College of Agricultural & Life Sciences
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Energy Efficient Lighting

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UW Extension Learning for life

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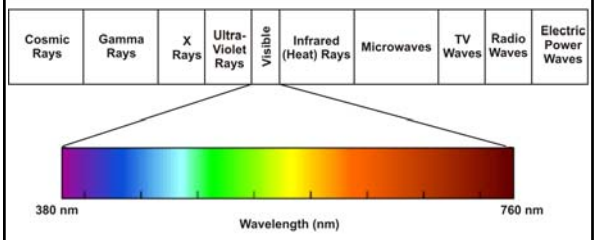
What is Light?
Electromagnetic Radiation



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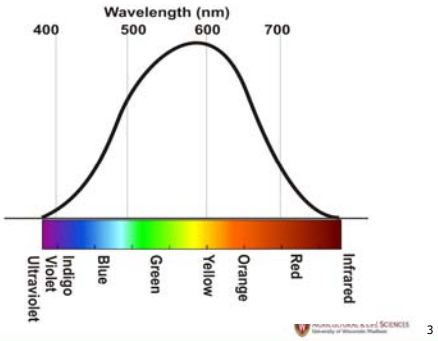
Sensitivity of an average humans eye



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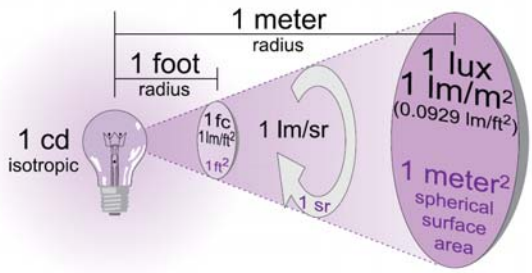
What is Light?



Source: The Light Measurement Handbook – Alex Ryer, International Light Technologies; http://files.intl-light.com/ILT-Light-Measurement-Handbook.pdf

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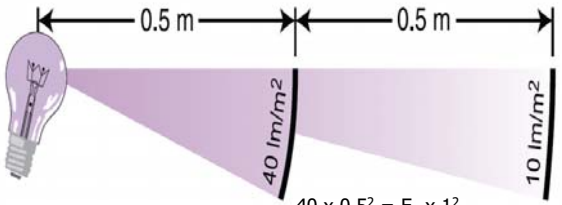
Effect of Distance
Inverse Square Law



$E_1 d_1^2 = E_2 d_2^2$

$40 \times 0.5^2 = E_2 \times 1^2$

$40 \times 0.25 = 10 = E_2$

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Terminology

- Lamps not bulbs
- Fixture – enclosure that provides support and mounting for ballast, lamps, reflector and diffuser
- Lamp output – Lumens
  - a measure of the power of light perceived by the human eye
  - (60 w incandescent = ~ 850 L)
- Intensity – measured in foot-candles (fc) or Lux
  - Office – 50 FC
  - Dairy barn – 10-20 FC
  - Inspection area – 100 FC
- Color Rendering Index (CRI)
  - Ability of humans to perceive colors under artificial light compared to natural sunlight express as a percent.

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Terminology

- Color Temperature (CT) – Units of Kelvin
  - Indicates the light color – red (lower number) to blue (higher number)
- Lamp Depreciation
  - Percentage reduction in lamp output as lamp ages (mean lumen output / initial lumen output).
- Light Loss Factor
  - Includes Lamp Depreciation plus environmental factors like dirt accumulation on diffuser
- Average Rated Life –
  - mean time for 50% of lamps to burn out or stop functioning properly

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Color Temperature

Skylight (clear blue sky)	12-20,000K
Daylight	5000 - 6500K
Cool white / Bright White	3500 - 4100K
Warm White / Soft White	2700 - 3000K
High pressure sodium lamp	2100K
Mercury Vapor	5700K
Incandescent	2500 - 2900K
Match or candle flame	1700 - 1900K

273ºK = 0ºC = 32ºF

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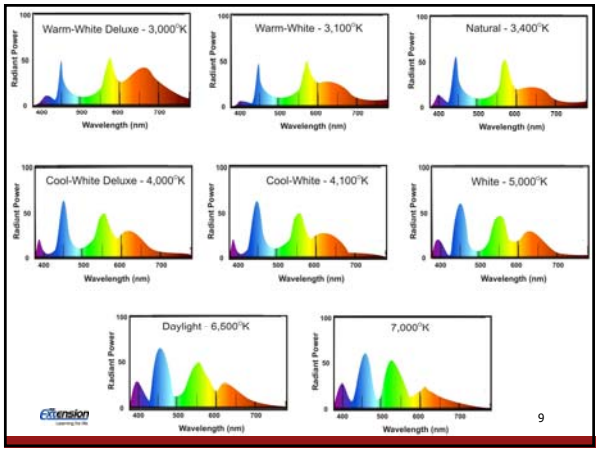

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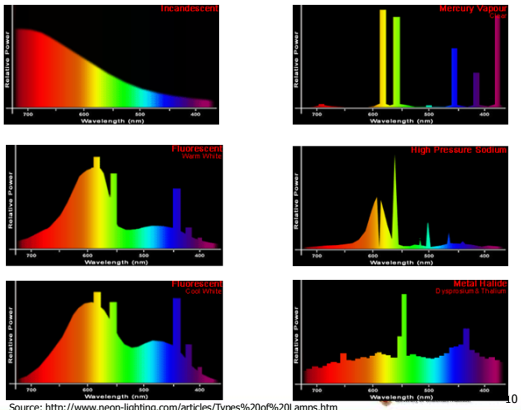

Source: http://www.neon-lighting.com/articles/Types%20of%20Lamps.htm

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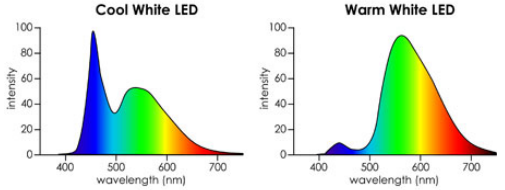
LED Light Spectrum



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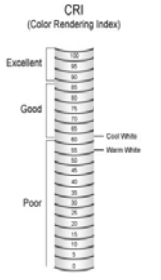
Color Rendering Index

- Ability of humans to perceive colors under artificial light compared to sunlight.
- 0-100 scale, 100% = sunlight
- 80% needed for color matching

Mercury Vapor Lamp	- 15
High pressure Sodium lamp	- 22 or 65
Pulse Start Metal Halide	- 65-75
T-12 Fluorescent	- 70-80
CFL	- 80
T-8 Fluorescent	- 80-85
T-5 Fluorescent	- 85
Incandescent	- 95



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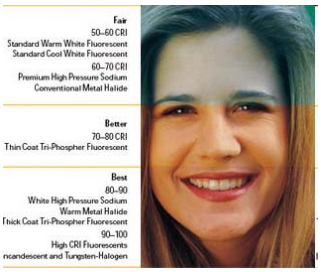
Color Rendering Index



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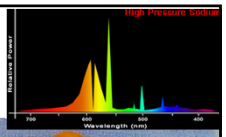
Low Pressure Sodium



Color of an object depends on sensitivity of the eye and the wavelengths (colors) produced by light source.

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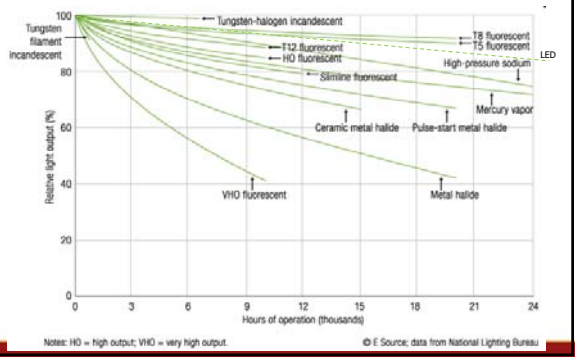
Lamp Depreciation vs Age



Lamp Dirt Depreciation Factor

- Dust
- Flies
- Birds

Cleaning Freq / Environment	12 months	36 months
Dirty / Diffuser cover	0.80	0.67
Clean / Diffuser cover	0.93	0.89
Dirty / open fixture	0.73	0.48

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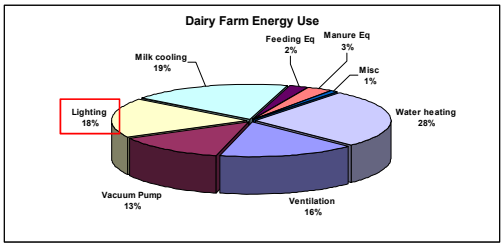
NYS Dairy Farm Survey



Source: Dairy Farm Energy Audit Summary, NYSERDA, July 2003

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Got Light?

- Why are we lighting?
  - "Security"
  - Work Area
  - Productivity improvement
- What are we lighting?
  - Driveway
  - Animal exercise lot
  - Work bench
- What amount and type of light required?
  - Intensity - Number of foot-candles needed for task
  - Color recognition - Color Rendering Index (CRI) 0-100 scale
  - Color Temperature (CT) – Units of Kelvin

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Incandescent Phase-Out

- Period: 2012 to 2014
  - Lights emitting 310 to 2600 lumens
    - Increased efficiency by 27%
    - ~ 25 watt to <150 watt bulbs
    - Jan 1, 2012 – 100 watt – 1690 L → ≤72W
    - Jan 1, 2013 – 75 watt – 1170 L → ≤53W
    - Jan 1, 2014 – 60 watt – 850 L → ≤43W
    - Jan 1, 2014 – 40 watt – 475 L → ≤29W
    - Doesn't ban specialty lamps
      - General Purpose only
- Energy Security Act of 2007

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Incandescent Replacements

- Halogen A-type Medium base
  - Meet new efficiency std. – 27%
- Compact Fluorescent Lamp (CFL)
  - 75% more efficient
- Linear Fluorescent – T8 or T5
  - 83% more efficient
- LED
  - 75% - 90% more efficient
  - Long Life - ~ 25,000 - 130,000 hours

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Halogen Lamps

- Type of incandescent lamp
- Efficiency ~ 15-21 L/watt (27%+)
- Life span ~2X incandescent
  - ~ 2000 hrs - (1000 to 6000 hours)
- Low light loss depreciation – 94%
- Dimmable
- Higher surface temperature
- Phase out in 2020
- No Mercury

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Compact Fluorescent Lamps (CFL)

- 75% less power than incandescent lamps
  - 60 watt incandescent = 13 or 14 watt CFL
- Excellent color rendering qualities
  - CRI – >80
- 6 to 12 times longer life than incandescent
  - Average Life: 6,000 to 12,000 hours
  - Shorter life in dusty / damp area
- Low starting temperatures
  - down to -20ºF or 0ºF
- Built-in ballast (most)
- Saves 500 lbs of coal over CFL's life
  - 1233 lbs of CO2 emissions
- Contain Mercury
- ***Not a good choice for Barns***

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Old versus New

- T-12 Fluorescent (1.5" dia)

Replaced by

- LED T8 Tube

LED Tube Lamp

- T-8 Fluorescent (1.0" dia)
  - Requires ballast replacement
- T-5 Fluorescent (5/8" dia)
  - New fixture required

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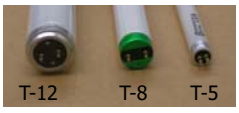
T-8 Fluorescent Lamps



- Rated Temperature 77ºF
- 1" dia – same lengths as T12
- Similar to popular T-12 lamps but 1" versus 1.5" diameter
- 20% more Lumens per watt than T-12 lamps
  - T-8 & T-12 - about the same output per bulb
  - Std – 2800 L (T12 – 2900 L)
- Longer life than T-12 lamps
  - Average Life: 20,000+ hours versus ~ 10,000 hours for T12
- More efficient ballasts - (electronic versus magnetic)
- Starting temperatures down to 0ºF (Depends on ballast)
  - -20ºF for High Output version
- No Flickering – T-12 flickers >50ºF
- Can retrofit T12 fixtures to T8

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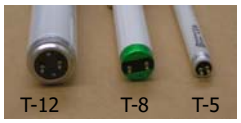
T-5 Fluorescent Lamps



- Rated Temperature – 95ºF
- 5/8" dia – different lengths than T8
- Efficiency ~ same to 5% more than T8 ***(at rating temp)
- 20-30,000 hrs life
- Mean Output for 45.2" lamp
  - Std – 2900 L HO – 4600 L
- Electronic ballasts
- 0ºF start temperatures for Std. version
- High output version → -20ºF start temperatures
- Not compatible with T12 fixtures - Different base and lengths
- Lamps not as readily available in Retail stores
- Lamps cost more

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Electrical Code for Ag Buildings

- If housing animals
  - Considered damp/wet & corrosive
  - NEC – Section 547
- Fixtures
  - Rated for damp/wet Location
  - Non-corrosive materials
    - Stainless Steel / Plastic
  - Cover with gasket
- Surface wiring in plastic conduit
- Wet-rated switch

•Utility Re-wiring Programs!!!

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Energy Act Changes

- Mercury Vapor lamps
  - No new ballasts can be Mfg or imported
  - No Sales after Jan 2008
  - Lamps Phase out – Jan 2016 (still available Nov 2017)
- Metal Halide Lamps
  - No new Probe-Start ballasts can be Mfg or imported
  - No Sales after Jan 2009
  - Replace with Pulse-Start Metal Halide or LED
    - 25% energy savings

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Mercury Vapor Lamp Replacements

- Mercury Vapor Lamps (Discontinued)
  - High Lamp depreciation / Low CRI
  - Efficiency – 35 Lumens / watt

Replaced by

- High Pressure Sodium
  - 150% more efficient - 90 Lumens / watt
    - 2.5 watts MV = 1 watt HPS
  - Yellow/orange light
  - Low CRI
- Pulse-Start Metal Halide
  - Uses 50% less energy - 70 lumens / watt
    - 2 watts MV = 1 watt PSMH
  - Good color rendering characteristics
    - Free stall barns
  - High Lamp Depreciation
- LED

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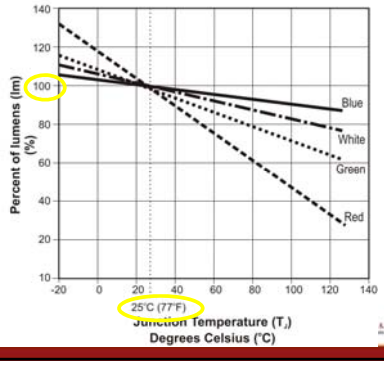
New Tech - LED

- LED (Light Emitting Diode)
  - Long life 10,000 to >100,000 hrs ++
    - Life ends at 70% lamp depreciation
  - Efficient - 80 -110 L/watt (and climbing)
    - Forecasted to reach 200 L/watt in 10 yrs.
  - Not cold sensitive – increase light output
  - No mercury
  - Recyclable (95%) – Contains Aluminum
  - Driver (Converts AC voltage to DC)
  - Directional light
  - Life not shorten by switching
  - Dimmable to 10% of full output

Temperature Impacts on an LED



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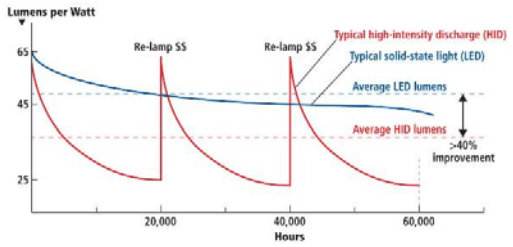
Lamp Depreciation / Efficiency



Source: LED Magazine – Oct 2011 (volume 8, issue 10)

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LED Exterior Lighting

- Long life – 50,000 - >100,000 hours
- High quality – white light
- Very efficient – 80-100+ lumen/watt
- Cold loving – brighter as temp drops

CBM - Flood

Stonco - Yard Lamp

RAB - Vapor-Proof

Street/yard Lamp
J&D Manufacturing

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Outdoor Area Lighting $ Justification

- Replacing Mercury Vapor yard light
- HPS vs LED
  - 12 hours / day – 365 days/yr
  - $0.12 / kWh
  - Lamp replacement cost included (no installation $)
  - Fixture cost annualize for 10 yrs @ 7%
  - LED - 50,000 hrs / HPS – 24,000 hrs

Lamp	Watts	Fixture $	Lamp $*#	Energy $*	Total Cost*
MV	213	Discont	$20	$112	$132
HPS	130	$90	$30	$68	$98
LED	80	$210	$22	$42	$65

* Annualized Costs; # Includes lamp replacement and fixture cost

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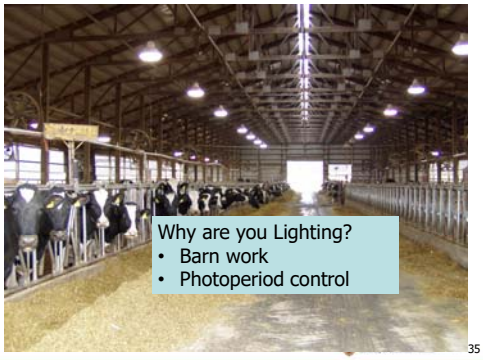
Free stall Barns



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HID High/Low Bay Fixtures

- Uses:
  - Freestall barns
  - Large parlors (high ceilings)
  - Shops

- High Pressure Sodium
  - High efficiency / low CRI
- Pulse Start Metal Halide
  - best color / higher lamp depreciation
- LED
- Heights 12-14 ft and higher
- Fixtures rated for Damp Environments

High Bay Fluorescent Fixtures

- 4, 6, 8 lamps per fixture
- High CRI
- Higher maintenance costs
  - More lamps
- Less light spreading
  - Typically no diffuser, only lens
  - More light variation between fixtures
- 30% more efficient than PS Metal Halide
- Convert T8 Fluorescent to T8 LED tubes

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LED Freestall Options

- High Efficiency
  - 80 to 110 L/watt +++
- High CRI: 70 – 80++
- CCT: 2700K – 7000K
- Life > 50-100,000+ hrs
- Higher initial cost
  - Lower annual cost
  - Less lamp replacement
- Directional
  - Diffuser to spread light

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LED Retrofit Lamps

- HID Lamp Replacement
  - Metal Halide / High Pressure Sodium
  - Mogul base (E26)
  - Re-wiring required
    - Bypass ballast
  - 50,000 hrs life
  - 80-93 L / watt
  - Damp rated
  - Up to 80% energy savings
    - Based on replacing 250 w lamp

Source: Light Efficient Design
www.led-llc.com

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Dairy Barn Lighting Update

- 34 ft x 200 ft barn
- 100 w Incandescent lamps
  - 3 rows / 10 ft apart (60 total)
    - 1530 Lumens/each
    - Life 750 hrs
    - 6000 watts total
- Use - 8 hours per day x 365
- Electric cost - $0.12 / kWh
- Replace with same or more light

Extension

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Potential Replacements

Lamp Type	Power use	Light output	Lumens/ watt	Lamp/bulb life	Cost/lamp
Incandescent	100 W	1530 L	15	750 hrs	$1.20
Halogen	72	1490	21	1000	$1.75
CFL	23	1600	69	10,000	$2.50
LED Screw-in	15	1600	106	15,000	$6.00
4-ft T8 Fluorescent*	68	5600	81	20,000	$3.50
4-ft LED Tube*	34	4200	123.5	50,000	$5.00

* 2-lamp fixture
W – Watts
L – Lumens

Economics

Lamp Type	Electric cost ($/yr)	Annualize Lamp Replacement Cost ($/yr) [4]	Annual Cost ($/yr)	Savings ($/yr)	$ per 100 lumen
Incandescent	$ 2102	$ 280	$ 2675	-	$2.91
Halogen	$ 1514	$ 307	$ 2039	$ 635	$2.28
CFL [1]	$ 484	$ 88	$ 615	$ 2060	$0.64
LED Screw-in	$ 336	$ 120	$ 464	$ 2210	$0.48
4-ft T8 Fluorescent [2]	$ 429	$ 389	$ 829	$ 1846	$0.84
4-ft LED Tube [3]	$ 250	$ 440	$ 702	$ 1973	$0.76

1 - Life de-rated to 5000 hours based on experience in damp environments;
2 - 18 fixture – includes cost of new fixture amortized for 10 years;
3 - 22 fixtures – includes cost of new fixture amortized for 10 years;
4 –Includes labor cost for lamp replacement – 5 min/bulb @ $15/hr

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Freestall Barn Lighting

- Low / High Bay - Metal Halide vs LED
  - 12 hours / day – 365 days/yr
  - $0.12 / kWh
  - Lamp replacement cost included
  - Installation excluded - assumed the same
  - Fixture cost annualize for 10 yrs @ 7%
  - 50,000 hrs LED

Lamp	Watts	Fixture $	Lamp / fixture $*	Energy $*	Total Cost*
PSMH (250w)	294	$325	$60	$154	$215
T5 – 4 lamp 54HO	245	$340	$50	$129	$179
LED	160	$170	$79	$84	$163

* Annualized Costs

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Lighting Controls

Does it need to be on all night?

- Control with Clock / timer
- Photo / Motion Sensor
  - Not with HID lamps
- Photo sensor w/ timer
  - Half-Night photo sensor
    - Measures night length daily and turns on light 1st half of night or has a time clock
  - Replaces standard photo sensor
  - Cost ~ $30 - $50
  - Brands (many others)
    - Intermatic - K4536SST
    - Mid-Night Tracker
    - Ripley Lighting Controls – RT8394 / RC8444
    - Dark to Light – DPN1242.6TJGN

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Light Modeling Program

- Reflectance Values for barns
  - Ceiling – 0% - no backlighting / dirty ceilings
  - Walls (Free stall) – 0% - sides open, no wall
  - Walls (Tie stall) – 0% - if whitewashed & kept clean – 10%
  - Floors – 0 to 10%

  (Don't use typical Industrial values)
- Photometric Lamp data
  - Map of light output from fixture
  - Available from manufacturer's web sites
- Programs / IES files
  - Visual - www.visual-3d.com/

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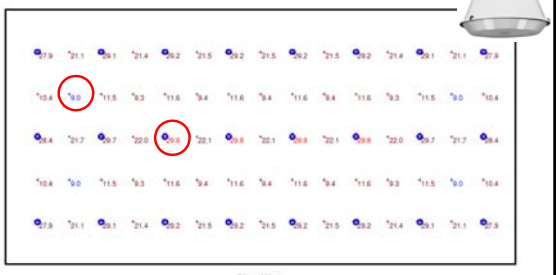
Freestall layout – 400w Metal Halide

100 ft x 200 ft x 14 ft side wall

High wattage "STD" Lamp – 24 lamps



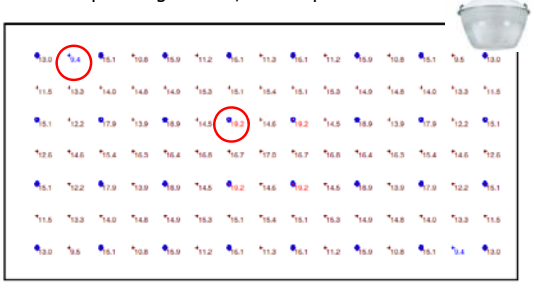
Plan View

Scale 1" = 25'

Freestall layout – 400w Metal Halide

100 ft x 200 ft x 14 ft side wall

Wide spreading diffuser, 32 lamps



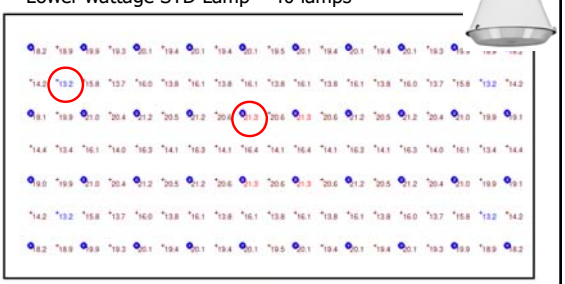
Plan View

Scale 1" = 25'

Freestall layout – 250w Metal Halide

100 ft x 200 ft x 14 ft side wall

Lower wattage STD Lamp – 40 lamps



Plan View

Scale 1" = 25'

Comparison of Lamp Types

Lamp type	Lumens/watt	Average life (hrs)	Color	CRI	CT (K)	Starting Temp. (F)	Instant On	Contain Mercury
Incandescent	7-20	1000	White	100	2800	>- 40° F	Yes	No
Halogen	12-21	1-6000	White	100	3000	>- 40° F	Yes	No
Mercury Vapor	26-39	24,000	White - Bluish	15-50	3800-5700	-22° F	No *	Recycling Require
Compact Fluorescent	45-55	6000 to 10,000	White	82	2700	-20° F or 0° F	Yes *	Recycling Require
T-12 HO Fluorescent	70	9000 – 12,000	White	52-90	3000 – 5000	-20° F	Yes	Recycling Require
Metal Halide	41-79	10,000 - 20,000	Bluish	65-70	3000-4300	-22° F	No *	Recycling Require
Pulse Start Metal Halide	60-74	15,000 - 32,000	Bluish	62-75	3200-4000	-40° F	No *	Recycling Require
T-12 (1.5") Fluorescent	62-80	9000 to 12,000	White	52-90	3000-5000	50° F	Yes	Recycling Require
T-8 HO Fluorescent	104	18,000	White	75	3000-5000	-20° F	Yes	Recycling Require
High Pressure Sodium	66-97	24,000	Yellow-orange	22-70	1900-2100	-40° F	No *	Recycling Require
T-8 (1.0") Fluorescent	83-93	15,000 - 40,000	White	60-86	3000-6500	0° F	Yes	Recycling Require
T-5 (5/8") Fluorescent	95	20,000 – 30,000	White	85	3000-6500	0° F	Yes	Recycling Require
Light Emitting Diodes - LED	80-120	10,000 – 130,000	White	70-92	2700-7000	- 40° F	Yes Full output	No

* Requires warm-up to reach full output

Indoor Lighting Level Recommendation

- Tie Stall barns
  - 10-20 foot-candles
- Free Stall barns
  - Feed alley – 10-20 foot-candles
  - Treatment area – 50-100 foot-candles
- Parlors
  - General - 20 foot-candles
  - Operator's pit - 50 foot-candles (cow's udder)
  - Holding area - 10 foot-candles
  - Manual wash sink – 100 foot-candles
- Other work areas
  - Office – 50 foot-candles (desk top)
  - Lunch Room - 50 foot-candles (desk top)

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Buy Lumens not watts

Energy use (watts) for different lighting Technologies*

Lumens	Incandescent	Halogen	CFL	LED
465-600	40	28	9	8
750-940	60	43	13	10-12
1050-1170	75	53	18	14-17
1490-1675	100	72	23	22
2680-2800	150	---	42	26

* General purpose – Omnidirectional lamps

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References

- Lighting Technology: LED Lamps for Home, Farm and Small Business, A4050
  - http://learningstore.uwex.edu/Assets/pdfs/A4050.pdf

ASABE Blue Ribbon Award

- Lighting Research Center at RPI
  - www.lrc.rpi.edu
- Energy-Efficient Agricultural Lighting
  - http://learningstore.uwex.edu/assets/pdfs/A3784-14.pdf
- Lighting system for Dairy Freestall barns and milking centers
  - http://www.uwex.edu/ces/dairymod/cowhousing/documents/LightingDairyFacilities.pdf
- Dairy Lighting Systems for barns
  - http://www.milkproduction.com/Library/?q=hidden:meta:category:Housing;Illumination
- National Lighting Bureau
  - www.nlb.org

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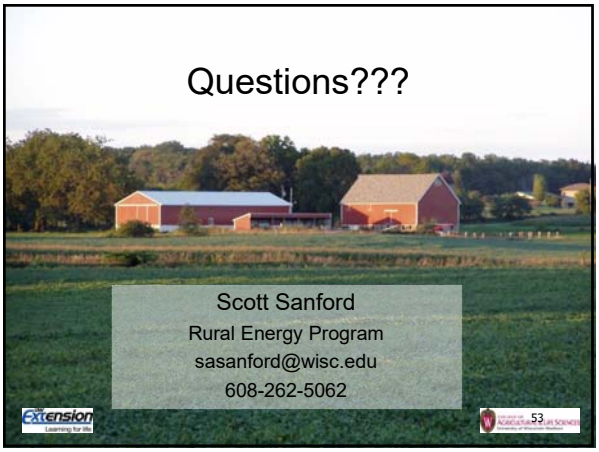
Questions???



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