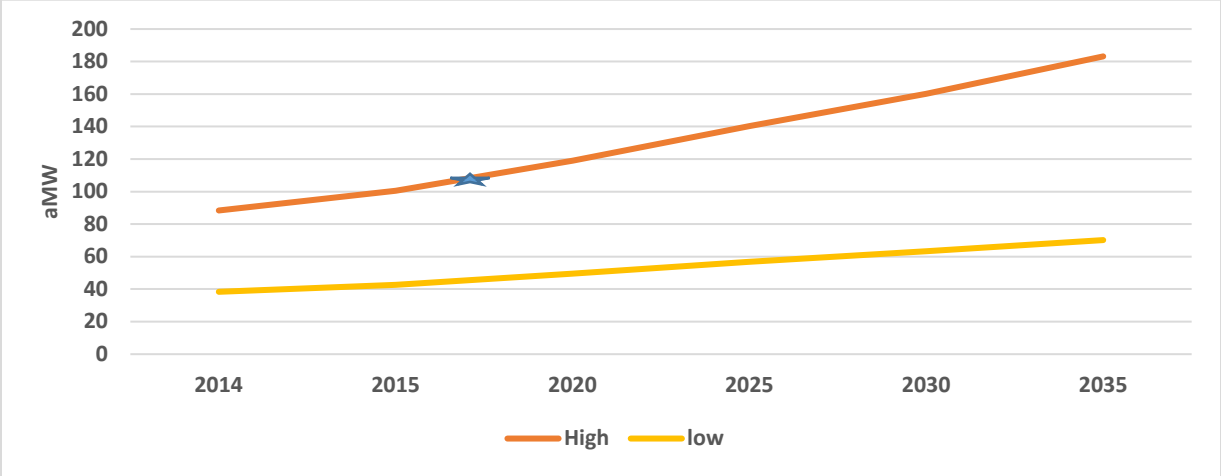
Electricity Consumption from Northwest Cannabis Production

The Northwest Power and Conservation Council's Seventh Power Plan includes an estimate of the electricity demand from medical and recreational cannabis producers. The analysis, conducted in 2014, found that production was highly energy intensive due to the use of high-wattage indoor lighting.

In its latest update, the Council analyzed the consumption pattern for cannabis and developed a range forecast of future loads from cannabis production for Oregon and Washington.

Figure 1 shows the range in the Seventh Power Plan. The low range forecast for 2016-2017 was 45 average megawatts and the high range forecast was about 110 average megawatts.

Figure 1: Cannabis Load Forecast for Oregon and Washington Combined



Working with the Oregon Department of Energy, Oregon Liquor Control Commission, Energy Trust of Oregon, Portland General Electric, Resource Innovation Institute, and a number of producers, the Council conducted a telephone and on-line survey of licensed producers in Oregon and Washington.

Survey participants provided detailed data on their operation and business practices. Using the survey data, the Council refined the estimates of electricity consumption for lighting, space conditioning, pumping, and various miscellaneous equipment used during the production of cannabis.

Summary

In 2017, there were over 29 million square feet of canopy licensed to produce cannabis in Oregon and Washington for recreational and medical markets. We estimate the total electricity consumption to be 112 average megawatts. Demand was significantly lower because a large percentage of production moved outdoors. If all of the licensed canopies had been cultivated indoors, demand would have been closer to 350 average megawatts.

We found that using more efficient lighting and heating, ventilation, and air conditioning design and technologies could achieve significant energy savings.

Key Findings:

- An LED or fluorescent lamp uses about half the power as a high-intensity discharge lamp—replacing the lighting design with high-efficient lamps would decrease power consumption by half.

- Heating, ventilation, and air conditioning efficiencies can lower energy use. The overall total HVAC energy efficiency potential is 826,814 kilowatt-hours for the facilities included in the survey. This represents an overall savings of 18.3 percent of total consumption.

- About one third of the survey respondents would like to work with their utilities to increase the energy efficiency of their operations.

- Cannabis production has become less energy intensive with more outdoor cultivation; using better designed facilities; and using more energy-efficient lighting and HVAC technologies.

Methodology for Estimating Demand

The Council conducted an online and telephone survey of 90 growers in Oregon and Washington to get a better picture of the business practices and energy consumption in cannabis production. Grower lists provided by the Oregon Liquor and Cannabis Control and Washington Liquor and Cannabis Board were used to contact the producers by phone. Producers were invited to participate in a detailed online survey.

Two main categories of end uses, lighting and HVAC, constitute the bulk of electricity demand. To estimate demand for lighting, survey responses were divided into three environment categories based on the stage of development of the plants: cloning, vegetative, and flowering.

For each environment, we divided surveys into indoor, greenhouse, and mixed settings. For each category, we then calculated the average kilowatt per square foot of space. For non-lighting end uses, which include HVAC, pumping, dehumidification, and miscellaneous equipment, we aggregated them into one end use and then calculated the kilowatt per square foot of canopy space. Tables 1-3 details the calculation.

Table 1: Lighting Power Density by Grow type

	kWh lighting	SQF in lighting analysis	Lighting kWh/SF of Canopy	# of Observations
Indoor Only	5,434,552	54,577	99.6	16
Greenhouse	712,202	103,539	6.9	7
Outdoor	66,975	129,180	0.5	4
Mix	2,544,967	94,868	26.8	8
aggregated	8,758,695	382,164	22.9	35

Table 2: HVAC Power Density by Grow type

	HVAC, Pumping, etc.	SQF in HVAC analysis	HVAC, etc. kWh /SF of Canopy	# of Observations
Indoor Only	2,945,371	106,127	27.8	19
Greenhouse	756,073	152,089	5.0	6
Outdoor	286,530	449,180	0.6	3
Mix	648,922	56,248	11.5	4
aggregated	4,636,896	763,644	6.1	32

Table 3- Total Power Density by Grow Type

	Total kWh /SF of canopy
Indoor Only	128
Greenhouse	12
Outdoor	1
Mix	38
Aggregated	29

Estimated Total Demand for Electricity

Table 4 and 5 summarize the information for each state. In 2017, over 29 million square feet of canopy was licensed for cannabis production. We estimate that the total estimated demand for electricity used in producing cannabis in 2017 in Oregon and Washington was about 112 average megawatts.

On a weighted average basis (square footage by canopy environment), demand for power was about 30 kilowatt-hours per square foot.

In Washington, a producer can also be a processor. In this analysis, we used the square footage of canopy for producers and producers/processors.

Table 4- Estimated demand for power - cannabis production in Washington

Table 4	Tier 1:<2000	Tier 2: 2001-10,000	Tier 3: 10,001-30,000	Total Square footage	KWH/SF of canopy	Total aMW
Indoor	215,010	1,188,782	1,597,797	3,001,589	128	44
Greenhouse	3,360	14,000	127,500	144,860	12	0.2
Outdoor	17,468	523,844	2,545,903	3,087,215	1	0.4
Mix	71,097	1,352,021	3,990,996	5,470,762	38	24
Aggregate	306,935	3,078,647	8,262,196	11,704,426	51	68

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Table 5- estimated demand for power - cannabis production in Oregon*

Table 5	Producer Indoor Sqf	Producer Outdoor Sqf	Total Sqf	KWh/sqf of canopy	aMW
Indoor	1,708,020	-	1,708,020	128	25
Mixed	577,423	3,490,455	4,067,878	38	18
Outdoor	-	11,823,860	11,823,860	1	1
Total	2,285,443	15,314,315	17,599,758	22	44

*- Oregon data from OLCC does not parse out greenhouse canopy.

Demand for Power by End Use and Canopy Space

Using the survey results, we estimated the kilowatt-hour of demand for lighting, HVAC, and other end uses.

Overall lighting represents 66 percent of the total demand for power in operations. The highest demand of lighting is in flowering rooms at 49 percent. Vegetative rooms use 12 percent of total electricity use.

HVAC and other end uses require about 33 percent of the total power consumption in the grow operations. Cooling end uses use 15 percent; ventilation takes up 12 percent; heating takes up 3 percent; and dehumidification 4 percent of total demand for power.

Table 6 shows the distribution of demand for electricity across different end uses and room types.

Table 6- Total annual kWh of electricity used for grow operations (Among survey participants)

	KWH	% of total
Lighting, by environment:	**8,874,327**	**66%**
Clone room	43,184	0.32%
Drying room	307	0.002%
Flowering room	6,594,946	49%
Vegetative room	1,686,266	12%
Greenhouse	549,624	4%
HVAC, by enduse type:	**4,515,188**	**33%**
Cooling	1,997,731	15%
Heating	384,489	3%
Ventilation	1,583,041	12%
Dehumidification	541,801	4%
Pumps	8,126	0.1%
Misc. equipment	765	0.01%
Carbon filter	122,535	1%
Total	13,512,815	100%

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Not All Producers Are Equal

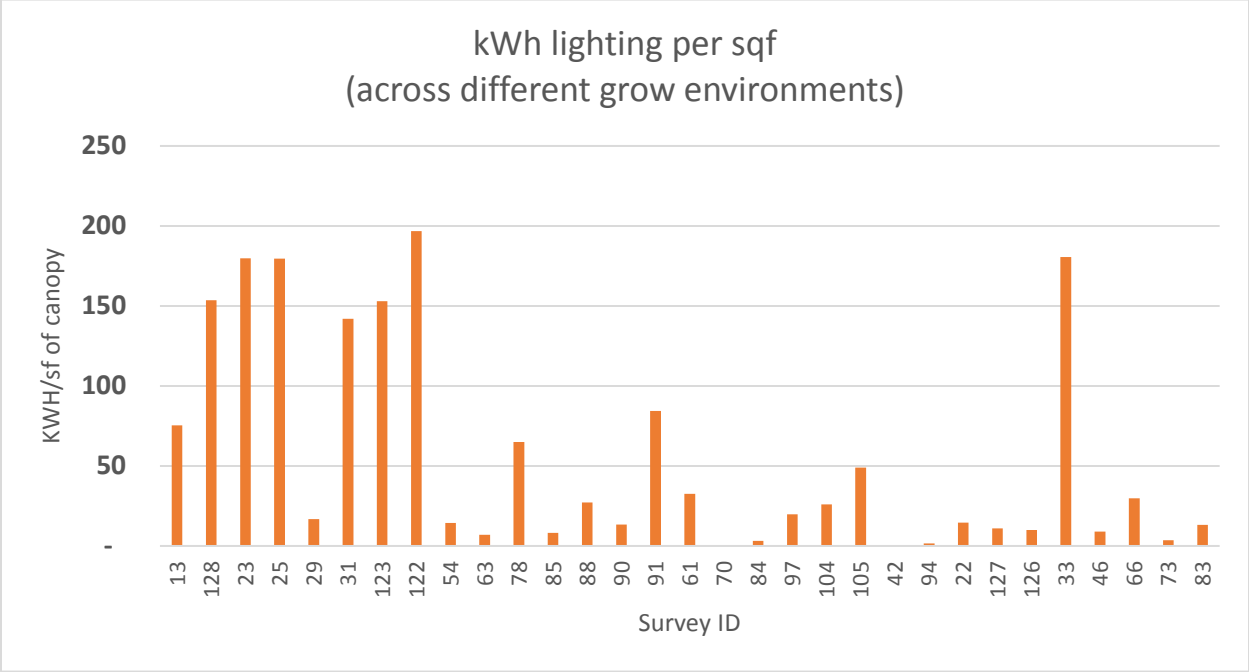
The estimated demand for power per square foot of canopy varies significantly depending on the lighting and HVAC technologies used and where the cultivation occurs: indoors, in a greenhouse, outdoors or in a mix of production spaces.

Although in this analysis we used an average metric for calculating the total demand for power by cannabis producers, lighting power densities vary widely across producers. Choice of lighting technology and lighting energy management controls are two factors that can affect lighting power density. Under counting the number of lamps could be another reason for low lighting power density.

Using the survey data, we see that for some producers, lighting power density is about 200 kilowatt-hours per square foot of canopy space, while other producers use significantly less electricity for lighting.

For an indoor grow environment, the average lighting power density is 104 kilowatt-hours per square foot; the lowest level is 7 kilowatt-hours per square foot; and highest level is about 200 kilowatt-hours per square foot. For greenhouses, the average is 22 kilowatt-hours per square foot; the lowest is 1 kilowatt-hour per square foot; and the highest is 49 kilowatt-hours per square foot.

Figure 1- Distribution of lighting power density across surveys



Energy Efficiency Potential

Indoor Lighting

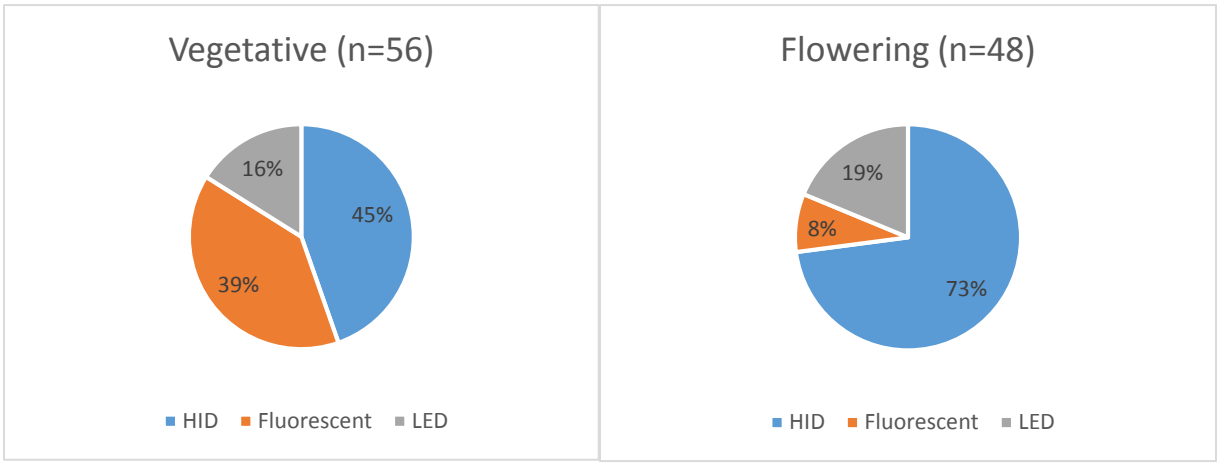
Based on the surveys, about 66 percent of a facility's electricity consumption is for lighting (see table 6).

A common practice, for both the vegetative and flowering room, is to use high-intensity discharge (HID) lamps (such as metal halide and high-pressure sodium). These lamps are typically around 1,000 watts each and operate 12 – 24 hours a day, depending on the growing cycle.

Growers use these bulbs because the color spectrum they produce is comparable to natural sunlight. However, they are not very efficient. Other lighting options--LEDs and fluorescent bulbs--produce the same amount of lumens while using much less power.

Some growers have adopted LEDs and fluorescent bulbs, but many others are concerned that their color spectrum does not mimic sunlight as closely as HIDs. Generally, growers use alternate lighting technologies more in the vegetative room, where the plant is less sensitive to light quality. Figures 2 and 3 show that more than half of the survey respondents are using efficient lighting in the vegetative room, while about 75 percent are using inefficient HIDs for the flowering room.[1]

Figures 2 and 3: Market share of lighting by grow environment



In general, an LED or fluorescent lamp uses about half the power as an HID—replacing the lighting design with high-efficient lamps would decrease power consumption by half.

In the vegetative room, where the lights are on about 18 hours a day, a full-year operation would save about 3,300 kilowatt-hours per bulb. In the flowering room, where the lights are on 12 hours per day, the savings per bulb would be around 2,200 kilowatt-hours per year.

Overall, if all inefficient lamps were replaced with 500-watt bulbs, lighting would go from nearly 9 million kilowatt-hours per year to around 5 million kilowatt-hours per year.

In addition to bulb replacements, using ducted lighting would also increase energy efficiency. Only one respondent indicated using these types of fixtures. Ducted lighting removes excess heat produced by the lights, which saves on air conditioning. Having lights on movable tracks or along the plants (instead of on top) uses fewer bulbs or less high-power lamps.

Lighting by Area.

Table 7 shows additional details on the type of lighting technologies in each grow environment. For example, in the flowering room, 73 percent of lighting was HID; 8 percent was fluorescent; and 19 percent LED. Survey results show that on average, 1 LED lamp is used for every 136 square feet of grow environment. If using HID lighting, 139 square feet is used.

Table 7- Breakdown of sites and lighting technologies across the survey participants**

	Clone (n=8, sites=7)	Drying (n=5, sites=5)	Flowering (n=48, sites=40)	Greenhouse (n=8, sites=6)	Vegetative (n=56, sites=47)	Total (n=98, sites=56)
HID*	25%	0%	73%	50%	45%	52%
Fluor	63%	40%	8%	38%	39%	34%
LED	13%	60%	19%	13%	16%	14%

[1] These percentages are based on sites with a given lamp technology by room type. Some sites have multiple lamps, and these were counted separately.

- HID includes high intensity discharge, high-pressure sodium, metal halide, induction. Fluor includes Linear Fluorescent (T5 and T8), and CFL.

** Note that in some grow environments the number of observations is small.

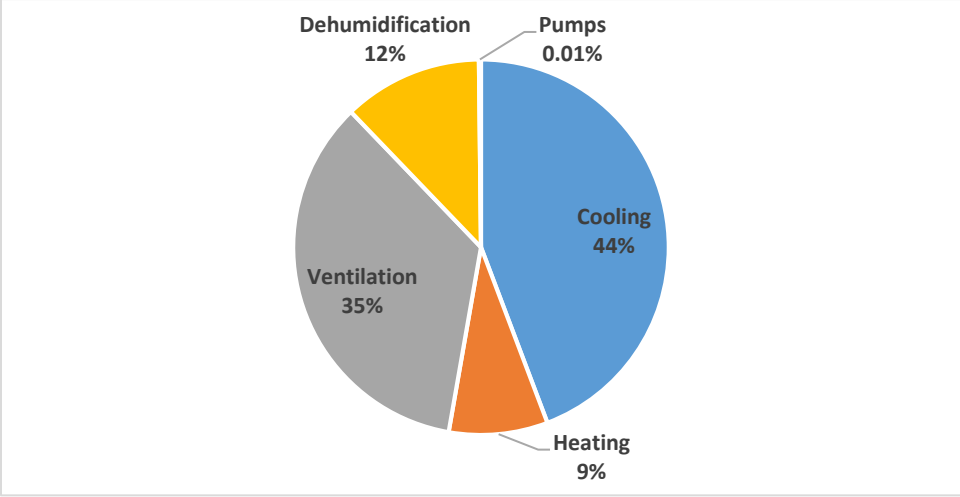
Potential Savings in HVAC

Heating, ventilation, and air conditioning is another area of energy consumption where efficiencies can be achieved. Figure 5 shows the five individual end uses in the HVAC category.

Cooling is the most significant at 44 percent, followed by ventilation at 35 percent. Dehumidification is relatively unique to grow facilities compared with other commercial buildings. All of the facilities have dehumidification systems.

Due to the limited observations and the different mix of lighting technologies used in indoor facilities, it was not possible to estimate the components of HVAC consumption by lighting technologies.

Figure 5- Components of HVAC consumption



The surveys indicated an average of 2.5 cooling units per facility. The primary types of cooling systems found in the grow facilities are listed in Table 8. The last column of the table shows the estimated per unit savings potential for each type of system.

Table 8- HVAC type and savings potential

Type	# of facilities using	Avg units	Savings Potential (%)
Air Cooled Chiller	1	1.0	10%
Packaged Terminal AC	3	3.0	20%
Rooftop Unit	4	2.3	30%
Split System	7	4.9	8%
Through-the-wall/Window Unit	10	1.1	25%
Water Cooled Chiller	2	1.0	8%
Grand Total	**23**	**2.5**	

A variety of sources support the percent savings estimates: ENERGY STAR, Department of Energy, and American Society of Heating, Refrigerating and Air-Conditioning Engineers.

In addition to cooling equipment upgrades, there are significant opportunities to save energy by optimizing controls and general system operations. Since the heating, cooling, ventilation, and dehumidification systems all interact, optimizing these systems can have a significant impact on overall energy consumption. We used a variety of sources to determine these system optimization savings, primarily regional case studies and the Seventh Power Plan.

Table 9 shows these estimates by end-use type. The overall total HVAC energy efficiency potential is 826,814 kilowatt-hours for the facilities included in the survey. This represents an overall savings of 18.3 percent of total consumption.

Table 9- Summary of Consumption and Potential Savings by End Use

	End-Use Consumption (kWh)	Energy Management Savings Potential (kWh)	Equipment Upgrades Potential (kWh)	Total EE HVAC Potential (kWh)
Cooling	1,997,731	203,768	278,802	482,570
Heating	384,489	39,217	NA	39,218
Ventilation	1,583,041	248,933	NA	248,933
Dehumidification	541,801	55,263	NA	55,264
Pumps	8,126	828	NA	829
Total	4,515,188	548,009	278,802	826,814

As part of the survey, we asked a number of questions to get a better understanding of the cannabis producers' operations. Although not all the survey participants responded to the full set of questions, the survey responses we did receive gives a general picture of regional producers.

Table 10: Business overview: Totals of all survey responses	
Administrative	
Number of survey respondents (facilities)	90
% medical	26%
% recreational	74%
Total growing sqf	Percent of total
Outdoor sqf	68%
Greenhouse sqf	15%
Indoor sqf	15%
Cloning room sqf	1%
Percent growing:	Percent total
Sativa	24%
Indica	24%
Ruderalis	3%
Hybrid	26%
Facility information	
% SQF growers owning	87%
% SQF growers leasing	13%

Does ownership of facilities make a different in power consumption?

Twenty-three producers provided information on whether they leased or owned their facilities. In general, producers who owned their facilities used less power.

Table 11- Impact of Facility Ownership on Energy Consumption (kWh per sqf of canopy)

	Average Lighting Power Density	Non-lighting Power Density
Lease	**104**	**36**
Indoor Only	183	55
Outdoor		
Mix	51	18
Own	**13**	**6**
Indoor Only	31	22
Greenhouse	23	2
Outdoor	1	1
Mix	12	8

Has Cannabis Production Become Less Energy Intensive?

Yes. During development of the Seventh Power Plan, the Council estimated the energy intensity of cannabis production to be 448 kilowatt-hours per square feet of canopy, using the cultivation experience in Colorado, which is mostly indoors.

Current survey results show an overall energy intensity of 29 kilowatt-hours per square feet: 128 kilowatt-hours for indoor and 1 kilowatt-hour for outdoor canopy (Table 3). This lower average energy intensity was achieved by cultivating more outdoors; using better designed facilities dedicated to cannabis production rather than generic warehouse space; and using more energy-efficient lighting and HVAC technologies and practices.

If producers had produced at the 448 kilowatt-hour per square feet level of intensity and all licensed canopy was fully cultivated (29 million square feet), demand for power would have been significantly higher.

If the 29 million square feet had been cultivated indoors, demand would have been about 1,500 average megawatts, compared to 112 average megawatts. Moving to outdoor production, using more LEDs, and using less air conditioning helped achieve the sharp decline in energy use.

Although these are positive developments, indoor and greenhouse cannabis growers should be encouraged continue to invest in efficient lighting and cooling technologies. Only 10 percent of survey participants indicated that their local utility had contacted them. As we have shown in this report, switching to highly efficient lights can reduce energy use by half; once lighting is improved, demand for HVAC is reduced, which creates even more energy savings.

Energy Efficiency and Alternative Energy Sources

About one third of the survey respondents would like to work with their utilities to increase the energy efficiency of their operations. About 10 percent have automated energy management in place; 10 percent of producers have already received incentives to purchase more energy efficient equipment; and about 10 percent are interested in investing in solar power. This interest in energy efficiency and solar power present opportunities for utilities.

Table 12- Snapshot of Energy Efficiency Practices

	Percent of respondents
% with automated energy management in place	8%
% been contacted by utility about energy conservation	9%
% received incentives to purchase more efficient equipment	10%
% want to learn about incentives for more efficient equipment	31%
% want to work with local utilities to decrease cost	32%
% interested in using solar power	11%

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Square Footage and Demand for Electricity by Utility Type

Although 21 percent of canopy square footage is in investor-owned utility service areas, it represents only 14 percent of their total demand. The largest square footage under cultivation and the largest demand for power is in municipal utility service areas. Table 13 shows the market share of cultivated square footage and demand for power.

Table 13: Oregon Cannabis Producers Demand by Utility Type

Oregon Cannabis Producers Load	Square footage of Cultivation	percent of total square footage of canopy	Estimated Demand for Power aMW	Percent Of Demand
Investor Owned	3,625,618	21%	6	14%
Cooperative	3,482,597	20%	12	27%
Municipal	10,383,825	59%	26	59%
Political Subdivision	103,458	1%	0	1%
Aggregate	17,595,498	100%	44	100%

Demand from producers in investor-owned utilities service areas is about 27 percent from indoor facilities; 5 percent from outdoor cultivation; and 67 percent from a mix of indoor, outdoor or greenhouse. For the public utility service area, the majority of power is going for indoor cultivation.

Table 14: Estimated square footage, demand for power and number of producers by utility for Oregon*

	indoor only sqf	demand from indoor only	Count of Indoor only producers	outdoor only sqf	aMW demand from outdoor only	Count of outdoor only producers	Mixed sqf	aMW demand from mixed canopy	Count of Mixed canopy producers	Total SQF	Demand for Power aMW	Sum of count of customers
Investor Owned	100,847	1.47	106	2,569,790	0.29	122	954,981	4.1	151	3,625,618	6	379
Idaho Power Co	-	-	1	40,000	0.00	2	7,887	0.0	2	47,887	0.04	5
PacifiCorp	72,552	1.06	93	2,429,790	0.28	113	892,609	3.9	133	3,394,951	5.21	339
Portland General Electric Co	28,295	0.41	12	100,000	0.01	7	54,485	0.2	16	182,780	0.66	35
Cooperative	465,267	6.80	183	1,916,575	0.22	112	1,100,755	4.8	233	3,482,597	12	528
Blachly-Lane County Coop El Assn	231,912	3.39	96	1,032,725	0.12	59	563,890	2.4	122	1,828,527	5.95	277
Central Electric Coop Inc - (OR)	114,649	1.68	34	204,550	0.02	10	67,552	0.3	37	386,751	1.99	81
Consumers Power, Inc	118,706	1.73	52	640,800	0.07	42	469,313	2.0	73	1,228,819	3.84	167
Harney Electric Coop, Inc	-	-	1	38,500	0.00	1	-	-	1	38,500	0.00	3
Municipal	1,118,789	16.35	415	7,277,495	0.83	300	1,987,541	8.6	508	10,383,825	26	1,223
Canby Utility Board	408,191	5.96	99	722,775	0.08	51	547,275	2.4	128	1,678,241	8.42	278
City of Ashland - (OR)	87,660	1.28	153	5,122,900	0.58	174	884,328	3.8	188	6,094,888	5.70	515
City of Bandon - (OR)	48,849	0.71	21	224,200	0.03	11	67,189	0.3	24	340,238	1.03	56
City of Cascade Locks - (OR)	340,948	4.98	72	523,400	0.06	20	78,471	0.3	77	942,819	5.38	169
City of Forest Grove	135,979	1.99	46	546,460	0.06	30	194,889	0.8	58	877,328	2.89	134
City of McMinnville - (OR)	97,162	1.42	24	137,760	0.02	14	215,389	0.9	33	450,311	2.37	71
Political Subdivision	18,857	0.28	7	60,000	0.01	4	24,601	0.1	9	103,458	0.39	20
Central Lincoln People's Ut Dt	18,857	0.28	7	60,000	0.01	4	24,601	0.1	9	103,458	0.39	20
Grand Total	1,703,760	24.90	711	11,823,860	1.35	538	4,067,878	17.6	901	17,595,498	44	2,150

* Multiple utilities may serve a county. This data is under review, awaiting new data from OLCC.

Table 15 shows that investor-owned utilities in Washington have 11 percent share of canopy and 13 percent of load while public power utilities have the largest share of canopy and load. Additional estimates of individual utility demand are in table 16.

The Washington Liquor and Cannabis Board is currently reviewing its producer data and there may be updates to the data used in this analysis.

Table 15- Washington Producer Canopy and Demand for Power by Utility Type

	Sum of Canopy SQF	% square footage	Demand aMW	% Total Demand
Investor Owned	**1,244,743**	**11%**	**8.51**	**13%**
Indoor	**428,992**	**4%**	**6.27**	**9%**
Greenhouse	**13,060**	**0.1%**	**0.02**	**0%**
Mix	**504,553**	**4%**	**2.19**	**3%**
Outdoor	**298,138**	**3%**	**0.03**	**0%**
Cooperative	**3,105,012**	**27%**	**17.06**	**26%**
Indoor	**726,347**	**6%**	**10.61**	**16%**
Greenhouse	**53,000**	**0.5%**	**0.07**	**0%**
Mix	**1,446,045**	**13%**	**6.27**	**9%**
Outdoor	**879,620**	**8%**	**0.10**	**0%**
Municipal	**770,977**	**7%**	**6.85**	**10%**
Indoor	**374,975**	**3%**	**5.48**	**8%**
Mix	**315,002**	**3%**	**1.37**	**2%**
Outdoor	**81,000**	**1%**	**0.01**	**0%**
Political Subdivision	**6,266,274**	**55%**	**34.06**	**51%**
Indoor	**1,414,875**	**12%**	**20.67**	**31%**
Greenhouse	**78,800**	**1%**	**0.11**	**0%**
Mix	**3,014,142**	**26%**	**13.08**	**20%**
Outdoor	**1,758,457**	**15%**	**0.20**	**0%**
Grand Total	**11,387,006**	**100%**	**66.48**	**100%**

Table 16- Estimates for Washington Producer Canopy and Demand for Power by Utility Type

Utility and Utility Type	Indoor			Greenhouse			Mix			Outdoor			Total		
	Sum of canopy SQF	Sum of total aMW	Count of Canopies	Sum of canopy SQF	Sum of total aMW	Count of Canopies	Sum of canopy SQF	Sum of total aMW	Count of Canopies	Sum of canopy SQF	Sum of total aMW	Count of Canopies	Sum of canopy SQF	Sum of total aMW	Count of Canopies
Investor Owned	**428,992**	**6.27**	**71**	**13,060**	**0.02**	**2**	**504,553**	**2.19**	**51**	**298,138**	**0.03**	**16**	**1,244,743**	**8.51**	**140**
Avista Corp		-			-		100,620	**0.44**	7	21,000	**0.00**	1	121,620	**0.44**	8
PacifiCorp	392	**0.01**	1		-		27,000	**0.12**	3	20,000	**0.00**	2	47,392	**0.13**	6
Puget Sound Energy Inc	428,600	**6.26**	70	13,060	**0.02**	2	376,933	**1.64**	41	257,138	**0.03**	13	1,075,731	**7.94**	126
Cooperative	**726,347**	**10.61**	**121**	**53,000**	**0.07**	**3**	**1,446,045**	**6.27**	**133**	**879,620**	**0.10**	**52**	**3,105,012**	**17.06**	**309**
Benton Rural Electric Assn	34,101	**0.50**	8		-		475,402	**2.06**	37	279,000	**0.03**	17	788,503	**2.59**	62
Big Bend Electric Coop, Inc	10,000	**0.15**	1	25,000	**0.03**	1	287,460	**1.25**	15	435,000	**0.05**	22	757,460	**1.48**	39
Clearwater Power Company	5,320	**0.08**	2		-		47,000	**0.20**	3	11,990	**0.00**	2	64,310	**0.28**	7
Columbia Rural Elec Assn, Inc	11,750	**0.17**	2		-		8,400	**0.04**	5		-		20,150	**0.21**	7
Elmhurst Mutual Power & Light Co	21,001	**0.31**	3		-			-			-		21,001	**0.31**	3
Inland Power & Light Company	241,070	**3.52**	54	21,000	**0.03**	1	546,681	**2.37**	57	110,230	**0.01**	7	918,981	**5.94**	119
Lakeview Light & Power	260,329	**3.80**	31		-		1,000	**0.00**	1		-		261,329	**3.81**	32
Modern Electric Water Company	6,200	**0.09**	3		-		20,000	**0.09**	3	10,000	**0.00**	1	36,200	**0.18**	7
Northern Lights, Inc	2,481	**0.04**	2		-		-	-	1		-		2,481	**0.04**	3
Orcas Power & Light Coop	89,995	**1.31**	7	7,000	**0.01**	1	18,701	**0.08**	5	23,400	**0.00**	2	139,096	**1.41**	15
Peninsula Light Company	18,700	**0.27**	5		-		31,000	**0.13**	3	10,000	**0.00**	1	59,700	**0.41**	9
Tanner Electric Coop	25,400	**0.37**	3		-		10,401	**0.05**	3		-		35,801	**0.42**	6
Municipal	**374,975**	**5.48**	**52**		-		**315,002**	**1.37**	**24**	**81,000**	**0.01**	**3**	**770,977**	**6.85**	**79**
City of Blaine - (WA)	21,001	**0.31**	4		-		20,001	**0.09**	2		-		41,002	**0.39**	6
City of Centralia - (WA)	56,532	**0.83**	6		-		24,000	**0.10**	3		-		80,532	**0.93**	9
City of Cheney - (WA)	15,400	**0.23**	3		-		261,401	**1.13**	14	51,000	**0.01**	2	327,801	**1.36**	19
City of Seattle - (WA)	165,571	**2.42**	28		-		5,600	**0.02**	4	30,000	**0.00**	1	201,171	**2.45**	33
City of Tacoma - (WA)	116,471	**1.70**	11		-		4,000	**0.02**	1		-		120,471	**1.72**	12
Political Subdivision	**1,414,875**	**20.67**	**215**	**78,800**	**0.11**	**6**	**3,014,142**	**13.08**	**250**	**1,758,457**	**0.20**	**111**	**6,266,274**	**34.06**	**582**
PUD 1 of Snohomish County	369,092	**5.39**	59	9,000	**0.01**	2	225,530	**0.98**	28	136,433	**0.02**	10	740,055	**6.40**	99
PUD No 1 of Benton County	67,782	**0.99**	6		-		496,547	**2.15**	31	300,160	**0.03**	17	864,489	**3.18**	54
PUD No 1 of Chelan County	43,983	**0.64**	10		-		398,715	**1.73**	31	332,000	**0.04**	19	774,698	**2.41**	60
PUD No 1 of Clallam County	40,908	**0.60**	12		-		130,235	**0.56**	13	30,000	**0.00**	1	201,143	**1.17**	26
PUD No 1 of Clark County - (WA)	95,664	**1.40**	16		-		65,021	**0.28**	13	4	**0.00**	1	160,689	**1.68**	30
PUD No 1 of Cowlitz County	59,234	**0.87**	13		-		82,099	**0.36**	7		-		141,333	**1.22**	20
PUD No 1 of Douglas County	54,940	**0.80**	4	21,000	**0.03**	1	393,900	**1.71**	22	182,401	**0.02**	15	652,241	**2.56**	42
PUD No 1 of Ferry County	20,628	**0.30**	5		-		278,544	**1.21**	23	129,050	**0.01**	10	428,222	**1.52**	38
PUD No 1 of Grays Harbor County	387,613	**5.66**	60	48,000	**0.07**	2	357,431	**1.55**	34	119,401	**0.01**	7	912,445	**7.29**	103
PUD No 1 of Klickitat County		-			-		17,800	**0.08**	6	20,000	**0.00**	1	37,800	**0.08**	7
PUD No 1 of Lewis County	83,166	**1.22**	8	800	**0.00**	1	84,000	**0.36**	6	5,200	**0.00**	2	173,166	**1.58**	17
PUD No 1 of Okanogan County	2,304	**0.03**	2		-		249,320	**1.08**	20	332,984	**0.04**	18	584,608	**1.15**	40
PUD No 1 of Pend Oreille County	39,139	**0.57**	5		-		9,500	**0.04**	3	27,000	**0.00**	3	75,639	**0.62**	11
PUD No 2 of Grant County	65,000	**0.95**	4		-		225,500	**0.98**	13	143,824	**0.02**	7	434,324	**1.94**	24
PUD No 2 of Pacific County	14,570	**0.21**	5		-			-			-		14,570	**0.21**	5
PUD No 3 of Mason County	70,852	**1.04**	6		-			-			-		70,852	**1.04**	6
Grand Total	**2,945,189**	**43.03**	**459**	**144,860**	**0.20**	**11**	**5,279,742**	**22.90**	**458**	**3,017,215**	**0.34**	**182**	**11,387,006**	**66.48**	**1,110**

Appendix

In the appendix section we are providing additional background material.

State of Washington data from the Washington State Liquor and Cannabis Board - Washington State report all applications Feb 2018- presents a rich level of details as to the growing environments and practices that can help in our endeavor to estimated total load for the cannabis growers. In the following section we see the square footage dedicated to each plant by plant strain and stage of development. On average each plant is dedicated 2 square feet of floor space. During the vegetative stage plants need less space between 1.05 and 1.44 square feet. As plants grow their need for space doubles. A flowering hybrid would need about 3 square feet per plant.

Table 17: Average of Footprint of plant *

	Hybrid	Indica	Sativa	Averaged
Flowering	**2.91**	**2.65**	**2.45**	**2.74**
Vegetative	**1.44**	**1.05**	**1.08**	**1.27**
Grand Total	**2.16**	**1.86**	**1.86**	**2.02**

*From Washington State report all applications Feb 2018

Table 18 shows the volume of space that different strains take, here again we see that at flowering stage plants take about 3 times the space as in vegetative stage.

Table 18: Average volume of plants

Average of Volume of plan (ft^3)	Hybrid	Indica	Sativa	Averaged
Flowering	**9.47**	**8.50**	**7.71**	**8.83**
Vegetative	**3.80**	**2.91**	**2.61**	**3.35**
Grand Total	**6.59**	**5.74**	**5.49**	**6.15**

Spacing and volume of plants at different stages are development is important because it effects level of lighting needed.

According to Washington State Liquor and Cannabis Board, lcb.wa.gov

As of March 2018, there are almost 1300 licensed producer, processor or producer/processor in state of Washington. Under the Washington regulations the same entity can be both a producer and processor, so of the 1300 approved licensees, 234 are purely producers and 888 are mixed producer and processor. These approved producers use over 11 million square feet of canopy.

Table 19- Washington state producers by type of canopy

Current Status	Approved			
Count of Canopy	**Column Labels**			
Row Labels	**Processor**	**Producer**	**Producer/Processor**	**Grand Total**
Indoor	10	77	385	472
Indoor/Outdoor	1	45	155	201
Greenhouse		1	10	11
Outdoor		63	122	185
Indoor/Greenhouse		2	24	26
Indoor/Outdoor/Greenhouse		4	41	45
Outdoor/Greenhouse	1	24	41	66
NA	154	18	110	282
Grand Total	**166**	**234**	**888**	**1,288**

Table 20- Washington state producer square footage by type of canopy

Current Status	Approved			
Sum of Canopy	**Column Labels**			
Row Labels	**Processor**	**Producer**	**Producer/Processor**	**Grand Total**
Indoor	2,400	404,043	2,595,146	3,001,589
Greenhouse		21,000	123,860	144,860
Indoor/Outdoor	-	559,144	2,189,804	2,748,948
Outdoor		1,121,405	1,965,810	3,087,215
Indoor/Greenhouse		40,000	238,737	278,737
Indoor/Outdoor/Greenhouse		28,000	482,091	510,091
Outdoor/Greenhouse	10,000	279,200	623,998	913,198
NA	96,000	138,104	785,684	1,019,788
Grand Total	**108,400**	**2,590,896**	**9,005,130**	**11,704,426**

Table 21- Washington state production levels

Total tonnage of product in state of Washington*	**Pounds of usable cannabis**	**Metric Tons**
2014 last 7 months of the year	**6,711**	**3.05**
2015	**470,272**	**213.76**
2016	**2,115,513**	**961.60**
2017- first 5 months of the year	**1,673,776**	**760.81**

- Data from Washington Website showing weights

Washington producers are categorized in three different tiers or size categories. Tier 1 is for producers with less than2000 sqf, tier 2 producers are those with 2001-10,000 sqf and all others greater than 10,000 sqf are in tier 3. The majority of producers, over 71% of square footage, are in large canopies over 10,000 square feet. In the three tables below, we can see that of the almost 12 million square feet of canopy, about 26%, are indoor. Majority of the indoor canopies are in tier 3 facilities. Purely greenhouse canopies present about 1% of total 12 million sqf. Outdoor canopy presents 26% of total canopy. Producers with largest market share of canopy are ones that have mix of canopy (indoor, greenhouse, outdoor combinations) representing about half, 47% of total canopy.

Table 22- Washington Producers by Canopy type and Tier

Canopy by tier	Tier 1:<2000	Tier 2: 2001-10,000	Tier 3: 10,001-30,000	Total
Indoor	215,010	1,188,782	1,597,797	3,001,589
Greenhouse	3,360	14,000	127,500	144,860
Outdoor	17,468	523,844	2,545,903	3,087,215
Mix	71,097	1,352,021	3,990,996	5,470,762
Aggregate	306,935	3,078,647	8,262,196	11,704,426

% Canopy by tier	Tier 1:<2000	Tier 2: 2001-10,000	Tier 3: 10,001-30,000	Total
Indoor	7%	40%	53%	100%
Greenhouse	2%	10%	88%	100%
Outdoor	1%	17%	82%	100%
Mix	1%	25%	73%	100%
Aggregate	3%	26%	71%	100%

% Canopy by tier	Tier 1:<2000	Tier 2: 2001-10,000	Tier 3: 10,001-30,000	Total
Indoor	70%	39%	19%	26%
Greenhouse	1%	0%	2%	1%
Outdoor	6%	17%	31%	26%
Mix	23%	44%	48%	47%
Aggregate	100%	100%	100%	100%

Additional Details from the surveys

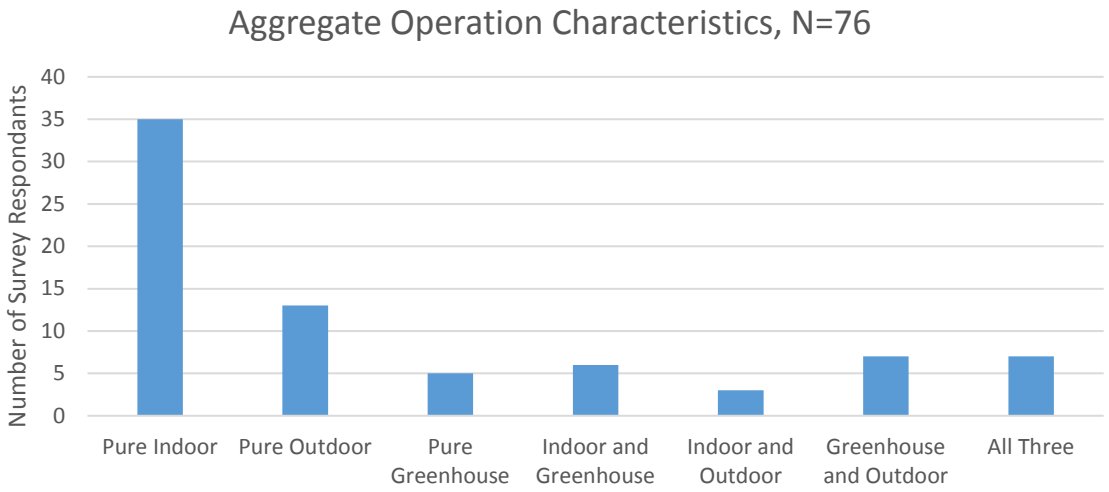
Classification of Operations:

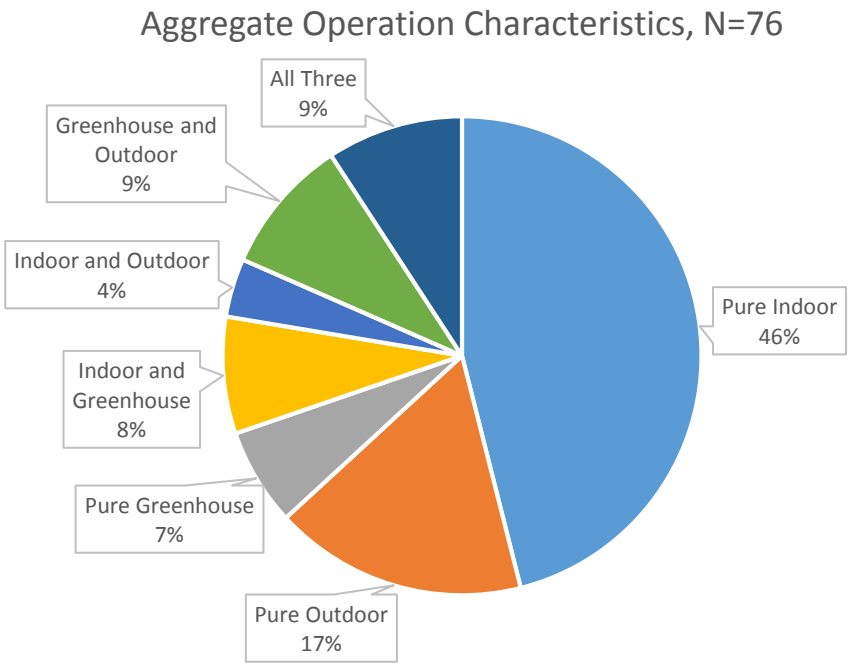
Of the 90 producers participating in the survey, 26% were medical and 74% were recreational producers. Total growing area was about 950,000 square feet with over 64,000 of outside growing and 144,000 square feet of greenhouse and 146,000 sqf of indoor operations with combined cloning area of about 11,000 sqf.

The recreational producers typically have larger operations with average size of 3500 sqf for their indoor grow operations. The largest recreational grow has over 21,000 sqf of indoor canopy. Medical producers operations were much smaller, on average about 955 square feet compared to 3500 average sqf for recreational producers. The smallest medical grower had canopy sized about 120 sqf.

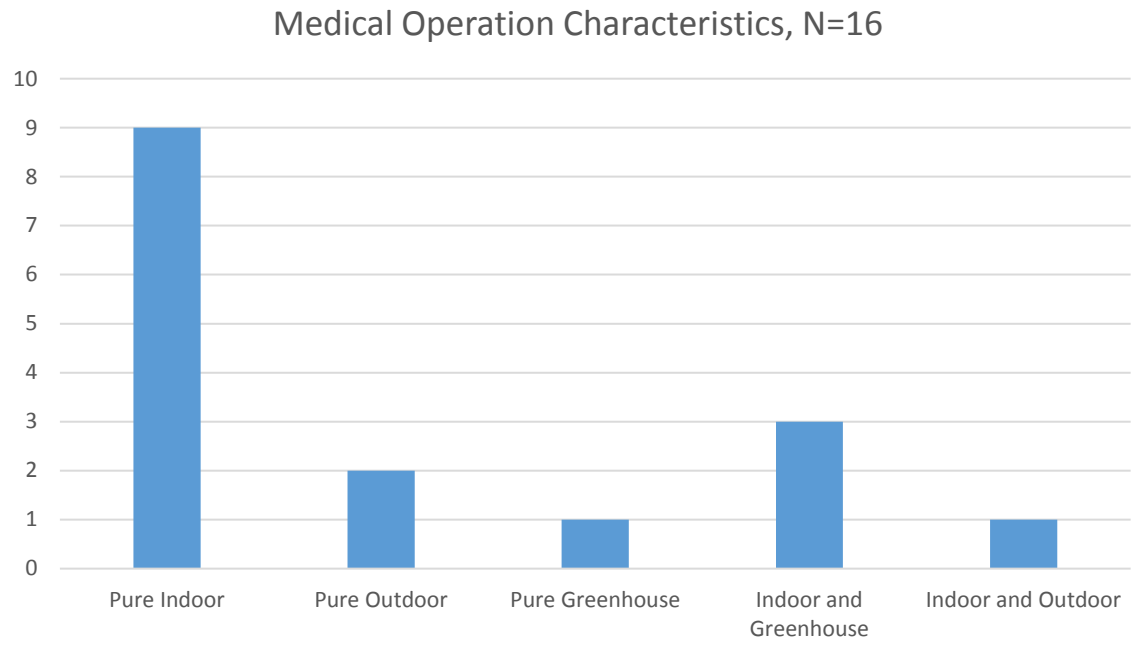
There is a mix of indoor and outdoor growing areas. 7 producers had indoor, greenhouse and outdoor grow canopies. 13 producers were purely outdoor growers, with total canopy of over 370,000 sqf.

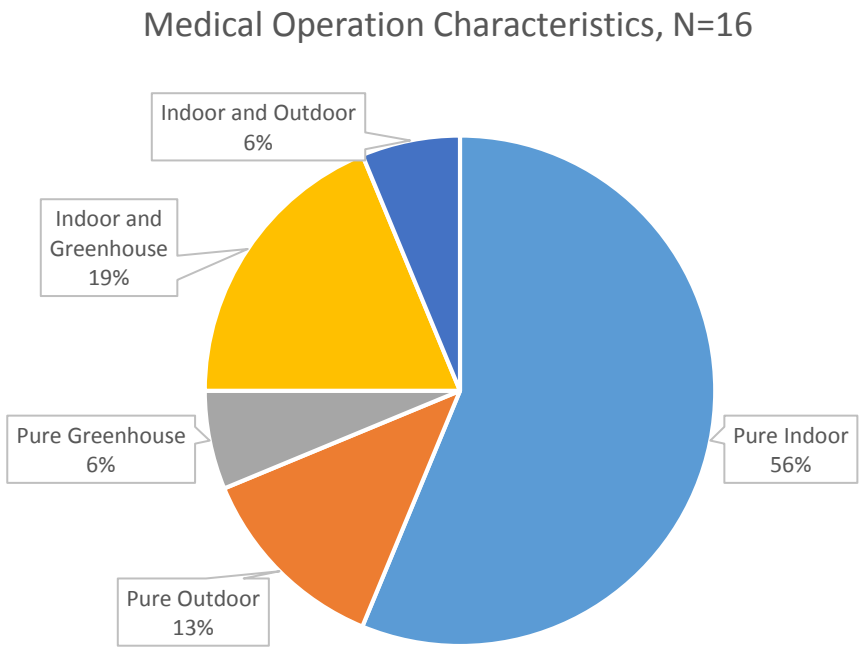
The producer operations are categorized as the following: indoor, greenhouse, outdoor, and various mixtures of the three. It is assumed that any omitted values in the canopy section imply an absence of that particular operation. In aggregate, there are 76 categorized observations with the following tables:

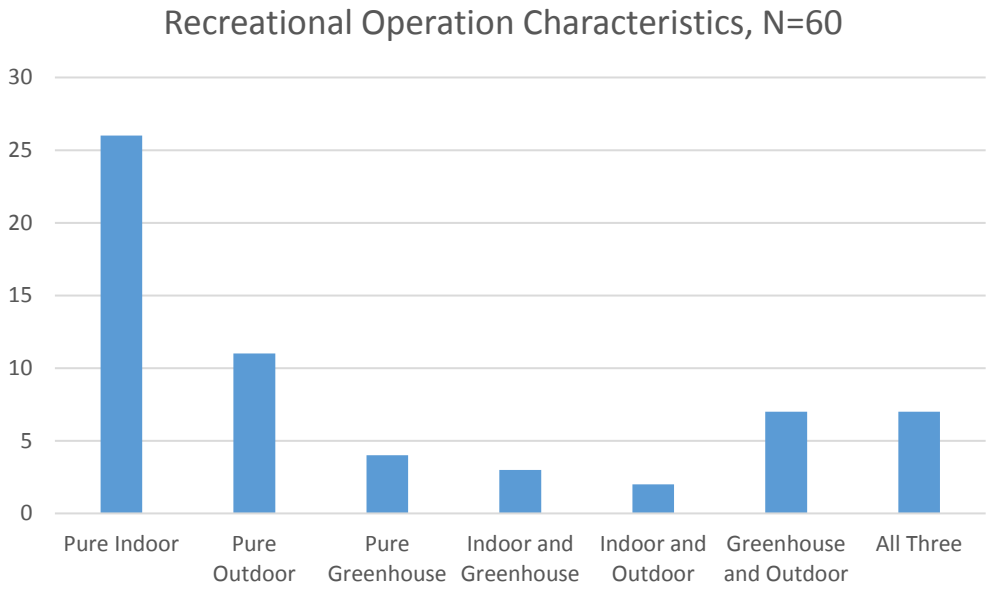


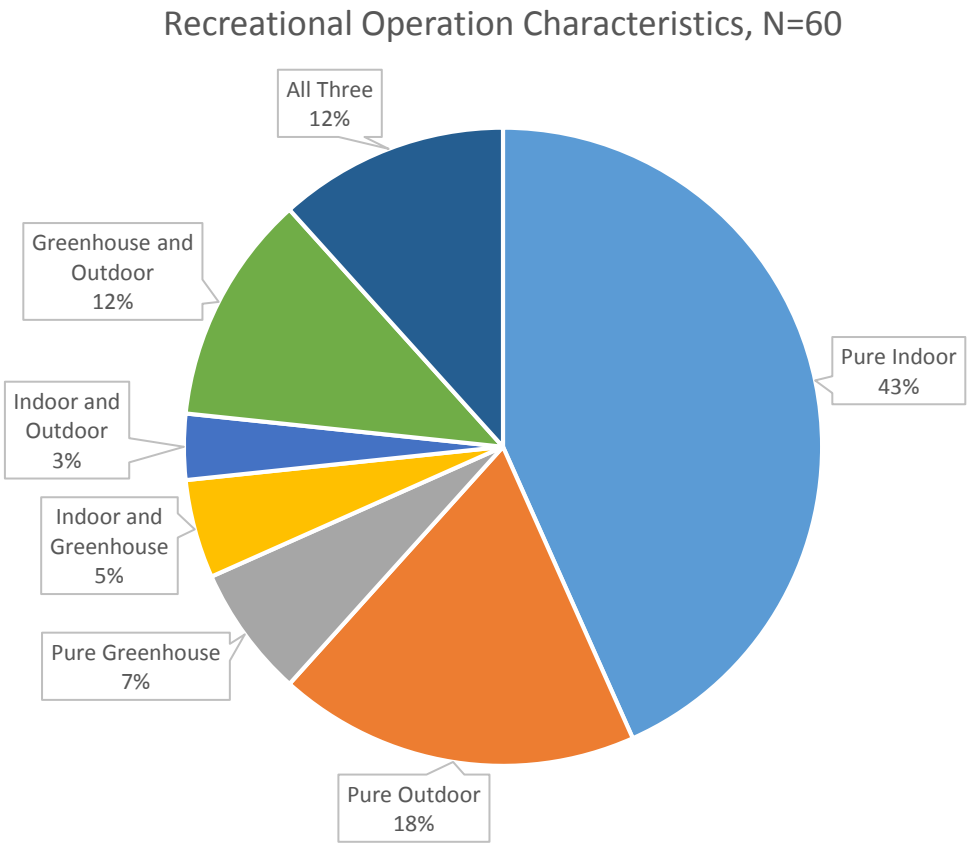


The 76 observations are also partitioned in terms of whether they are medical or recreational.




Medical Operation Characteristics, N=16
Indoor and Outdoor 6%
Indoor and Greenhouse 19%
Pure Greenhouse 6%
Pure Outdoor 13%
Pure Indoor 56%

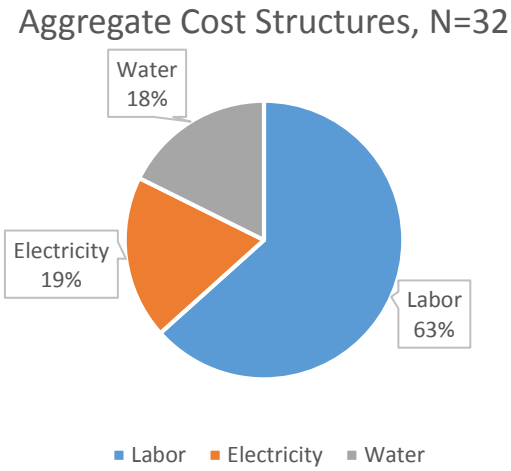

Recreational Operation Characteristics, N=60
30
25
20
15
10
5
0
Pure Indoor
Pure Outdoor
Pure Greenhouse
Indoor and Greenhouse
Indoor and Outdoor
Greenhouse and Outdoor
All Three



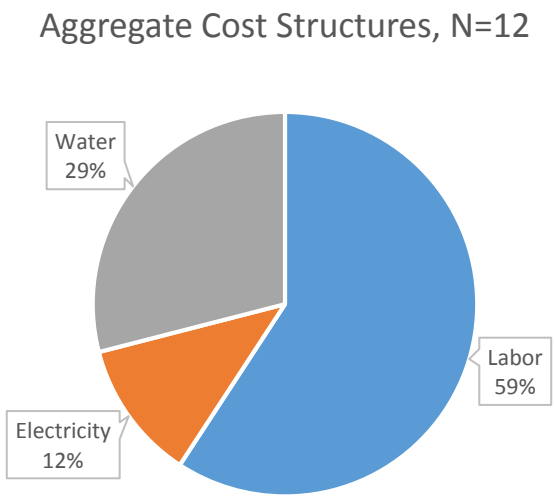
Ownership of facilities:
59% of survey participants owned their own facility while rest leased.

Cost Descriptions:

The electricity, water, and labor expenses are examined across 36 observations. It is assumed that omitted values imply no expense of that category. In aggregate, we observe the following characteristics:

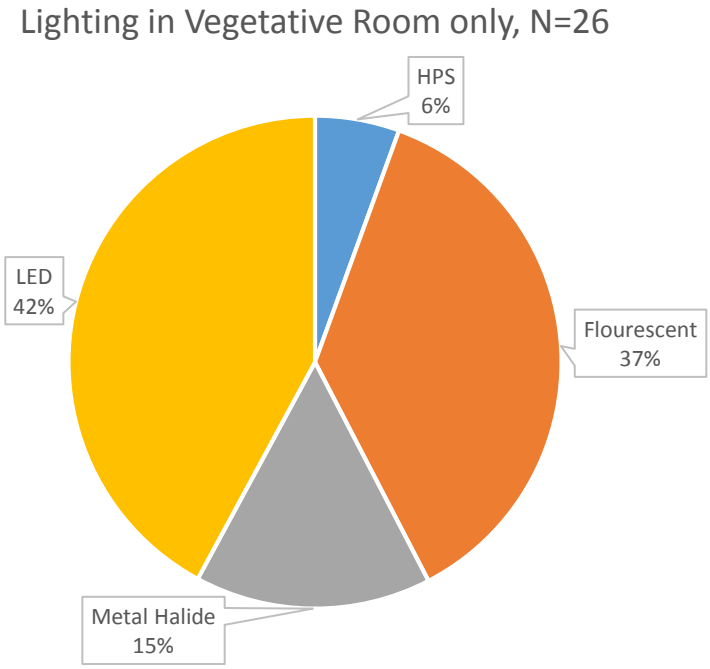


The assumption about omitted values can be deemed unreasonable. There are 12 observations with all three expenses filled in. We observe the following:

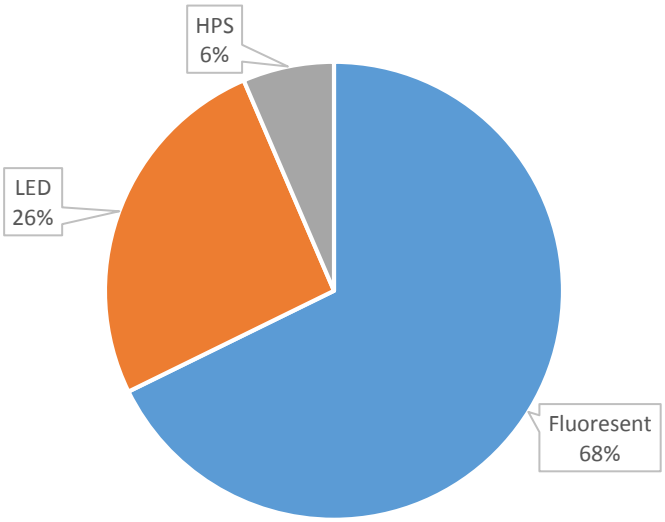


Lighting Characteristics:

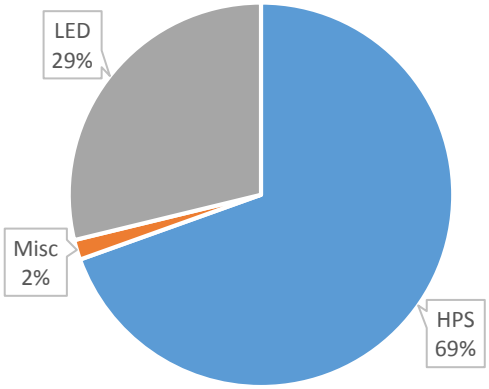
We have categorized the type of lighting used in all rooms and identified their relative proportions. It should be noted that HPS denotes High Pressure Sodium lights. All light classifications encompass themselves and their respective variations with the exception of Miscellaneous.



Lighting in Clone Room only, N=6



Lighting in Flowering Room only, N=23



Lighting in Greenhouse, N=4