Indoor (Vertical) Farming

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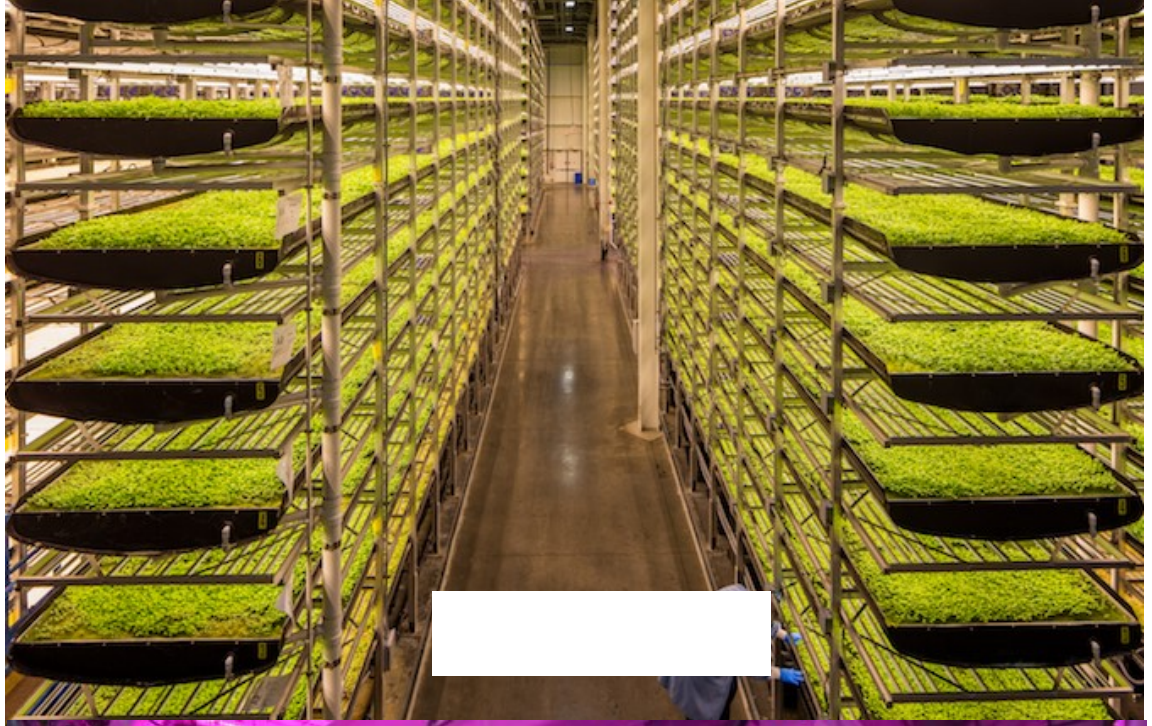
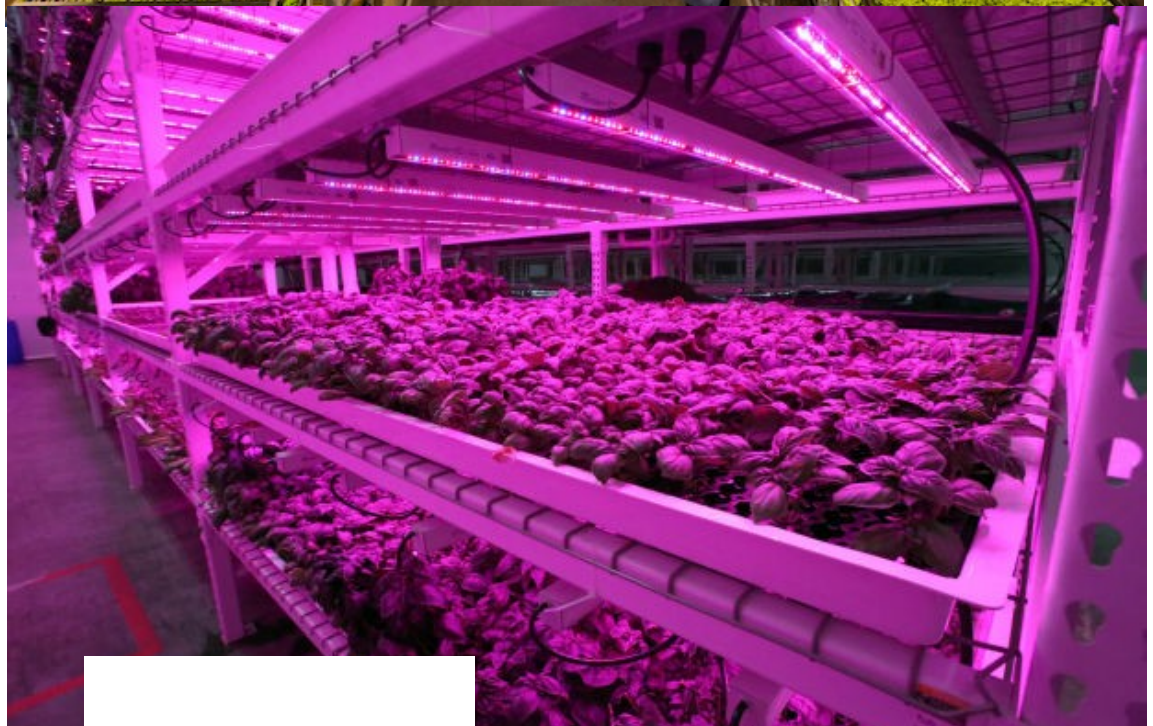
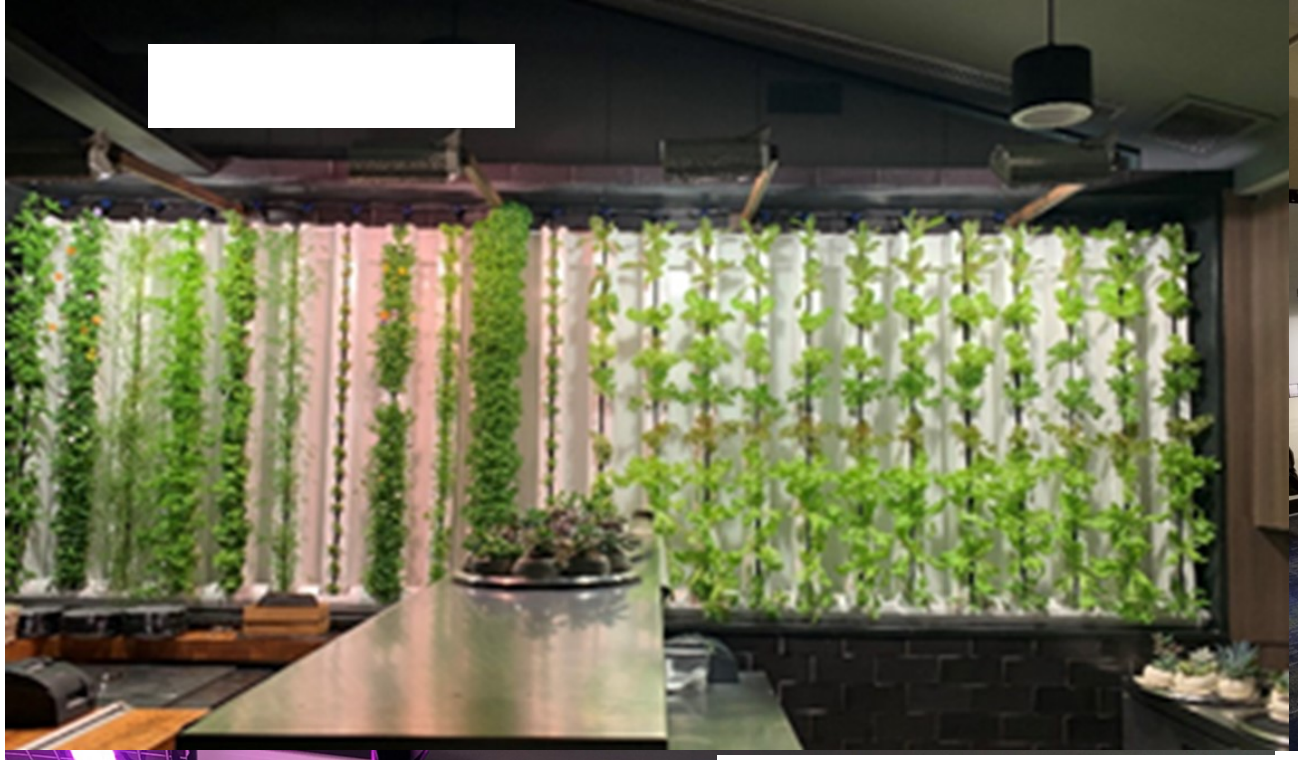
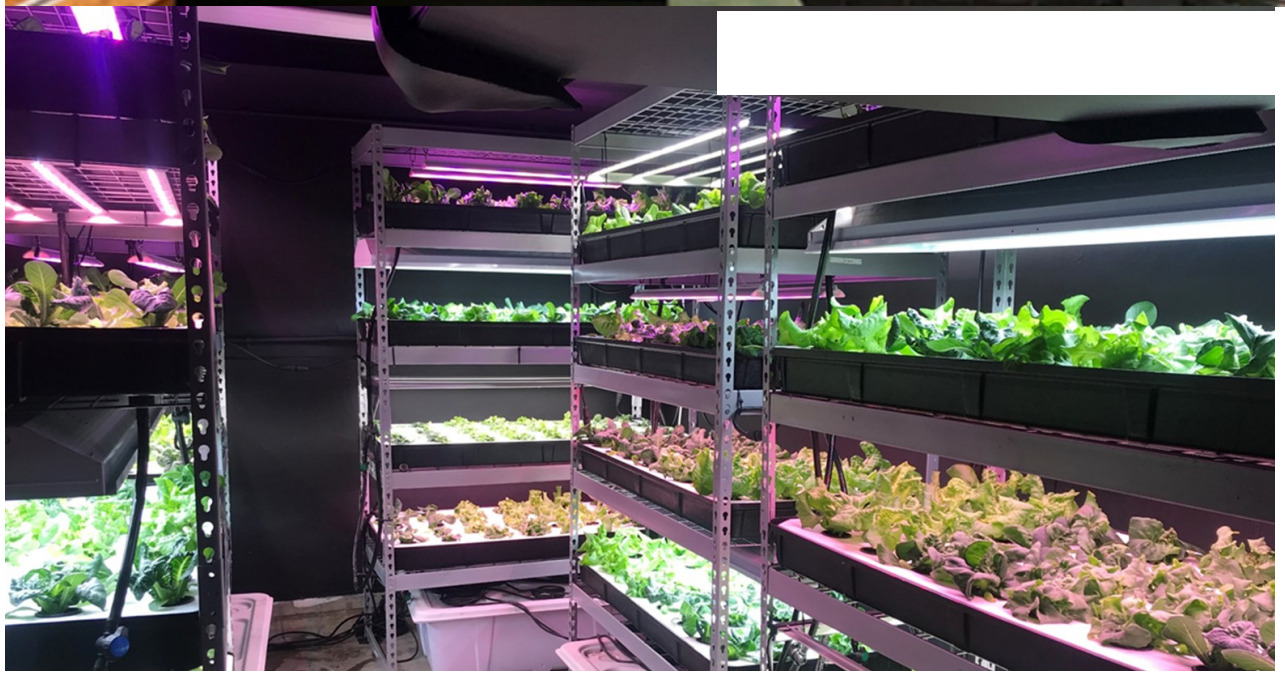
InFarm, Berlin









Hospitals

Low-Income Housing Groups

Veterans

People with Disabilities

Produce more in less space

Produce per level

Butterhead Lettuce: 0.69 $lb \cdot ft^{-2}$

Romaine Lettuce: 0.53 $lb \cdot ft^{-2}$

Red Leaf Lettuce: 0.67 $lb \cdot ft^{-2}$

Green Leaf Lettuce: 1.0 $lb \cdot ft^{-2}$

Field

Iceberg lettuce : 0.86 $lb \cdot ft^{-2}$

Source: UC Davis, 2017

Produce crops year-round

10 to 14 cycles possible in indoor farming

Produce pesticide-free crops

Produce more with less water

<u>To finish a crop:</u>

Vertical Farms : 90-100 $L \cdot m^{-2}$

Field: 350-370 $L \cdot m^{-2}$

~ 75% less water than field production

100,000,000,000 gallons of water can be saved every year

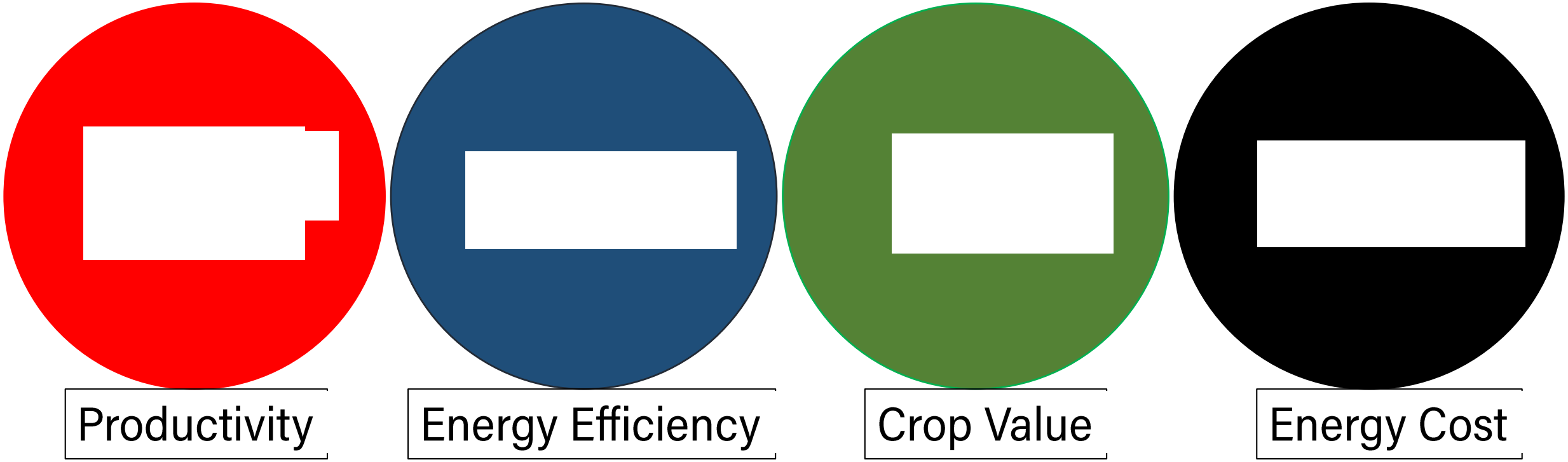
(equivalent to total water used by Hoosiers in 6.5 months)

Many indoor farms are closing due to lack of profits

- Artificial lights are used for 16 h per day on an average
- Lettuce grows best when 12-15 $mol \cdot m^{-2}$ are provided each day
- Total cost of lighting a 1000 m^2 farm at 15 $mol \cdot m^{-2} \cdot d^{-1}$ is $225 per day

Temperature control and artificial lighting costs are generally equally split

Factors[1] affecting profits in indoor farming



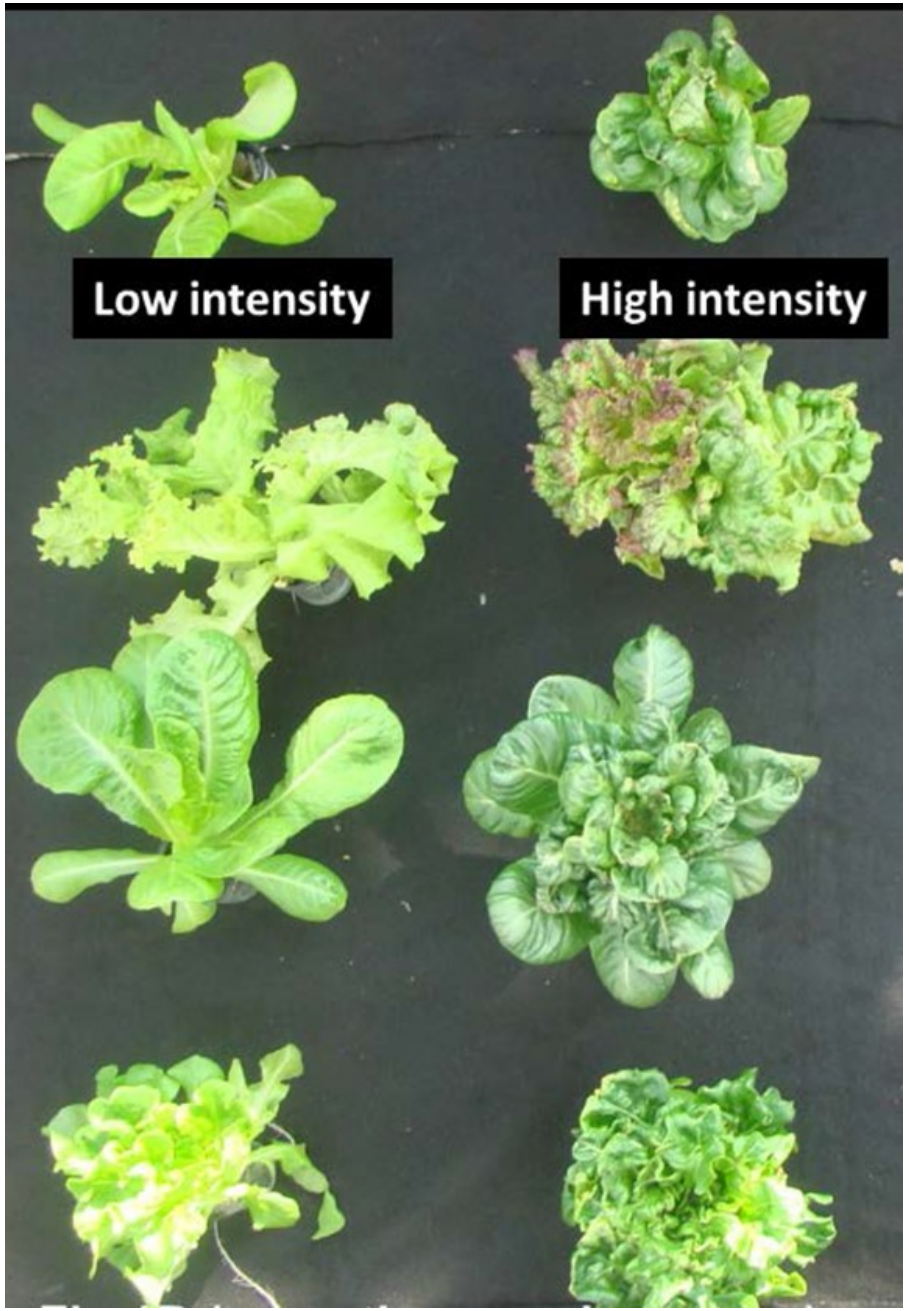
[1]Assumes that sufficient startup capital is available

Light intensity can affect lettuce growth

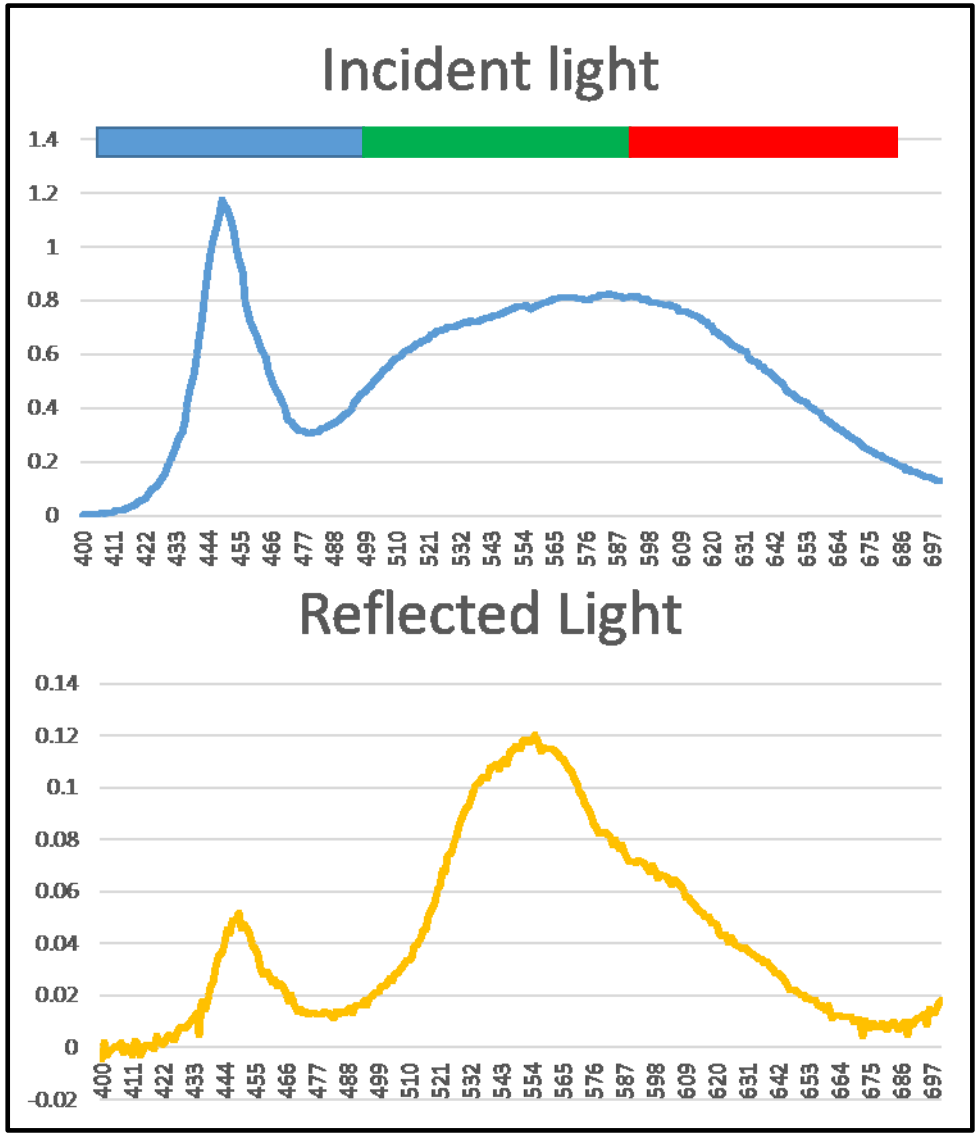
Lettuce grown in low light has poor quality and reduced weight

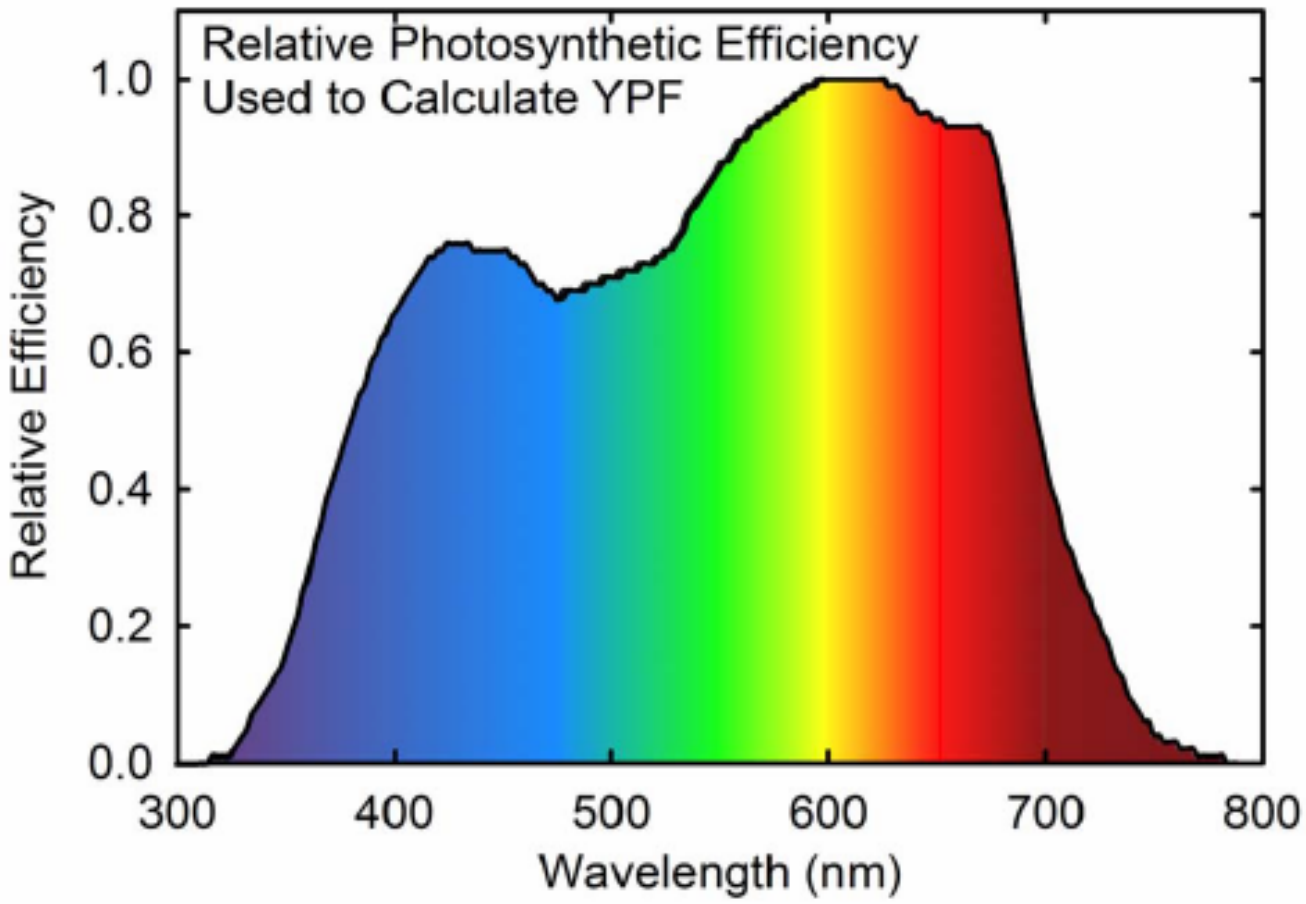
Leaf color formation is reduced in low light

< 10 mol/m^2/d 10-15 mol/m^2/d



Light is composed of different wavelengths





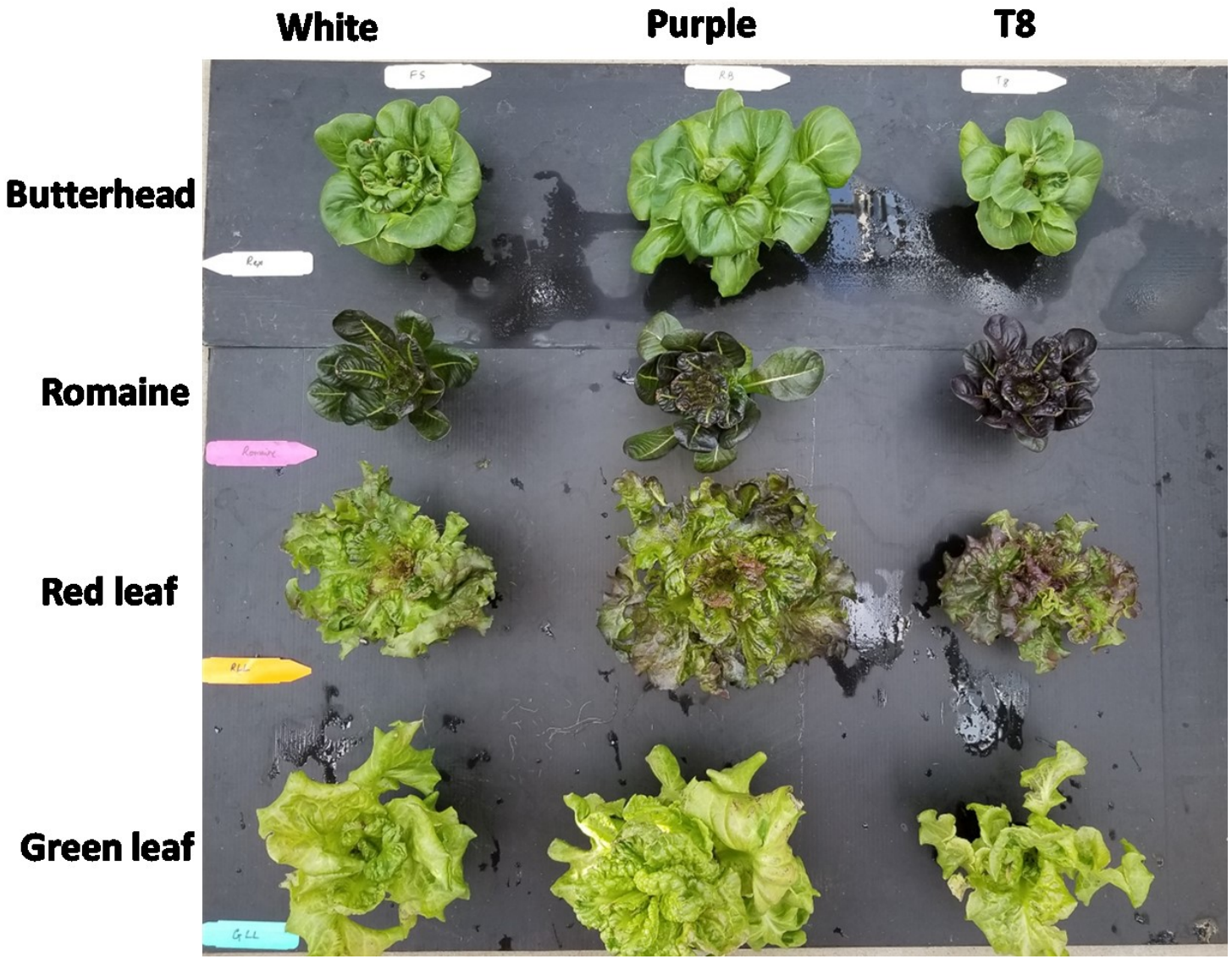
Spectral composition of light can affect lettuce productivity

lb/ft^2

Fixture	Warm-white	Warm-Purple	Cool-white
Blue	20	13	25
Green	44	19	46
Red	36	68	29

Light composition can affect lettuce productivity

lb/ft^2



Fixture	Yield (lb./ft^2)
Warm-white	0.48
Warm-purple	0.58
Cool-white	0.42

Energy Efficiency and Photon Efficiency

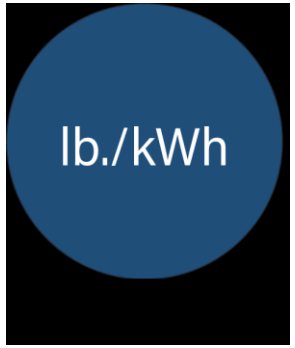
lb./kWh

1. Photon efficiency determines how much light is produced for a given amount of electrical energy consumed by a fixture
    - It is measured as 'intensity of light (μmol)' of light produced when a 'joule' of electrical energy is used by the fixture (μmol/J)
    - A total measure of light is used in photon efficiency measurement
    - Manufacturers use this value as efficiency indicator

2. Energy efficiency is crop yield per unit of electrical energy consumed by the fixture (lb./ 100kWh)

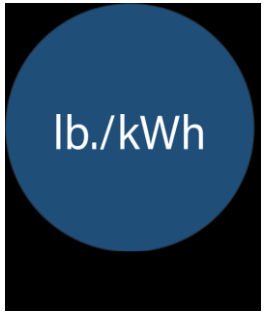
    A higher value is better as it costs less to produce crop

Photon efficiency of a fixture was not related to energy efficiency



Fixture	Blue	Green	Red	PE	EE
	%	%	%	µmol/J	lb./ 100kWh
1	16.6 a	45.6 a	37.4 c	2.3	3.7
2	22.2 a	24.7 b	52.6 b	1.3	2.4
3	22.0 a	47.8 a	30.0 c	1.9	2.2
4	14.9 a	21.6 b	63.5 a	2.1	9.3

Light spectrum affects energy efficiency



- Energy efficiency was maximum when spectrum contained red to blue light ratio of 4.3
- Optimal spectral composition for maximum energy efficiency for lettuce is 65% red: 20% green : 15% blue

Fixture	Power	Intensity	PE	Blue	Green	Red	R: B	EE
	$W \cdot m^{-2}$	$\mu mol \cdot m^{-2} \cdot s^{-1}$	$\mu mol/J$	%	%	%		lb./kWh
1	178	290	2.3	20	45	35	1.7	8.5
2	175	247	2.1	15	22	63	4.3	10.6

Quality traits that increase crop value

- Freshness/ locally grown
- Flavor
- Crispiness
- Pesticide-free
- Organic
- Safe (no bacterial contamination)
- Color
- Texture (smooth / curly)

What about nutritional quality?

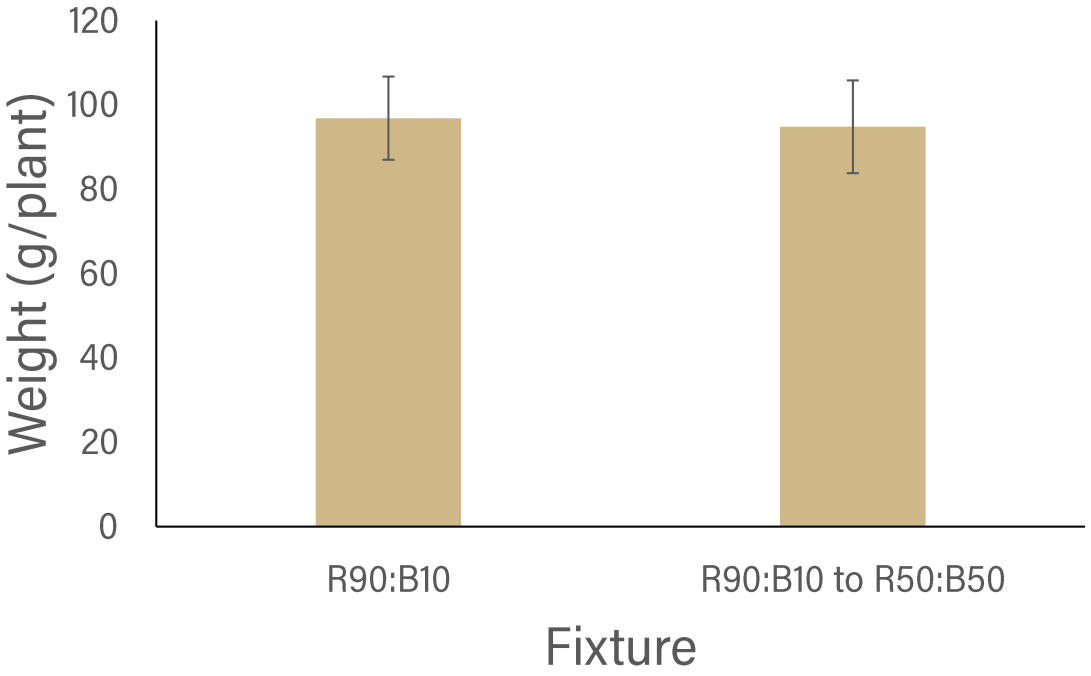
Crop value can be increased by improving nutritional quality

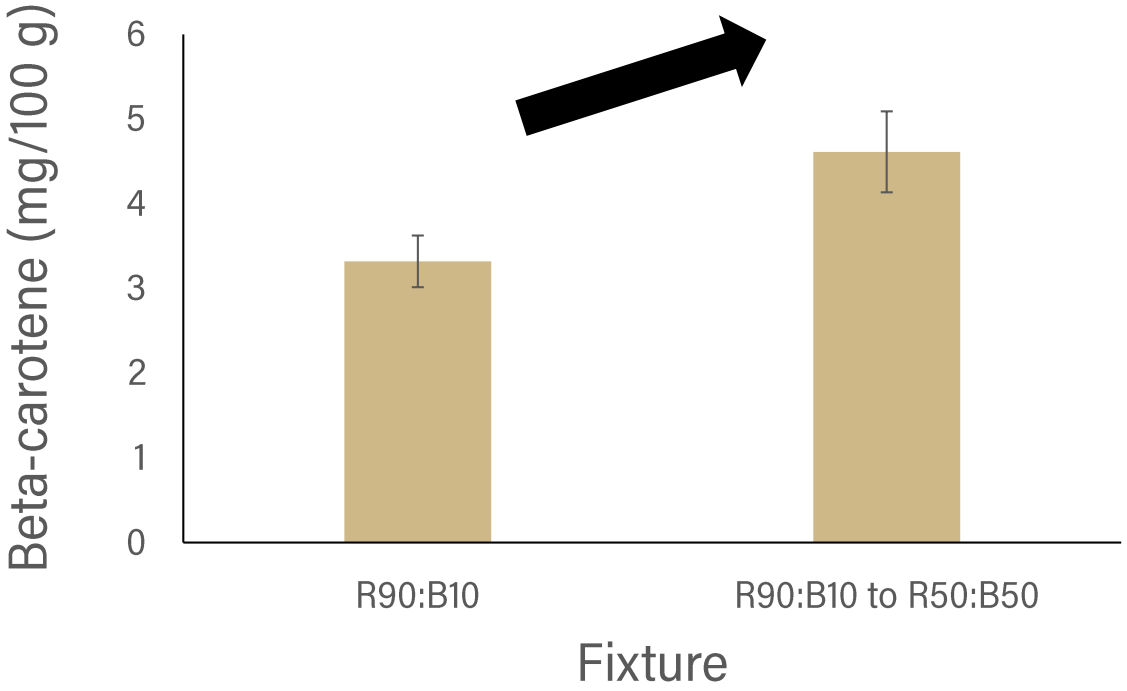
Measure: 1 cup of leaf/romaine lettuce (60 g)

Vitamin	Nutritional value (mcg)	RDA (mcg)
A	320-440 mcg	900 mcg
K	56-60 mcg	135 mcg

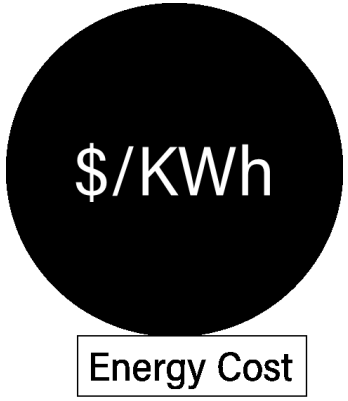
USDA Home and Garden Bulletin 72

Increasing blue light composition during the last 10 days improved nutritive value



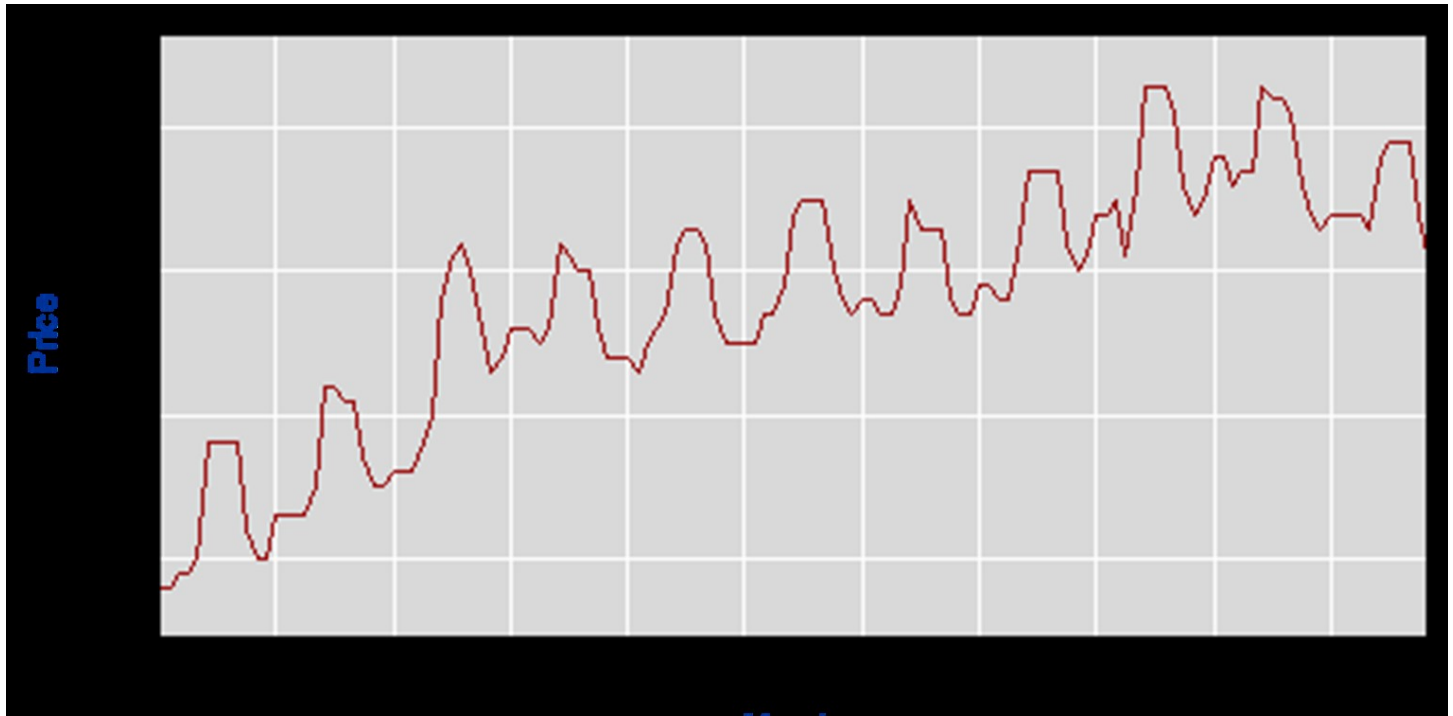


Electrical energy consumption: KWh



Kilo Watt hour (kWh): A measure of electrical energy consumption; equivalent to 1000 W of electrical power consumed in an hour.

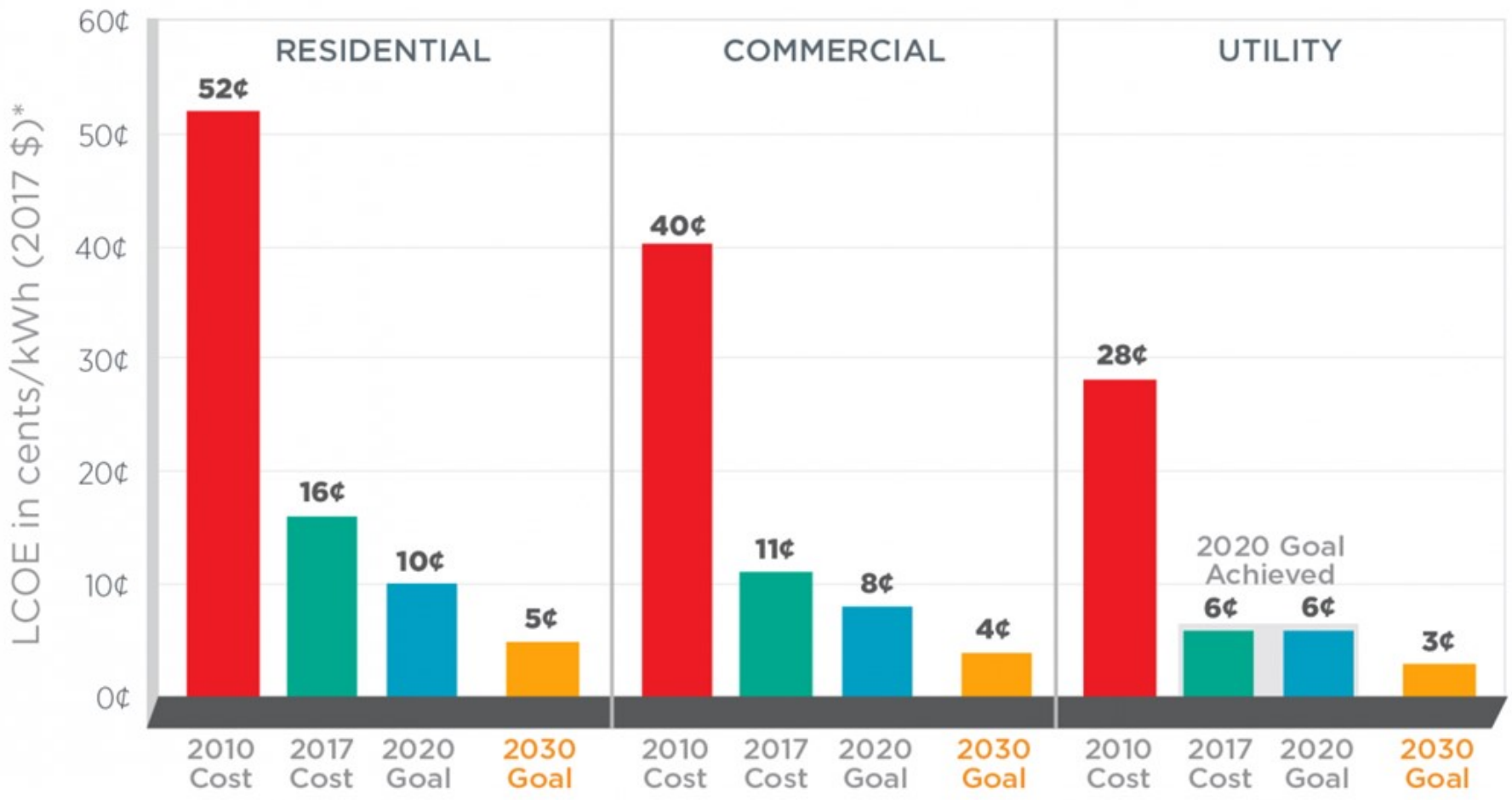
Example: HPS lamps: 1000 W or 1 KWh



Solar energy can reduce overall energy consumption

$/KWh

Energy Cost



Energy.gov

Solar energy: What does numbers mean?

$/KWh

- In Indiana (and Midwest) solar panels can produce approximately 3 kWh per day per kW of solar panel capacity

- Usually 1.35 to 1.5 kWh or 22-24 kWh per day (16 h lighting) is needed to illuminate 100 square feet of area.

- A 8 kW (8 x 3 = 24 kWh produced per day) solar panel will provide sufficient electrical energy to run 100 square feet vertical farm

- Total cost of installation for 8 kW system is approximately $15000. Life expectancy is 20 years.

- The system produces electrical energy equal to 24 kWh/day x 365 days/year x 20 years = 175,200 kWh

- This is equal to $15000/175200 kWh = 8.5 cents per kWh

Key Points

- Grow lettuce with 12-15 mol/m^2/day of light containing 60-70% red and 15% blue
- Use energy efficient lighting determined by optimal spectrum
- If possible, add light containing high percentage of blue during the last week to increase nutritional value. This may need additional blue LED bars
- Use solar energy to lower the cost of energy for lighting
- Customers believe in numbers. Advertise your product with data. Show that your product is grown local, does not contain any pesticide residue, free of any bacteria (E. coli), and has increased nutritional value to receive premium price
- Vertical farms can take up to 5-6 years before becoming profitable