AeroFarms®
Farming Locally. Globally.®

DESIGNING LED LIGHTING SOLUTIONS FOR NEW APPLICATIONS

Overview

1. Introduction
2. Macro tensions
3. Background and farm tour
4. Evolution of horticulture lighting
5. New Lights for New Applications
6. Why spectrum matters (and how we can use it)
7. Consideration for lighting efficiency
8. How can industry help AeroFarms?

Select Leadership Biographies

Roger Buelow
Chief Technology Officer

- As CTO, Roger leads AeroFarms' innovation and capabilities team and works closely with R&D and Business Development.
- LED innovator and engineering technologist.
- 20+ years of experience in government and the private sector.
- Previously served as CTO of Energy Focus (a publicly traded company) for ten years leading their R&D, Engineering, and Operations to refit the U.S. Navy with LEDs.
- Developed lights that help regulate sleep cycles.
- Set the world record for most efficient solar cell.
- Principal investigator on over a dozen federally funded research contracts spanning military and civilian technologies Holder of 20 patents covering a wide array of technologies.
- Brought over 50 products from concept, through R&D, into engineering and then onto the open market.
- B.S. in Mathematics and an M.S. in Systems and Control Engineering from Case Western Reserve University, Cleveland, Ohio.

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Drought

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Industrialized Farming

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Pesticides

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River Runoff

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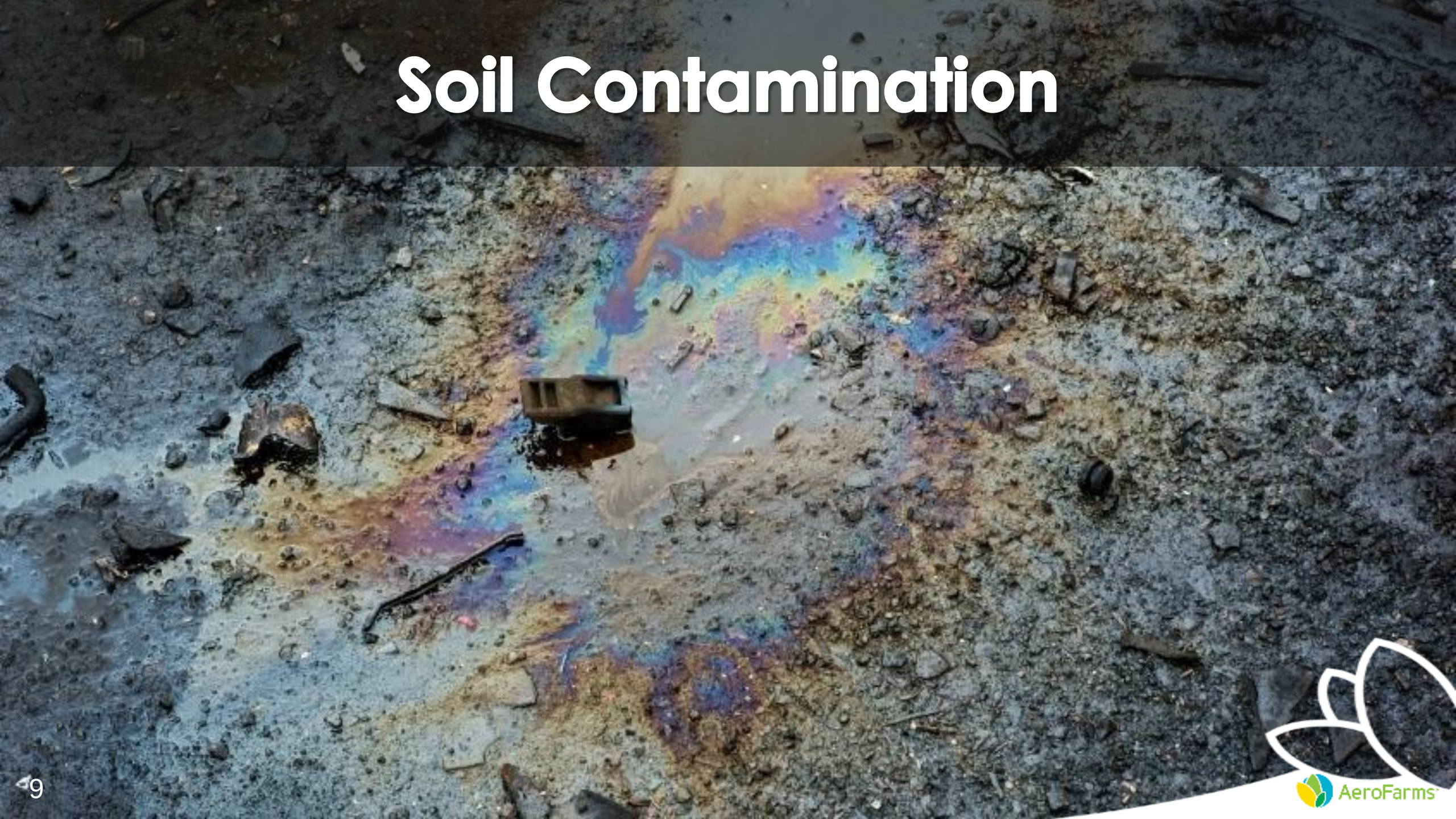
Soil Contamination



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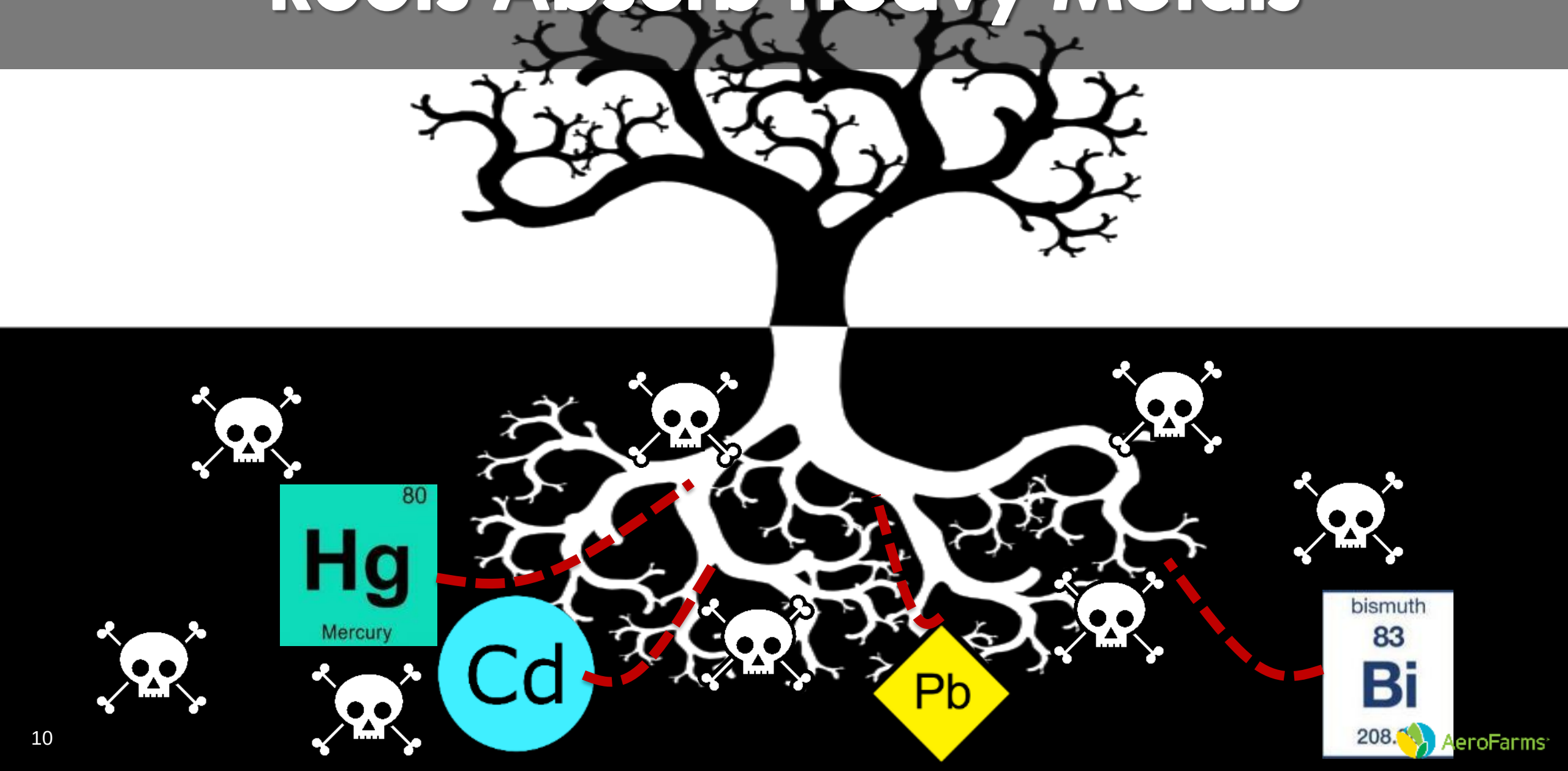
Roots Absorb Heavy Metals



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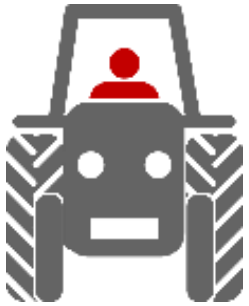
Heavy use of fertilizers and pesticides

+

Over farming



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Record soil degradation

Source: http://www.scientificamerican.com/article/deadly-algae-are-everywhere-thanks-to-agriculture/

Source: http://www.theguardian.com/environment/2015/dec/02/arable-land-soil-food-security-shortage

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Food Waste

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Background

Using 95% less water	$100mm raised to date	Farming since 2004
390x more productive	Zero pesticides	700 varieties grown
Nine farms built to date	World's largest vertical farm	Maximizing taste and nutrition

A Technology Company

AeroFarms' technology includes machine vision, machine learning, AI, IoT hardware and software - capable of mapping plants inside and out.

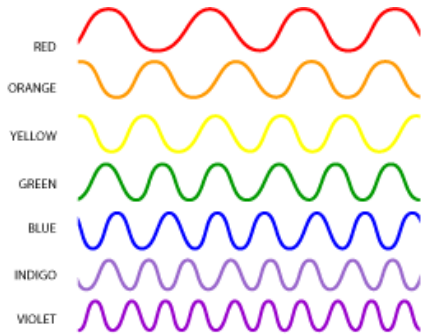
A Farming Company

Aeroponics used to grow more with less: water, fertilizer, land, and time.

World's Largest and Most Productive Vertical Farm

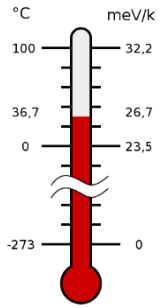
Abiotic Stresses

AeroFarms has mastered how to leverage abiotic stresses to enhance desirable plant attributes such as taste, texture, appearance and nutrition

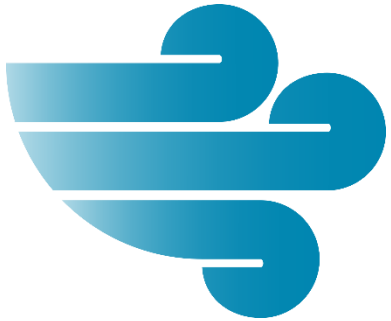


Light Spectrum

Water Delivery

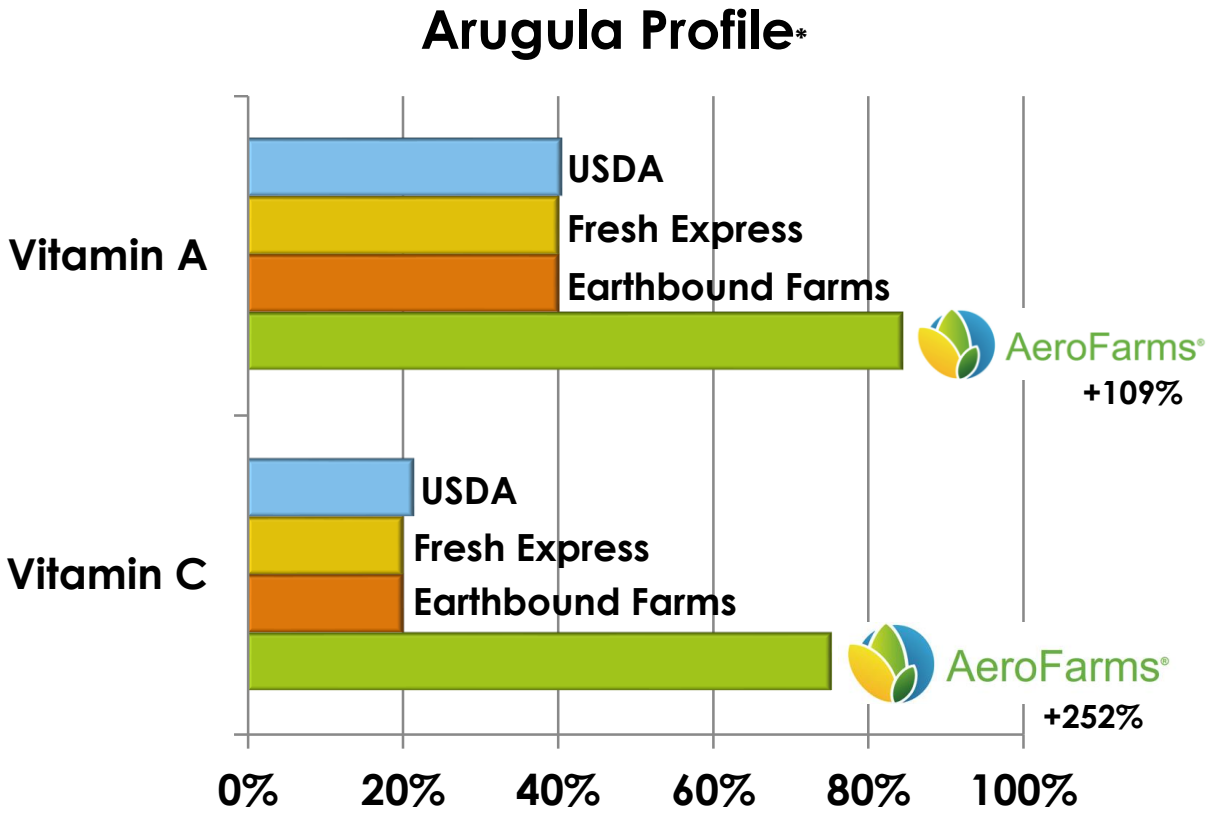


Temperature



Air Flow

Example: Vitamin Content



- Percent Daily Values based on 2,000 calorie diet; Assessment of 85g serving size.
- 3rd Party IEH/Sanipure Testing for AeroFarms. Competitors data taken from their packaging label.

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LOCALLY GROWN IN NJ
CAREFULLY AeroFarms GROWN BY
PEAK FLAVOR ALWAYS®
baby super greens
Our powerhouse baby kale blends with baby arugula and pac choi for ultimate nutrition and top-notch taste.
dream GREENS®
Indoor grown for happy, healthy plants
Pesticide free
Responsibly grown with 95% less water
Non-GMO • Ready to Eat
Product of USA • Net Wt. 4.5 oz (128 g)
PEEL AND RESEAL
LOCALLY GROWN IN NJ
CAREFULLY AeroFarms GROWN BY
PEAK FLAVOR ALWAYS®
baby arugula
Our tender baby arugula bursts with peppery flavor second to none.
dream GREENS®
Indoor grown for happy, healthy plants
Pesticide free
Responsibly grown with 95% less water
Non-GMO • Ready to Eat
Product of USA • Net Wt. 4.5 oz (128 g)
PEEL AND RESEAL
LOCALLY GROWN IN NJ
CAREFULLY AeroFarms GROWN BY
PEAK FLAVOR ALWAYS®
baby spring mix
Our baby lettuces mix with peppery arugula for bright and balanced flavor, sweet and surprisingly zesty.
dream GREENS®
Indoor grown for happy, healthy plants
Pesticide free
Responsibly grown with 95% less water
Non-GMO • Ready to Eat
Product of USA • Net Wt. 4.5 oz (128 g)
PEEL AND RESEAL
LOCALLY GROWN IN NJ
CAREFULLY AeroFarms GROWN BY
PEAK FLAVOR ALWAYS®
baby spicy spring mix
Our bold blend of peppery arugula, crisp watercress and zesty mustard greens, sure to spice up any meal.
dream GREENS®
Indoor grown for happy, healthy plants
Pesticide free
Responsibly grown with 95% less water
Non-GMO • Ready to Eat
Product of USA • Net Wt. 4.5 oz (128 g)
PEEL AND RESEAL
LOCALLY GROWN IN NJ
CAREFULLY AeroFarms GROWN BY
PEAK FLAVOR ALWAYS®
baby kale
Our baby kale is a nutritional powerhouse, super tender and surprisingly sweet.
dream GREENS®
Indoor grown for happy, healthy plants
Pesticide free
Responsibly grown with 95% less water
Non-GMO • Ready to Eat
Product of USA • Net Wt. 4.5 oz (128 g)
PEEL AND RESEAL
LOCALLY GROWN IN NJ
CAREFULLY AeroFarms GROWN BY
PEAK FLAVOR ALWAYS®
baby watercress
Our baby watercress is bright and crisp with a slight sweetness and a healthy dose of spice.
dream GREENS®
Indoor grown for happy, healthy plants
Pesticide free
Responsibly grown with 95% less water
Non-GMO • Ready to Eat
Product of USA • Net Wt. 4.5 oz (128 g)
PEEL AND RESEAL

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Industry Partnerships

Airport Ads in NY/JFK, Boston, Austin, and San Francisco


Lighting
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What's typical?

- Mostly New Installations
  - (Not pulling out fluorescent tubes)
- Lights need to be slim
- 9-12" from lights to seeds
- 2MW is a typical AeroFarms

What's important?

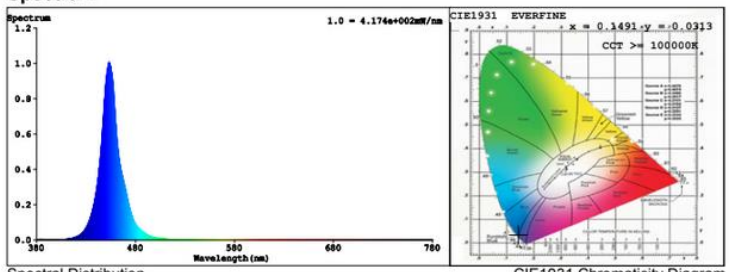
1. Efficiency
2. First Cost
3. Ease of installation
4. Spectrum
5. Reliability
6. Uniformity

When qualifying lights, our specification includes spectrum, efficiency, electromechanical, reliability.

Test Condition

Temprature	: 25.5Deg	RH	: 41.3%
WL Range	: 380nm-780nm	IP	: 53747 (82%)
Test Mode	: Fast Test	T	: 5 ms
Sensitivity	: High		

Spectrum



Spectral Distribution CIE1931 Chromaticity Diagram

Colorimetric Parameters

Chromaticity Coordinate: x = 0.1491 y = 0.0313 / u' = 0.1938 v' = 0.0915 (duv=-2.05e-01)
CCT>=100000K Prcp WL: Ld=458.3nm Purity=98.6%
Peak WL: Lp=454nm FWHM: =17.7nm Ratio:R=0.4% G=8.3% B=91.2%

Render Index: Ra = 0.1

R1 =0	R2 =0	R3 =0	R4 =0	R5 =1	R6 =0	R7 =0	
R8 =0	R9 =0	R10=0	R11=0	R12=0	R13=0	R14=0	R15=0

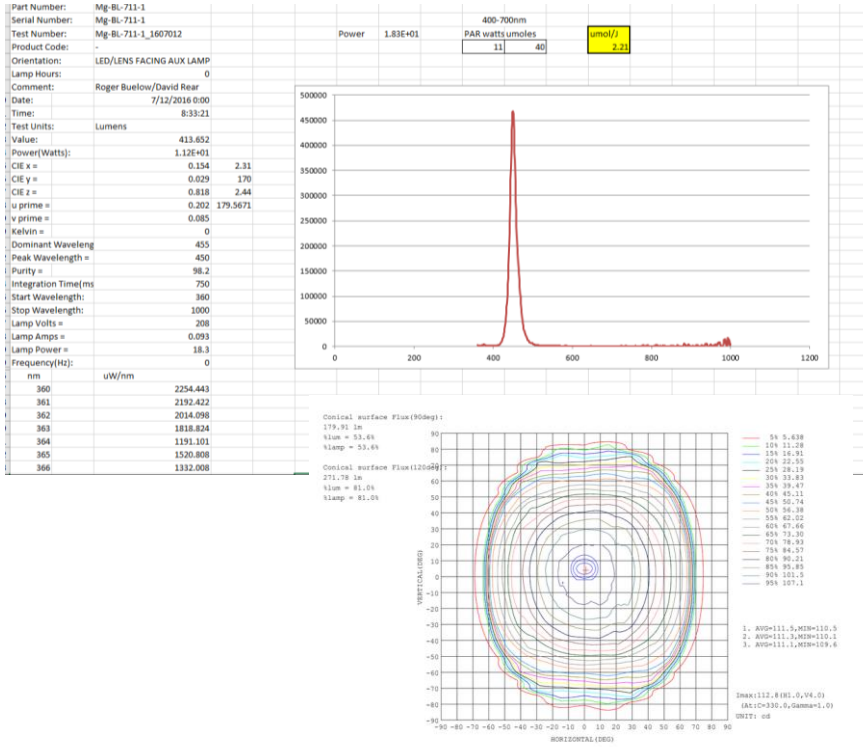
WHITE:OUT

Photometric & Radiometric Parameters

Flux = 341.60 lm Eff. : 19.62 lm/W Fe = 8.3325 W
Photons1:3.164e+001 μmol/s(400~700nm) Photons2:3.170e+001 μmol/s(380~780nm)
Photosynthetic:PPF(400-700nm):37.102μmol/s PRF(400-700nm):9751.1mW
Eff(PPF) (400-700nm):2.13μmol/s/W

Electrical parameters

V = 208.1 V I = 0.08757 A P = 17.41 W PF = 0.9539 F=49.99 Hz



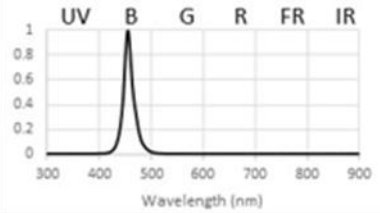
Summary Lighting Facts, Horticultural Applications			
Brand / Model	XXXX	PAR flux (μmol·s⁻¹)	35.3
Lamp type	LED	PAR efficacy (μmol·J⁻¹)	2.03
		PAR efficacy (mol·kWh⁻¹)	7.29
		PAR conversion efficiency (%)	53
Voltage (VAC)	120	Luminous flux (lm)	372.3
Current (A)	0.15	CCT (K)	22,000
Power (W)	17.4	CRI (R_a)	-62.82
PSS (-)	0.51	Case temperature (°C)	N/A
R/FR (-)	1.19		

Photon flux density (PFD) (at 9 inch mounting height):

Waveband (nm)	PFD (μmol·m⁻²·s⁻¹)
300-399	0.32 *(0.48%)*
400-499	65.63 *(97.9%)*
500-599	0.71 *(1.06%)*
600-699	0.11 *(0.16%)*
700-799	0.09 *(0.14%)*
800-900	0.18 *(0.27%)*
300-900	67.04 *(100%)*
400-700	66.44 *(99.1%)*

Measurements performed according to IESNA LM-79-08: *Approved Method for Electrical and Photometric Measurements of Solid-State Lighting Products.*

Normalized photon flux density:



PAR intensity (at 9" mounting height):

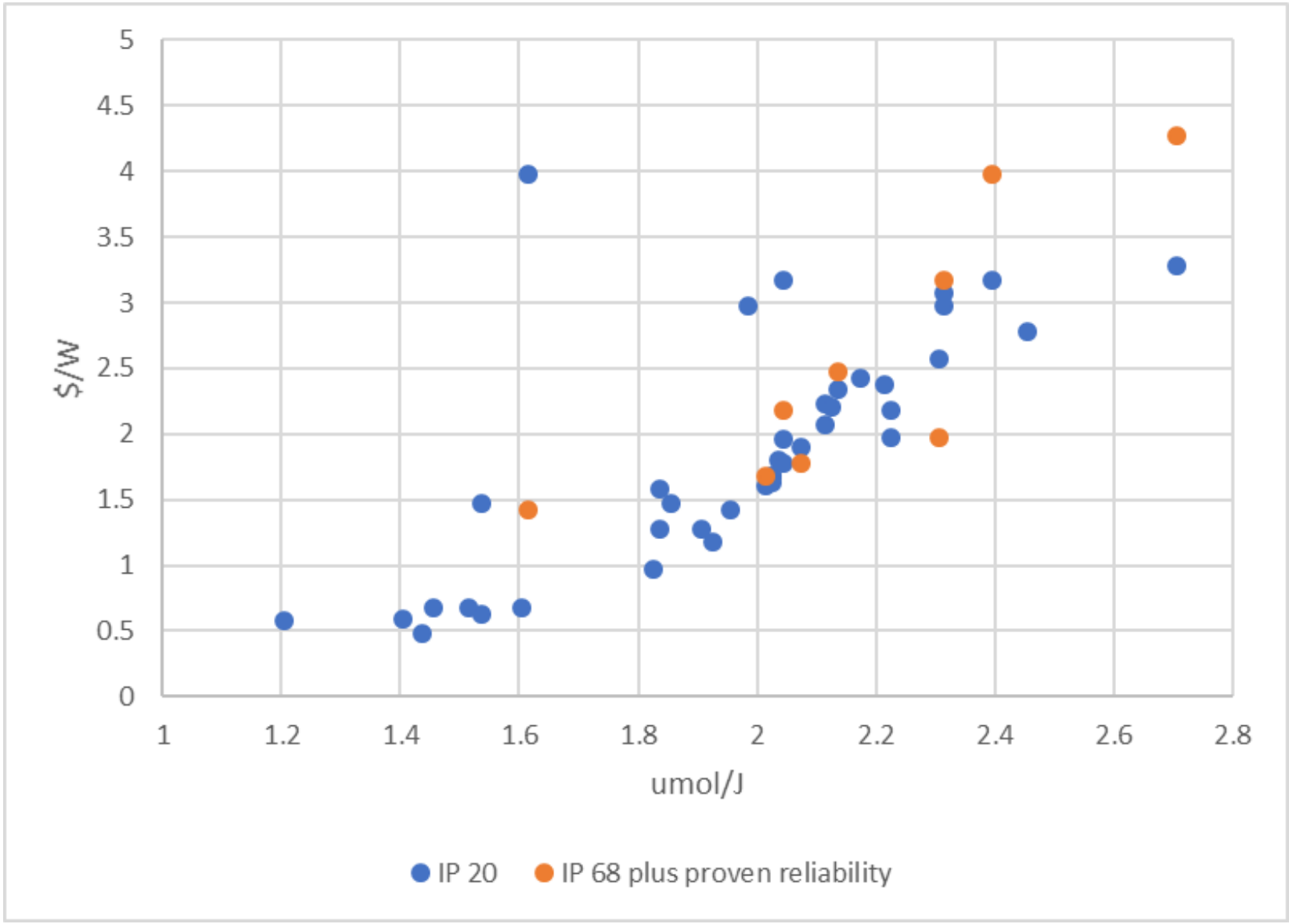
Not yet available

Potential vendors must supply photometry…

… in house checks …

… Independent checks (here, Rutgers)

In most cases, price premium for the most efficient is too high



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Retrofit example

	Existing	Upgraded	
Efficiency	1.9	2.4	umol/J
Total power	2.5	2.0	MW
Investment			
Capex per W		$2	$/W
Install, per W		$0.50	$/W
Capex, total		4.9	$M
Energy/year	21,900	17,338	MWhr/yea
Cost	1,752	1,387	$M/yr
Savings		$ 365	$M/yr
Payback		14	years
Rebate		$1	$/W
Payback with rebate		12	years

New construction			
	Existing	Upgraded	
Efficiency	2.4	2.7	umol/J
Total power	2	1.78	MW
Investment			
Capex per W	$2	$3	$/W
Install, per W	$0.50	$0.50	$/W
Capex, total	5.0	6.2	$M
Energy/year	17,520	15,573	MWhr/yea
Cost	1,402	1,246	$M/yr
Savings		$ 156	$M/yr
Payback		8	years
Rebate		$1	$/W
Payback with rebate		6	years

Opportunities in Vertical Farming

- Megawatts of PFC load in one customer
- Tie in rates/rebates with service upgrades (substation?)
- Popping up all over the country

Vertical Farms Needs: “R&D Topics for the Advancement of SSL in Horticulture”

- High efficiency, low cost
- Low cost (free) spectrum tuning
- Special beam spreads to keep light in the towers
- Feedback loops between plants and lights
- Very high reliability
- Waterproof
- Integrate other functions
- Married with a 277V personnel safety GFCI
- High efficiency, low cost (again)

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