Utah State University
DEPARTMENT OF PLANTS, SOILS, & CLIMATE

Economic Analysis of Greenhouse Lighting LED vs HID

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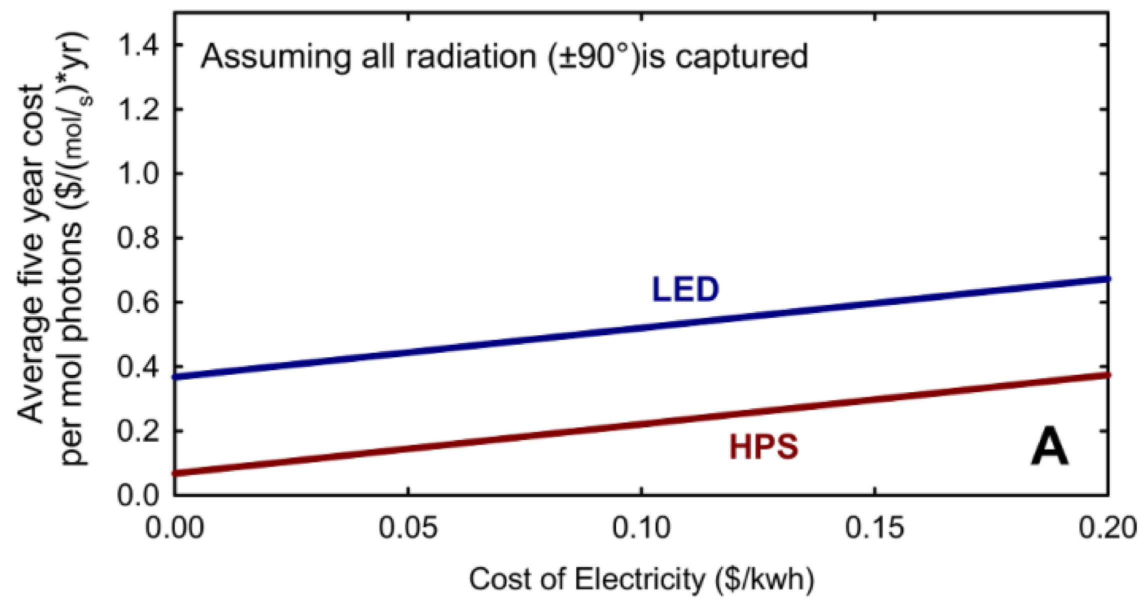
Photon efficiency and cost per mole photons Assuming all photons are captured by plants / Cost per mole photons for two photon capture assumptions

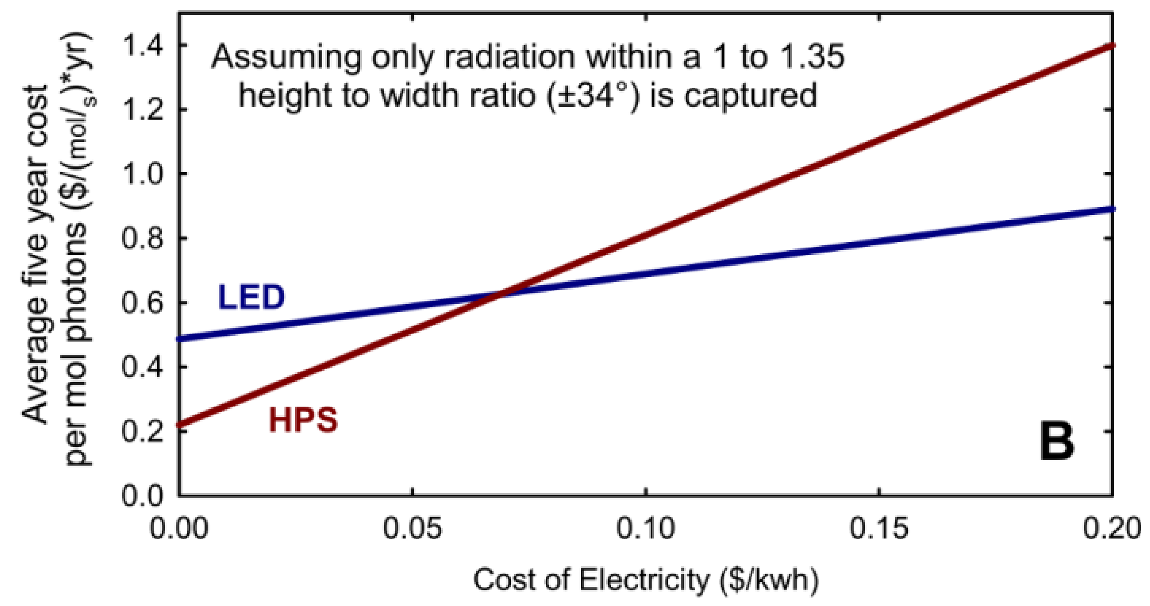
Lamp Type and Ballast	Fixture manufacturer	Electrical input (J/s or Watts)	Photon output[z] (µmol/s)	Photon efficiency[y] (µmol/J)	Cost of one fixture[x] ($)	Fixtures needed per mmol photons per second[w]	Fixture cost per µmol photons per second ($/(µmol/s))	Electric cost per µmol photons[v] $/(µmol/s)*yr	Five year electric plus fixture cost per µmol photons[u] $/(µmol/s)*yr	Assuming radiation within a 1 to 2.38 height to width ratio (±50°) is captured: Fixtures needed per mmol photons per second[z]	Assuming radiation within a 1 to 2.38 height to width ratio (±50°) is captured: Five year electric plus fixture cost per µmol photons[y] $/(µmol/s)*yr	Assuming radiation within a 1 to 1.35 height to width ratio (±34°) is captured: Fixtures needed per mmol photons per second[z]	Assuming radiation within a 1 to 1.35 height to width ratio (±34°) is captured: Five year electric plus fixture cost per µmol photons[y] $/(µmol/s)*yr
High Pressure Sodium													
400 W magnetic	Sunlight Supply	443	416	0.94	$200	2.40	$0.48	$0.35	$0.40	3.99	$0.66	8.51	$1.42
1000 W magnetic	Sunlight Supply	1067	1090	1.02	$275	0.92	$0.25	$0.32	$0.33	1.71	$0.61	3.60	$1.30
1000 W magnetic	PARsource GLXI	1004	1161	1.16	$350	0.86	$0.30	$0.29	$0.31	1.31	$0.47	2.82	$1.01
1000 W electronic	PARsource GLXI	1024	1333	1.30	$380	0.75	$0.29	$0.25	$0.28	1.14	$0.42	2.49	$0.92
1000 W electronic	PARsource GLXII	1026	1334	1.30	$310	0.75	$0.23	$0.25	$0.27	1.33	$0.47	2.81	$1.00
1000 W electronic	Gavita	1033	1751	1.70	$500	0.57	$0.29	$0.19	$0.23	0.96	$0.38	2.12	$0.84
1000 W electronic	ePapillon	1041	1767	1.70	$600	0.57	$0.34	$0.19	$0.24	1.46	$0.61	3.47	$1.45
LED													
red/blue	Lighting Sciences Group	384	653	1.70	$1,200	1.53	$1.84	$0.19	$0.54	1.62	$0.57	2.03	$0.71
red/white	BML	326	541	1.66	$1,000	1.85	$1.85	$0.20	$0.54	2.13	$0.62	3.17	$0.93
red/white	Lighting Sciences Group	390	634	1.63	$1,200	1.58	$1.89	$0.20	$0.55	1.67	$0.59	2.09	$0.73
red/white	Illumitex	279	390	1.40	$1,400	2.56	$3.59	$0.24	$0.92	2.66	$0.96	3.82	$1.37
red/white/blue	Lumigrow (Pro 325)	304	390	1.29	$1,000	2.56	$2.56	$0.26	$0.73	3.05	$0.87	4.95	$1.42
red/white	California Lightworks	337	350	1.04	$1,000	2.85	$2.85	$0.32	$0.85	3.09	$0.92	4.92	$1.46
multiple	Black Dog LED	339	339	1.00	$950	2.95	$2.80	$0.33	$0.85	4.43	$1.27	8.64	$2.48
red/white	Apache	169	163	0.96	$860	6.14	$5.28	$0.34	$1.35	6.58	$1.45	8.21	$1.81
red/blue	Lumigrow (ES330)	318	284	0.90	$1,200	3.52	$4.22	$0.37	$1.16	2.82	$1.07	4.33	$1.65
red/white	Hydrogrow	423	378	0.89	$1,300	2.64	$3.44	$0.37	$1.01	5.05	$1.67	10.70	$3.54
Ceramic Metal Halide													
315 W 3100 K (Agro)	Cycloptics	337	491	1.46	$640	2.04	$1.30	$0.23	$0.46	5.43	$1.22	19.55	$4.38
315 W 4200 K	Cycloptics	340	468	1.38	$640	2.14	$1.37	$0.24	$0.48	5.72	$1.29	20.71	$4.66
630 W 3100 K (Agro)	Boulderlamp	651	817	1.25	$1,000	1.22	$1.22	$0.26	$0.47	1.56	$0.60	2.90	$1.12
Fluorescent													
400 W	iGrow	394	374	0.95	$1,200	2.68	$3.21	$0.35	$0.94	4.69	$1.65	10.17	$3.58
60 W	T8	58	48	0.84	$40	20.77	$0.83	$0.40	$0.51	38.03	$0.93	83.81	$2.05

z- Integrated total photon output of fixture, measurements made by integrating sphere or flat plane integration.
y- Photon output per electrical Input (µmol per second divided by joules per second).
x- Cost of fixtures as of April 2014.
w- The number of fixtures to get a total photon output of one mmol (1000 µmol) of photons per second.
v- Assumes 3000 hours per year operation and $0.11/kWh.
u- Cost of fixture (multiplied by fixtures needed) plus cost of electricity over 5 years. We used a discounted cash flow model assuming a 5% per year cost of capital.

z- The number of fixtures to get 1 mmol (1000 µmol) of photons per second.
y- Cost of fixture (multiplied by fixtures needed) plus cost of electricity over 5 years. We used a discounted cash flow model assuming a 5% per year cost of capital.

Lighting technologies for plant growth are improving rapidly, providing numerous options for supplemental lighting in greenhouses. **The most efficient fixtures are LED and HPS at 1.70 µmol/J**, which represents a dramatic improvement over the 1.02 µmol/J efficiency of the mogul-base HPS fixtures that are in common use**.** Based on 2014 prices, **the five-year electric plus fixture *cost per mole of photons* is 2.3 times higher for LED fixtures**, due to the high capital cost per photon delivered.





The value of sunlight

Based on the current efficiency of plant lighting we can calculate the cost to turn electricity to sunlight:

$$\frac{1.7\ \mu mol}{J} * \frac{3.6\ MJ/_{kW\cdot hr}}{\$0.10/_{kW\cdot hr}} = \frac{60\ mol}{\$}$$

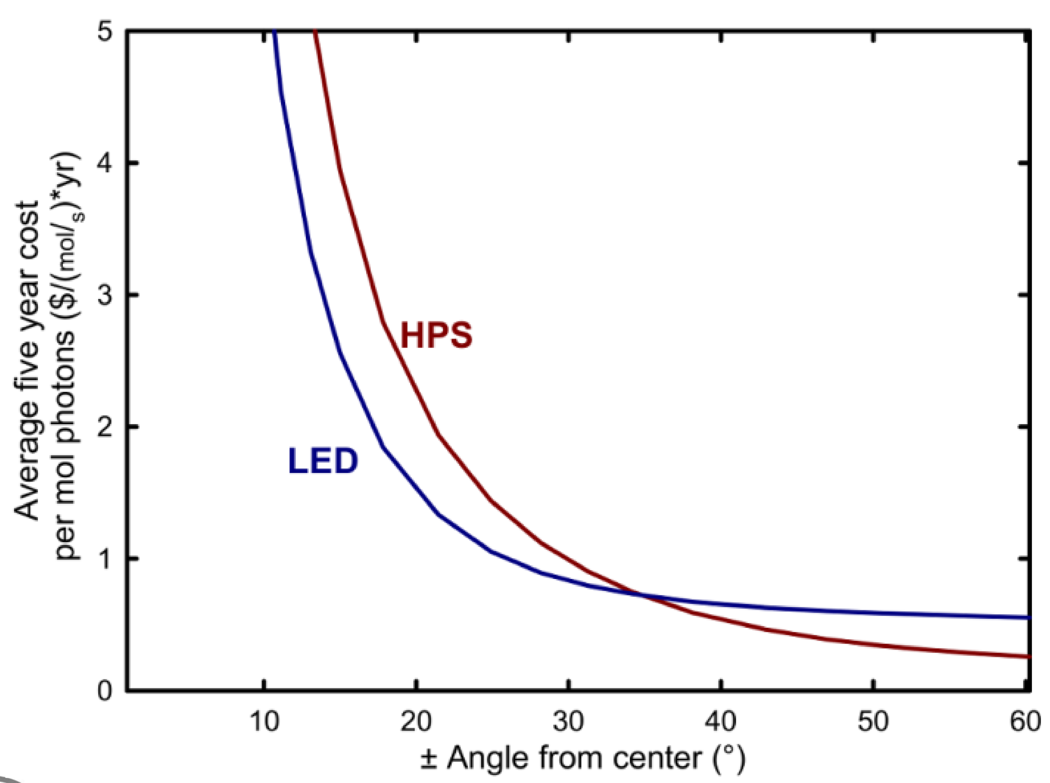
If we assume a DLI of $^{60\ \mu mol}/_{m^2 d}$ over a 100 day season:

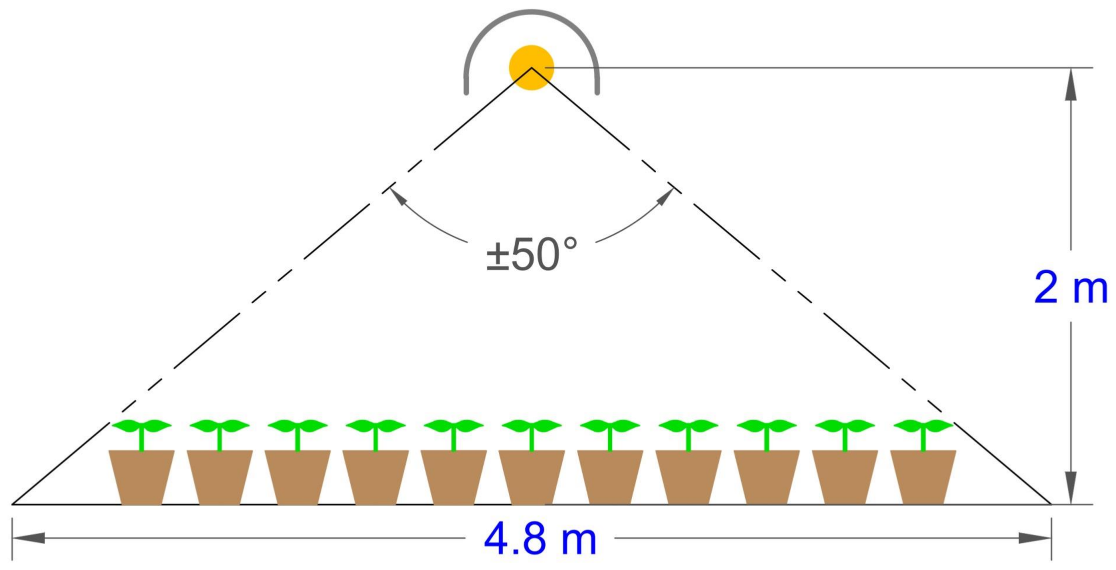
$$\frac{60\ mol}{m^2\ d} * \frac{\$}{60\ mol} = \frac{\$1}{m^2\ d} \Longrightarrow \frac{\$10{,}000}{ha \cdot d}$$

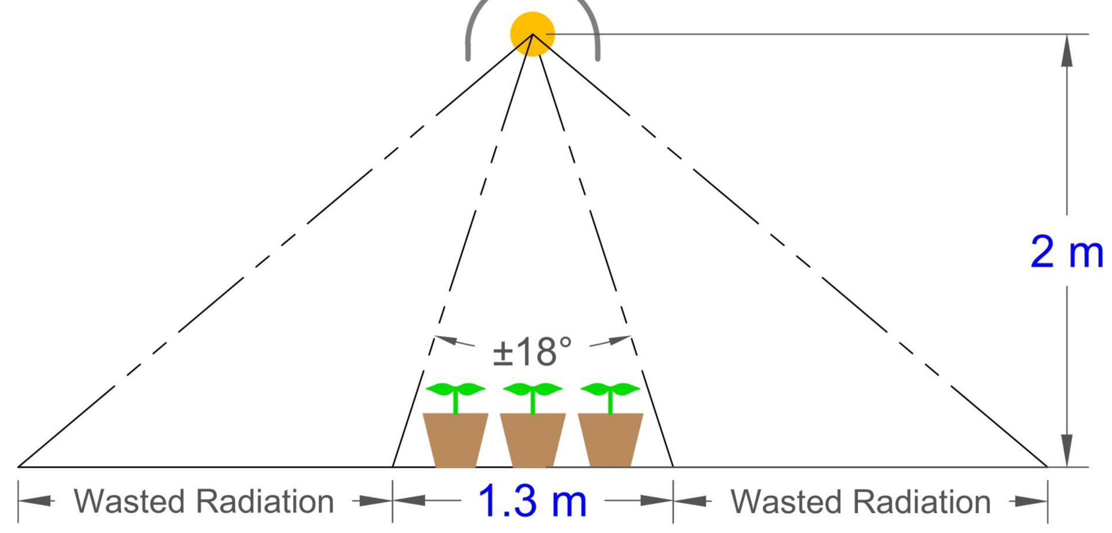
$$\Longrightarrow \frac{\$1{,}000{,}000}{ha \cdot season}$$

Importance of photon capture

Precision luminaires, lenses, or adjustable angle LEDs can be used to apply highly focused lighting specifically to the plant growth areas. If widely spaced benches are a necessary part of a production system, LED fixtures can be a more cost effective option for supplemental greenhouse lighting.







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