



# LED LIGHTING PERFORMANCE AND QUALITY RANKINGS



9/15/2014

Class A Horticulture LED Lighting

A ranking of leading horticulture LED lighting systems using 30 performance and quality measures.

# LED Lighting Performance and Quality Rankings

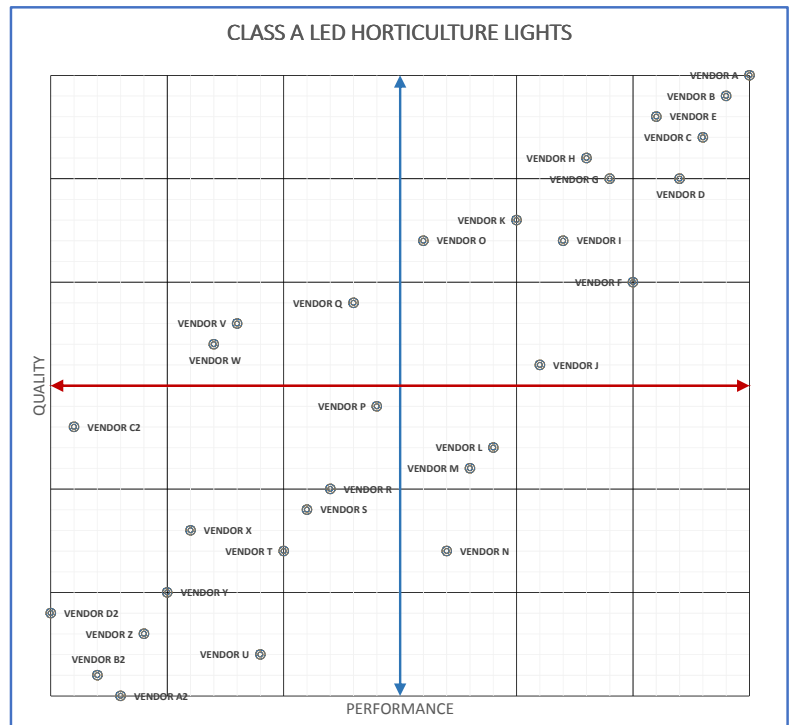
## CLASS A HORTICULTURE LED LIGHTING

### Introduction

The Association of Vertical Farming Economics is a global association of entrepreneurs, business managers, horticulturists, equipment and service suppliers, government agencies, and subject-matter experts focused on accelerating the adoption and success of vertical farming.

The Association publishes a quarterly report that ranks technology, equipment, and materials that have a direct impact on the economics of a vertical farm or controlled environment agriculture.

The report uses published specifications and quantitative data gathered from suppliers which is reviewed and organized to rank-order each product on a two-axis basis of performance and quality. Criteria for quality rankings are weighted to emphasize aspects of the product that have a greater impact on overall quality of the product. In addition, the report renders a Standardized Operating Cost (SOC) score for each product, which provides a formula for comparing products on the basis of operating costs. The Association does not recommend or endorse product suppliers and the report make no recommendations or endorsements. The report is intended to be used as a guide for the Association members as they navigate the decision-making process of determining the products that most correctly match their particular needs.



### Class A Horticulture LED Lighting

The Class A designation includes LED lighting designed for use in scalable commercial growing operations that are characterized by high intensity light output, long life, low maintenance, and manufactured from high quality materials suitable for industrial use.

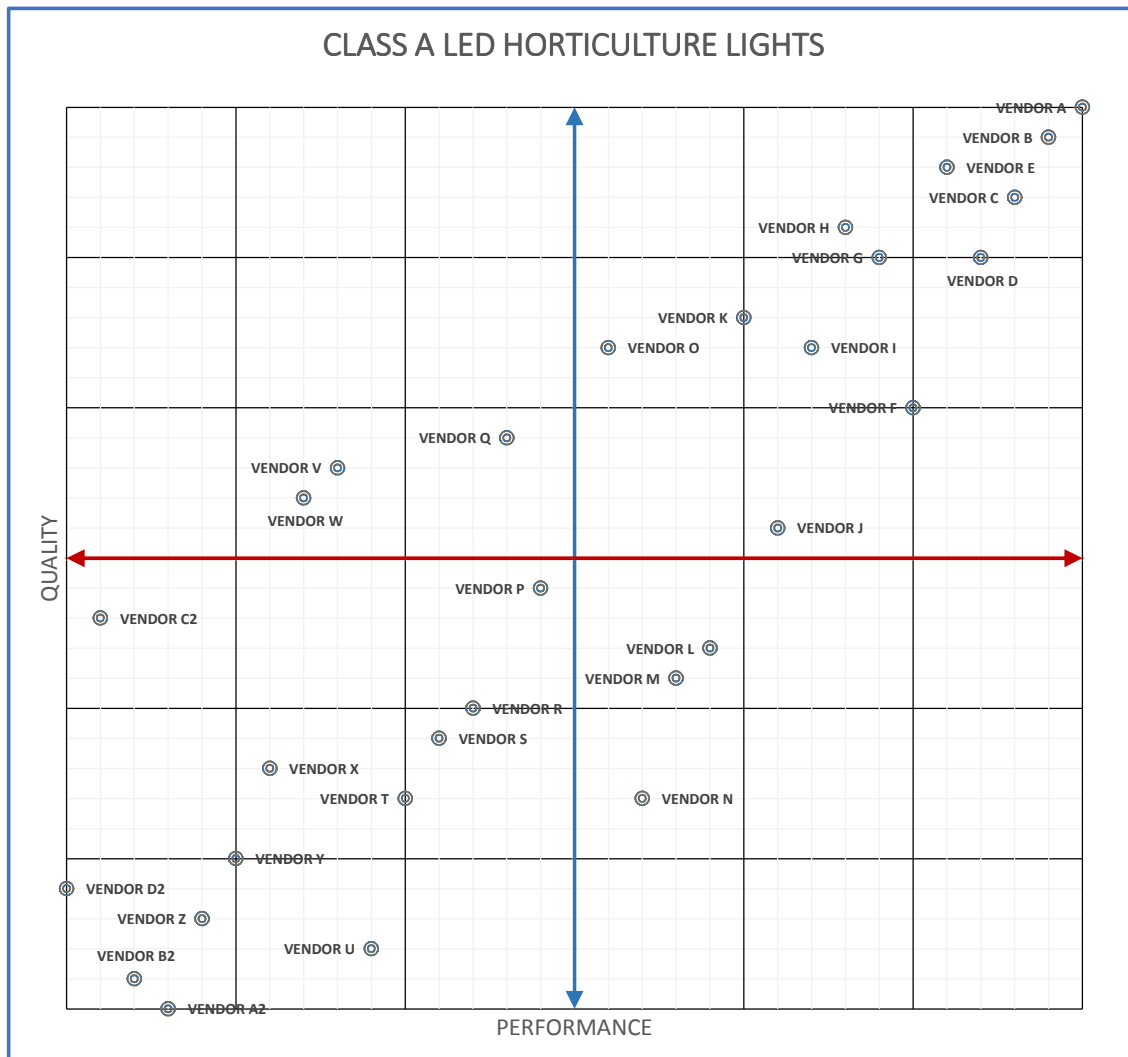
## The Technology Quadrant™ (TQ)

The TQ is a visual representation of a product's relative rank in two categories – Performance and Quality. Products in the upper-right quadrant are ranked in the top half in **both** performance and quality, whereas those in the bottom-left are ranked in the bottom half in both categories.

### An Overview of the TQ

The TQ displays the aggregate of 17 performance and 13 quality specifications and codifies the information that might otherwise go unnoticed. It provides the buyer with the most comprehensive view of the universe of available products, and a starting point for evaluating products using a common set of measures. This helps buyers identify products that might otherwise be unfamiliar to them and identify strengths or weaknesses that are often hard to discern from other marketing communication formats.

The TQ has three important limitations: (1) it does not display the relative differences between each product (with the exception of the SOC ranking – see below), (2) there is no association between the rankings and the product price, (3) it does not consider value-added services of vendors. This means that a product could have a lower composite ranking, with small differences in performance and quality, and still be a better choice than a higher ranked product due to either a lower price or the value of the expertise the vendor adds to the process.



## Analyst's Summary

Each edition includes a narrative summary of the contents of the report. It will note highlights of the report including technical breakthroughs, meaningful improvements to an existing product, significant changes in rankings, and other notes of material value to the reader. Each edition includes a narrative summary of the contents of the report. It will note highlights of the report including technical breakthroughs, meaningful improvements to an existing product, significant changes in rankings, and other notes of material value to the reader. Each edition includes a narrative summary of the contents of the report. It will note highlights of the report including technical breakthroughs, meaningful improvements to an existing product, significant changes in rankings, and other notes of material value to the reader. Each edition includes a narrative summary of the contents of the report.

## New Products

New product additions will be summarized separately so that readers are alerted to the addition. New products will be characterized regarding their relative ranking within the peer group. An introductory overview of the product's manufacturer will also be included. New product additions will be summarized separately so that readers are alerted to the addition. New products will be characterized regarding their relative ranking within the peer group. An introductory overview of the product's manufacturer will also be included. New product additions will be summarized separately so that readers are alerted to the addition.

## New Technology

Advances in LED lighting technology will be evaluated and reviewed separately with expert commentary regarding the technology's application and economic benefits. Advances in LED lighting technology will be evaluated and reviewed separately with expert commentary regarding the technology's application and economic benefits. Advances in LED lighting technology will be evaluated and reviewed separately with expert commentary regarding the technology's application and economic benefits. Advances in LED lighting technology will be evaluated and reviewed separately with expert commentary regarding the technology's application and economic benefits. Advances in LED lighting technology will be evaluated and reviewed separately with expert commentary regarding the technology's application and economic benefits.

## TQ Details

**Performance Rankings** are based on quantifiable specifications including light intensity, uniformity, efficacy, lumen maintenance losses, and color shift. Each product is ranked by category (1 through N) with a composite score determining the final rank<sup>1</sup>.

**Quality Rankings** evaluate materials used in manufacturing, thermal management properties, IP ratings, power supply quality, regulatory approvals, and the product's warranty. Weighted scores are used to distinguish the importance of one category over another (IP ratings are more important than power supply warranties).

**Standardized Operating Cost (SOC)** is a measure of energy consumption under standardized light intensity, photoperiod, electric rates, and an adjustment for lumen maintenance losses – a frequently misunderstood operating cost impact. The top ranked product is assigned an index score of 1.000 with each subsequent product assigned a relative index score – for example 1.050 which would indicate the second product would cost 5%. The SOC captures both photon flux efficacy and a heuristic for comparing differences in lumen maintenance losses. Comparing lumen maintenance losses is an important process as reduced light intensity has a practically-linear relationship to crop yields. We use the most conservative method for measuring losses – a simple 'electrical put-back' calculation that would be required maintain a zero lumen maintenance loss rate.

*[We do not accept advertising, endorse or recommend individual products]*

<sup>1</sup> There are instances when a complete data set is not available from the vendor which will lower the product's relative rank. These instances are footnoted.

Performance Rank

PRODUCT	RANK	AVG PFD <sup>2</sup>	MAX PFD	MIN PFD	AVERAGE <sup>3</sup> UNIFORMITY	EFFICACY <sup>4</sup>	L70 TM21 <sup>5</sup> FORECAST	MOST L70 HRS TESTED <sup>6</sup>	SHORTEST L70 <sup>7</sup>	FEWEST L70 HRS TESTED	LM80 COLOR SHIFT <sup>8</sup>	COMPOSITE
Product A	1	1	1	1	11	1	1	1	1	1	1	1.73
Product B	2	2	2	2	16	8	2	2	2	2	2	3.45
Product C	3	6	6	6	1	3	9	9	9	9	9	5.27
Product D	4	3	3	3	21	12	2	18	2	2	2	6.00
Product E	5	8	8	8	16	11	4	18	4	4	4	7.36
Product F	6	5	5	5	6	26	4	24	4	4	4	7.55
Product G	7	3	3	3	14	4	18	2	18	18	18	7.55
Product H	8	11	11	11	1	6	18	2	18	18	18	8.73
Product I	9	9	9	9	21	17	9	9	9	9	9	9.18
Product J	10	15	15	15	21	21	4	2	4	4	4	9.18
Product K	11	7	7	7	26	2	14	24	14	14	14	10.45
Product L	12	17	17	17	1	10	14	12	14	14	14	10.55
Product M	13	22	22	22	6	29	4	8	4	4	4	11.00
Product N	14	23	23	23	1	18	9	9	9	9	9	11.27
Product O	15	10	10	10	6	27	14	24	14	14	14	11.73
Product P	16	16	16	16	6	28	9	24	9	9	9	12.09
Product Q	17	29	29	29	1	19	4	18	4	4	4	12.45
Product R	18	12	12	12	26	5	22	15	22	22	22	13.45
Product S	19	13	13	13	14	7	25	17	25	25	25	13.82
Product T	20	18	18	18	26	9	18	14	18	18	18	14.27
Product U	21	19	19	19	11	13	22	15	22	22	22	14.73
Product V	22	24	24	24	26	14	14	12	14	14	14	15.09
Product W	23	14	14	14	16	15	28	18	28	28	28	15.91
Product X	24	20	20	20	16	22	25	2	25	25	25	15.91
Product Y	25	25	25	25	11	20	18	18	18	18	18	16.18
Product Z	26	30	30	30	26	16	9	24	9	9	9	16.64
Product A2	27	26	26	26	16	23	22	2	22	22	22	16.82
Product B2	28	21	21	21	21	24	28	24	28	28	28	19.64
Product C2	29	28	28	28	6	30	28	18	28	28	28	20.18
Product D2	30	27	27	27	21	25	25	24	25	25	25	20.55

<sup>2</sup> Average of five calculations using an emission-point to target area of 30cm, 45cm, 60cm, 75cm, and 90cm

<sup>3</sup> Minimum PPFd / Average PPFd

<sup>4</sup> Average PPFd / Watts (at wall)

<sup>5</sup> A calculation to provide lumen maintenance life (L70) projection, or to predict estimated lumen output values at a given time duration

<sup>6</sup> Applicable when a fixture has two or more distinct LED components

<sup>7</sup> Applicable when a fixture has two or more distinct LED components

<sup>8</sup> Color or chromaticity shift is the fixture level measurement of changes to the spectrum as case temperatures rise.

## Performance Details

PRODUCT	RANK	AVG PFD <sup>9</sup>	MAX PFD	MIN PFD	AVERAGE <sup>10</sup> UNIFORMITY	EFFICACY <sup>11</sup>	L70 TM21 FORECAST <sup>12</sup>	MOST L70 <sup>13</sup> HRS TESTED	SHORTEST L70 <sup>14</sup>	FEWEST L70 HRS TESTED	LM80 <sup>15</sup> COLOR SHIFT	COMPOSITE
Product A	1	310.00	379.75	248.00	0.800	1.0333	60,500	10,000	60,500	6,000	0.00070	1.73
Product B	2	294.50	360.76	235.60	0.780	0.9203	57,475	9,000	57,475	5,700	0.00067	3.45
Product C	3	292.95	358.86	234.36	0.770	0.8797	57,475	8,000	57,475	5,700	0.00067	5.27
Product D	4	292.02	357.72	233.62	0.810	0.7449	52,635	7,000	52,635	5,220	0.00061	6.00
Product E	5	291.40	356.97	233.12	0.880	0.9945	52,030	8,600	52,030	5,160	0.00060	7.36
Product F	6	288.30	353.17	230.64	0.670	1.0010	51,425	7,000	51,425	5,100	0.00060	7.55
Product G	7	292.95	358.86	234.36	0.800	0.9765	50,820	9,000	50,820	5,040	0.00059	7.55
Product H	8	285.20	349.37	228.16	0.780	0.8913	52,635	8,000	52,635	5,220	0.00061	8.73
Product I	9	283.65	347.47	226.92	0.770	0.8518	52,030	8,600	52,030	5,160	0.00060	9.18
Product J	10	280.55	343.67	224.44	0.810	0.7157	51,425	7,000	51,425	5,100	0.00060	9.18
Product K	11	279.00	341.78	223.20	0.880	0.9522	50,820	9,000	50,820	5,040	0.00059	10.45
Product L	12	277.45	339.88	221.96	0.670	0.9634	50,215	8,300	50,215	4,980	0.00058	10.55
Product M	13	277.14	339.50	221.71	0.800	0.9238	49,005	8,100	49,005	4,860	0.00057	11.00
Product N	14	276.52	338.74	221.22	0.780	0.8641	48,400	8,000	48,400	4,800	0.00056	11.27
Product O	15	274.35	336.08	219.48	0.770	0.8239	52,635	9,000	52,635	5,220	0.00061	11.73
Product P	16	269.70	330.38	215.76	0.810	0.6880	52,030	7,000	52,030	5,160	0.00060	12.09
Product Q	17	266.60	326.59	213.28	0.880	0.9099	51,425	8,500	51,425	5,100	0.00060	12.45
Product R	18	263.50	322.79	210.80	0.670	0.9149	50,820	8,400	50,820	5,040	0.00059	13.45
Product S	19	260.40	318.99	208.32	0.800	0.8680	50,215	8,300	50,215	4,980	0.00058	13.82
Product T	20	257.30	315.19	205.84	0.780	0.8041	49,005	9,000	49,005	4,860	0.00057	14.27
Product U	21	254.20	311.40	203.36	0.770	0.7634	48,400	7,000	48,400	4,800	0.00056	14.73
Product V	22	251.10	307.60	200.88	0.810	0.6406	52,635	8,700	52,635	5,220	0.00061	15.09
Product W	23	249.55	305.70	199.64	0.880	0.8517	52,030	8,600	52,030	5,160	0.00060	15.91
Product X	24	249.24	305.32	199.39	0.670	0.8654	51,425	8,500	51,425	5,100	0.00060	15.91
Product Y	25	248.93	304.94	199.14	0.800	0.8298	50,820	8,000	50,820	5,040	0.00059	16.18
Product Z	26	248.62	304.56	198.90	0.780	0.7769	50,215	9,000	50,215	4,980	0.00058	16.64
Product A2	27	248.31	304.18	198.65	0.770	0.7457	49,005	7,000	49,005	4,860	0.00057	16.82
Product B2	28	248.00	303.80	198.40	0.810	0.6327	48,400	8,000	48,400	4,800	0.00056	19.64
Product C2	29	247.38	303.04	197.90	0.880	0.8443	52,635	8,000	52,635	5,220	0.00061	20.18
Product D2	30	247.07	302.66	197.66	0.670	0.8579	52,030	7,000	52,030	5,160	0.00060	20.55

<sup>9</sup> Average of five calculations using an emission-point to target area of 30cm, 45cm, 60cm, 75cm, and 90cm

<sup>10</sup> Minimum PPF / Average PPF

<sup>11</sup> Average PPF / Watts (at wall)

<sup>12</sup> A calculation to provide lumen maintenance life (L70) projection, or to predict estimated lumen output values at a given time duration

<sup>13</sup> Applicable when a fixture has two or more distinct LED components

<sup>14</sup> Applicable when a fixture has two or more distinct LED components

<sup>15</sup> Color or chromaticity shift is the fixture level measurement of changes to the spectrum as case temperatures rise

## Quality Scores and the SOC Index

PRODUCT	RANK	LIGHT ENGINE QUALITY <sup>16</sup>	THERMAL MGT <sup>17</sup>	FIXTURE QUALITY <sup>18</sup>	CONTROLS <sup>19</sup>	POWER SUPPLY <sup>20</sup>	WARRANTY <sup>21</sup>	REGULATORY	TOTAL	SOC	RANK	INDEX
Product A	1	10	24.12	39	25	21	45	18	182.12	Product A	1	1.000
Product F	2	10	22.35	39	15	21.8	15	18	141.15	Product Y	2	1.020
Product A2	3	10	22.35	39	15	21	15	18	140.35	Product K	3	1.021
Product B2	4	10	18.24	39	15	21.8	15	18	137.04	Product I	4	1.028
Product D2	5	10	20.00	34	15	20.6	15	18	132.60	Product G	5	1.033
Product D	6	10	24.12	26	15	24	15	18	132.12	Product D	6	1.038
Product M	7	10	22.35	26	15	24	15	18	130.35	Product H	7	1.043
Product J	8	10	17.06	29	15	22	15	18	126.06	Product V	8	1.049
Product Y	9	5	10.59	39	10	12	25	18	119.59	Product M	9	1.054
Product P	10	5	10.59	39	10	12	25	18	119.59	Product S	10	1.059
Product B	11	5	8.82	39	10	12.8	25	18	118.62	Product J	11	1.065
Product K	12	5	12.94	34	10	11.6	25	18	116.54	Product B	12	1.070
Product I	13	5	15.29	29	10	13	25	18	115.29	Product C	13	1.075
Product Z	14	5	1.12	39	15	21	15	18	114.12	Product T	14	1.076
Product C	15	5	(0.65)	39	15	21.8	15	18	113.15	Product D2	15	1.077
Product O	16	5	12.94	29	10	13	25	18	112.94	Product O	16	1.078
Product N	17	5	12.94	26	10	15	25	18	111.94	Product U	17	1.083
Product T	18	5	12.35	26	10	15	25	18	111.35	Product X	18	1.084
Product	19	5	2.88	34	15	20.6	15	18	110.48	Product R	19	1.082
Product W	20	5	(0.65)	34	15	20.6	15	18	106.95	Product Z	20	1.083
Product Q	21	5	(0.65)	29	15	22	15	18	103.35	Product Q	21	1.083
Product C2	22	1	(4.06)	39	10	12.8	25	18	101.74	Product N	22	1.083
Product G	23	1	(4.06)	39	10	12.8	25	18	101.74	Product P	23	1.085
Product H	24	5	(3.00)	29	15	22	15	18	101.00	Product E	24	1.086
Product S	25	5	(4.76)	26	15	24	15	18	98.24	Product C2	25	1.088
Product V	26	1	(9.35)	39	10	12	25	18	95.65	Product L	26	1.089
Product E	27	1	(4.06)	34	10	11.6	25	18	95.54	Product A2	27	1.092
Product L	28	1	(8.18)	34	10	11.6	25	18	91.42	Product F	28	1.093
Product R	29	1	(6.41)	29	10	13	25	18	89.59	Product W	29	1.095
Product X	30	1	(6.41)	26	10	15	25	18	88.59	Product B2	30	1.096

<sup>16</sup> Evaluates the materials and method for seating LED components to the heatsink, typically using metal core PCB boards

<sup>17</sup> Assigns a weighted score based on the method for cooling LED components (passive and three types of active cooling)

<sup>18</sup> Assigns a weighted score based on the materials used in the construction of the fixture including aluminum, plastic and food grade materials.

<sup>19</sup> Assigns a weighted score for dimming method and whether functions like scheduling or other communication are included

<sup>20</sup> Assigns a weighted score for power supply class, rated life hours, and whether PS is integrated or separated from fixture

<sup>21</sup> Assigns a weighted score for the length of warranties for the product light engine, the fixture, and accessories

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