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To: Stakeholders of new policy for desktop power supplies

From:

Ecova – Jason Boehlke, Doug McIlvoy (Consultant)

EPRI – Tom Geist, Baskar Vairamohan, Peyton Sizemore, Daniel Gagnon

Subject: Results from laboratory testing for the performance of desktop-computer power supplies operating at minimal loading.

Dear Stakeholder:

As you are aware, the California Energy Commission (CEC) considered drafting policy for the future of desktop computers and internal power supplies (IPS) for desktop computers. The CEC specifically considered a performance standard for power supplies under conditions of minimal loading—such as when the computer is in idle mode. EPRI and Ecova—who have tested and certified over 5,000 power supplies from over 200 manufacturers throughout the last ten years—is in a unique position to support this effort. This has already happened with stakeholders use of data from the 80 PLUS program that is publicly available via the 80 PLUS website.[1] While helpful, the data is limited to higher power levels (20, 50 and 100 % loading). To further inform the process, EPRI and Ecova teamed to gather and make publicly available additional performance data of power supplies at minimal loading (<5%).

The objective of the testing was to investigate the performance of computer power supplies at 0 – 5% loading. Research goals include better understanding of the capabilities of the 80 PLUS test area—will the setup allow for measurement at low power—and better understanding of the performance of power supplies at minimal power in terms of efficiency and power factor. Finally, what conclusions and recommendations are possible based on the additional data.

The following information is an update to the original report issued in January 2016. The continued interest in minimal loading of desktop power supplies by the National Resources Defense Council (NRDC) and the Environmental Protection Agency's Energy Star program suggested the need for a more significant sampling of desktop IPS products for minimal loading efficiency performance. This report increases the sampling by 21 units to a total of 33 units.

The 80 PLUS Program is supportive of the EPA adding a percentage, or wattage, load requirement to collect low power efficiency performance data on desktop internal power supplies.

This commentary is in draft form, not proprietary, and open for comments. Please share as widely as possible.

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[1] http://www.plugloadsolutions.com/Default.aspx

Sample Description

Selected were 33 power supplies from various manufacturers submitted to the 80 PLUS program for testing and certification as Desktop IPS products. Samples 1-12 are the original PSUs tested in 2015 for low power, while the remaining 21 samples were submitted within the last six months. Diversity factors included form factor, 80 PLUS badge level, and power rating. Of the power supplies 26 had an ATX/EPS form factor, 1 had an 1U form factor, and the rest were miscellaneous "Other" form factors. The criteria for badge levels is shown in Table 1. The breakdown of samples by badge level is shown in Table 2. The breakdown of power supplies by power rating is shown in Table 3.

Table 1, Badge levels and criteria of the 80 PLUS program.

	115V Internal Non-Redundant 80 PLUS Efficiency-Level			
Level	**10%**	**20%**	**50%**	**100%**
Standard	-	80%	80%	80% PF ≥0.9
Bronze	-	82%	85% PF ≥0.9	82%
Silver	-	85%	88% PF ≥0.9	85%
Gold	-	87%	90% PF ≥0.9	87%
Platinum	-	90%	92% PF ≥0.95	89%
Titanium	90%	92% PF ≥ 0.95	94%	90%

Table 2, Number of samples by badge level.

Badge Level	Number of Samples
Standard	3
Bronze	16
Silver	1
Gold	8
Platinum	4
Titanium	1

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Table 3, Number of samples by power rating.

Power Rating	Number of Samples
198	1
200	1
250	1
280	1
300	3
350	3
400	4
450	4
500	5
550	2
650	1
700	1
750	1
850	2
1050	1
1080	1
1400	1

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Test Setup

Samples were measured on EPRI's 115 V, multi-output test bench, which is the same bench used to provide data to Ecova for certification (see Figure 1). The same instrumentation was used with the exception of the power meter. To provide greatest accuracy, a Yokogawa WT3000 was substituted for the Yokogawa WT2030, which is normally used. A comparison of the key accuracy metrics between the two meters—as well as the WT210, which is commonly used by others—is shown in table 4. Note that the stated accuracy is applicable when the power factor is unity (1).

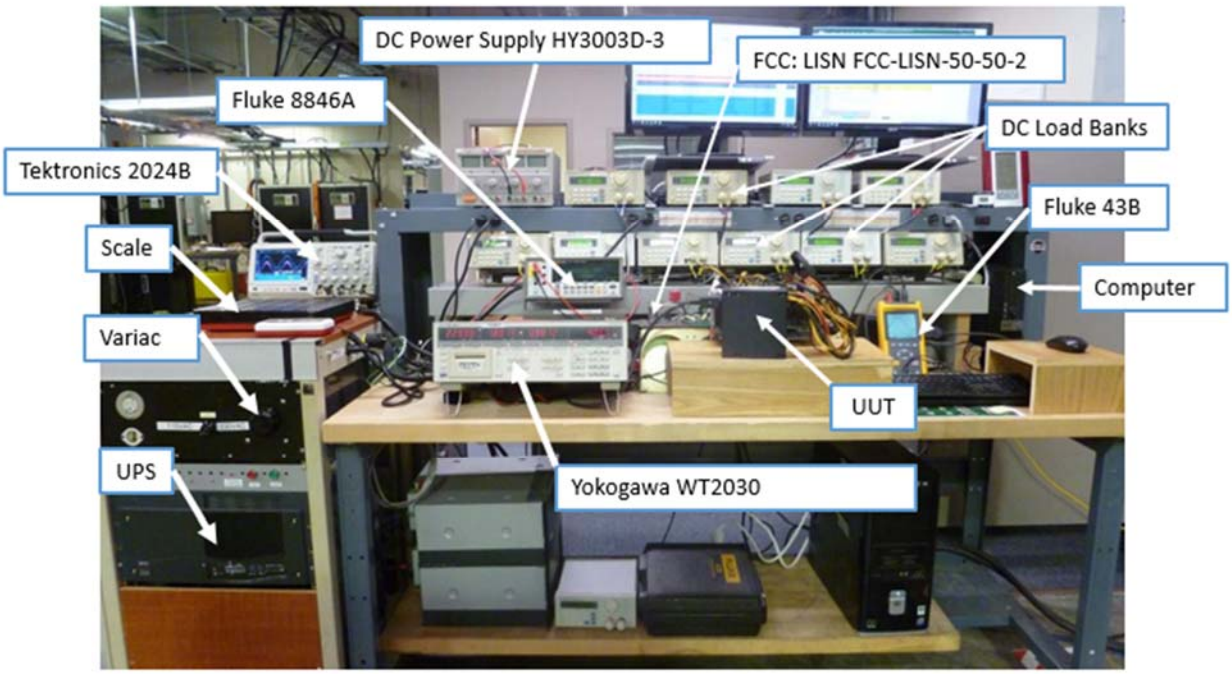

Figure 1, Photograph of EPRI's 115V, multi-output test bench for testing of desktop-computer power supplies.

Table 4, Comparison of key metrics between the WT2030, WT3000, and WT210 (115V, 60 Hz, single-phase input, and no line filter).

Parameter	WT2030	WT3000	WT210
Voltage	0.1% of reading + 0.05% of range	0.01% of reading + 0.03% of range	0.1% of reading + 0.1% of range
Current	0.1% of reading + 0.05% of range.	0.01% of reading + 0.03% of range	0.1% of reading + 0.1% of range
Power	0.2% of reading + 0.1% of range	0.04% of reading + 0.04% of range	0.1% of reading + 0.1% of range

Data was measured and recorded following the *Generalized Test Protocol for Calculating the Energy Efficiency of Internal AC-DC and DC-DC Power Supplies, Revision 6.7* and EPRI's internal test protocol.[2] However, power supplies were not powered for 15 minutes before data was recorded.

Measurements (input/output power and power factor) were taken under conditions of 6 W loading, 1% loading, 3% loading, and 5% loading. Data at 10, 20, 50, and 100% was gathered from the existing database.[3] Data at no-load was measured and is presented in a separate section on input power. Data on fan power (see the section Fan Power) was collected using a Fluke 8846A. Various waveform data was gathered using a Lecroy oscilloscope (Waverunner 6030) and is in the section on impact of harmonics.

Results

Efficiency

For each of the 33 samples, the measured efficiency at the loading points is provided in Table 5. A plot of the efficiency data is shown in Figure 2. As expected, efficiency decreases with lessening load. In general, efficiency of the power supplies begins tapering at 30% loading, drops appreciable as load decreases to 20%, and even further as the load nears 10%. Below 10% loading there is a dramatic decrease in efficiency. Surprisingly, three samples maintained efficiency at a level greater than 80% to about 3% loading, which is more clearly seen in Figure 3. The data shown in Figure 3 also suggests that badge level may predict efficiency performance above loading of 3%, but does not predict efficiency performance below 3% loading—as evidenced by the fact that several samples rated bronze outperformed the titanium sample at 1% loading. The one sample rated Silver performed best at 1% load.

For sample 1, which is rated 200 W, loading is the same for both the 6 W and 3 %. The power supply was measured two separate times. The difference in efficiency is 0.17% (58.16-57.99), which is within the repeatability specification of the test bench (+/- 0.3 %)—a number that represents the measured repeatability of the bench over ten years of testing—and well within the specification for repeatability within the published protocol (+/- 0.5%).

Regarding absolute load conditions; the only absolute loading was done at 6W and at 20W. As you would expect with a range of power supply ratings from 198 Watts to 1400 Watts the efficiency of all units was better at 20 Watts. The loading range for 6 watts varied from 0.4% to 3%, and efficiency varied from 37% to 60%. This suggests the use of power groupings to combine similar rated products. At 20 Watts the loading range varied from 1.4% to 10%. The efficiency at 20 W varied from 60% to 81%.

Regarding the loading at a percentage of the rating; The range of efficiency at 1% loading was similar and not much better than efficiency range at 6 W loading. The efficiency range at 3%

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[2] Available from: http://www.plugloadsolutions.com/docs/collatrl/print/Generalized_Internal_Power_Supply_Efficiency_Test_Protocol_R6.7.pdf

[3] Manufacturers typically provide two identical samples for testing. No attempt was made to control for which of the samples were used for gathering the original data.

loading was very similar to efficiency range at 20 W loading although 3% load varied from 6 W to 42 W.

Efficiency at 5% was improved and the range varied from 67% to 86%. In addition, PF was now active on most units and the range of PF varied from 0.52 (non-active PF) to 0.93.

Table 5, Measured efficiency of power supplies at various loading.

Sample #	Rated Power	80 PLUS Badge Level	6W	1%	3%	5%	10%*	20%*	50%*	100%*
1	200	Bronze	57.99%**	37.54%	58.16%**	67.50%	77.04%	83.27%	86.62%	83.81%
2	300	Standard	53.42%	41.93%	59.05%	65.59%	74.37%	81.63%	85.32%	83.54%
3	350	Bronze	52.78%	43.71%	61.76%	66.98%	77.10%	83.45%	86.57%	85.34%
4	350	Platinum	56.90%	45.17%	69.68%	77.81%	86.10%	91.00%	92.51%	90.18%
5	400	Bronze	59.89%	53.49%	68.28%	74.16%	81.44%	86.05%	87.62%	84.67%
6	400	Bronze	47.68%	37.89%	60.53%	69.93%	79.22%	84.46%	86.82%	85.06%
7	450	Gold	41.97%	35.68%	61.17%	71.47%	83.59%	88.57%	90.80%	88.10%
8	450	Standard	32.51%	27.85%	50.45%	61.72%	73.65%	81.40%	84.85%	82.53%
9	500	Titanium	34.98%	38.94%	83.08%	87.72%	91.98%	94.05%	94.21%	91.88%
10	500	Bronze	44.78%	40.30%	64.96%	73.82%	82.68%	87.17%	88.17%	83.65%
11	500	Bronze	43.19%	40.28%	61.77%	69.74%	79.27%	84.42%	86.32%	83.23%
12	500	Gold	43.76%	43.57%	50.47%	70.95%	83.38%	89.26%	90.77%	88.36%
13	450	Bronze	49.22%	49.22%	45.53%	62.72%	69.46%	45.53%	62.72%	69.46%
14	650	Bronze	46.81%	46.81%	49.22%	68.46%	74.01%	49.22%	68.46%	74.01%
15	198	Gold	59.47%	59.47%	40.73%	59.72%	69.87%	40.73%	59.72%	69.87%
16	400	Bronze	48.52%	48.52%	39.95%	63.22%	71.57%	39.95%	63.22%	71.57%
17	350	Bronze	53.28%	53.28%	42.31%	65.82%	72.56%	42.31%	65.82%	72.56%
18	1050	Platinum	38.00%	38.00%	49.74%	73.35%	81.51%	49.74%	73.35%	81.51%
19	300	Bronze	51.63%	51.63%	39.17%	58.43%	68.55%	39.17%	58.43%	68.55%
20	850	Platinum	38.46%	38.46%	46.62%	71.04%	79.35%	46.62%	71.04%	79.35%
21	500	Gold	43.17%	43.17%	38.91%	64.40%	74.33%	38.91%	64.40%	74.33%
22	700	Gold	37.77%	37.77%	40.86%	66.09%	75.16%	40.86%	66.09%	75.16%
23	450	Standard	43.43%	43.43%	36.82%	57.55%	67.05%	36.82%	57.55%	67.05%
24	280	Bronze	52.58%	52.58%	39.20%	60.32%	69.79%	39.20%	60.32%	69.79%
25	400	Bronze	53.60%	53.60%	46.51%	63.09%	71.46%	46.51%	63.09%	71.46%
26	750	Platinum	45.09%	45.09%	50.44%	72.95%	80.68%	50.44%	72.95%	80.68%
27	550	Gold	44.53%	44.53%	43.22%	67.92%	76.72%	43.22%	67.92%	76.72%
28	850	Gold	43.23%	43.23%	51.81%	73.74%	80.50%	51.81%	73.74%	80.50%
29	1080	Gold	40.32%	40.32%	48.44%	80.57%	85.49%	48.44%	80.57%	85.49%
30	1400	Silver	40.88%	40.88%	63.02%	81.39%	85.88%	63.02%	81.39%	85.88%
31	300	Bronze	53.77%	53.77%	40.51%	60.28%	69.41%	40.51%	60.28%	69.41%
32	250	Bronze	55.99%	55.99%	44.21%	60.36%	71.79%	44.21%	60.36%	71.79%
33	550	Bronze	36.92%	36.92%	32.54%	56.85%	68.79%	32.54%	56.85%	68.79%

**Data taken from previous set up, may not be the same device (one of two samples provided).*
***Same loading level.*

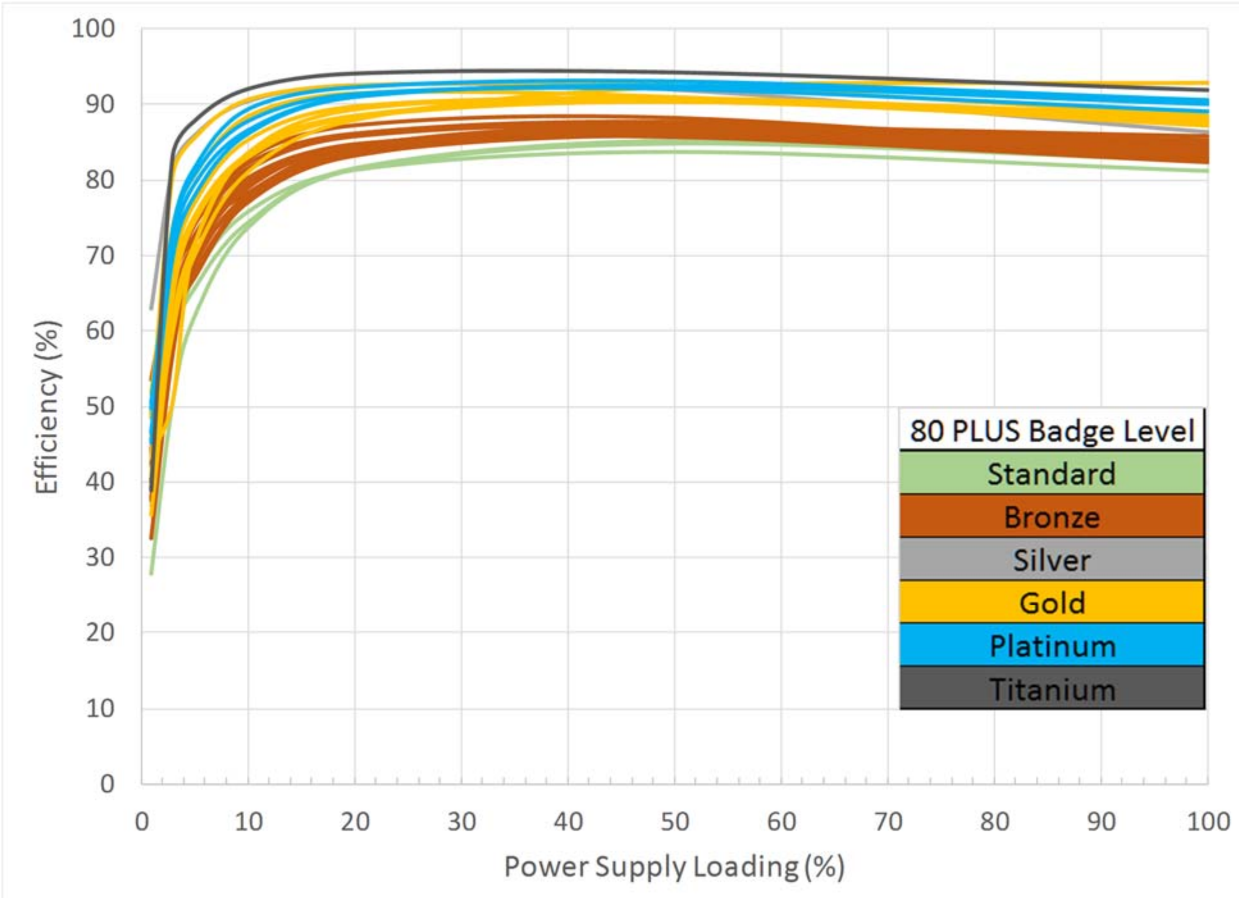

Figure 2, Loading versus efficiency with 80 PLUS badge level

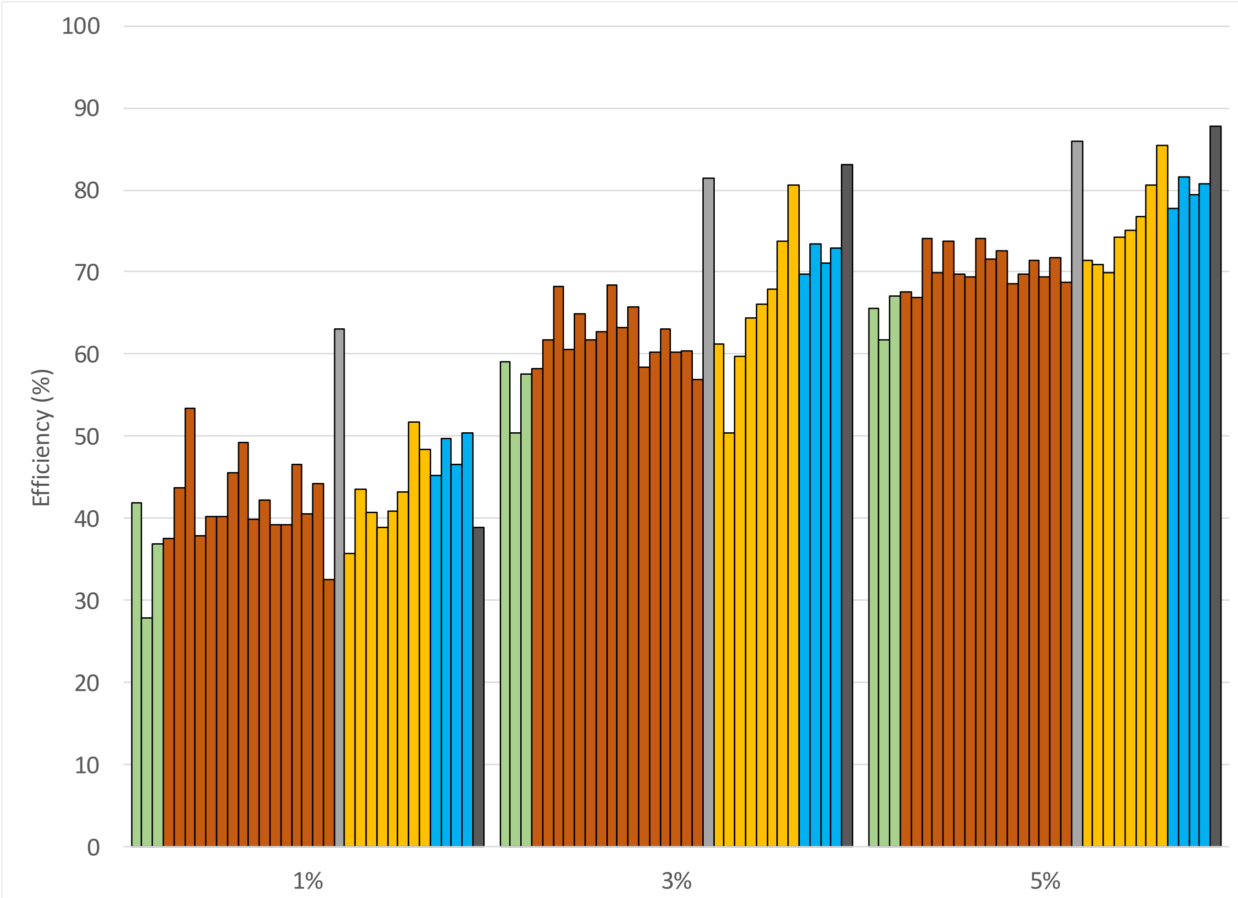

Figure 3, Bar chart with badge levels showing measured efficiency at 1, 3, and 5% loading. The color of the bar corresponds to the 80 PLUS badge level.

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The three bar charts(Figure 4,5,6) below show the efficiency of each sample at 6 W. For ease of viewing the bar charts each contain arbitrarily chosen wattage limits. The groupings make it easy to compare efficiency performance of similar power rated units. Figure 4 shows an efficiency variation of only ±2.9% for units rated from 198W to 350 Watts at 6 w load. Figure 5 shows an efficiency variation of ±13.8% for units rated form 400 W to 500 W at 6 W load. Figure6 shows an efficiency variation of ±4.5% for units rated above 500 W at 6 W load.

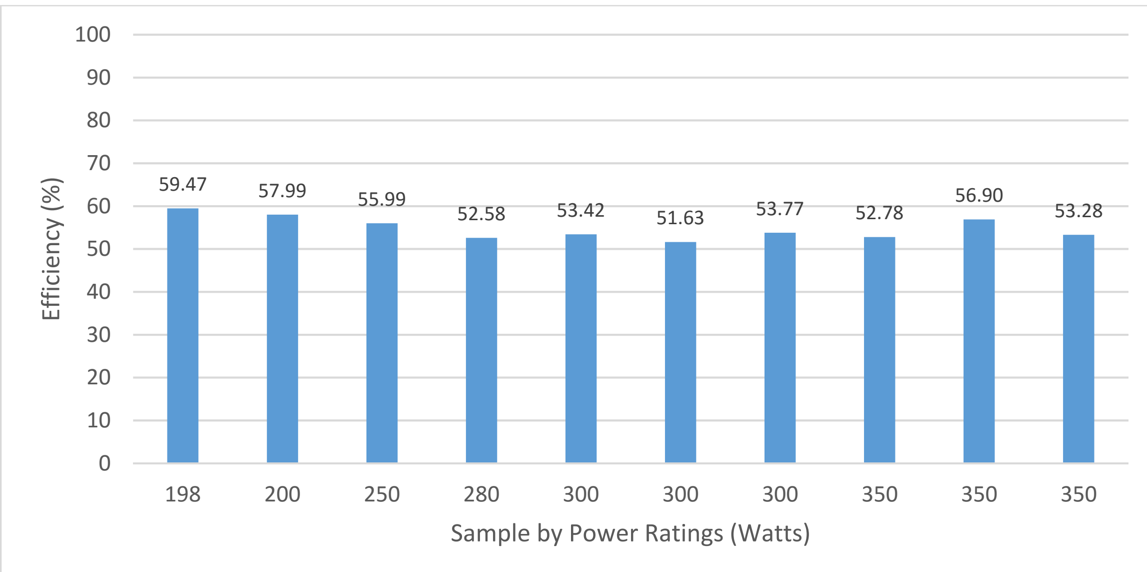

Figure 4, Bar chart showing efficiency for samples rated from 198 W to 350 W listed by rated wattage for loading of 6 W.

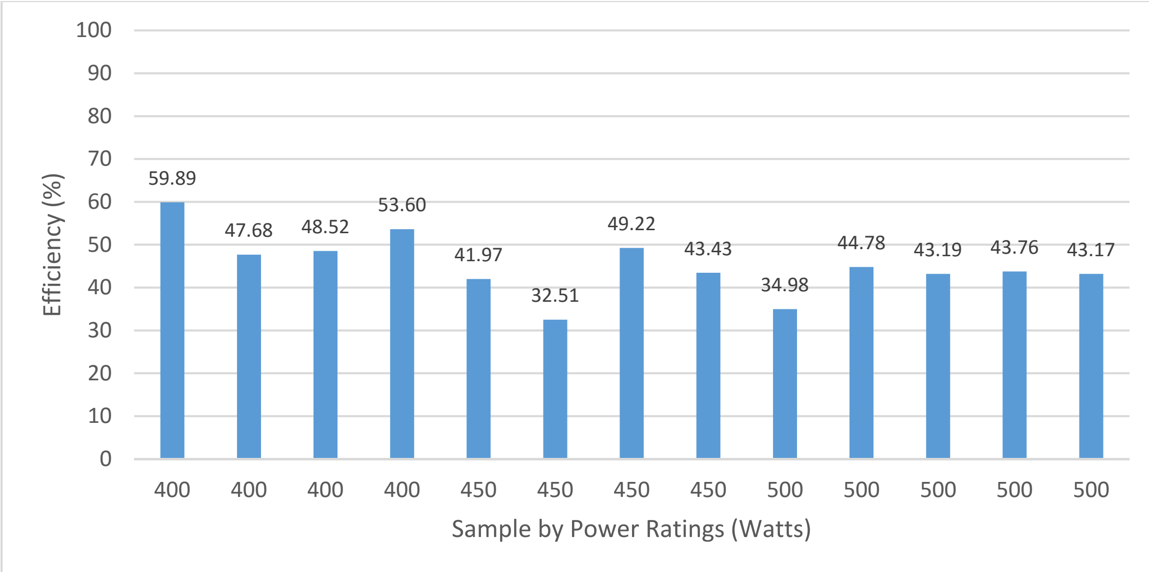

Figure 5, Bar chart showing efficiency for samples rated from 400 W to 500W listed by rated wattage for loading of 6 W.

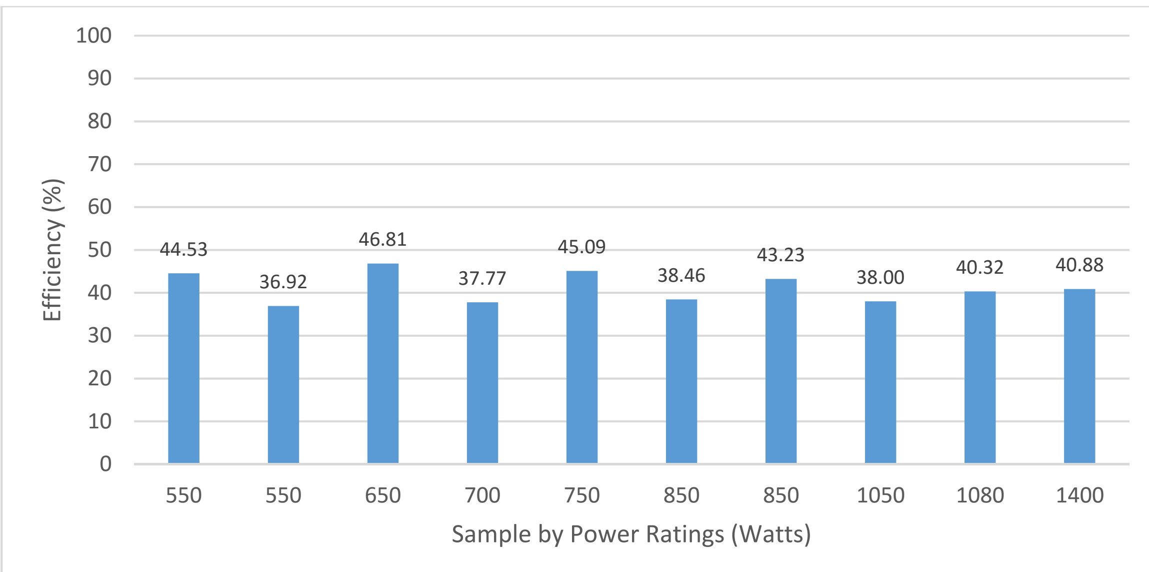

Figure 6, Bar chart showing efficiency for sample sratedabove 500 W listed by rated wattage for loading of 6 W.

Power Factor

For each of the 33 samples, the measured power factor at the loading points is provided in Table 6. Figure 7 is a plot of the power factor data. And Figure 8 is a bar chart of the power factor data. Similar to efficiency, power factor is relatively constant above 0.9 down to about 15% loading and below 10% loading falls appreciably. The data shown in Figure 7 suggests that badge rating at light loading is not a predictor of power factor performance.

Table 6. Measured power factor at each loading point.

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Sample #	Rated Power	80 PLUS Badge Level	6W	1%	3%	5%	10%*	20%*	50%*	100%*
1	200	Bronze	0.6973**	0.5085	0.6999**	0.8012	0.9068	0.9591	0.9850	0.9897
2	300	Standard	0.6492	0.5102	0.7425	0.8151	0.8729	0.9031	0.9854	0.9945
3	350	Bronze	0.6566	0.5515	0.7880	0.8454	0.8732	0.9200	0.9895	0.9956
4	350	Platinum	0.5264	0.4285	0.6580	0.7821	0.8967	0.9663	0.9928	0.9980
5	400	Bronze	0.3713	0.3212	0.6685	0.8292	0.9207	0.9596	0.9728	0.9787
6	400	Bronze	0.5183	0.4692	0.6695	0.7826	0.9253	0.9733	0.9860	0.9948
7	450	Gold	0.5058	0.4761	0.6270	0.7326	0.9247	0.9626	0.9919	0.9972
8	450	Standard	0.7581	0.7152	0.8463	0.9002	0.9537	0.9812	0.9949	0.9949
9	500	Titanium	0.6937	0.6093	0.7219	0.8365	0.9346	0.9678	0.9751	0.9910
10	500	Bronze	0.6354	0.6121	0.7750	0.8334	0.9049	0.9493	0.9788	0.9906
11	500	Bronze	0.5396	0.5010	0.7400	0.8553	0.9726	0.9671	0.9870	0.9926
12	500	Gold	0.5146	0.4503	0.7410	0.8230	0.9244	0.9748	0.9936	0.9973
13	450	Bronze	0.5192	0.4395	0.7164	0.8340	0.9262	0.9698	0.9894	0.9921
14	650	Bronze	0.5318	0.5393	0.8030	0.8925	0.9497	0.9730	0.9887	0.9954
15	198	Gold	0.6042	0.3507	0.5942	0.7063	0.8537	0.9370	0.9784	0.9883
16	400	Bronze	0.6078	0.5341	0.7508	0.8480	0.9337	0.9719	0.9846	0.9943
17	350	Bronze	0.5984	0.4958	0.7084	0.8064	0.9048	0.9501	0.9784	0.9890
18	1050	Platinum	0.3811	0.4472	0.6456	0.7052	0.7901	0.9135	0.9874	0.9945
19	300	Bronze	0.6393	0.4956	0.7302	0.8283	0.9171	0.9692	0.9831	0.9867
20	850	Platinum	0.5080	0.6123	0.8104	0.8943	0.9439	0.9763	0.9962	0.9980
21	500	Gold	0.5596	0.5333	0.7275	0.8267	0.9132	0.9635	0.9946	0.9976
22	700	Gold	0.6006	0.6225	0.8207	0.9046	0.9819	0.9919	0.9963	0.9977
23	450	Standard	0.4899	0.4487	0.6399	0.7253	0.9720	0.9884	0.9958	0.9991
24	280	Bronze	0.7043	0.5624	0.7557	0.8401	0.9144	0.9546	0.9850	0.9922
25	400	Bronze	0.5209	0.4287	0.6980	0.8175	0.9019	0.9763	0.9789	0.9860
26	750	Platinum	0.3700	0.3962	0.5511	0.6385	0.8084	0.9282	0.9733	0.9879
27	550	Gold	0.5524	0.5375	0.7470	0.8452	0.9295	0.9671	0.9849	0.9894
28	850	Gold	0.4960	0.5453	0.7958	0.8923	0.9530	0.9801	0.9895	0.9931
29	1080	Gold	0.4994	0.6594	0.8327	0.9080	0.9693	0.9499	0.9880	0.9975
30	1400	Silver	0.5088	0.6512	0.8689	0.9251	0.9558	0.9675	0.9940	0.9983
31	300	Bronze	0.3315	0.2468	0.4061	0.5145	0.7290	0.8935	0.9905	0.9896
32	250	Bronze	0.5177	0.3271	0.5627	0.6726	0.7598	0.8874	0.9637	0.9839
33	550	Bronze	0.5076	0.4947	0.6706	0.8031	0.8975	0.9650	0.9890	0.9941

*Data taken from previous set up, may not be the same device (one of two samples provided).

**Same loading level.

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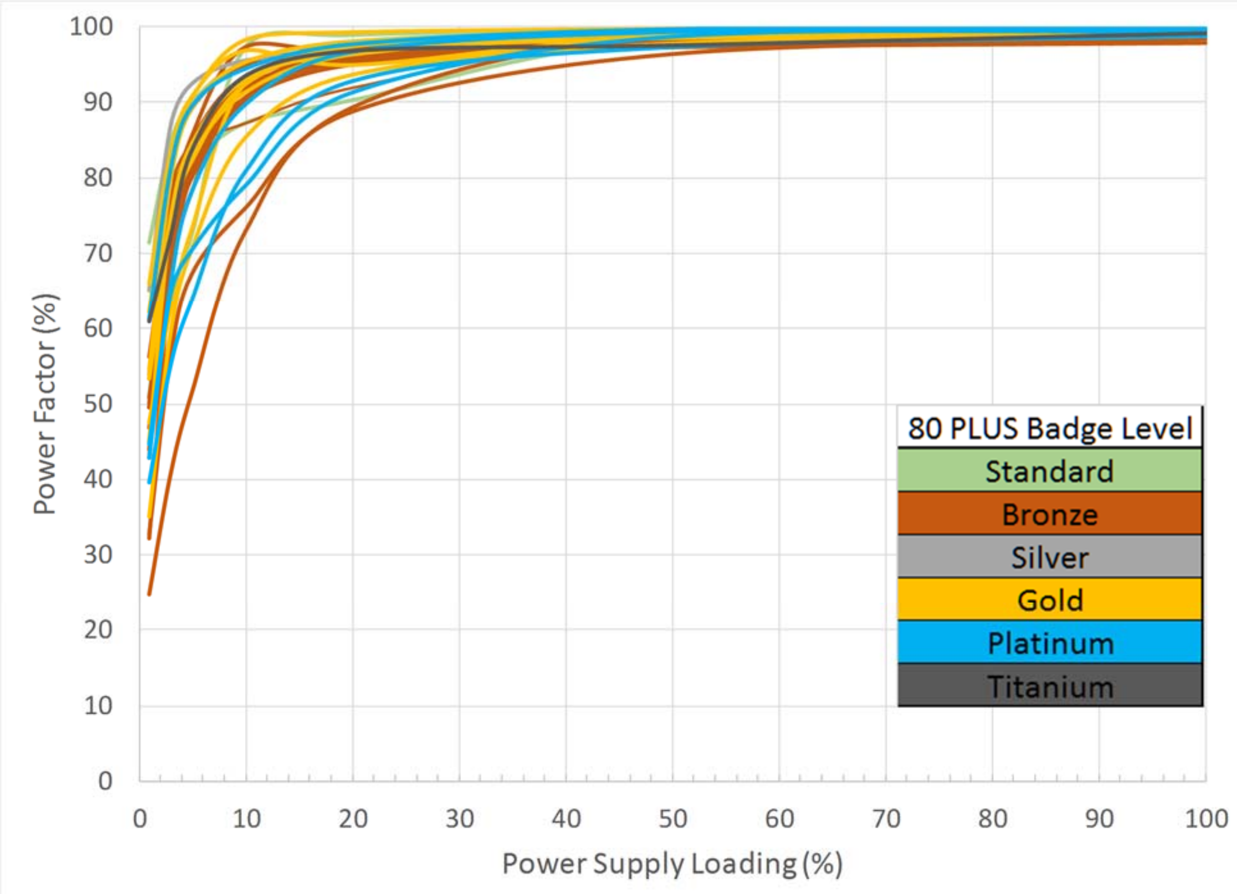

Figure 7, Plot of power supply loading versus power factor.

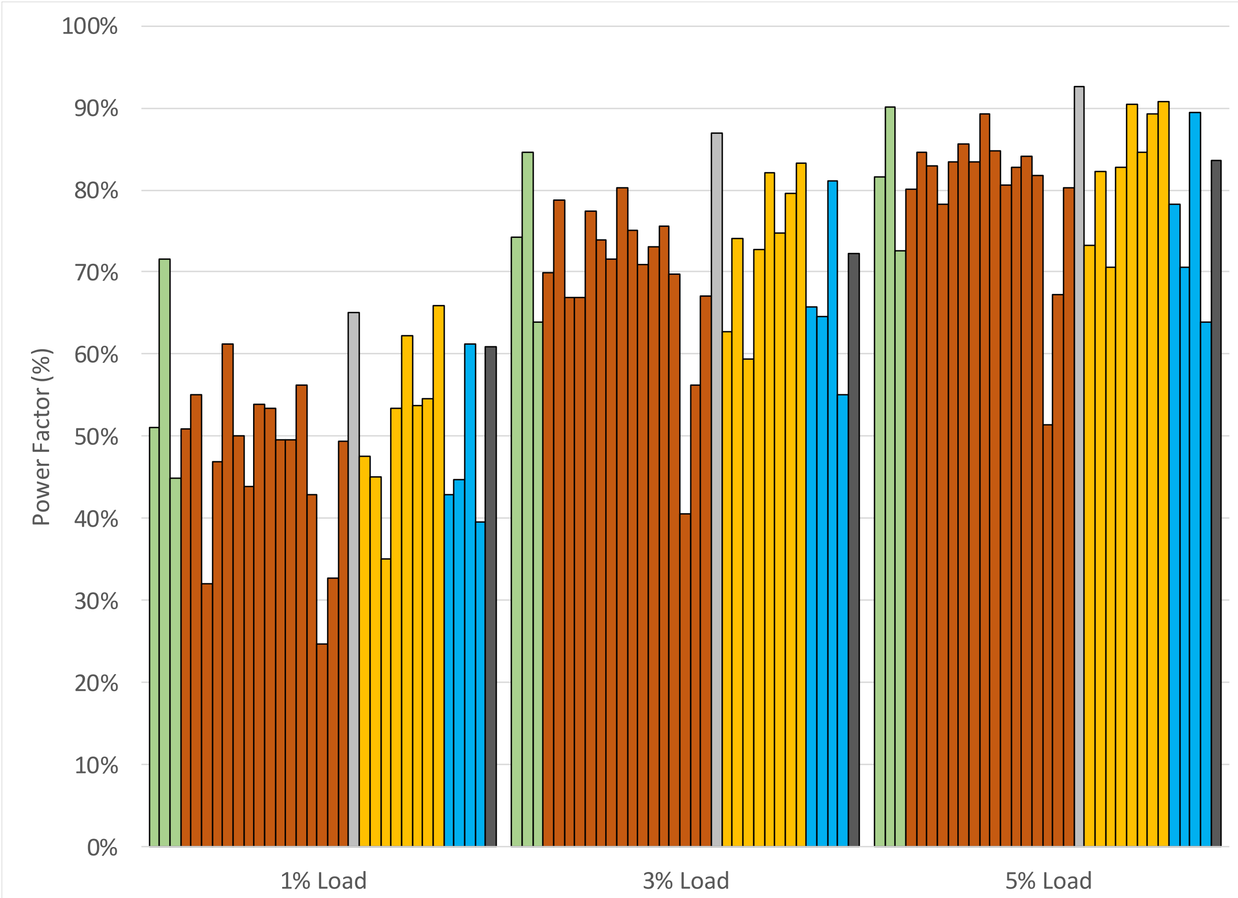

Figure 8, Bar chart with badge levels showing power factor at 1, 3, and 5% loading.

Input Power

For each of the 33 samples the measured input and output power for loading conditions of no-load, 6 W, 1%, 3%, and 5%, is shown in table 7. Note, for samples 9 and 11 no-load input power was not recorded because the readings were not stable. Power readings are provided instead of efficiency in order to inform the stakeholders who are considering an absolute power number not to exceed, which is easier and cheaper to measure, rather than an efficiency number.

Figure 9 is a scatterplot of the input power versus the output power for all loading conditions. Figure 9 shows that at no-load 29 of the power supplies had an input power less than 10 W, two were not stable enough to allow measurement, and two power supplies measured more than 10 W. At 6 W the input power ranged from 10 W to just under 20 W. The data suggest that a 60% efficiency or better at 6 W (6 W out/10 W In) seems unrealistic with the current state of technology (although the sample set is small and not statistically significant).

The other loading conditions (1%, 3%, and 5%) do not coincide. Nevertheless, the scatterplot of Figure 9 provides an indication of the range in input power to be expected, especially below 5 W in output power where the grouping is closer.

Table 7, measured input and output power (W) at each loading condition.

Sample #	Input Power at No Load	Input Power at 6W	Output Power at 6W	Input Power 1%	Output Power 1%	Input Power 3%	Output Power 3%	Input Power 5%	Output Power 5%
1	2.83	10.60	6.14	5.55	2.08	10.57	6.15	15.17	10.22
2	2.65	11.63	6.21	7.45	3.12	15.76	9.31	23.65	15.49
3	2.94	11.69	6.17	8.26	3.61	17.32	10.70	26.95	17.95
4	4.39	10.80	6.14	7.95	3.59	15.40	10.73	22.94	17.85
5	1.56	10.17	6.09	7.60	4.06	17.77	12.13	27.21	20.18
6	5.41	13.03	6.21	10.95	4.15	20.53	12.43	29.64	20.71
7	8.28	14.59	6.12	12.90	4.60	22.41	13.71	31.98	22.83
8	11.93	18.38	5.97	16.10	4.48	26.58	13.41	36.21	22.35
9	N/A*	17.70	6.19	13.20	5.14	18.46	15.33	29.13	25.55
10	7.75	13.39	5.99	12.43	5.01	23.03	14.96	33.74	24.91
11	N/A*	14.17	6.12	12.69	5.11	24.71	15.26	36.42	25.40
12	4.46	14.16	6.20	11.86	5.17	27.27	13.76	36.29	25.73
13	3.95	12.53	6.17	10.17	4.63	21.98	13.78	32.99	22.92
14	4.38	13.02	6.10	13.37	6.58	28.80	19.72	44.32	32.80
15	1.93	10.24	6.09	4.94	2.01	10.08	6.02	14.32	10.01
16	4.11	12.52	6.08	10.16	4.06	19.17	12.12	28.21	20.19
17	3.82	11.36	6.05	8.34	3.53	16.08	10.59	24.31	17.64
18	0.07	15.99	6.08	21.36	10.62	43.29	31.75	64.90	52.90
19	3.76	11.75	6.07	7.80	3.06	15.56	9.09	22.11	15.16
20	9.34	15.85	6.10	18.48	8.62	36.27	25.77	54.08	42.91
21	7.91	14.10	6.09	13.01	5.06	23.51	15.14	33.91	25.20
22	9.80	16.43	6.20	17.23	7.04	32.53	21.50	47.59	35.77
23	3.70	13.76	5.98	12.24	4.51	23.26	13.38	33.24	22.28
24	3.34	11.68	6.14	7.34	2.88	14.20	8.57	20.44	14.27
25	2.63	11.47	6.15	8.86	4.12	19.40	12.24	28.50	20.36
26	6.98	13.55	6.11	15.17	7.65	31.38	22.89	47.43	38.27
27	7.52	13.76	6.13	13.04	5.63	24.72	16.79	36.44	27.96
28	7.48	14.07	6.08	16.58	8.59	35.01	25.82	53.47	43.05
29	0.95	15.13	6.10	22.64	10.97	40.60	32.71	63.72	54.47
30	4.61	14.99	6.13	22.62	14.25	52.43	42.68	82.70	71.02
31	2.73	11.37	6.11	7.58	3.07	15.16	9.14	21.92	15.21
32	1.28	10.79	6.04	5.76	2.55	12.50	7.55	17.50	12.56
33	11.36	16.19	5.98	17.25	5.61	29.58	16.82	44.06	30.31

**Data not available. Measurements were not stable.*

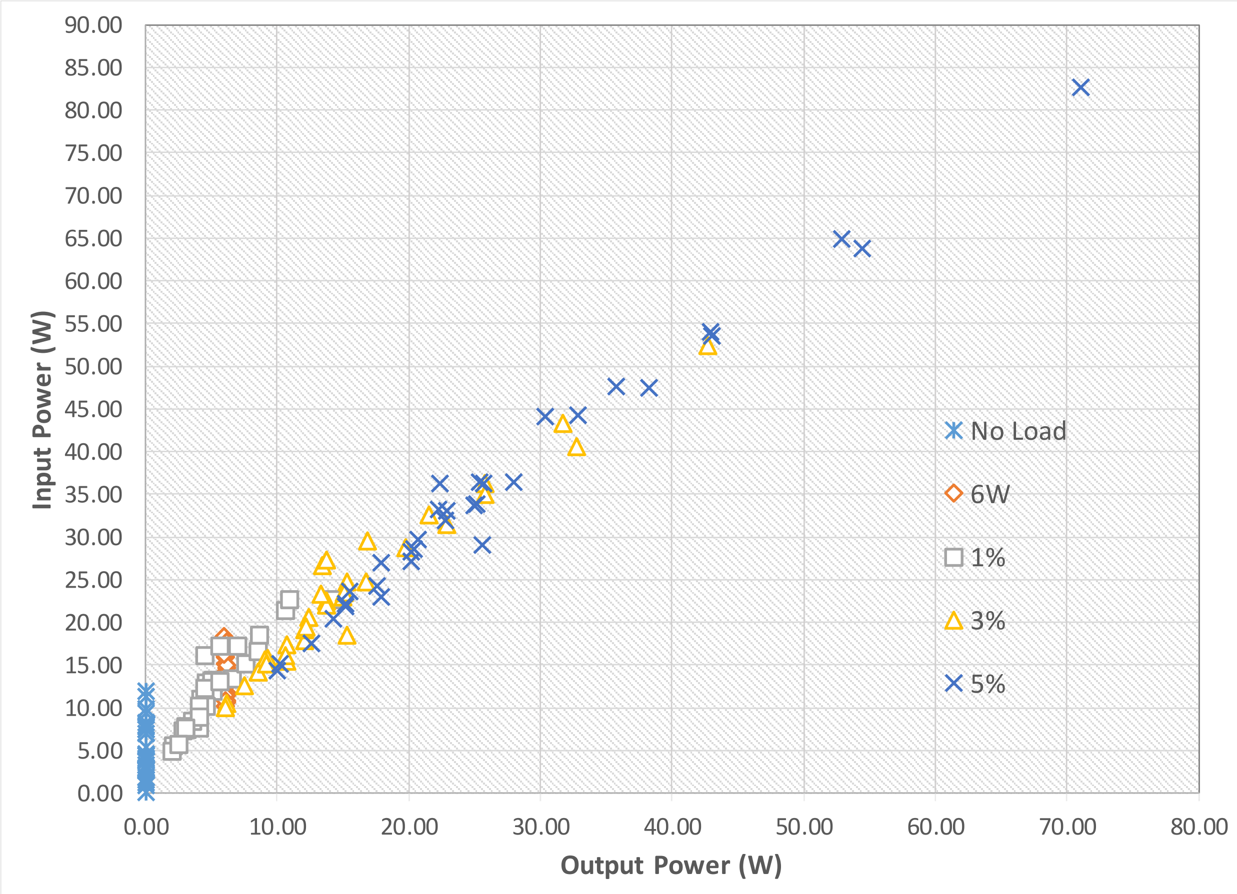

Figure 9, Scatterplot showing input power versus output power for all loading conditions.

The input power is the combination of the housekeeping power— the power needed to operate the power supply—and the power needed for the load as well as the losses from conversion of AC to DC power. Figure 10 provides insight into the difference between housekeeping power and conversion losses by showing the output power divided by the sum of input power minus the input power at no-load, which for this document is defined as the incremental conversion efficiency and is shown for each of the samples loaded to 6 W. Per Figure 10 the incremental conversion efficiency is quite good and exceeds 60% for all of the samples. However, there is significant variation in conversion efficiency, which suggests an opportunity among manufacturers for improvement.

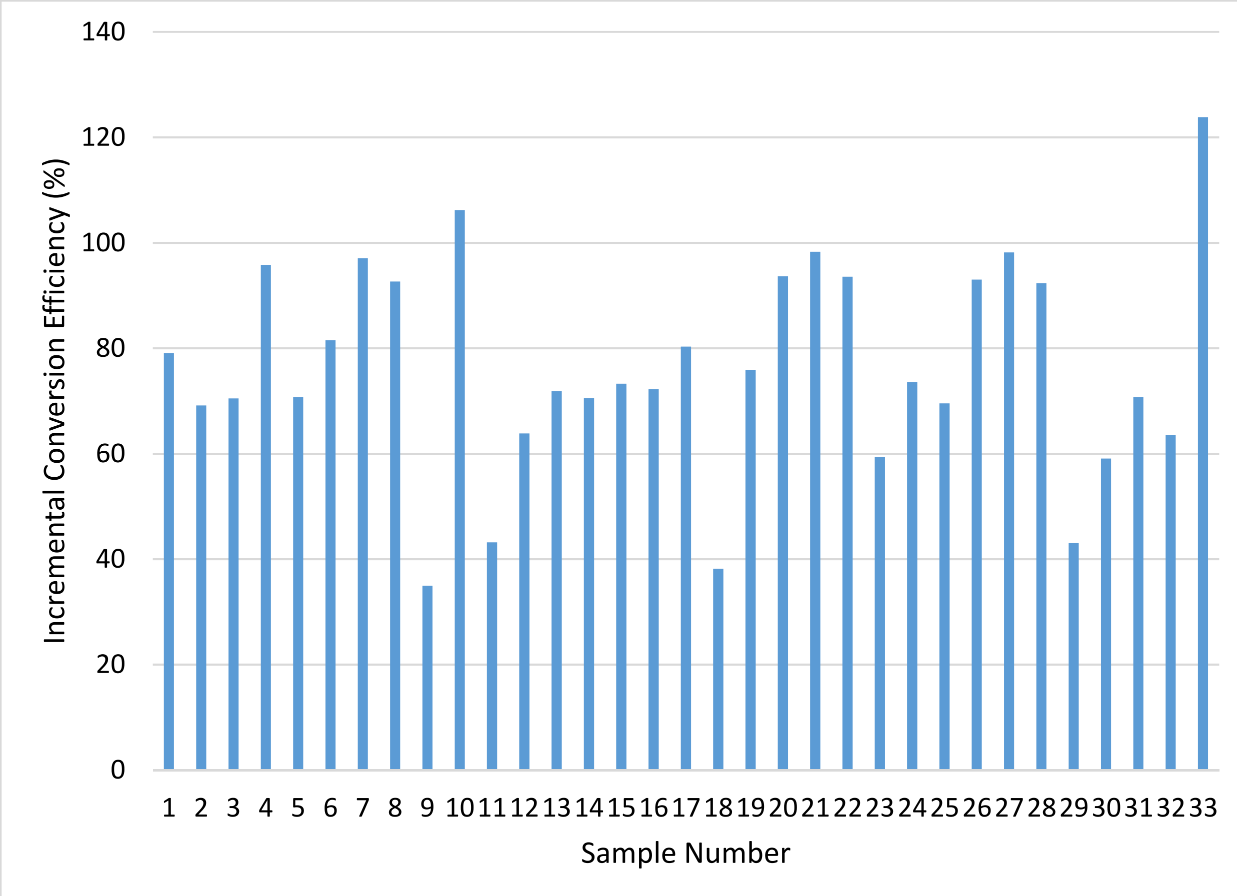

Figure 10, Bar chart showing the incremental conversion efficiency (Output power/(Input power minus input power at no load) for each of the samples loaded to 6 W.

Fan Power

To provide insight into a possible reason for the variation in power supply performance EPRI decided to measure fan performance. Table 8 shows the status of the fan in terms of on/off for each of the original 12 samples. Note that the fan status was consistent for all loading points at least up to 5%. Table 8 shows that all of the fans were enabled except for the sample rated titanium.

In an ad hoc test, EPRI measured the efficiency of sample 12 (gold) at the low-power loading points (6W, 1%, 3%, 5%) with and without the fan connected. The results are shown in Figure. 11. Power saved ranged from 1.53 W at no load to 2.79 W at 5% load. For samples 13 – 33, the fan status was recorded at the no load condition, and for the 21 samples only four did not enable the fan. The fan data suggests that simply turning the fan off at 5% load would save almost 3 W of power. More work is needed to determine how best to encourage manufacturers to adopt more aggressive energy strategy for controlling fan operation.

Table 8, Fan status for all loading conditions (no load, 6 W, 1%, 3%, and 5%)

Sample #	Rated Power	80 PLUS Badge Level	Fan On
1	200	Bronze	Yes
2	300	Standard	Yes
3	350	Bronze	Yes
4	350	Platinum	Yes
5	400	Bronze	Yes
6	400	Bronze	Yes
7	450	Gold	Yes
8	450	Standard	Yes
9	**500**	**Titanium**	**No (Off)**
10	500	Bronze	Yes
11	500	Bronze	Yes
12	500	Gold	Yes

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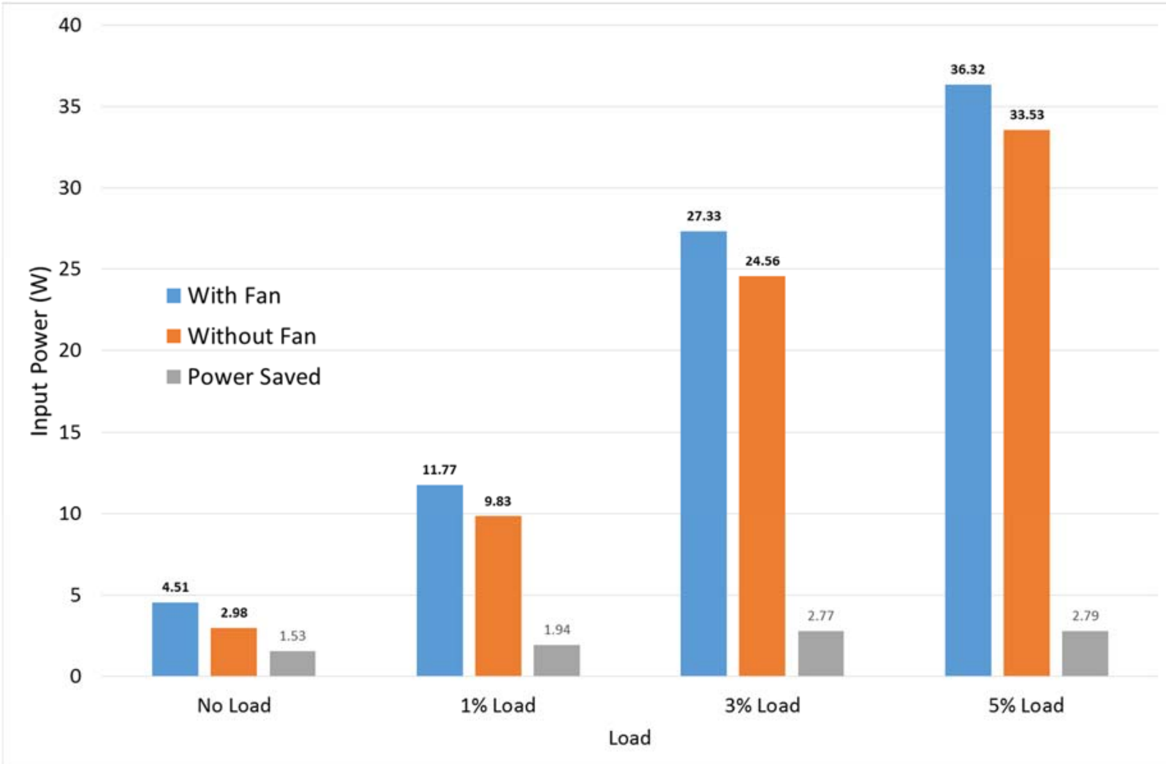

Figure 11, Input power versus load with and without the fan connected for sample 12 (Gold).

Impact of Harmonics

For the original 12 samples, capture of the waveforms for input voltage and current indicate a significant difference in harmonic current when the power supplies operate at minimal loading compared to traditional loading (20-100%). To illustrate, Figure 12 shows the input voltage and current for a representative power supply loaded at 20%. Figure 13 shows the same power supply loaded to 1.2% (6 W). The significant amount of distortion at minimal loading affects the ability to measure power factor mandating the use of sophisticated equipment to make the measurement because of the complex calculations involved to determine power factor. Repeatability between laboratories is a concern given that line impedance may affect measurement value. Given this, any specification for power factor at minimal loading may require a tolerance wider than is typical or than expected.

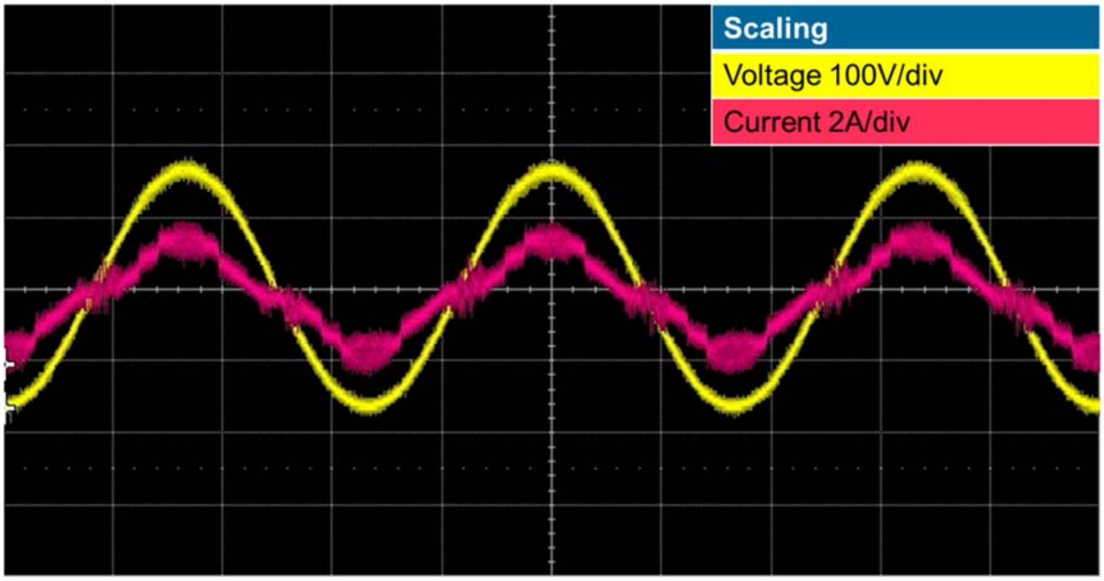

Figure 12, Screen capture of the input voltage and input current of a power supply loaded to 20% (100 W) Note the current is shown at 2 A/division.

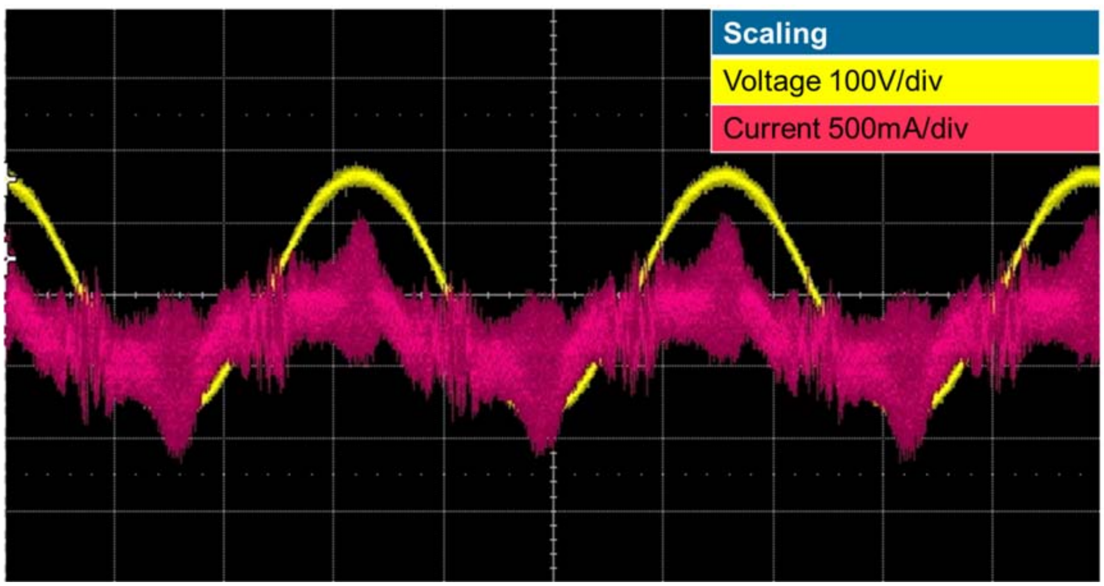

Figure 13, Screen capture of the input voltage and input current of a power supply loaded to 1.2% (6 W). Note the current is shown at 500 mA/division.

Summary

The expanded sampling data continues to suggest it is viable to perform the measurements and efficiency calculation at minimal loading using EPRI's existing test bench and efficiency test protocol. The operation of the electronic load equipment is stable at the minimal power levels.

With an output load of 6 W none of the power supplies achieved 60% efficiency, which is the minimum required to limit input power to 10 Watts during desktop idle operation. It is reasonable to assume that for designers to improve efficiency at 6 watt loads to above 60% requires investment for development of power devices with lower leakage currents and switching losses as well as new techniques for addressing emissions through better filter designs or switching algorithms. The data suggests that one relatively easy way to improve efficiency at low power, and for relatively low cost, is for manufacturers to implement more aggressive strategies for fan control. Approximately 2 W of power is saved by turning off the fan at minimal loading.

Not all power supplies delivered good power factor correction (>0.8) down to and below 10% loading. Near 3% loading PF correction circuits begin to cease operation or go into a burst mode of operation. A specification that held PF to above 0.8 at 10% load could be easily met. At minimal loading measurement of power factor is complicated by the shape of the current waveform, which is not sinusoidal, and may mandate specification of a loose measurement tolerance in order to insure measurement repeatability.

No Load power consumption is of interest because it summarizes the losses occurring just to make the output voltages available for use. No-load power consumption is the power used to operate various circuits within the power supply, such as the input filter, fan (although the fan is likely not needed at minimal loading), switches, switching losses, bleeder string losses, and excitation losses. The data suggests that no-load power consumption measurements do not correlate to either power supply rating or to badge level and is not a predictor of performance. Moreover, 2 of the 33 samples failed to stabilize at the no-load condition. However, measurement of no-load data was useful for insight into the variation of incremental conversion efficiency and the data suggests an opportunity among manufacturers for improvement.

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