Consumer Issues
Economic Analysis
Life Cycle Impact Assessment

John F. Burr PhD
Purdue University
Krannert School of Management
jburr@purdue.edu

Qualitative Results
non-users

- Lack of cost analysis and awareness
  - Perception of it being too expensive
  - Unclear ROI (payback period most common)
- Uneducated about additional benefits
  - Red/Blue mix and impact
  - Durability
  - Even Germination
- Lighting not a top priority
  - Greenhouse capacity
  - Watering systems
  - Soil technology
- LED suppliers seen as bias
  - Integration in normal lighting channels increase credibility

Qualitative Results
users

- Reasons for use
  - Night interrupt benefits clear
  - Getting to mkt sooner with product
  - Even germination for shaded layer
- Early adopters say lighting not top priority
- Practice in Holland referred to as tech leaders

Models

- Equivalent production (non-hybrid)
  - Tell us which is the best economic alternative for supplemental lighting
- Hybrid models
  - Used when the cheapest alternative is limited
  - Tells us if the marginal production is worth using the next best alternative

Rain is Free
(use first)

Well: Not Free
(use when out of Free)

Higher Cost Alternative
(used if others are limited)

At times the production is not worth the cost of input and conversion

Net Present Value v. Payback Period

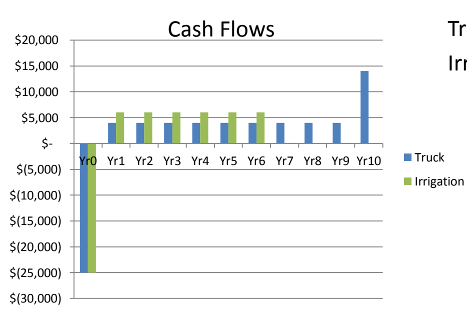
- NPV = net present value. The value of costs and savings adjusted for time value of money and cost of capital
  - Time value of money: $100 now is worth more than $100 five years from now
  - NPV captures the value added to the firm with a project
- Payback period = the number of years it takes for the savings to equal the cost.
  - Ignores any savings after the break even year
  - Does not adjust for time value of money

Two competing projects

F150 for $25k which will generate $4k/yr and have a salvage value after 10 years of $10k

Or

Irrigation system for $25k which will save you $6k/yr with a 6 year life



Truck Payback:	6.25 years
Irrigation Payback:	4.2 years
Truck NPV:	$7,643
Irrivation NPV:	$3,364
Truck ROI:	31%
Irrigation ROI:	13%

Caution on use of payback period

Hours of Use / yr	1000	1500	2000	2500	3000
Cost/kW	$ 0.100	$ 0.100	$ 0.100	$ 0.100	$ 0.100
NPV	$13,929	$14,672	$15,521	$16,326	$16,554
ROI	50%	53%	56%	59%	60%
Payback Period (yrs)	6.00	6.00	6.00	6.00	6.00

The model will calculate all three

Imagine if you only took projects with a 5 year payback period. You would be turning down a 59% return on investment

Why? Payback period ignores positive cash flows after the initial payback which can be substantial or enduring

Installed Cost (250umol)

HID $.49 uMol/m2 (~270 uMol, 7.2 m2/lamp)
LED $1.20 uMol/m2

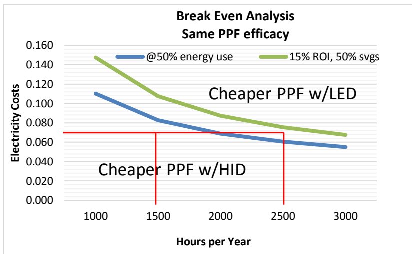
HID $945/lamp installed including 3 rebuilds
- Take total cost/number of lamps

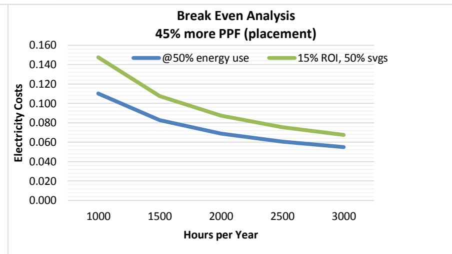
LED $2,314/lamp installed

Break Even

High Supplement (~240 PPF)

1) Choose electricity cost
2) Choose amount of use





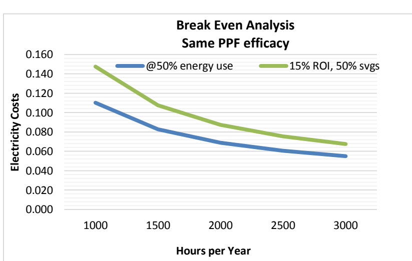
Interpretation :
If your electricity cost is $0.07/kW and you use the lighting more than 2500 hours per year, it is economically beneficial to use LED technology

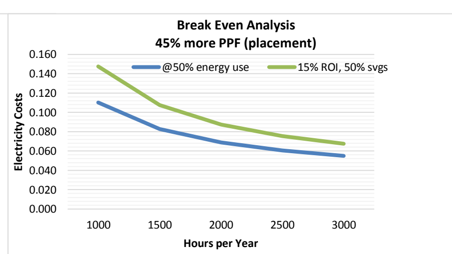
If your electricity cost is $0.07/kW and you use the lighting only 1500 hours per year, it is economically beneficial to use HID technology

If you are considering a hybrid model, the further left of the blue line, the smaller your margins on incremental production

Break Even

High Supplement (~240 PPF)





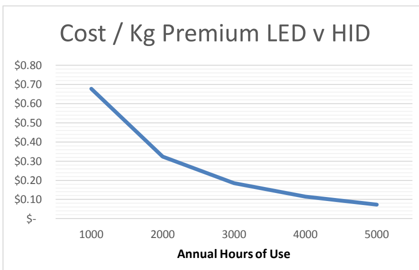
Assumptions (user selected):
- 1000W HPS versus LED with 1:1 replacement
- Similar fixture size
- Cost of capital 7%
- Tax Rate 17%
- Natural gas at 85% efficient
- Natural gas price $8/1000ft3
- Equivalent yield per uMol
- Installed cost $.49/umol/m2 HID. $1.20 for LED

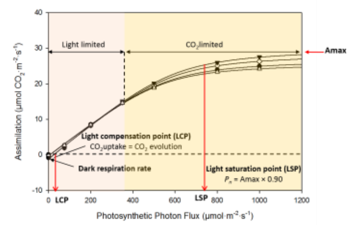
Assumptions (user selected):
- 1000W HPS versus LED with 1 : 0.7 replacement
- Similar as previous case

Hybrid Model

Tomato Production 9g/Mol

If the marginal production is known, the impact hybrid system can be calculated
Graph below shows the difference in cost of production for adding Hyrbid LED's
LED's may be more expensive, but still profitable for marginal production
Users can look at typical gross margin and add cost of production for marginal units

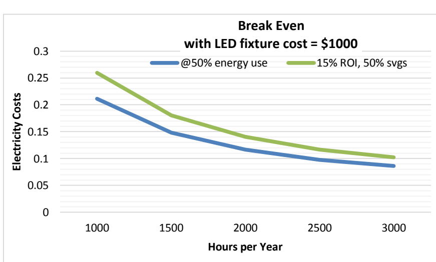


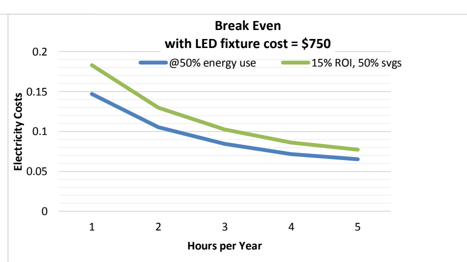


Assumptions:
Installed system cost 2.45x/uMol for LED
50% energy use for LED
15 year life (max) or cum hrs = 15*ann hrs
45% adjustment factor

Break Even

Medium Supplement (100 PPF*)





Assumptions (user selected):

- 600W HPS versus LED with 1:1 replacement
- $290/fixture, $40/bulb, 10k hrs/bulb
- Similar fixture size
- Cost of capital 7%
- Tax Rate 17%
- Natural gas at 85% efficient
- Natural gas price $8/1000ft3
- Equivalent yield per uMol

*analysis applies at any level of lamp density

This uses the same model as the high supplement
However, prices for LED drop considerably when comparing with a 600W HPS versus 1000W

LCIA

Journal of Cleaner Production

Contents lists available at ScienceDirect

Journal of Cleaner Production

Journal homepage: www.elsevier.com/locate/jclepro

ELSEVIER

Cleaner Production

Life Cycle Assessment (LCA) of LED Lighting for Crop Production in Greenhouses

Hao Zhang[a], John Burr[b*], Fu Zhao[a]

[a] School of Mechanical Engineering, Purdue University, West Lafayette, USA
[b] Krannert School of Management, Purdue University, West Lafayette, USA

LCIA

Weigh each type of material in comparative systems
Define system boundaries

- Manufacturing
- Use (life of product- 50K hours)
- Disposal (50% waste, 1% reuse, 49% recycle)

SimaPro TRACI method or EIO-LCA*
Assess cumulative energy demand (Mj) and
impact in several US EPA categories
We compare both average energy and clean energy
Case 1) HPS 1000W v LED 650W
Case 2) Incandescent 150 W v 18 W LED

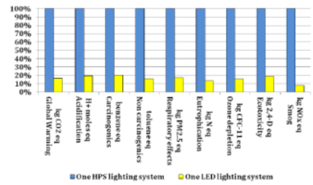
Example of LCIA for HPS Bulb

Impact category	Unit	One HPS bulb
Global Warming	Kg CO_2 eq.	13.900
Acidification	Kg SO_2 eq.	0.080
Carcinogenics	benzene eq.	0.130
Non carcinogenics	toluene eq.	66.060
Respiratory effects	Kg PM10 eq.	0.024
Eutrophication	Kg N eq.	0.002
Ozone depletion	Kg CFC-11 eq.	0.000
Ecotoxicity	Kg 2,4-D eq.	0.002
Smog	Kg O_3 eq.	1.300

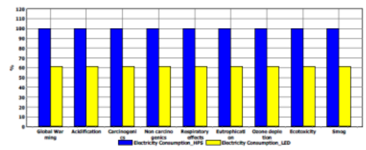
222. 2 MJ eq.

*HPS bulb is not available in SimaPro

LCIA HPS v LED

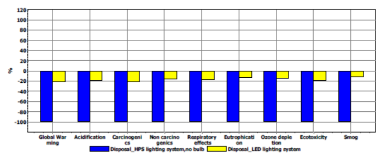


Manufacturing
LED 2,364 MJ v. HPS 16,628. MJ



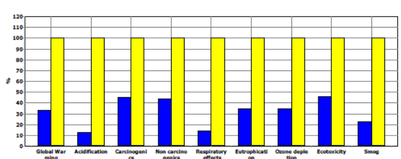
Use
LED 361,290 MJ v. HPS 589,181 MJ

Note the use phase dwarfs the other phases

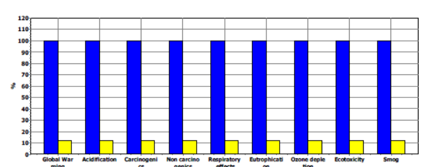


Disposal
LED -23.9 v. HPS -172.8 MJ
(higher negative is better)

LCIA Night Interrupt

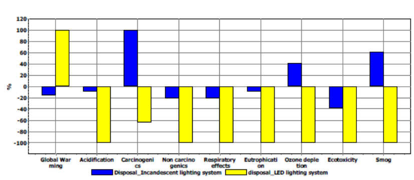


Manufacturing
38 MJ incandescent v. 102 MJ eq. LED



Use
7,782 MJ incandescent v. 934 MJ LED

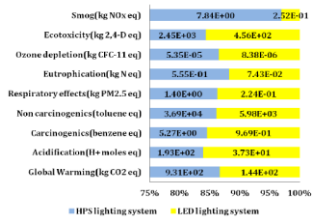
5.6 incandescent : 1 LED



Disposal
-0.1485 MJ incandescent v. -2.0746 MJ LED

LCIA Summary

HPS w/ clean energy

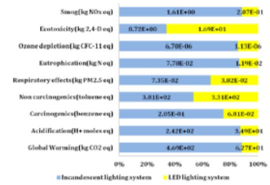


HPS 605,637 MJ v. 363,630 MJ LED

HPS is much less eco-friendly regardless of energy type

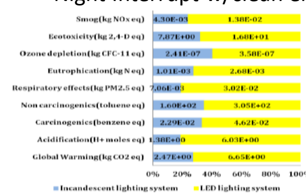
Incandescent is more eco-friendly **if** clean energy is used

Night Interrupt



7814.88 MJ incandescent v. 1033.26 MJ LED

Night Interrupt w/clean energy



33.25 MJ incandescent v. 99.46 MJ LED