Indoor Cannabis Grow Operations

Improving Energy Efficiency & Sustainability

Presented by Stevan Bratic




Outline

- Elements of indoor, controlled grow environment
  - Complete Grow Systems
  - Lighting
  - CHP (Combined Heat & Power)
  - Controlled Dehumidification
  - Solar System
  - Vertical Systems
  - Destratification
  - Roofs

ELEMENTS OF AN INDOOR GROW-ROOM

- Building envelope
  - typically sealed environment
  - in insulated building, envelope htg/clg loads negligible
- Lighting (100% artificial)
- Heating (minimal)
- Ventilation (air movement only)
- Cooling & Dehumidification (dominate HVAC)
- Delivery of nutrients
  - CO_2, water, fertilizer
- Energy Supply:
  - electric utility, solar (PV), natural gas – combined heat & power (CHP)

Complete Grow Systems

Power Options
- Combined Heat and Power (CHP) systems
- From 5 kW to 10 MW systems
- Light schedule / utility rate optimization
- Solar Photovoltaics can supplement
- Off-grid, stand-alone microgrids
- Backup power

Implementation
- No utility electrical feed? No problem.
- Lower infrastructure costs
- Faster implementation timeframe
- Low carbon, sustainable design
- Application engineering support from

Dehumidification
- Chilled water systems
- Desiccant systems

Lighting Options
- Recommend LED for less power, less cooling, less infrastructure cost
- Less NET capital cost to install when accounting for power, chilling and lighting
- Significantly lower operating costs

Destratification
- Air flow systems

Gas Cooling Systems
- Lowest operating cost per ton
- Absorption chillers
- Engine driven chillers
- Engine driven VRF
- Many manufacturer options

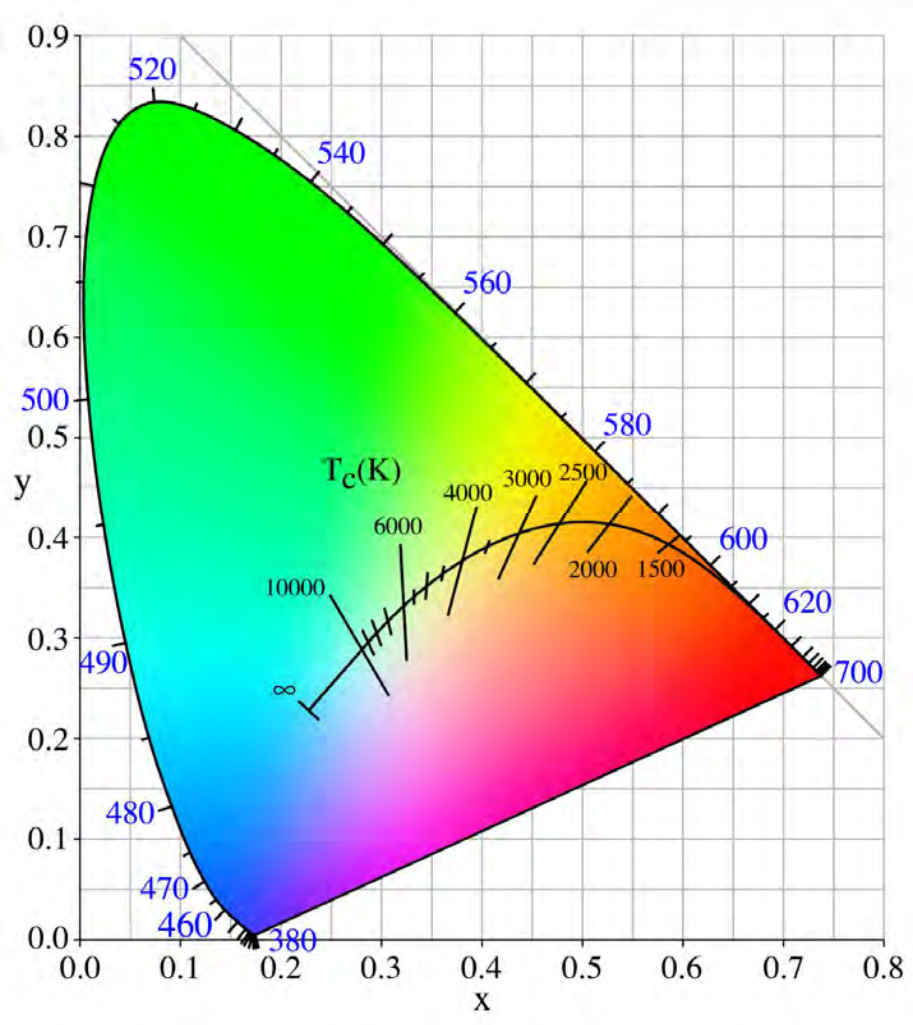
CO2 Supplementation
- Lowest cost CO2 is direct natural gas combustion with condensing heat recovery
- CHP exhaust CO2 recovery is possible
- Liquid CO2 systems

Heating
- CHP waste heat
- Condensing boilers
- Engine driven VRF

Vertical Grow Systems
- Optimize your grow space

LIGHTING

Understanding Color Spectrum Chart



The colors of the visible light spectrum	
color	wavelength interval
red	~ 700–635 nm
orange	~ 635–590 nm
yellow	~ 590–560 nm
green	~ 560–490 nm
blue	~ 490–450 nm
violet	~ 450–400 nm

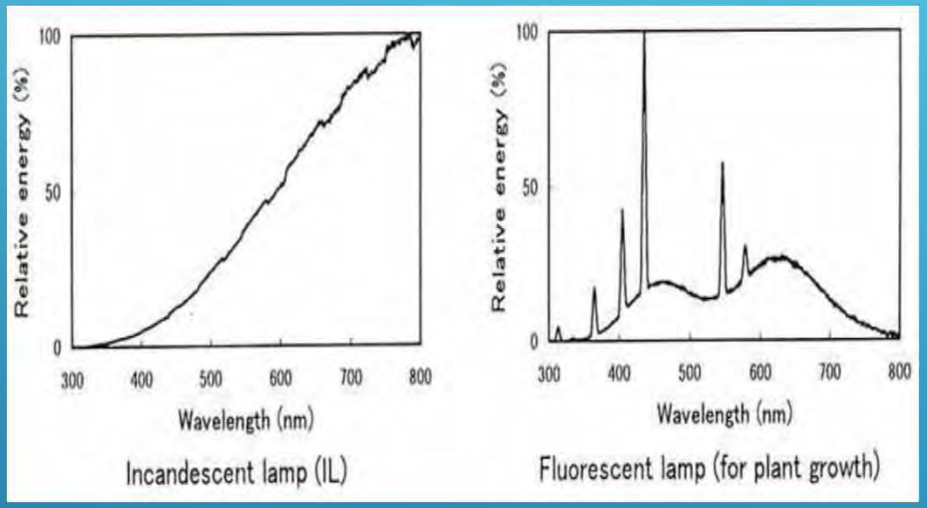
LIGHTING

Traditional HID Lighting

- HPS (High Pressure Sodium)
  - 600W
  - 1000W
- MH (Metal Halite)
  - 600W
  - 1000W
- CMH (Ceramic Metal Halite)
  - 315W

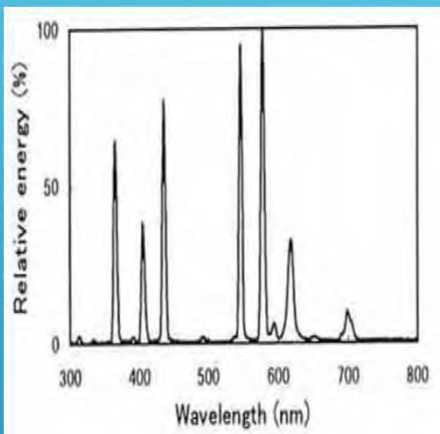
LIGHTING

Typical Incandescent, Fluorescent, HPS, MH, ML, & CMH Lighting Color Spectrum

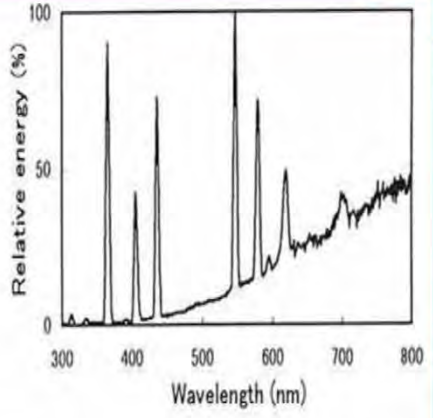


Incandescent lamp (IL)

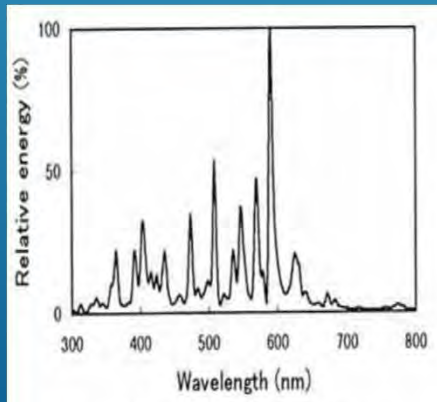
Fluorescent lamp (for plant growth)



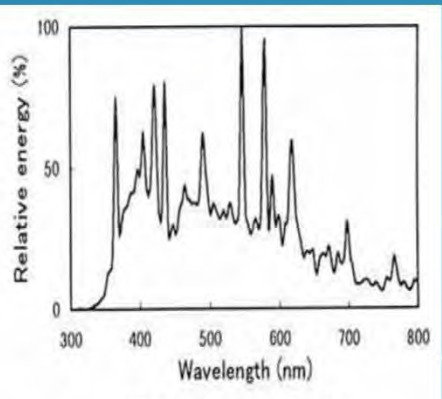
Fluorescent mercury lamp (HPMVL)



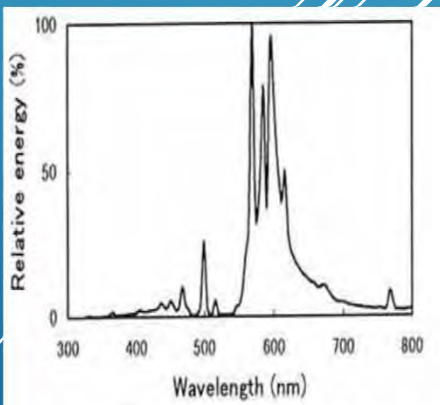
Self-ballasted mercury lamp(SBML)



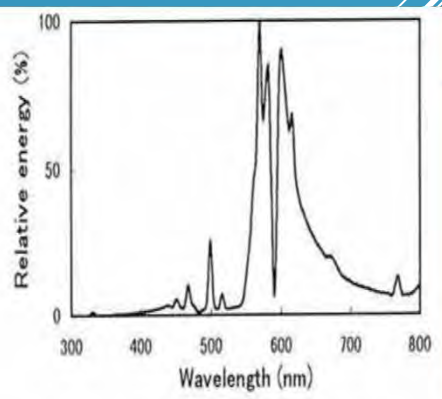
Metal halide lamp (MHL)



High color rendition type
metal halide lamp (MHL)



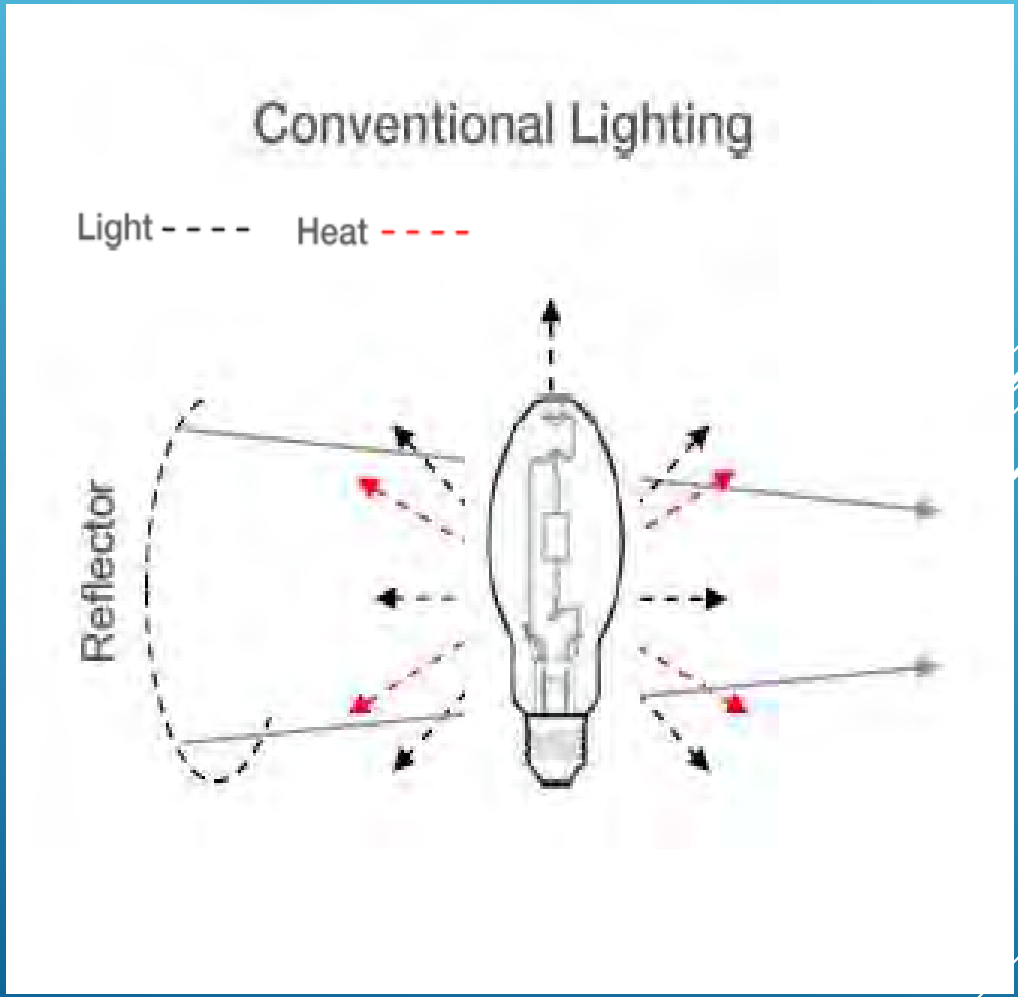
High pressure sodium lamp (HPSL)



High color rendition type
high pressure sodium lamp (HPSL)

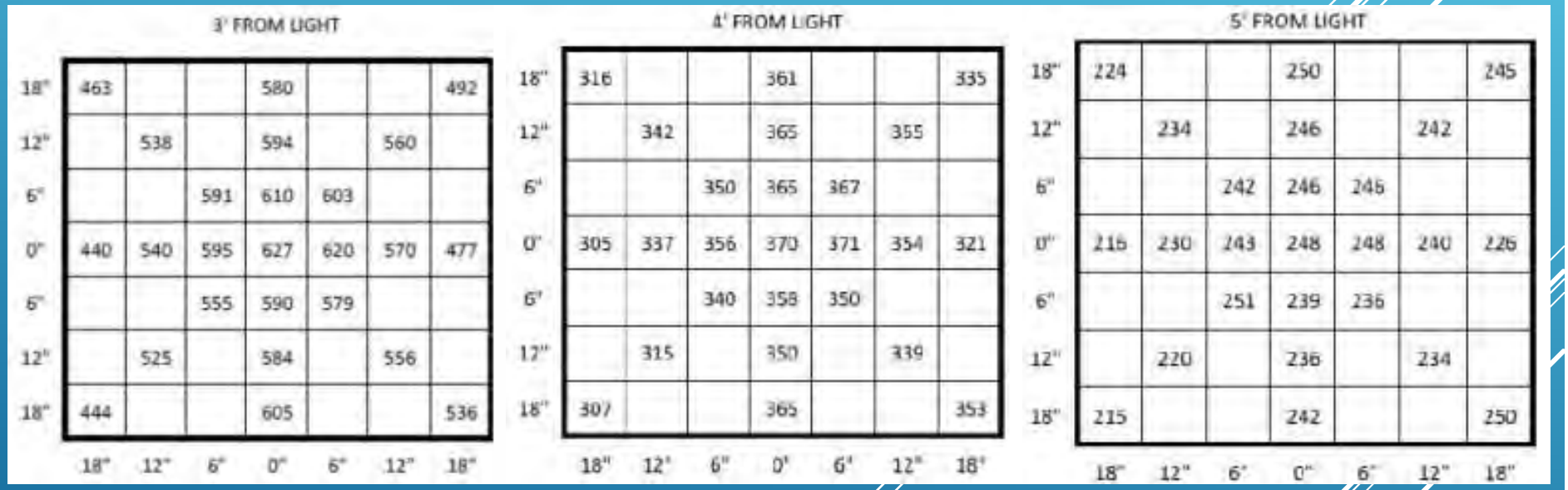
LIGHTING

How Does Traditional HID Lighting Work



LIGHTING

1000W HPS PPFD Results (Gevita DE)



3' FROM LIGHT

	18"	12"	6"	0"	6"	12"	18"
18"	463			580			492
12"		538		594		560	
6"			591	610	603		
0"	440	540	595	627	620	570	477
6"			555	590	579		
12"		525		584		556	
18"	444			605			536

4' FROM LIGHT

	18"	12"	6"	0"	6"	12"	18"
18"	316			361			335
12"		342		365		355	
6"			350	365	367		
0"	305	337	356	370	371	354	321
6"			340	358	350		
12"		315		350		339	
18"	307			365			353

5' FROM LIGHT

	18"	12"	6"	0"	6"	12"	18"
18"	224			250			245
12"		234		246		242	
6"			242	246	246		
0"	216	230	243	248	248	240	226
6"			251	239	236		
12"		220		236		234	
18"	215			242			250

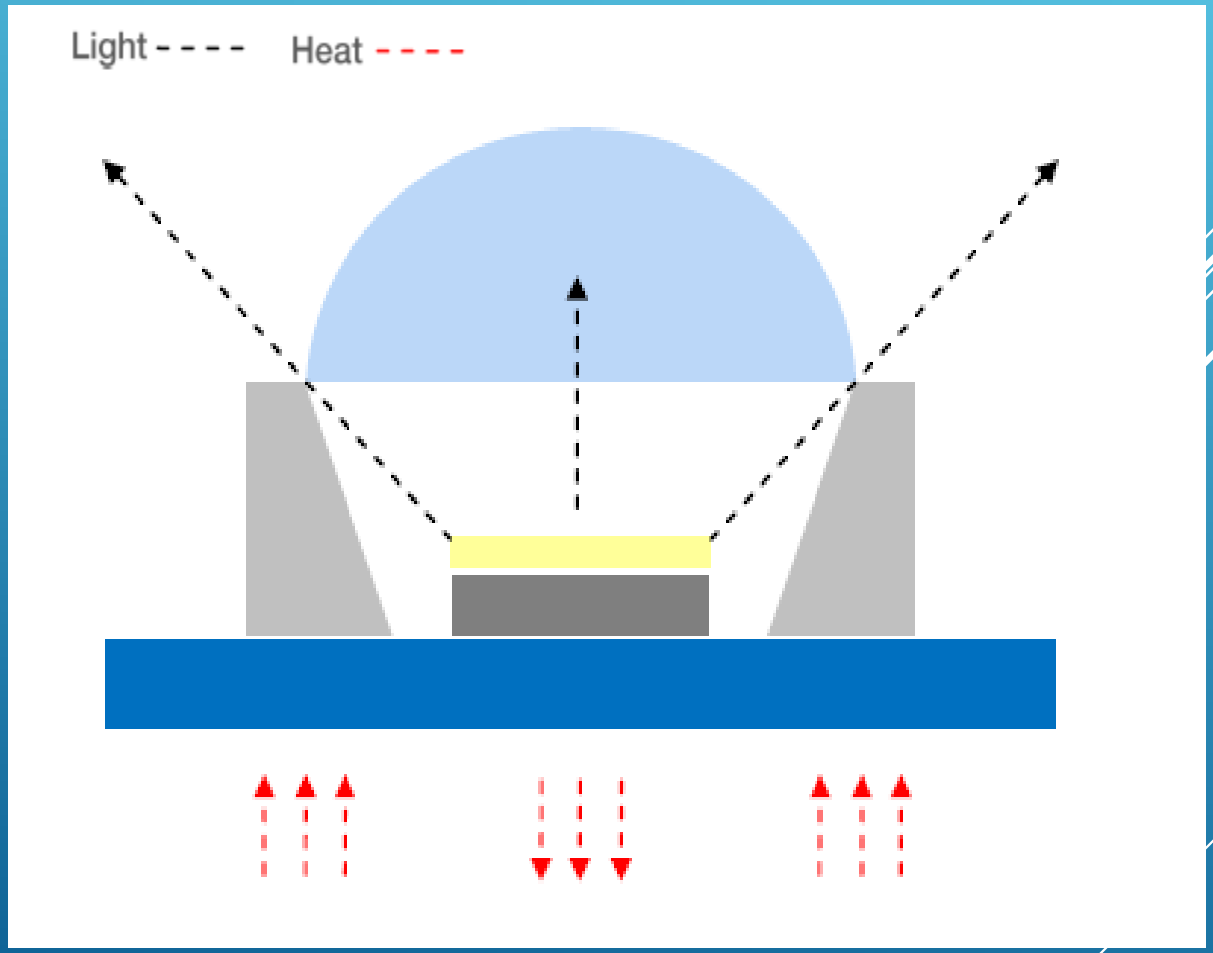
LIGHTING

LED Grow Lights (3 Options)

- Slim Series - High Yield
  - 300W equivalent to 600W
  - 600W equivalent to 1000W
- Linear Series - Large Footprint
  - 480W equivalent to 600W
  - 720W equivalent to 1000W

LIGHTING

How Does LED Lighting Work



LIGHTING

How Does LED Lighting Work (continued)

OPTION 1

Slim LED Grow Light

325 Module

330W Full Spectrum for Veg & Flower

1 fixtures to are equivalent to 600 HPS

Slim LED Grow Light

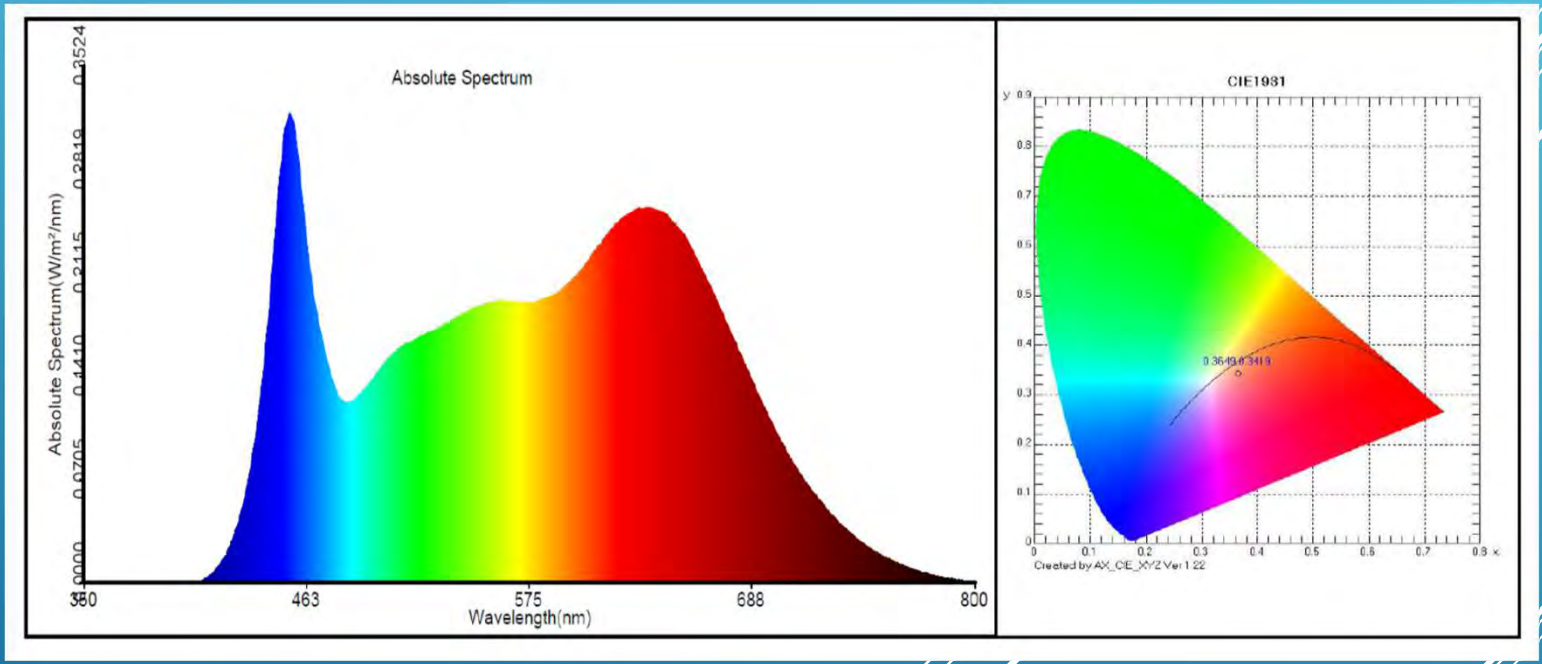
650 Module

660W Full Spectrum for Veg & Flower

2 fixtures to are equivalent to 1000W HPS

LIGHTING

Slim LED Color Spectrum



LIGHTING

330W Slim LED PPFD Results

Mounting Height (4' x 4' area):

1'

	24"	18"	12"	6"	0"	6"	12"	18"	24"
24"	N/A				N/A				N/A
18"		N/A			N/A			N/A	
12"			N/A		N/A		N/A		
6"				N/A	N/A	N/A			
0"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6"				N/A	N/A	N/A			
12"			N/A		N/A		N/A		
18"		N/A			N/A			N/A	
24"	N/A				N/A				N/A

1.5'

	24"	18"	12"	6"	0"	6"	12"	18"	24"
24"	10				56				11
18"		23			349			25	
12"			202		940		238		
6"				948	1294	1044			
0"	20	67	327	834	1361	1010	435	92	19
6"				922	1285	1078			
12"			142		1086		205		
18"		19			339			22	
24"	9				55				9

2'

	24"	18"	12"	6"	0"	6"	12"	18"	24"
24"	12				103				13
18"		41			395			45	
12"			277		693		303		
6"				736	892	775			
0"	40	150	366	722	1000	826	446	165	39
6"				750	947	834			
12"			253		778		323		
18"		33			375			39	
24"	11				87				10

2.5'

	24"	18"	12"	6"	0"	6"	12"	18"	24"
24"	15				70				14
18"		89			193			65	
12"			321		397		303		
6"				581	653	602			
0"	188	387	535	657	775	667	542	372	153
6"				589	660	603			
12"			321		389		323		
18"		103			210			82	
24"	20				92				16

3'

	24"	18"	12"	6"	0"	6"	12"	18"	24"
24"	33				121				29
18"		135			225			125	
12"			309		385		301		
6"				485	522	475			
0"	191	317	408	496	570	503	403	309	189
6"				459	506	452			
12"			285		345		299		
18"		124			206			120	
24"	33				118				30

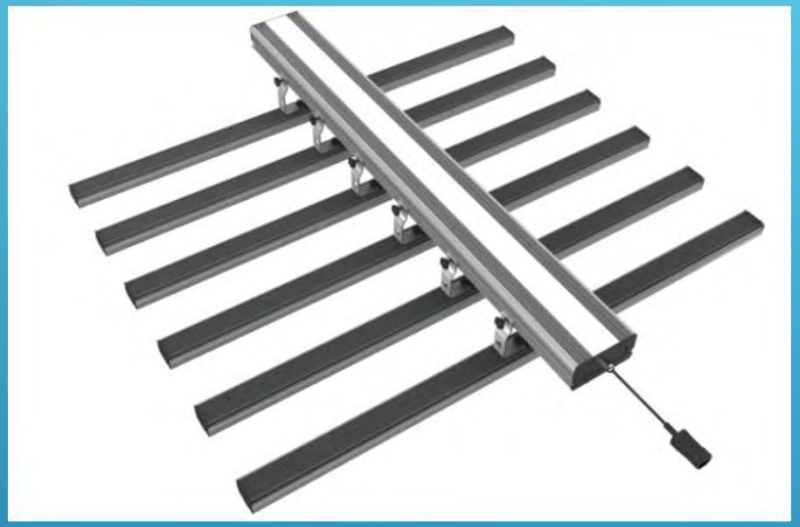
4'

	24"	18"	12"	6"	0"	6"	12"	18"	24"
24"	63				135				71
18"		141			213			147	
12"			232		292		245		
6"				303	333	325			
0"	162	215	266	312	348	319	285	233	184
6"				297	328	311			
12"			207		266		228		
18"		117			181			130	
24"	58				114				61

5'

	24"	18"	12"	6"	0"	6"	12"	18"	24"
24"	75				124				74
18"		125			166			124	
12"			169		196		176		
6"				203	211	206			
0"	134	163	191	209	216	209	189	162	135
6"				201	210	202			
12"			167		193		169		
18"		118			164			120	
24"	73				119				71

OPTION 2



Linear Strip Grow Light

6 Strip Series

480W Full Spectrum for Veg

1 fixtures to are equivalent to 1000W HPS at 480W

Linear Strip Grow Light

9 Strip Series

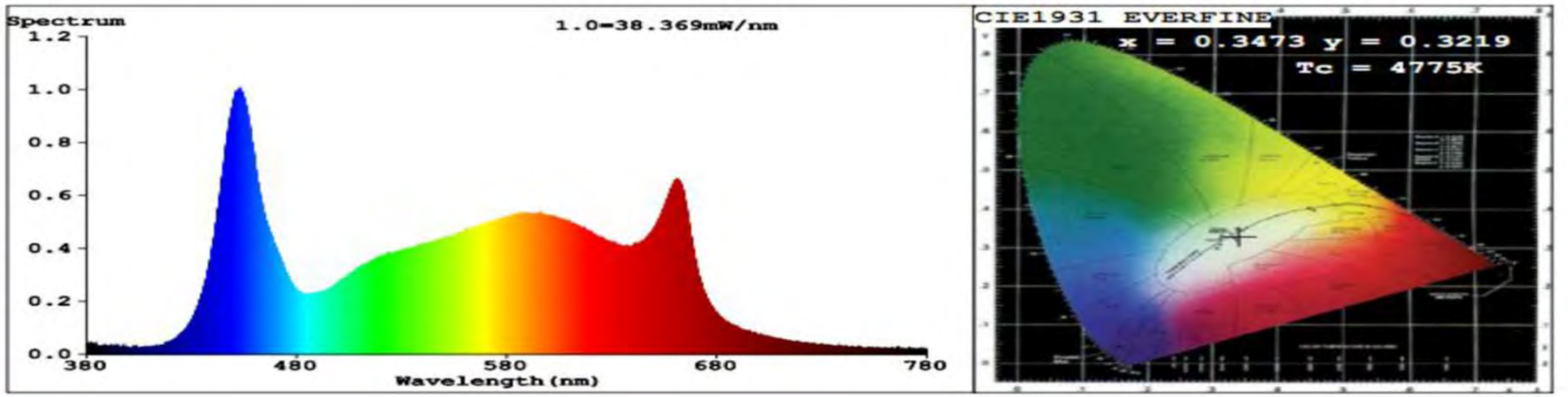
720W Full Spectrum for Flower

1 fixtures to are equivalent to 1000W HPS at 720W

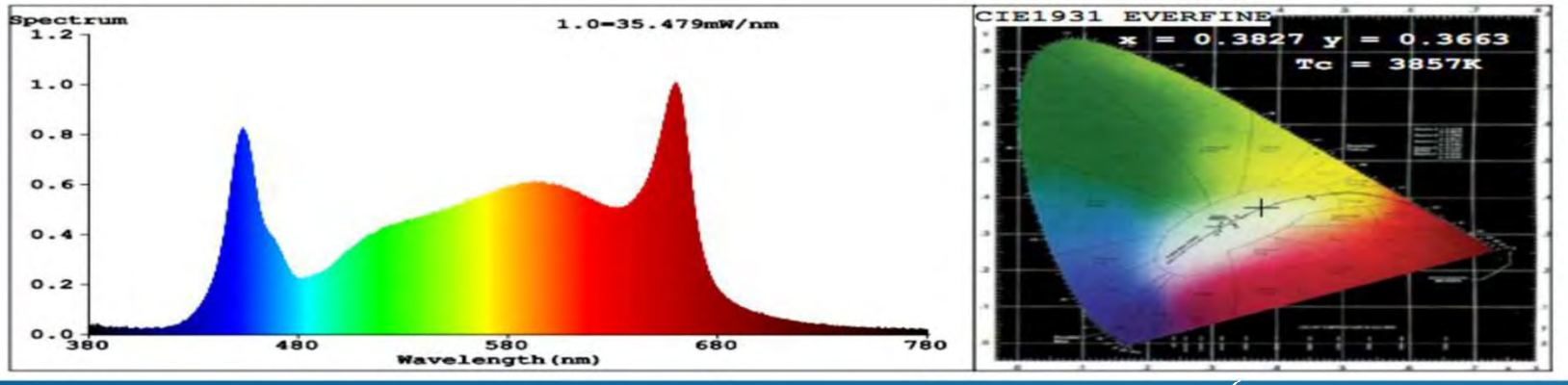
LIGHTING

Color Spectrum

Veg. spectrum:



Blooming. spectrum:



LIGHTING

480W (Veg) & 720W (Flower)Linear LED PPFD Results

480W, 120-277V, UL Horticultural, Mounting Height:

1′

1ft From Light

	24"	18"	12"	6"	0"	6"	12"	18"	24"
24"	66				522				26
18"		368			824			487	
12"			803		930		872		
6"				927	954	976			
0"	102	400	816	944	969	970	882	558	170
6"				955	962	953			
12"			825		935		864		
18"		397			856			520	
24"	76				620				121

2′

2ft From Light

	24"	18"	12"	6"	0"	6"	12"	18"	24"
24"	130				437				175
18"		316			606			382	
12"			558		725		627		
6"				738	786	775			
0"	227	407	615	756	799	786	673	475	283
6"				750	775	778			
12"			575		747		634		
18"		340			635			399	
24"	141				487				188

3′

3ft From Light

	24"	18"	12"	6"	0"	6"	12"	18"	24"
24"	156				353				189
18"		281			447			323	
12"			426		526		464		
6"				540	575	565			
0"	255	383	475	556	586	564	522	412	312
6"				547	587	574			
12"			437		545		478		
18"		294			465			340	
24"	171				380				213

4′

4ft From Light

	24"	18"	12"	6"	0"	6"	12"	18"	24"
24"	163				284				179
18"		246			337			263	
12"			334		384		349		
6"				389	378	410			
0"	244	306	368	409	432	422	386	332	259
6"				407	418	415			
12"			344		397		356		
18"		258			349			270	
24"	178				300				178

720W, 120-277V, UL Horticultural, Mounting Height:

1′

1ft From Light

	24"	18"	12"	6"	0"	6"	12"	18"	24"
24"	124				705				136
18"		642			1228			672	
12"			1216		1416		1224		
6"				1418	1461	1420			
0"					1453				
6"				1414	1434	1390			
12"			1231		1419		1229		
18"		641			1298			720	
24"	130				955				200

2′

2ft From Light

	24"	18"	12"	6"	0"	6"	12"	18"	24"
24"	225				611				216
18"		523			874			508	
12"			887		1077		873		
6"				1132	1185	1128			
0"					1211				
6"				1142	1186	1129			
12"			915		1112		903		
18"		560			968			553	
24"	274				747				268

3′

3ft From Light

	24"	18"	12"	6"	0"	6"	12"	18"	24"
24"	280				430				300
18"		480			631			515	
12"			700		789		727		
6"				857	895	865			
0"	550	700	836	908	937	923	835	735	594
6"				872	884	885			
12"			715		768		726		
18"		483			619			505	
24"	286				449				323

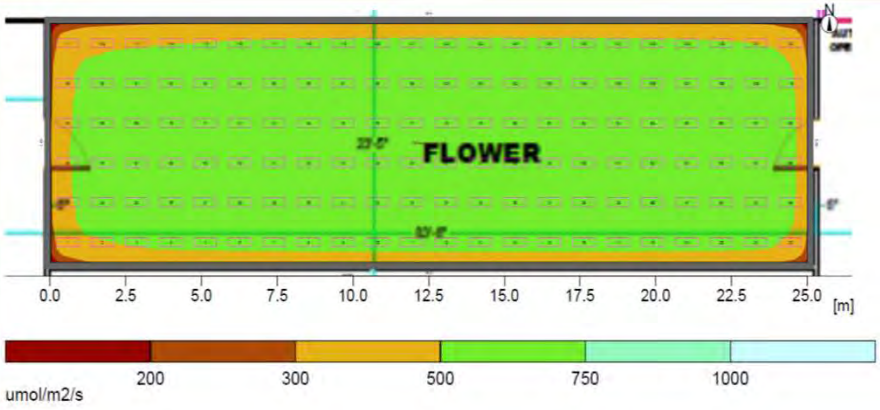
4′

4ft From Light

	24"	18"	12"	6"	0"	6"	12"	18"	24"
24"	266				412				250
18"		398			505			372	
12"			515		570		496		
6"				601	611	585			
0"	389	481	559	609	621	594	533	450	355
6"				590	602	575			
12"			503		556		481		
18"		382			485			354	
24"	265				398				245

LIGHTING

Simulations Results



General

Calculation algorithm used	Average indirect fraction
Height of luminaire plane	3.00 m
Maintenance factor	0.80
Total power	44880.0 W
Total power per area (175.00 m²)	256.46 W/m²

Evaluation area 1	**Reference plane 1.1**
	Horizontal
Em	591 umol/m2/s
Emin	338 umol/m2/s
Emin/Eav (Uo)	0.57
Emin/Emax (Ud)	0.51
UGR (4.0H 14.3H)	<10.0
Position	0.00 m

Type	**No.\Make**		
1	132	Order No.	: !
		Luminaire name	: Slim LED Grow Light-325 (60 deg) [110v]
		Equipment	: 1 x 340 W

[m]									
24	382	469	493	506	514	509	505	491	417
	449	565	589	604	613	604	605	592	496
	470	587	612	627	635	627	628	615	518
22	479	594	620	633	641	634	634	621	527
	486	603	627	642	649	641	642	630	534
	490	606	630	644	652	643	645	632	537
20	489	605	631	643	651	644	644	631	536
	494	611	635	649	656	648	649	636	541
	496	614	637	651	659	650	652	639	542
18	494	610	635	648	655	649	649	635	540
	497	613	638	652	658	651	652	638	544
	497	616	640	654	661	653	654	642	544
16	496	613	637	651	658	651	651	638	542
	497	614	639	652	659	652	652	639	543
	498	617	640	655	[662]	654	655	642	545
14	497	614	638	651	659	651	652	639	544
	497	612	637	650	657	651	651	638	543
	497	616	639	654	661	653	654	641	544
12	495	613	637	651	658	650	651	638	542
	493	609	634	647	654	648	648	634	540
	494	612	635	649	657	649	650	638	541
10	492	609	632	647	654	646	647	635	539
	487	602	627	640	647	641	641	628	534
	486	602	626	640	647	640	641	629	534
8	479	597	621	635	643	635	637	625	530
	469	587	612	626	633	627	627	615	522
6									

Height of the reference plane : 0.00 m

Average illuminance	Eav	: 591 umol/m2/s
Minimum illuminance	Emin	: 338 umol/m2/s
Maximum illuminance	Emax	: 662 umol/m2/s
Uniformity Uo	Emin/Eav	: 1 : 1.75 (0.57)
Diversity Ud	Emin/Emax	: 1 : 1.96 (0.51)

LIGHTING

Why is it important to follow electrical standards when buying any lighting product?

- **If you have a fire and your insurance company finds out you did not purchase UL or related products, your insurance company will not cover you for the repair.**
- **Electrical standard have markings you should be looking for:**

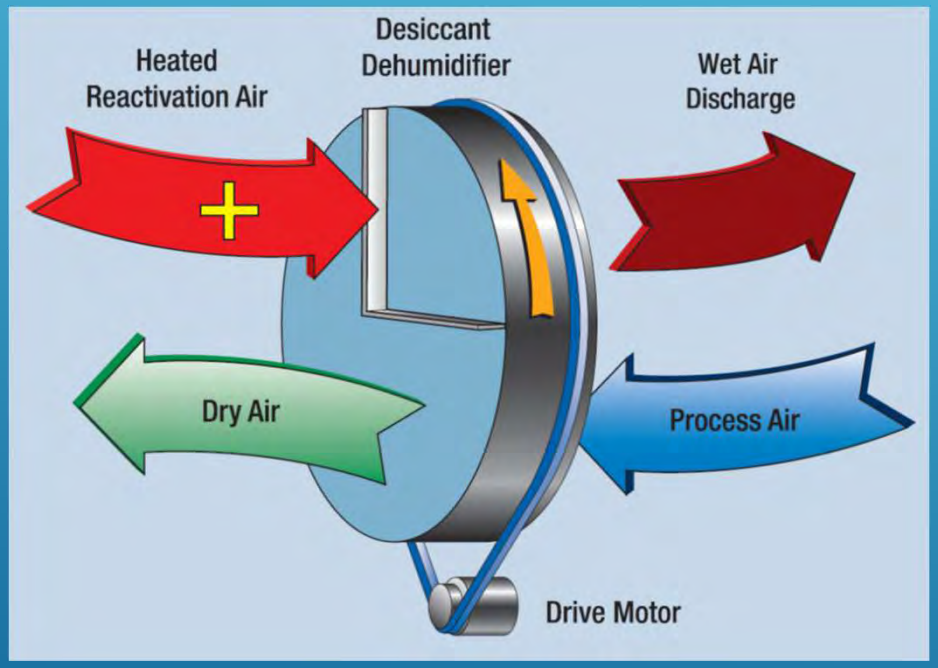
LIGHTING

Conclusion:

- On average, 50% reduction from Traditional Lighting to LED
- LED life is 50K hrs typically vs HID at around 10K hrs
  - LED also has lower degradation rate than HID
- Due to the lower intensity levels and heat of LED
  - Learn how to manage the lack of heat from LED
    - HVAC
    - Dehumidification
  - Mounting the LED much closer to the plants vs HID

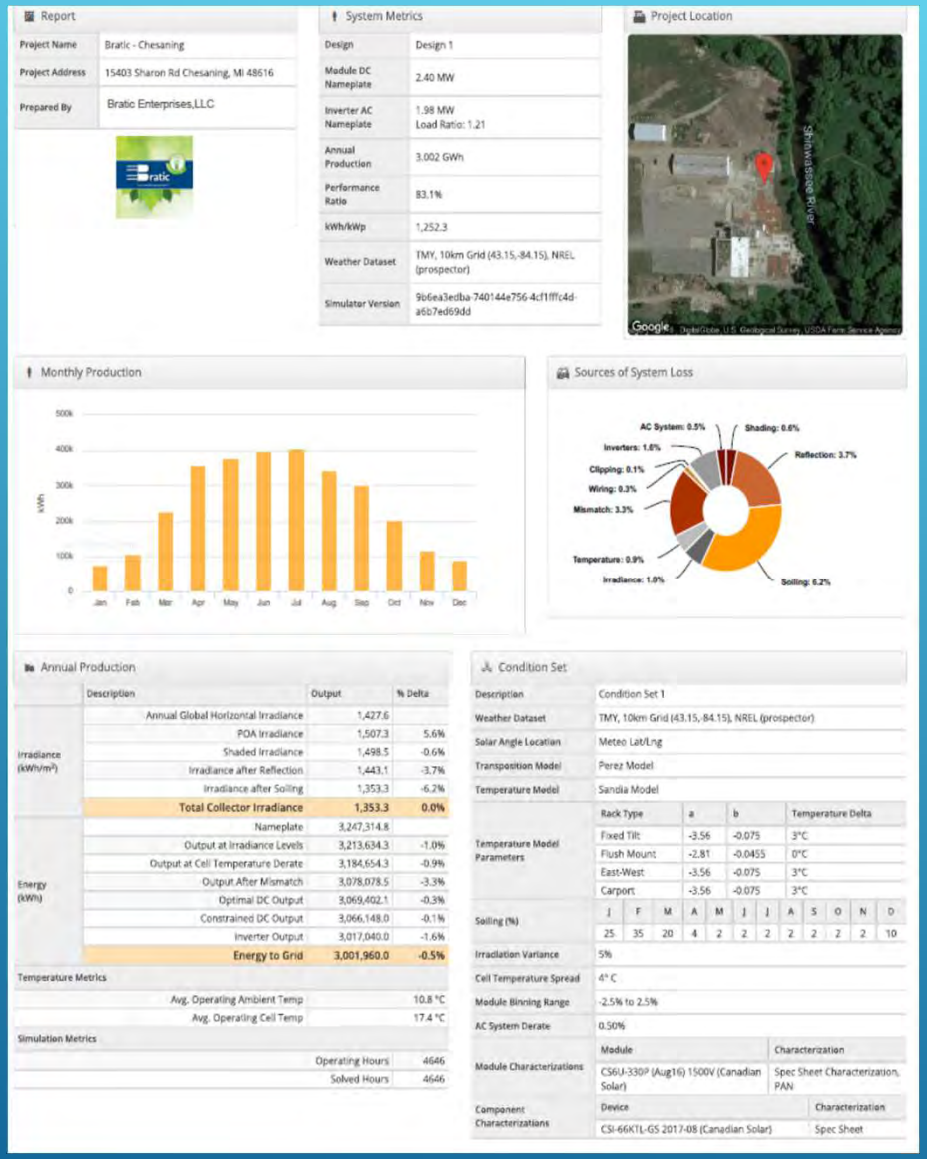
300kW- 10MW CHP System

CONTROLLED DEHUMIDIFICATION



Controlled Dehumidification provides equipment that delivers the deepest drying system available. Utilizing the power of desiccant dehumidification and vapor pressure reduction with optional discharge temperature control.

SOLAR



Report

Project Name	Bratic - Chesaning
Project Address	15403 Sharon Rd Chesaning, MI 48616
Prepared By	Bratic Enterprises,LLC

System Metrics

Design	Design 1
Module DC Nameplate	2.40 MW
Inverter AC Nameplate	1.98 MW Load Ratio: 1.21
Annual Production	3.002 GWh
Performance Ratio	83.1%
kWh/kWp	1,252.3
Weather Dataset	TMY, 10km Grid (43.15,-84.15), NREL (prospector)
Simulator Version	9b6ea3edba-740144e756-4cf1fffc4d-a6b7ed69dd

Project Location

Monthly Production

Sources of System Loss

Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,427.6	
	POA Irradiance	1,507.3	5.6%
	Shaded Irradiance	1,498.5	-0.6%
	Irradiance after Reflection	1,443.1	-3.7%
	Irradiance after Soiling	1,353.3	-6.2%
	Total Collector Irradiance	**1,353.3**	**0.0%**
Energy (kWh)	Nameplate	3,247,314.8	
	Output at Irradiance Levels	3,213,634.3	-1.0%
	Output at Cell Temperature Derate	3,184,654.3	-0.9%
	Output After Mismatch	3,078,078.5	-3.3%
	Optimal DC Output	3,069,402.1	-0.3%
	Constrained DC Output	3,066,148.0	-0.1%
	Inverter Output	3,017,040.0	-1.6%
	Energy to Grid	**3,001,960.0**	**-0.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp		10.8 °C
	Avg. Operating Cell Temp		17.4 °C
Simulation Metrics			
	Operating Hours		4646
	Solved Hours		4646

Condition Set

Description	Condition Set 1
Weather Dataset	TMY, 10km Grid (43.15,-84.15), NREL (prospector)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model

Temperature Model Parameters

Rack Type	a	b	Temperature Delta
Fixed Tilt	-3.56	-0.075	3°C
Flush Mount	-2.81	-0.0455	0°C
East-West	-3.56	-0.075	3°C
Carport	-3.56	-0.075	3°C

Soiling (%)

J	F	M	A	M	J	J	A	S	O	N	D
25	35	20	4	2	2	2	2	2	2	2	10

Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	-2.5% to 2.5%
AC System Derate	0.50%

Module Characterizations

Module	Characterization
CS6U-330P (Aug16) 1500V (Canadian Solar)	Spec Sheet Characterization, PAN

Component Characterizations

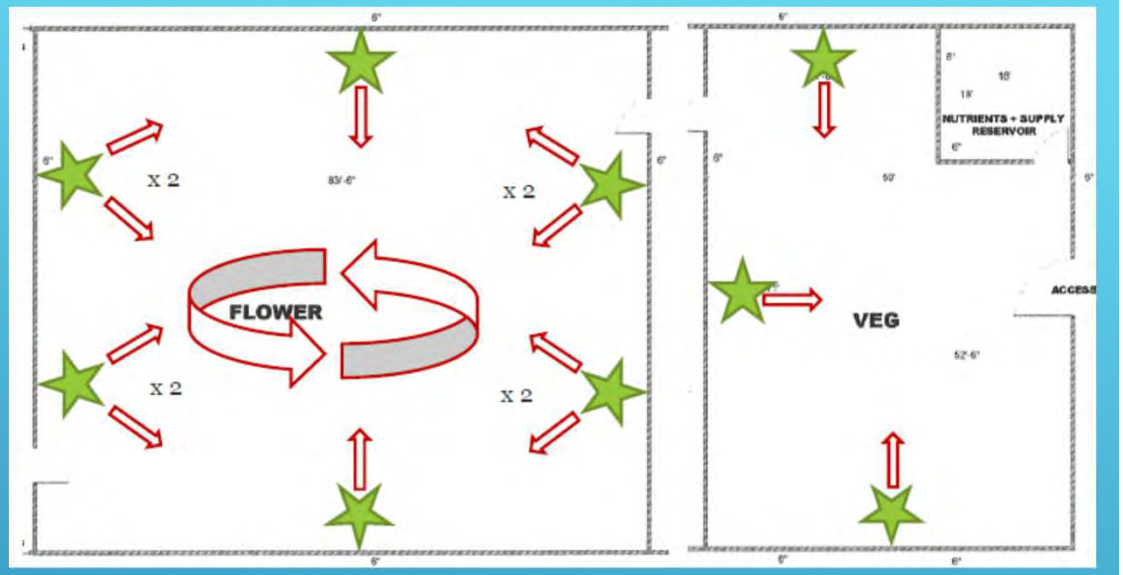
Device	Characterization
CSI-66KTL-GS 2017-08 (Canadian Solar)	Spec Sheet

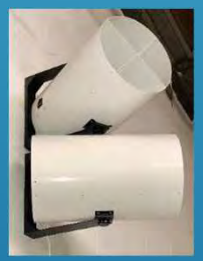
SB1

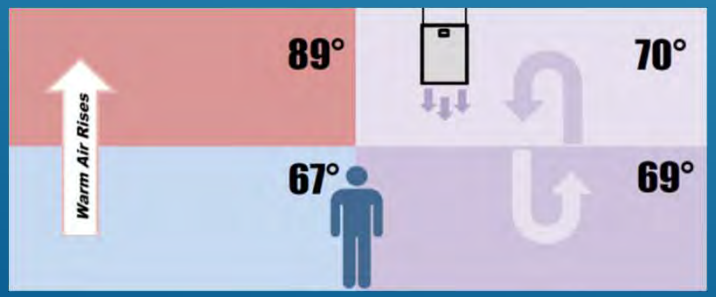
VERTICAL GROW SYSTEMS

Vertical Systems allow for higher plant count and requires much less square footage.

DESTRATIFICATION







23 running watts producing 620 CFM per fan

- Cut HVAC-related energy costs by more than 30%
- Extend the performance life of HVAC equipment
- Maintain dry floors and prevent accidents for improved customer safety
- Redistribute air and eliminate stale air to improve air quality standards
- Improve overall comfort for employees and customers
- Target air to strategically resolve building challenges

ENERGY STAR RATED ROOF

Big Savings

- High R value (R19-30)
- High reflectivity
  - helpful in reducing peak energy demand, or the sharp peak in electrical demand observed in almost every building during the busiest hours of the day.
  - Peak demand is a problem because it: • Requires additional power capacity

QUESTIONS?

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