt: ≥ Power x 0.50 1~51 Watts: ≥[0.09 x Ln(Power)] + 0.5 51~250 Watts: ≥85%
V	Standard Voltage Ac-Dc Models (>6 Vout)	
	0~49 Watts: ≤0.3 W of No Load Power	≤1 Watt: 0.48 x Power + 0.140
	50~250 Watts: ≤0.5 W of No Load Power	1~49 Watts: [0.0626 x Ln(Power)] + 0.622
		50~250 Watts: ≥87%
	Low Voltage Ac-Dc Models (<6 Vout)	
	0~49 Watts: ≤0.3 W of No Load Power	≤1 Watt: 0.497 x Power + 0.067
	50~250 Watts: ≤0.5 W of No Load Power	1~49 Watts: [0.0750 x Ln(Power)] + 0.561
		50~250 Watts: ≥86%

DOE LEVEL VI

Power supply manufacturers such as CUI prepared well in advance for the transition to the more stringent Level VI standards. Along with tightened regulations for existing adapters, this standard expanded the range of regulated products. It should be noted that the current voluntary EU CoC Tier 1 requirements are broadly equivalent to DoE Level VI. However, there are differences in how the DoE and EU define external power supplies and the scope of which classes of supply are included or exempt from these rules. Regulated products now include:

- Multiple-voltage external power supplies
- Products with power levels >250 watts

The Level VI performance thresholds are summarized in the tables below:

Figure 5: The current US DoE Level VI efficiency requirements that became law in February 2016

SINGLE-VOLTAGE EXTERNAL AC-DC POWER SUPPLY[1], BASIC-VOLTAGE		
Nameplate Output Power (P_{out})	Minimum Average Efficiency in Active Mode (expressed as a decimal)	Maximum Power in No-Load Mode (W)
$P_{out} \leq 1$ W	$\geq 0.5 \times P_{out} + 0.16$	≤ 0.100
$1\ W < P_{out} \leq 49$ W	$\geq 0.071 \times \ln(P_{out}) - 0.0014 \times P_{out} + 0.67$	≤ 0.100
$49\ W < P_{out} \leq 250$ W	≥ 0.880	≤ 0.210
$P_{out} > 250$ W	≥ 0.875	≤ 0.500

SINGLE-VOLTAGE EXTERNAL AC-DC POWER SUPPLY, LOW-VOLTAGE[2]		
Nameplate Output Power (P_{out})	Minimum Average Efficiency in Active Mode (expressed as a decimal)	Maximum Power in No-Load Mode (W)
$P_{out} \leq 1$ W	$\geq 0.517 \times P_{out} + 0.087$	≤ 0.100
$1\ W < P_{out} \leq 49$ W	$\geq 0.0834 \times \ln(P_{out}) - 0.0014 \times P_{out} + 0.609$	≤ 0.100
$49\ W < P_{out} \leq 250$ W	≥ 0.870	≤ 0.210
$P_{out} > 250$ W	≥ 0.875	≤ 0.500

SINGLE-VOLTAGE EXTERNAL AC-AC POWER SUPPLY[3], BASIC-VOLTAGE		
Nameplate Output Power (P_{out})	Minimum Average Efficiency in Active Mode (expressed as a decimal)	Maximum Power in No-Load Mode (W)
$P_{out} \leq 1$ W	$\geq 0.5 \times P_{out} + 0.16$	≤ 0.210
$1\ W < P_{out} \leq 49$ W	$\geq 0.071 \times \ln(P_{out}) - 0.0014 \times P_{out} + 0.67$	≤ 0.210
$49\ W < P_{out} \leq 250$ W	≥ 0.880	≤ 0.210
$P_{out} > 250$ W	≥ 0.875	≤ 0.500

SINGLE-VOLTAGE EXTERNAL AC-AC POWER SUPPLY, LOW-VOLTAGE		
Nameplate Output Power (P_{out})	Minimum Average Efficiency in Active Mode (expressed as a decimal)	Maximum Power in No-Load Mode (W)
$P_{out} \leq 1$ W	$\geq 0.517 \times P_{out} + 0.087$	≤ 0.210
$1\ W < P_{out} \leq 49$ W	$\geq 0.0834 \times \ln(P_{out}) - 0.0014 \times P_{out} + 0.609$	≤ 0.210
$49\ W < P_{out} \leq 250$ W	≥ 0.870	≤ 0.210
$P_{out} > 250$ W	≥ 0.875	≤ 0.500

[1] Single-Voltage External Ac-Dc Power Supply: An external power supply that is designed to convert line voltage ac into lower-voltage dc output and is able to convert to only one dc output voltage at a time

[2] Low-Voltage External Power Supply: An external power supply with a nameplate output voltage less than 6 volts and nameplate output current greater than or equal to 550 milliamps. Basic-voltage external power supply means an external power supply that is not a low-voltage power supply

[3] Single-Voltage External Ac-Ac Power Supply: An external power supply that is designed to convert line voltage ac into lower-voltage ac output and is able to convert to only one ac output voltage at a time

[4] *Multiple-Voltage External Power Supply: An external power supply that is designed to convert line voltage ac input into more than one simultaneous lower-voltage output*

MULTIPLE-VOLTAGE EXTERNAL POWER SUPPLY[4]		
Nameplate Output Power (P_{out})	Minimum Average Efficiency in Active Mode (expressed as a decimal)	Maximum Power in No-Load Mode (W)
$P_{out} \leq 1$ W	$\geq 0.497 \times P_{out} + 0.067$	≤ 0.300
$1 \text{ W} < P_{out} \leq 49$ W	$\geq 0.075 \times \ln(P_{out}) + 0.561$	≤ 0.300
$P_{out} > 49$ W	≥ 0.860	≤ 0.300

DIRECT VS INDIRECT OPERATION EPSs

EPSs DoE Level VI also defines power supplies as direct operation and indirect operation products. A direct operation product is an external power supply (EPS) that functions in its end product without the assistance of a battery. An indirect operation EPS is not a battery charger but cannot operate the end product without the assistance of a battery. The new standard only applies to direct operation external power supplies. Indirect operation models will still be governed by the limits as defined by EISA2007. It is important to note that the current voluntary EU CoC Tier 1 and Tier 2 standards do not distinguish between direct and indirect operation. Figure 6 illustrates the instructions provided by the DoE to help distinguish between direct and indirect operation power supplies.

Figure 6: These instructions have been provided by the DOE to help distinguish between direct and indirect operation power supplies

1 If the external power supply (EPS) can be connected to an end-use consumer product and that consumer product can be operated using battery power, the method for determining whether that EPS is incapable of operating that consumer product directly is as follows:

Step (i)

If the end-use product has a removable battery, remove it for the remainder of the test and proceed to ***Step (v)***.

If not, proceed to ***Step (ii)***

Step (ii)

Charge the battery in the application via the EPS such that the application can operate as intended before taking any additional steps.

Step (iii)

Disconnect the EPS from the application. From an off mode state, turn on the application and record the time necessary for it to become operational to the nearest five second increment (5 sec, 10 sec, etc.).

Step (iv)

Operate the application using power only from the battery until the application stops functioning due to the battery discharging.

Step (v)

Connect the EPS first to mains and then to the application. Immediately attempt to operate the application. If the battery was removed for testing and the end-use product operates as intended, the EPS is not an indirect operation EPS and paragraph 2 of this definition does not apply.

If the battery could not be removed for testing, record the time for the application to become operational to the nearest five second increment (5 seconds, 10 seconds, etc.).

2 If the difference between ***Step (v)*** and ***Step (iii)*** is greater than five seconds, the EPS cannot operate the application directly and is an indirect operation EPS.

LEVEL VI EXEMPTIONS

The latest Level VI mandate also defines exemptions for EPS products. Direct operation EPS standards do not apply if:

- It is a device that requires Federal Food and Drug Administration listing and approval as a medical device in accordance with section 360c of title 21;

OR

- A direct operation, ac-dc external power supply with nameplate output voltage less than 3 volts and nameplate output current greater than or equal to 1,000 milliamps that charges the battery of a product that is fully or primarily motor-operated.

VOLUNTARY EUROPEAN REQUIREMENTS

The European Union published its Code of Conduct (CoC) on Energy Efficiency of External Power Supplies Version 5 in October 2013. Tier 1 effectively harmonizes the EU with DoE Level VI, noting the differences in scope detailed below, and became effective as a voluntary requirement from January 2014, some two years ahead of DoE Level VI. Its adoption as an EU Ecodesign rule is currently under review, along with the more stringent CoC Tier 2 requirement which became effective on a voluntary basis from January 2016. Please note, that an official date has not been announced for these standards becoming mandatory, but regardless many manufacturers have already begun certifying their power supplies to the tighter regulations.

Figure 7: The current EU CoC Tier 1 voluntary EPS efficiency requirements that are expected to become law

COC TIER 1 SINGLE-VOLTAGE EXTERNAL AC-DC POWER SUPPLY, BASIC-VOLTAGE

Nameplate Output Power (P_{out})	Minimum Average Efficiency in Active Mode (expressed as a decimal)	10% Load Average Efficiency in Active Mode (expressed as a decimal)	Maximum Power in No-Load Mode (W)
0.3 W ≤ P_{out} ≤ 1 W	≥ 0.50 x P_{out} + 0.146	≥ 0.50 x P_{out} + 0.046	≤ 0.150
1 W < P_{out} ≤ 49 W	≥ 0.0626 x ln(P_{out}) + 0.646	≥ 0.0626 x ln(P_{out}) + 0.546	≤ 0.150
49 W < P_{out} ≤ 250 W	≥ 0.890	≥ 0.790	≤ 0.250
P_{out} > 250 W	N/A	N/A	N/A

COC TIER 1 SINGLE-VOLTAGE EXTERNAL AC-DC POWER SUPPLY, LOW-VOLTAGE

Nameplate Output Power (P_{out})	Minimum Average Efficiency in Active Mode (expressed as a decimal)	10% Load Average Efficiency in Active Mode (expressed as a decimal)	Maximum Power in No-Load Mode (W)
0.3 W ≤ P_{out} ≤ 1 W	≥ 0.50 x P_{out} + 0.086	≥ 0.50 x P_{out}	≤ 0.150
1 W < P_{out} ≤ 49 W	≥ 0.0755 x ln(P_{out}) + 0.586	≥ 0.072 x ln(P_{out}) + 0.50	≤ 0.150
49 W < P_{out} ≤ 250 W	≥ 0.880	≥ 0.780	≤ 0.250
P_{out} > 250 W	N/A	N/A	N/A

The key difference between the CoC requirements and Level VI is the new 10% load measure, which imposes efficiency requirements under a low-load condition where historically most types of power supplies have been notoriously inefficient. As already noted, CoC does not distinguish between direct and indirect operation external power adapters. While CoC Tier 1 includes the new 10% load measure, its no-load and active mode limits are less stringent than DoE Level VI.

CoC Tier 2 further tightens the no-load and active mode power consumption limits for key classes of power adapters enacted by Level VI i.e. at output powers ≤49 W and 49 W < Pout ≤ 250 W and covers both standard voltage and low voltage adapters. The table in figure 8 details these and other new requirements.

LOOKING FORWARD

The Level VI requirements became effective on February 10, 2016, two years after their publication in the Federal Register. It is important to note that compliance with the DoE Level VI standard is regulated from the date of manufacture in the US or import into the US, so legacy products can still be shipped as long as existing power supplies meet these stipulations. Labeling requirements will be mandated to meet the same International Efficiency Marking Protocol for External Power Supplies Version 3.0 as the previous Level V standard.

Figure 8: The current EU CoC Tier 2 voluntary EPS efficiency requirements that are expected to become law

COC TIER 2 SINGLE-VOLTAGE EXTERNAL AC-DC POWER SUPPLY, BASIC-VOLTAGE

Nameplate Output Power (P_{out})	Minimum Average Efficiency in Active Mode (expressed as a decimal)	10% Load Average Efficiency in Active Mode (expressed as a decimal)	Maximum Power in No-Load Mode (W)
$0.3\ W \le P_{out} \le 1\ W$	$\ge 0.50 \times P_{out} + 0.169$	$\ge 0.50 \times P_{out} + 0.060$	≤ 0.075
$1\ W < P_{out} \le 49\ W$	$\ge 0.071 \times \ln(P_{out}) - 0.00115 \times P_{out} + 0.670$	$\ge 0.071 \times \ln(P_{out}) - 0.00115 \times P_{out} + 0.570$	≤ 0.075
$49\ W < P_{out} \le 250\ W$	≥ 0.890	≥ 0.790	≤ 0.150
$P_{out} > 250\ W$	N/A	N/A	N/A

COC TIER 2 SINGLE-VOLTAGE EXTERNAL AC-DC POWER SUPPLY, LOW-VOLTAGE

Nameplate Output Power (P_{out})	Minimum Average Efficiency in Active Mode (expressed as a decimal)	10% Load Average Efficiency in Active Mode (expressed as a decimal)	Maximum Power in No-Load Mode (W)
$0.3\ W \le P_{out} \le 1\ W$	$\ge 0.517 \times P_{out} + 0.091$	$\ge 0.517 \times P_{out}$	≤ 0.075
$1\ W < P_{out} \le 49\ W$	$\ge 0.0834 \times \ln(P_{out}) - 0.0011 \times P_{out} + 0.609$	$\ge 0.0834 \times \ln(P_{out}) - 0.00127 \times P_{out} + 0.518$	≤ 0.075
$49\ W < P_{out} \le 250\ W$	≥ 0.880	≥ 0.780	≤ 0.150
$P_{out} > 250\ W$	N/A	N/A	N/A

Globally, it is expected that other nations will soon follow suit with the DoE Level VI standard. In the EU, the current voluntary CoC Tier 1 and Tier 2 requirements for external power supplies are expected to become mandatory European Ecodesign Directives, first essentially harmonizing with the US Level VI standard and then taking the lead with the more stringent Tier 2 rules. It should also be expected that countries with existing efficiency regulations previously in-line with the US, including Canada, will move to harmonize with these newer US and European standards.

SUMMARY

The EPA estimates that external power supply efficiency regulations implemented over the past decade have reduced energy consumption by 32 billion kilowatts, saving $2.5 billion annually and reducing CO2 emissions by more than 24 million tons per year. Beyond the mandated government regulations, many OEMs are now starting to demand “greener” power supplies as a way to differentiate their end-products, driving efficiencies continually higher. In late 2014, CUI Inc began introducing DoE Level VI compliant adapters that now range from 3 W to 250 W. Recently, the company has further qualified the majority of its Level VI line to also conform to the more stringent CoC Tier 2 standards. Moving forward, CUI will continue to implement the latest energy saving technologies into its external power supplies in order to comply with current and future standards as the regulatory landscape continues to evolve.

DoE level VI and CoC Tier 2 compliant power supplies

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