A close-up photograph of vibrant green cannabis leaves with serrated edges, growing in a greenhouse. The background shows the structural beams of the greenhouse, creating a pattern of light and shadow. The overall color palette is dominated by various shades of green and blue.

Energy Use in the Colorado Cannabis Industry

FALL 2018 REPORT



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Prepared By:

The Cannabis Conservancy

Brittney Anderson, Jacob Policzer, Erin Loughney, and Kelsey Rodriguez

With Support from: Jonathan Valdman, Brian farmer, Lane Martin

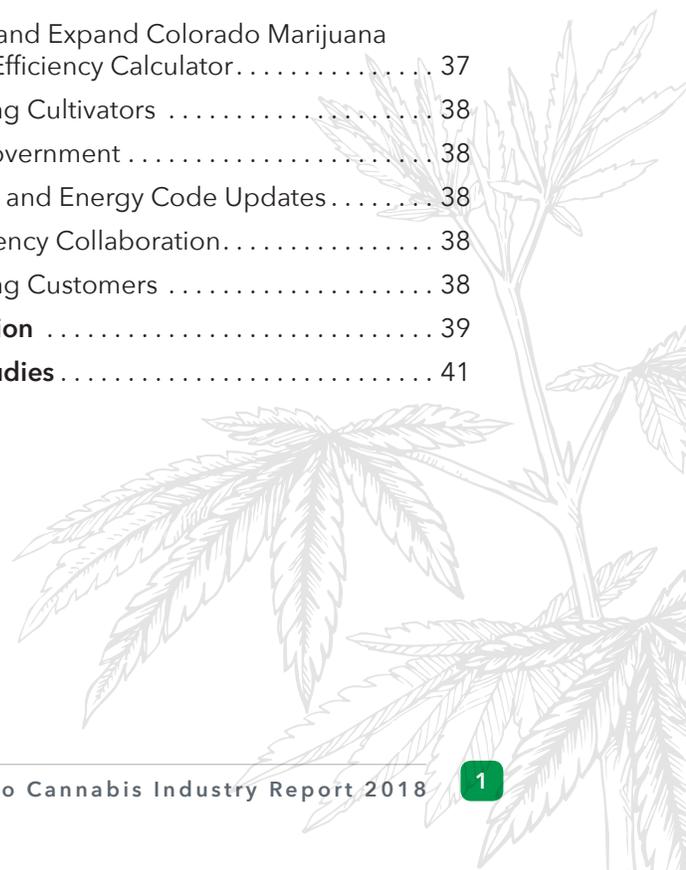
Contributions from: Tim McDowell, Angela Weiss, Andrew Linvingston

Editorial content by:

S. Reifer

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DISCLAIMER

Though this report attempts to help gather data and disperse information, there are still significant barriers to be overcome before we have an educated and fair market. Good policy is informed by facts and data, and active efforts to track data, to publicize information, and to encourage collaboration among market participants is key to promoting energy and water efficiency opportunities in this sector. This report was prepared as an account of work sponsored by an agency of the State of Colorado. Neither the Colorado government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the Colorado government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the Colorado government or any agency thereof.

Introduction

The marijuana industry continues to evolve rapidly both throughout Colorado and nationwide, but research in this market has been unable to keep pace with the growth. Regulators and industry advocates alike are left making policy and business decisions with insufficient data and information. This becomes especially apparent in an industry that is lacking both clear best practices and participants willing to share their knowledge.

The *Energy Use in the Colorado Cannabis Industry* report covers the history of marijuana legalization in Colorado, assesses baseline energy and water use for production, examines municipal policy development and its impacts on industry growth, and looks at what opportunities exist for cultivators to improve efficiencies or reduce costs.

Background

Following a multitude of state bans on the substance, marijuana was first made federally illegal with the passage of the Marijuana Tax Act in 1937. This law criminalized any marijuana production without a federal license, a license which the federal government refused to issue. Although population attitudes toward the drug grew increasingly positive throughout the 1960's, in 1970, the federal government passed the Controlled Substances Act, federally prohibiting all growing of marijuana.

Colorado was one of the first states to decriminalized marijuana in 1975 (five years after the passage of the Controlled Substances Act), where the state made the transportation, possession, and private use of the substance a petty offense.¹ In 2000, Coloradans approved Amendment 20 to the state Constitution, allowing marijuana to be prescribed to people with symptoms such as chronic weight loss, muscle spasms, seizures, and more, which kicked off the progression of the marijuana retail market that we know today.²

History of Colorado Cultivation Laws

AMENDMENT 20

Colorado voters approved Amendment 20³, making Colorado one of eight states to decriminalize medical marijuana use between 1996 and 2000. When Colorado passed Amendment 20, the legal marijuana market was non-commercial and unregulated. A physician would provide a medical marijuana prescription of up to six plants for a debilitating medical condition. The plants could be cultivated by the patient or the patient's caregiver (a person who is not the patient or the patient's physician and has significant responsibility for managing the wellbeing of the patient), for the patient's personal medical use.⁴ The permissible use of marijuana and the accompanying registry identification cards were the extent to which the industry was regulated.

1 Breathes, W. "The History of Cannabis in Colorado...or How the State Went to Pot" *West Word*, Nov. 2012, <http://www.westword.com/news/the-history-of-cannabis-in-colorado-or-how-the-state-went-to-pot-5118475>.

2 Colorado Constitution Article. XVIII, Amendment 20, § XIV

3 Colorado Constitution Article. XVIII, Amendment 20, § XIV

4 If required for the patient's medical condition, a physician can recommend that the patient requires an extended plant count of more than six plants.

EARLY DISPENSARIES

In the early 2000s, some caregivers attempted to expand their customer base by operating delivery services or opening storefronts in discreet locations. In an attempt to restrain the commercialization of the market, the Colorado Department of Public Health and Environment (CDPHE) created an informal rule barring caregivers from providing for more than five patients.⁵

Two regulatory actions freed Colorado's commercial market for marijuana in the late 2000s. In 2007, Denver's District Judge Larry Naves overturned CDPHE's informal rule, claiming the restriction of five patients was not interpretable from the original statute. In 2009, the U.S. Department of Justice issued the Ogden Memorandum, instructing federal prosecutors to not prioritize marijuana patients and caregivers who were operating in compliance with state law. These developments triggered unfettered growth in Colorado's metropolitan marijuana industry and its storefronts, creating a legal and unregulated market for medical marijuana. In 2010, Colorado legislators passed House Bill 1284 to comprehensively regulate medical marijuana businesses.⁶

HB 1284

This new law was an effort to regulate, guide, and rein in the marijuana market by imposing requirements on medical marijuana centers (the term for medical marijuana storefronts as designated in House Bill 1284)⁷, including abiding by set hours of operation, implementing security requirements, and vertical integration. By requiring these medical marijuana centers to be vertically integrated, retail fronts were required to own and pull supply from linked cultivation facilities. As such, in Denver, many existing medical marijuana centers teamed up with cultivation facilities (called "Optional Premises Cultivation Operations" in Colorado's medical laws)⁸ to form licensed vertically-integrated businesses. Under House Bill 1284, local governments are able to prohibit medical marijuana businesses within their jurisdiction, and many did.⁹ Colorado's current concentration and spread of marijuana cultivations is a direct result of the initial medical licensure that occurred in Denver and outlying metropolitan areas. Because Denver and Boulder were some of the first few cities to regulate medical marijuana businesses, most of the first licenses were located in those areas.

AMENDMENT 64

Shortly after the formation of the regulated medical market, stakeholders started to take action to create another marijuana market in Colorado. In November 2012, Colorado citizens passed Amendment 64 to the state Constitution, legalizing marijuana for personal use. Personal use includes possessing, using, displaying, purchasing or transporting one ounce of marijuana or six marijuana plants by people who are age 21 and older.¹⁰

5 "History of Colorado's Medical Marijuana Laws" *Sensible Colorado*, <http://sensiblecolorado.org/history-of-co-medical-marijuana-laws/>

6 Breathes, W. "The History of Cannabis in Colorado...or How the State Went to Pot" *West Word*, Nov. 2012, <http://www.westword.com/news/the-history-of-cannabis-in-colorado-or-how-the-state-went-to-pot-5118475>.

7 Concerning Regulation of Medical Marijuana, HB 10-1284, 67th Cong. (2010)

8 "Permanent Rules Related to Colorado Retail Marijuana Code", *Marijuana Enforcement Division, Department of Revenue*. Sep. 2013, https://www.colorado.gov/pacific/sites/default/files/Retail%20Marijuana%20Rules,%20Adopted%20090913,%20Effective%20101513%5B1%5D_0.pdf

9 Breathes, W. "The History of Cannabis in Colorado...or How the State Went to Pot" *West Word*, Nov. 2012, <http://www.westword.com/news/the-history-of-cannabis-in-colorado-or-how-the-state-went-to-pot-5118475>.

10 CO Const. art. XVIII, amend. 64, § XVI

The next month, Governor Hickenlooper appointed a task force to govern Amendments 64's implementation. The Task Force was directed to make recommendations for a "regulatory framework that promotes the health and safety of the people of Colorado" and released its 58 recommendations in March of 2013.¹¹ After a year of strategizing and implementing a regulatory framework, personal use retail stores opened to the public on January 1st, 2014.

Regulatory Differences in Production for Medical and Retail Use

Colorado's medical and personal use marijuana regulatory systems are separated, not only in law, but also in the way production is limited and controlled.

House Bill 1284 established the first cultivation requirements and set forth the process by which medical cultivation facilities establish their marijuana supply. Under Amendment 20, medical marijuana patients or their caregivers can cultivate a limited number of marijuana plants for medical use. For an optional premises cultivation operation to grow marijuana plants, House Bill 1284 requires a patient to designate a medical marijuana center (also known as a medical dispensary) as its primary caregiver.¹² The medical marijuana center's associated cultivation facility can then cultivate on the patient's behalf. This established the state's first production management system. For each patient, a medical marijuana center signs up its vertically integrated cultivation facility to cultivate additional plants. In this way, an optional premises cultivation operation's production is linked directly to the demand for its products.

Personal use marijuana in Colorado does not require vertical integration and does not limit a business's marijuana production by the number of consumers registered at associated storefronts. Instead, marijuana cultivation facilities (term designated by Amendment 64 for entities that cultivate for personal use and hereinafter referred to as retail cultivation facilities) are assigned a production management tier that limits the number of plants that can be grown at one time.¹³ This production tier was put in place in an effort to track and manage production of the industry.

PRODUCTION MANAGEMENT TIERS:¹⁴

- ▶ **Tier 1:** 1-1,800 plants;
- ▶ **Tier 2:** 1,801-3,600 plants;
- ▶ **Tier 3:** 3,601-6,000 plants;
- ▶ **Tier 4:** 6,001-10,200 plants; and
- ▶ **Tier 5:** 10,201-13,800+ plants.

11 Finlaw & Brohl, "Task Force Report on the Implementation of Amendment 64", *Amendment 64 Task Force*, Mar. 2013, <https://www.colorado.gov/pacific/sites/default/files/A64TaskForceFinalReport%5B1%5D.pdf>

12 Concerning Regulation of Medical Marijuana, HB 10-1284, 67th Gen. Assembly (2010)

13 CO Const. art. XVIII, amend. 64, § XVI

14 When the production management system for retail marijuana cultivation facilities started in 2014 there were only three tiers: 0-3,600 plants; 3,601-6,000 plants; and 6,001-10,200 plants. New retail marijuana cultivation facilities that were not transitioned from existing medical establishments would start off with an authorized plant count of 3,600 plants. Starting November 30, 2015, the Marijuana Enforcement Division added two production tiers and all retail marijuana cultivation licenses issued from then on, including those transitioned from existing medical establishments, would start with a production limitation of 1,800 plants.

To move up production management tiers, a retail cultivation facility must cultivate at or near its maximum plant count for a minimum of six months and transfer at least 85% of the inventory it produced during that period to a licensed retail marijuana store.



When the market opened for personal use, existing medical businesses had a head-start in permitting and licensing.¹⁵ From October 1, 2013 until October 1, 2014 the Department of Revenue only permitted existing medical marijuana businesses who applied for retail licenses. As such, many of the first retail cultivation facilities in the state were tied closely to their medical counterparts and would often be situated within the same licensed premises. Only a plant tag, corresponding to the separate tracking identity within the state's seed to sale tracking system, is needed to establish required physical separation between medical and retail inventories.¹⁶

When newly transitioned retail cultivation facilities began to operate, their cultivation limitations were tied to the corresponding medical licensee's history as a vertically integrated business. To account for the expected surge of demand at retail marijuana stores, regulators and industry members determined that a retail marijuana cultivation facility should be permitted to cultivate about twice as much as its corresponding optional premises cultivation operation. Medical marijuana centers and their associated optional premises cultivation operations were divided into three types based on the number of patients that designated the center as their primary caregiver. Type 1 medical marijuana centers, with zero to 300 patients, could start their retail cultivation facility with up to 3,600 plants. Type 2 medical marijuana centers, with 301 to 500 patients, were permitted to grow at most 6,000 plants at their associated retail cultivation facility. Finally, the largest medical marijuana centers, Type 3 with 501 or more patients, could cultivate up to 10,200 plants at one time within their retail license. By adding a retail marijuana cultivation license during the transition phase, existing vertically integrated medical marijuana businesses effectively tripled their authorized production capacity.

As previously stated, when the first vertically integrated medical marijuana businesses began to transition to retail production, most licenses were situated in Denver. Unsurprisingly, the largest vertically integrated businesses were also located in the city. In October 2013, Denver held 40% of the state's 472 Medical Marijuana Center licenses and 59.1% (13 out of 22) of the largest Type 3 Centers. This concentration was a result of both the history of Denver's medical businesses as well as the population demographics of the state. In October 2013, more patients lived in Denver County than any other county, and 46.6% of Colorado's total 112,149 patients lived within the Denver Metropolitan Area (Arapahoe, Adams, Denver, and Jefferson Counties).¹⁷

15 Existing medical marijuana businesses that transitioned were permitted to either add an additional adult use marijuana License of the same type or terminated their medical license and convert entirely to adult use.

16 "Permanent Rules Related to Colorado Retail Marijuana Code", *Marijuana Enforcement Division, Department of Revenue*. Sep. 2013, https://www.colorado.gov/pacific/sites/default/files/Retail%20Marijuana%20Rules,%20Adopted%20090913,%20Effective%20101513%5B1%5D_0.pdf

17 MED Collection Data (2016), *Marijuana Enforcement Division* [Data Set]

Cultivation Facilities

Cultivation facilities operate in a variety of different environments including open fields, greenhouses, homes, and fully enclosed warehouses. These operations use a wide variety of irrigation and lighting techniques based on the cultivators' preferences, backgrounds, knowledge, skills, management types, and access to capital. This variety in the industry makes assessing its energy and water usage complicated.

This next section looks at cultivations outside of the medical and retail market, how medical and retail licenses are dispersed throughout the state, and provides an estimate for the marijuana industry's baseline energy and water usage. By understanding where most marijuana businesses are located, what policies created their spread, and what the industry's resource consumption is, localities can identify opportunities to best manage this growing demand on energy and water supplies and make policies that effectively direct the industry.

Caregiver Facilities and Home Cultivations

Home cultivations are marijuana cultivation operations that are located inside residential buildings and operated by Colorado residents that are not caregivers. Caregiver facilities are cultivation operations owned and maintained by a caregiver. These cultivations have just as variable operations as retail and medical grow facilities, except they are generally located in residential buildings.

In Colorado, any adult 21 years or older may possess, grow, process, or transport up to six marijuana plants, with a maximum of three mature (flowered) plants at any time.¹⁸ Based on the 2013-2014 two-year average in Colorado, 3.3% of the population who acquired marijuana self-reported acquiring marijuana through cultivation.¹⁹ Combined with the fact that the Colorado's State Demography Office estimates the state population to be 5.5 million in 2016, we can conclude a modest estimate of approximately 160,000 people cultivating marijuana at home in Colorado.²⁰

Amendment 64 also allowed any adult to "assist" any other adult in "possessing, growing, processing, or transporting" their marijuana,²¹ allowing for people who live in the same residence to justify large quantities of plants or product by claiming that residents are helping one another with growing. To make things even more complicated, there was no limit for how many individuals could cooperate with one another, allowing there to be limited legal recourse for large residential marijuana cultivations.

Caregivers and patients growing for their own use, until recently, could get licenses to grow up to 99 plants on their property in a residential setting and would not be severely punished if their cultivation was not registered with the state. This is because caregivers and patients growing for medical purposes

18 CO Const. art. XVIII, amend. 64, § XVI

19 "National Survey on Drug Use and Health" *Substance Abuse and Mental Health Services Administration, Center for Behavioral Health Statistics and Quality*, (2014) http://www.samhsa.gov/sites/default/files/topics/data_outcomes_quality/colorado-2002-2014.pdf Accessed September 10

20 "Population Estimates - years (1985 to 2016): Final Estimates, State, Sub-state regions, and counties 2000 to Current" (2017) *State Demography Office, Colorado Department of Local Affairs*, <https://drive.google.com/uc?export=download&id=0B2FMBVetYCVCRFRacjRjdG9VckE>

21 CO Const. art. XVIII, amend. 64, § XVI



were not regulated like their medical cultivation center counter parts, making it difficult to both track this market and to prosecute illegal grow operations due to the lack of boundaries.

In the 2017 legislative session, a bill was passed to close these loopholes. House Bill 17-1220 placed a cap of sixteen plants that can be possessed or grown on a residential property (unless the local jurisdiction permits possessing or growing more than sixteen plants). Additionally, medical patients and caregivers can apply for an exemption to increase their grow limit to 24 plants.²² In September 2017, almost 94% of patients had prescriptions between one and 24 plants, meaning the vast majority of the market resided under the 24 plant cap.²³ By limiting production on residential property, this bill gives law enforcement authority to confront illegal grow operations.

Even with this regulation, data collected and provided about caregiver facilities and home cultivations is limited. CDPHE puts out a singular monthly report on data collected through their registration system, but only started including information about how many patients have assigned their prescription to a caregiver, medical cultivation facility, or themselves to grow in January 2017. Because residential cultivation facilities are still largely unregulated, there is no way to accurately determine the number of people growing plants or their dispersion across the state.

Licensed Medical and Retail Cultivation Facilities

Colorado has been a trailblazer in marijuana regulation and as a result, legal production. As of the end of 2017, the state had more than 1,400 cultivation licenses spread across hundreds of businesses, 42 counties, and 108 local jurisdictions²⁴, as can be seen in Figures 1, 2, and 3, and 4.²⁵

22 Concerning Measures to Stop Diversion of Legal Marijuana to the Illegal Market, HB 17-1220, 71st Gen. Assembly (2017)

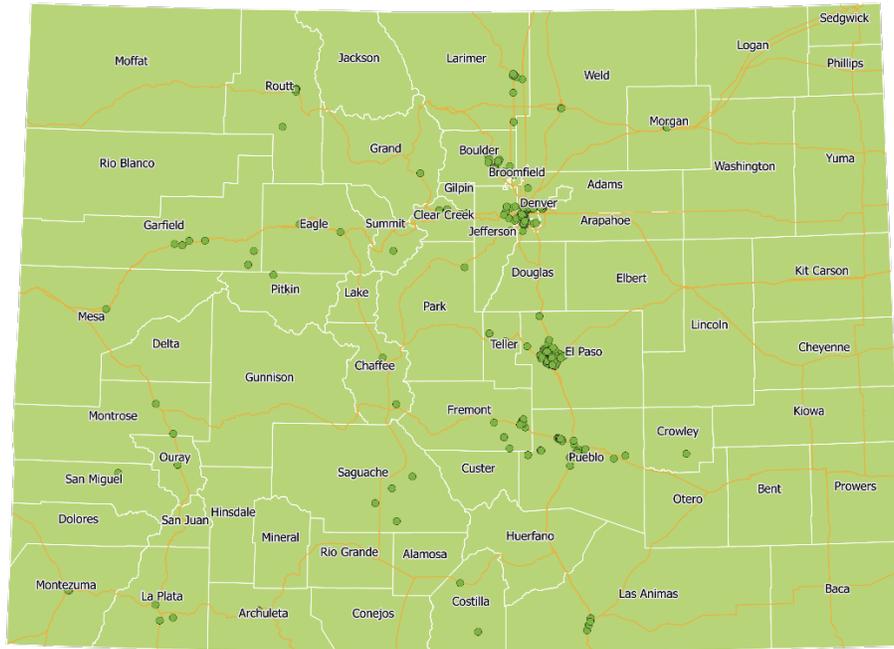
23 "Medical Marijuana Registry Program Statistics Report" (9/2017) CDPHE https://www.colorado.gov/pacific/sites/default/files/CHED_MMR_Monthly_Report-SEPTEMBER-2017.pdf Accessed: October 13th, 2017

24 Brohl, Humphreys, Kammerzell & Burack, "MED 2016 Annual Report" Colorado Department of Revenue, MED, https://www.colorado.gov/pacific/sites/default/files/2016%20MED%20Annual%20Report_Final_1.pdf

25 Colorado Department of Revenue, MED, (2016), MED Licensed Medical Marijuana Centers & MED Licensed Retail Marijuana Centers [Data Sets] <https://www.colorado.gov/pacific/enforcement/med-licensed-facilities>.

Figure 1. Colorado Licensed Medical marijuana Cultivation Facilities

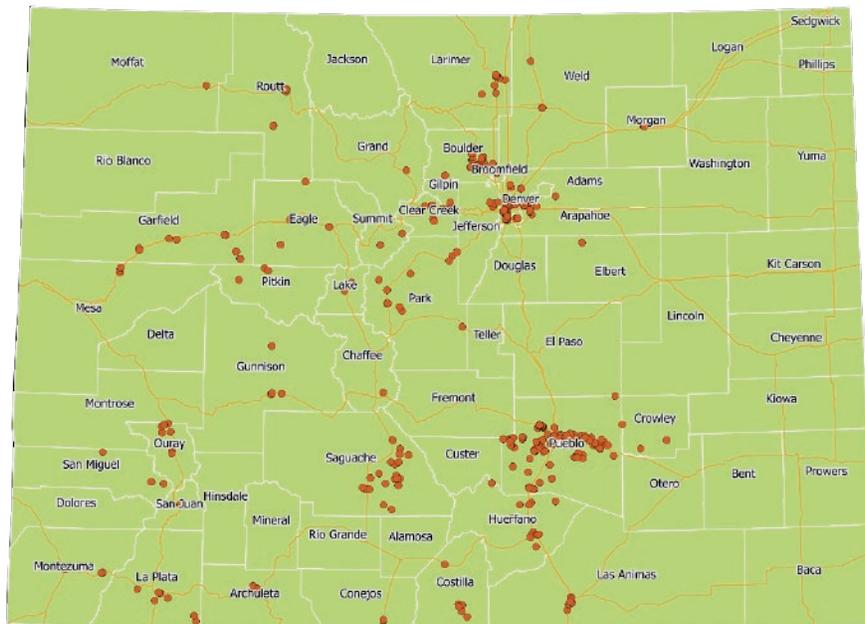
Medical Marijuana Cultivation Licenses (December 1, 2017)



Source: Colorado Department of Revenue; Marijuana Enforcement Division

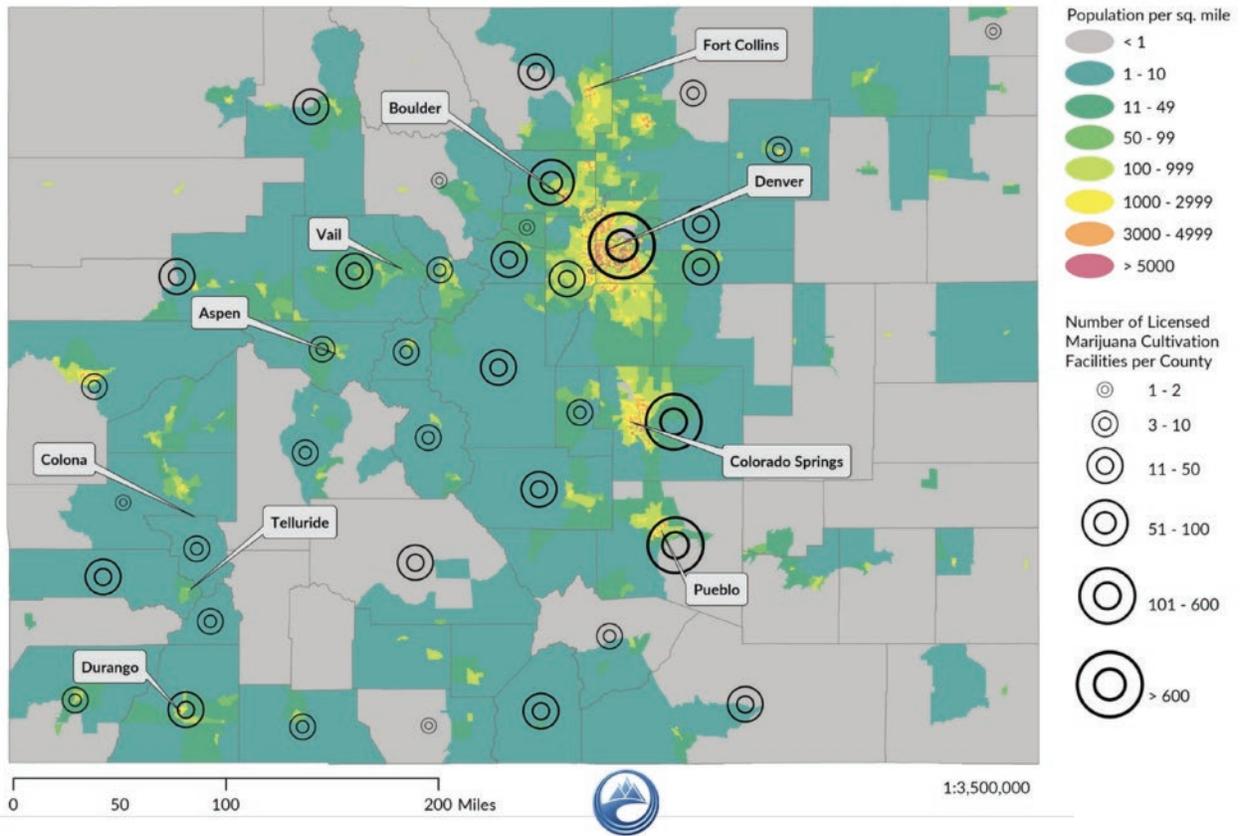
Figure 2. Colorado Licensed Retail Marijuana Cultivation Facilities

Retail Marijuana Cultivation Licenses (December 1, 2017)



Source: Colorado Department of Revenue; Marijuana Enforcement Division

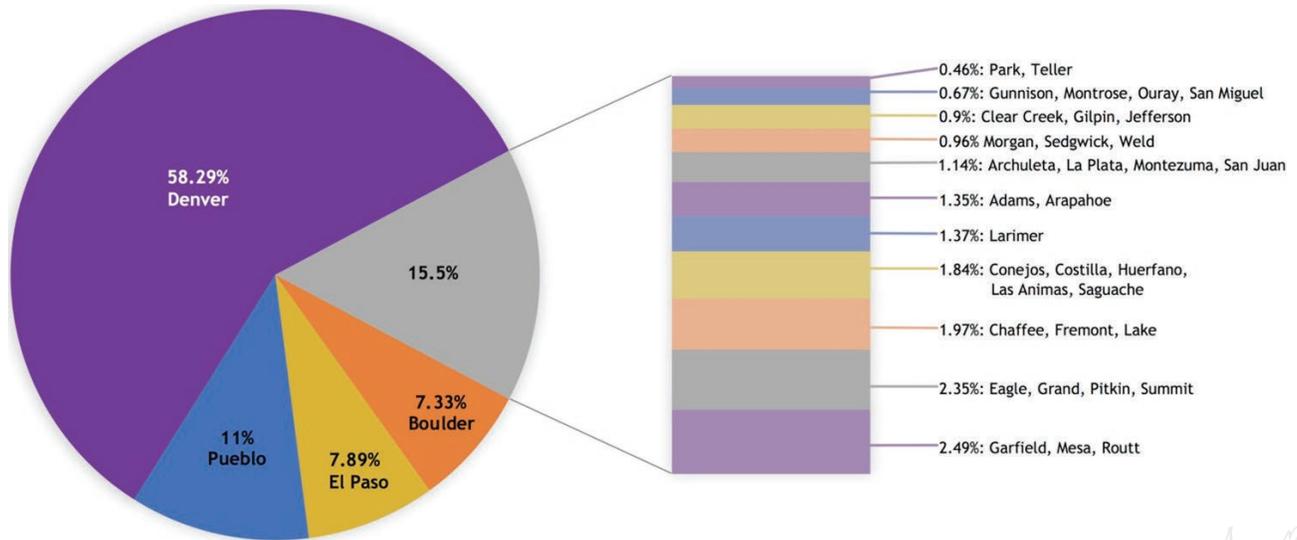
Figure 3. Colorado Population and Marijuana Cultivation Facility Density



Source 1. 2010 Census GIS Data; Colorado Department of Local Affairs, 2010 US Census; US Census Bureau, Marijuana Enforcement Division, CDPHE, Colorado Department of Transportation



Figure 4. Percentage of Marijuana Plants Cultivated in Colorado by County Cluster, September 2016 ²⁶



Colorado’s marijuana cultivators are dispersed throughout the state but the vast majority of licenses are held in just a handful of jurisdictions in Colorado’s Front Range counties. As of September 2016, the four counties with the most marijuana cultivation licenses (Denver, Pueblo, El Paso, and Boulder) hold 75.9% of all cultivation licenses in the state. During that same month those four localities grew 84.5% of the state’s regulated marijuana crop. In 2016, Denver alone was home to 45.5% of all cultivation licenses and grows 58.3% of the state’s total marijuana crop.²⁷ As of December 2017, the four top counties still hold 75% of the licenses but Denver’s share of licenses dropped to 43%.²⁸ According to Xcel Energy, between 2012 and 2013 Denver’s electrical consumption increased by 1.2%. Of that increased consumption, 50% is attributed to marijuana cultivation.²⁹



²⁶ Colorado Department of Revenue, MED, *Monthly Plant Counts 2014-2016 by County* (2016) [Data Set]

²⁷ Colorado Department of Revenue, MED, *Monthly Plant Counts 2014-2016 by County* (2016) [Data Set]

²⁸ Colorado Department of Revenue, MED, *MED Licensed Facilities Data; Medical Marijuana Facility Cultivations & Retail Marijuana Establishment Cultivations* (2017) [Data Set]

²⁹ Mulqueen, Kee, Zafar, (2017) “Energy Impacts of Marijuana Cultivation: Workshop Report and Staff Recommendations” *California Public Utilities Commission Policy and Planning Division*



Demand and Consumption of Energy and Water

Estimating Energy and Water Use



Data on the industry collected by the Marijuana Enforcement Division (MED) and the CDPHE is statutorily protected. The MED tracks every plant from “seed to sale” through a plant identification system, but to protect the identity of marijuana businesses, the MED was only able to share production information by county (and if there were too few grow operations in one county, by county cluster). This report also only utilized public CDPHE data. Since the marijuana sector is new and competitive, most cultivations consider their production data to be proprietary. Most importantly, many cultivations are too busy maximizing production in an effort to seize market share to consider, let alone track, their energy and water consumption. The combination of these factors has resulted in limited public information about this market and its energy and water usage. In this section, we provide an estimate for energy and water baseline usage for this industry based off data collected in the case studies attached to this report.

Methodology

For this baseline estimate of production and energy and water consumption of flower product in the state, we assumed that marijuana use in Colorado is fully served by production within the state. We also assumed that the marijuana produced within the state serves resident demand, tourist demand, or is diverted out of state.

To create our estimate, we looked at the demand in Colorado. Relying on the assumptions above, we determined that the demand is defined as the combination of resident demand, tourist demand, and out of state diversion. We assessed these demand estimates by using the MED’s Market Size and Demand for Marijuana in Colorado (hereafter referred to as the MED’s Market and Demand Report), with data from the El Paso Intelligence Center provided Jack Reed at the Office of Research and Statistics, and from data in the Rocky Mountain High Intensity Drug Trafficking Area’s annual reports. All data sources rely on only the dried weight of flower product as there is no current methodology for converting edible, concentrate, and vaporizer sales into dried flower weight equivalents to make them comparable.

After we determined an estimate for statewide marijuana demand in metric tons, we use the energy and water use metrics (collected from the Case Studies at the end of this report) to assess a baseline for energy and water use for the marijuana industry.

Demand Estimates

RESIDENT DEMAND

We assessed tourist and resident demand by utilizing the methodology put forth in the MED’s Market Size and Demand Report. In order to estimate resident demand, the MED’s report uses the below equation.

Equation 1. Resident Demand Equation from MED’s Market Size and Demand for Marijuana in Colorado report³⁰

$$D_r = \sum_{t=1}^7 \frac{days_t * g_t * n_t}{1,000,000}$$

Where

- D_r = the total demand for marijuana in Colorado by adult residents, measured in metric tons of marijuana
- $Days_t$ = number of use days per year by user type, t (1-365)
- g_t = number of grams consumed per day for each user type, t
- n_t = number of people included in each marijuana user classification, t.

In order to apply the MED’s framework for our report, we had to tackle two issues. First, we had to solve for annual use days (days that a person consumed marijuana) for each type of smoker profile with the proposed equation and information provided in MED’s report (please reference the MED’s Market and Demand Report for a more thorough explanation of their equation). Second, we had to adjust the population for years 2015 and 2016 by looking at the estimated population growth provided by the Colorado State Demography Office.

30 Light, Orens, Lewandowski, Pickton, Prepared by the Marijuana Policy Group for the Colorado Department of Revenue, *Market Size and Demand for Marijuana in Colorado*, 2014, <https://www.colorado.gov/pacific/sites/default/files/Market%20Size%20and%20Demand%20Study%2C%20July%2009%2C%202014%5B1%5D.pdf>, accessed November, 2017.

By using the below changes in population, we adjust the MED’s estimate for users in each smoker sub class by that population change.

Table 1. Colorado Population Estimates³¹

Year	Population	Growth Since 2011
2010	5,049,935	–
2011	5,119,538	–
2012	5,191,086	1.40%
2013	5,268,413	2.91%
2014	5,350,118	4.50%
2015	5,448,055	6.42%
2016	5,538,180	8.18%

Note: Each percentage is growth from 2011, (i.e. there has been an 8.18% population growth from 2011 to 2016.)

The above chart provided us with the following table of Colorado marijuana user population by frequency.

Table 2. “Adjusted Colorado Marijuana User Populations by Frequency Use” 2014-2016³²

			2014	2015	2016
Use Frequency (Days per Month)	2010/2011 NSDUH	Underreporting Adjustment	Population Adjustment	Population Adjustment	Population Adjustment
<1	156,000	22.2%	199,218	202,865	206,221
1-5	131,000	22.2%	167,292	170,354	173,172
6-10	40,000	22.2%	51,082	52,017	52,877
11-15	17,000	22.2%	21,710	22,107	22,473
16-20	31,000	22.2%	39,588	40,313	40,980
21-25	47,000	11.1%	54,569	55,568	56,487
26-31	127,000	11.1%	147,452	150,151	152,635
Yearly User Total	549,000		680,234	693,374	704,845
Monthly User Total	393,000		481,692	490,510	498,624

31 “Population Estimates - years (1985 to 2016): Final Estimates, State, Sub-state regions, and counties 2000 to Current” (2017) *State Demography Office, Colorado Department of Local Affairs*, <https://drive.google.com/uc?export=download&id=0B2FMBVetYCVCRFRacjRjdG9VckE>

32 Light, Orens, Lewandowski, Pickton, “Market Size and Demand for Marijuana in Colorado” (2014) *Colorado Department of Revenue, Marijuana Policy Group*, <https://www.colorado.gov/pacific/sites/default/files/Market%20Size%20and%20Demand%20Study%2C%20July%209%2C%202014%5B1%5D.pdf>

We then multiplied each user population class by its low, medium, and high estimates for grams used per use day and then by the class's use days per year to calculate the average grams consumed by each customer class per year. Our numbers for 2014 are slightly lower than what is reported in the MED's Market and Demand report due to our approximation of their estimates for the annual usage amounts in '000 grams. For our model, we later converted these numbers to metric tons by dividing by 1000.

Table 3. 2014 Demand Estimates by Frequency of Use Groups³³

2014			
Frequency of Use:	Annual Usage Amounts: ('000 grams)		
Per Month	Low	Med	High
<1	239	359	717
1-5	2,590	4,035	5,721
6-10	2,109	3,286	4,659
11-15	1,456	2,269	3,217
16-20	3,677	5,729	8,123
21-25	19,579	24,098	28,616
26-31	65,557	80,686	95,814
Total:	98,228	120,493	146,913

Table 4. 2015 Demand Estimates by Frequency of Use Groups

2015			
Frequency of Use:	Annual Usage Amounts: ('000 grams)		
Per Month	Low	Med	High
<1	243	365	730
1-5	2,637	4,109	5,826
6-10	2,147	3,346	4,744
11-15	1,483	2,311	3,276
16-20	3,744	5,834	8,272
21-25	19,938	24,539	29,140
26-31	66,757	82,163	97,568
Total:	96,950	122,666	149,557



³³ Light, Orens, Lewandowski, Pickton, "Market Size and Demand for Marijuana in Colorado" (2014) *Colorado Department of Revenue, Marijuana Policy Group*, <https://www.colorado.gov/pacific/sites/default/files/Market%20Size%20and%20Demand%20Study%2C%20July%209%2C%202014%5B1%5D.pdf>

Table 5. 2016 Demand Estimates by Frequency of Use Groups

2016			
Frequency of Use:	Annual Usage Amounts: ('000 grams)		
Per Month	Low	Med	High
<1	247	371	742
1-5	2,681	4,177	5,922
6-10	2,183	3,401	4,822
11-15	1,507	2,349	3,330
16-20	3,806	5,931	8,409
21-25	20,268	24,945	29,622
26-31	67,862	83,522	99,182
Total:	98,554	124,695	152,031



After we collected and calculated the resident demand estimates, we again use the MED’s Market and Demand Report to estimate tourist demand.

TOURIST DEMAND

To assess tourist demand, we adjusted the MED’s estimates by assessing growth rates of Colorado tourists with numbers provided by Colorado’s Tourism Office for the years 2015 and 2016. With the tourist counts for 2015 and 2016, 77.7 million³⁴ and 82.4 million³⁵ respectively, we calculate the year to year growth rate, which we then apply to the MED’s tourist demand estimates. By taking the low, medium, and high tourist demand estimates from the MED’s Market and Demand Report and multiplying them by 1+ the respective growth rate, we calculate our tourist demand estimate ranges for 2015 and 2016.

Table 6. Tourist Demand Estimates

Year	# of Tourists	Growth Rate	Metric Tonnes		
			Low	Med	High
2014	71,300,000	–	8.15	8.90	9.84
2015	77,700,000	8.98%	8.88	9.70	10.74
2016	82,400,000	6.05%	9.42	10.29	11.37

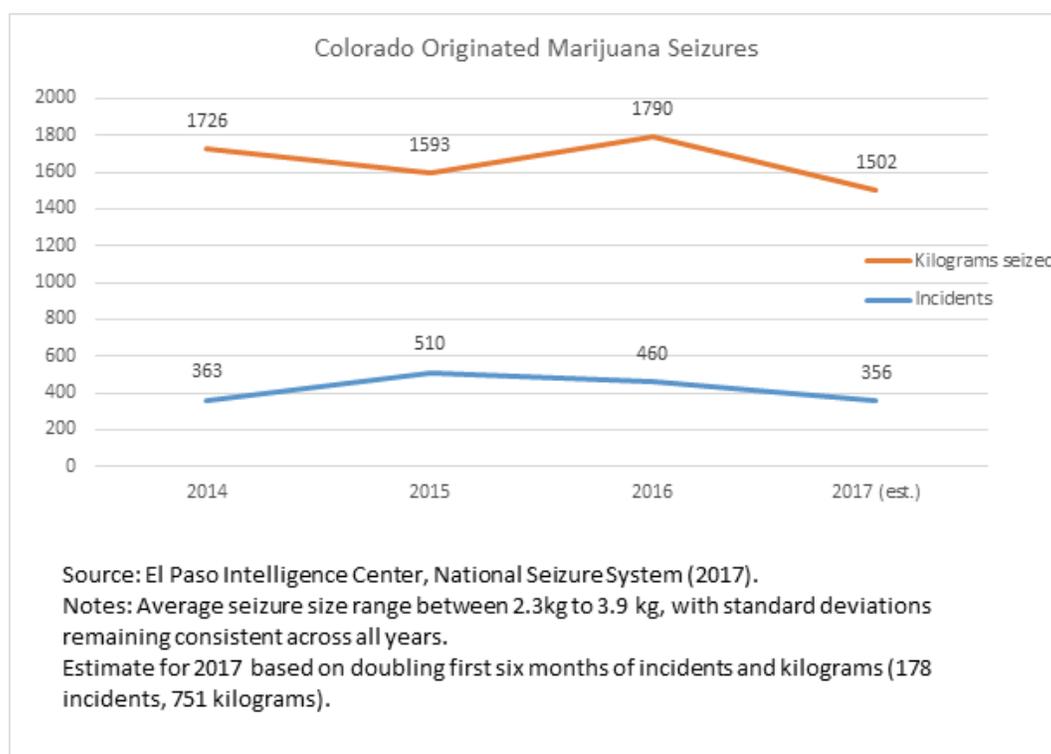
34 “Colorado Longwoods Report” (2015) Colorado Office of Tourism, Longwoods International <http://industry.colorado.com/research/longwoods-international>

35 “Colorado Longwoods Report” (2016) Colorado Office of Tourism, Longwoods International <http://industry.colorado.com/research/longwoods-international>

OUT OF STATE DIVERSION

In order to finish the demand side of our equation, we needed to estimate out of state diversion. For this portion, we used data from the National Seizure Database, provided by Jack Reed, an Analyst at the Colorado Office of Research, which was collected by the Drug Enforcement Agency's El Paso Intelligence Center from Colorado localities on a volunteer basis.

Figure 5. Colorado Originated Marijuana Police Seizures³⁶



Because this data is voluntarily provided by Colorado localities, the data is incomplete. Therefore, we established a low, medium, and high estimate for what percentage the seizures are of the actual Colorado trafficking market. The El Paso Intelligence Center seizure number only reports police seizures. In order to get postal service seizures, we utilized the Rocky Mountain High Intensity Drug Trafficking Area (RMHIDTA) 5th Report for its dried flower weight of post office seizures for the years 2014, 2015, and 2016.³⁷ According to a 2016 report from the RMHIDTA, it is estimated that law enforcement seizes at maximum 10% of marijuana being illegally sold in or transported out of Colorado.³⁸ With our high boundary being set at 10%, we set our medium estimate as 2% and our low estimate to be 1% of all marijuana being diverted out of state.

36 Reed, J. (2017) *Department of Revenue, Colorado Office of Research & Statistics*

37 "The Legalization of Marijuana in Colorado: The Impact" (2017) *Strategic Intelligence Unit, Rocky Mountain High Intensity Drug Trafficking Area*, <http://www.rmhidta.org/html/FINAL%202017%20Legalization%20of%20Marijuana%20in%20Colorado%20The%20Impact.pdf>

38 "The Legalization of Marijuana in Colorado: The Impact" (2016) *Strategic Intelligence Unit, Rocky Mountain High Intensity Drug Trafficking Area*, <http://www.rmhidta.org/html/2016%20FINAL%20Legalization%20of%20Marijuana%20in%20Colorado%20The%20Impact.pdf>

Table 7. Out of State Diversion by Year and Percent of the Estimated Black Market

					Total diversions Metric tonnes)			Total diversions (Plants)		
	Police Seizures	Mail Seizures			Seizure % of total diversions			Seizure % of total diversions		
	Kilograms seized	Kilograms seized	Metric tonnes	Incidents	1.00%	2.00%	10%	1.00%	2.00%	10%
2014	1,726	212.000	1.938	363	193.800	96.900	19.380	1,751,050	875,525	175,105
2015	1,593	565.000	2.158	510	215.800	107.900	21.580	1,949,828	974,914	194,983
2016	1,790	782.000	2.572	460	257.200	128.600	25.720	2,323,891	1,161,945	232,389

By combining the resident demand, tourist demand, and out of state diversion estimates, we concluded the below low, medium, and high demand estimates for dried flower product in metric tons and plants being produced in Colorado.

Table 8. Resident Demand, Tourist Demand, and Out of State Diversion Estimates for Colorado

	Metric tons (annual)			Metric tons (annual)			Metric tons (annual)		
	Low Scenario			Medium Scenario			High Scenario		
	2014	2015	2016	2014	2015	2016	2014	2015	2016
Resident Demand	95.207	96.950	98.554	120.461	122.666	124.695	146.868	149.557	152.031
Tourist Demand	8.150	8.900	9.840	8.882	9.699	10.723	9.419	10.286	11.372
Out of State Diversion	19.380	21.580	25.720	96.900	107.900	128.600	193.800	215.800	257.200
Total	122.737	127.430	134.114	226.242	240.265	264.018	350.087	375.642	420.603

Energy and Water Use Estimate

With the calculated resident demand, tourist demand, and out of state diversion estimates, we multiplied the average energy and water consumption metrics from the case studies in this report to estimate energy and water consumption of the marijuana industry for production of its dried flower product in the state of Colorado.

First, because we have a small sample size, we chose to use the median (instead of the average) of the consumption metrics provided by cultivations who participated in the following case studies. These numbers include energy and water consumption rates from all indoor, outdoor, and greenhouse grow operations plus consumption estimates from scientific literature (scientific literature only includes energy use estimates). To estimate the electricity consumption from the scientific literature range, we used the middle point by adding the high and low limits together and then dividing by two.

Table 9. Summary of Resource Consumption Data from all Sources

Source	Facility Type	Electricity Consumption Rate (kWh/lb. of flower)	Water Consumption Rate (gal/lb. of flower)
Anonymous	Indoor	1,256	184
The Clinic (Historical)	Indoor	1,202	564
The Clinic (Current)	Indoor	1,136	564
Midwest Ranch	Greenhouse	236	91
Pot Zero	Outdoor	1.75*	968*
Scientific Literature	Mix	2,600-3,259	—
Median	—	1,202	564

* A kWh and gal respectively per lb. of total useable product (102 pounds of flower and 887 pounds of trim)

After deriving the demand estimates, we converted our metric ton demand estimates into pounds by multiplying our demand estimates by 2,205 (the number of pounds in a metric ton). When we had our new demand estimates, we computed the low, medium, and high annual energy and water consumption estimates by multiplying the demand estimates by the median consumption rates for electricity and water. For the electricity consumption estimate, instead of dividing between the two middle numbers, 1,202 and 1,136, to get the median, we chose to go with the higher number in order to better represent the mostly inefficient marijuana cultivation market. This gave us a consumption estimate in kWh and gallons. Finally, we converted our estimates into thousand megawatt hours (000 MWh) and acre feet by dividing the consumption estimates by one million.

These estimates are lower than the actual industry baseline because these numbers only estimate the marijuana industry’s energy and water consumption for dried flower product. While flower is still the dominant product in the market, concentrates, edibles, and vaporizers have been increasingly more popular options of consumption and require more plants for each dose.





Energy Use Estimates

Table 10. 2014 Low, Medium, and High Marijuana Industry Energy Consumption Estimates for Dried Flower Product

	Low Scenario						Medium Scenario		High Scenario	
2014	Annual Demand	Pounds/Metric Ton	Electricity Consumption Rate	Annual Electricity Consumption	Annual Electricity Consumption	Annual Electricity Consumption	Annual Demand	Annual Electricity Consumption	Annual Demand	Annual Electricity Consumption
	Metric Tons	Pounds	kWh/lb of flower	kWh	MWh	000 MWh	Metric Tons	000 MWh	Metric Tons	000 MWh
Resident Demand	95	2,205	1,202	252,348,473	252,348	252	120	319	147	389
Tourist Demand	8	2,205	1,202	21,597,119	21,597	22	9	24	9	25
Out of State Diversion	19	2,205	1,202	51,356,094	51,356	51	97	257	194	514
Total	123			325,301,686	325,302	325	226	600	350	928

Table 11. 2015 Low, Medium, and High Marijuana Industry Energy Consumption Estimates for Dried Flower Product

	Low Scenario						Medium Scenario		High Scenario	
2015	Annual Demand	Pounds/Metric Ton	Electricity Consumption Rate	Annual Electricity Consumption	Annual Electricity Consumption	Annual Electricity Consumption	Annual Demand	Annual Electricity Consumption	Annual Demand	Annual Electricity Consumption
	Metric Tons	Pounds	kWh/lb of flower	kWh	MWh	000 MWh	Metric Tons	000 MWh	Metric Tons	000 MWh
Resident Demand	97	2,205	1,202	256,912,550	256,913	257	123	325	150	396
Tourist Demand	9	2,205	1,202	23,584,584	23,585	24	10	26	10	27
Out of State Diversion	22	2,205	1,202	57,185,991	57,186	57	108	286	216	572
Total	127			337,683,125	337,683	338	240	637	376	995

Table 12. 2016 Low, Medium, and High Marijuana Industry Energy Consumption Estimates for Dried Flower Product

	Low Scenario						Medium Scenario		High Scenario	
2016	Annual Demand	Pounds/Metric Ton	Electricity Consumption Rate	Annual Electricity Consumption	Annual Electricity Consumption	Annual Electricity Consumption	Annual Demand	Annual Electricity Consumption	Annual Demand	Annual Electricity Consumption
	Metric Tons	Pounds	kWh/lb of flower	kWh	MWh	000 MWh	Metric Tons	000 MWh	Metric Tons	000 MWh
Resident Demand	99	2,205	1,202	261,162,552	261,163	261	125	330	152	403
Tourist Demand	10	2,205	1,202	26,075,540	26,076	26	11	28	11	30
Out of State Diversion	26	2,205	1,202	68,156,797	68,157	68	129	341	257	682
Total	134			355,394,889	355,395	355	264	700	421	1,115



Water Estimates

Table 13. 2014 Low, Medium, and High Marijuana Water Consumption Estimates for Dried Flower Product

	Low Scenario						Medium Scenario		High Scenario	
2014	Annual Demand	Pounds/Metric Ton	Water Consumption Rate	Total Water Consumption	Total Water Consumption	Total Water Consumption	Annual Demand	Total Water Consumption	Annual Demand	Total Water Consumption
	Metric Tons	Pounds	gal/lb of flower	gal	000 gal	Acre-feet	Metric Tonnes	Acre-feet	Metric Tonnes	Acre-feet
Resident Demand	95	2,205	564	118,380,954	118,381	118	120	150	147	183
Tourist Demand	8	2,205	564	10,133,756	10,134	10	9	11	9	12
Out of State Diversion	19	2,205	564	24,097,202	24,097	24	97	120	194	241
Total	123			152,611,912	152,612	153	226	281	350	435

Table 14. 2015 Low, Medium, and High Marijuana Water Consumption Estimates for Dried Flower Product

	Low Scenario						Medium Scenario		High Scenario	
2015	Annual Demand	Pounds/Metric Ton	Water Consumption Rate	Total Water Consumption	Total Water Consumption	Total Water Consumption	Annual Demand	Total Water Consumption	Annual Demand	Total Water Consumption
	Metric Tons	Pounds	gal/lb of flower	gal	000 gal	Acre-feet	Metric Tonnes	Acre-feet	Metric Tonnes	Acre-feet
Resident Demand	97	2,205	564	120,547,985	120,548	121	123	153	150	186
Tourist Demand	9	2,205	564	11,066,311	11,066	11	10	12	10	13
Out of State Diversion	22	2,205	564	26,832,695	26,833	27	108	134	216	268
Total	127			158,446,990	158,447	158	240	299	376	467

Table 15. 2016 Low, Medium, and High Marijuana Water Consumption Estimates for Dried Flower Product

	Low Scenario						Medium Scenario		High Scenario	
2016	Annual Demand	Pounds/Metric Ton	Water Consumption Rate	Total Water Consumption	Total Water Consumption	Total Water Consumption	Annual Demand	Total Water Consumption	Annual Demand	Total Water Consumption
	Metric Tons	Pounds	gal/lb of flower	gal	000 gal	Acre-feet	Metric Tonnes	Acre-feet	Metric Tonnes	Acre-feet
Resident Demand	99	2,205	564	122,542,162	122,542	123	125	155	152	189
Tourist Demand	10	2,205	564	12,235,112	12,235	12	11	13	11	14
Out of State Diversion	26	2,205	564	31,980,394	31,980	32	129	160	257	320
Total	134			166,757,668	166,758	167	264	328	421	523

Although these are vast ranges, mostly influenced by the assumptions for our out of state diversion, we will conclude this section with some observations about the high limit estimates. We are focusing on the higher limits because our estimates only reflect consumption for dried flower product, meaning the higher estimates are more likely to capture some of the demand and consumption for edibles, vaporizers, and concentrates.

For 2016, our high scenario predicts that the Colorado marijuana industry used 1,115 thousand MWh to produce its dried flower product. In comparison, in 2016, Colorado generated 54,418 thousand MWh of electricity. This means that the state's marijuana cultivation industry can potentially be consuming about 2% of Colorado's annual electric generation. This large demand in a new and competitive industry is an opportunity to promote energy efficiency as a cost saving opportunity. It is estimated that by simply upgrading their lights, cultivators could reduce their lighting demand by 20-50%, resulting in huge reductions in a cultivation's energy bill.³⁹

The Colorado Water Conservation Board has estimated that Colorado consumes about 5.3 million acre-feet (AF) of water per year.⁴⁰ An acre-foot is enough water to cover one acre in a foot's depth. Compared to the energy impacts, our estimated water consumption of the marijuana cultivation industry in Colorado (523 AF) is a much smaller portion Colorado's annual water consumption (less than a half a percent). Ensuring that the marijuana industry is a leader in water efficiency and not simply a reactive market participant is imperative as Colorado's population and economy, and their strains on Colorado's water resources, continue to grow.

Industry Health

Demand in Colorado for marijuana within the retail market has continued to increase since the start of commercial sales in 2014. The number of cultivated retail plants increased 70% in 2016 from the year prior, while the number of medical plants cultivated only increased by 10% over the same period, signaling that there is high demand for this product recreationally.⁴¹

As can be seen in Figure 6, marijuana cultivation in the state has increased in line with the expansion of legal sales. Although retail-level prices are insulated from wholesale price fluctuations because many businesses are vertically integrated, increased competition has driven down the price of medical and adult use marijuana flower. In the Colorado market, wholesale prices of flower have fallen 48% at the beginning of 2017 since retail sales started in 2014.⁴² This significant price decline suggests that supply is likely increasing faster than demand.

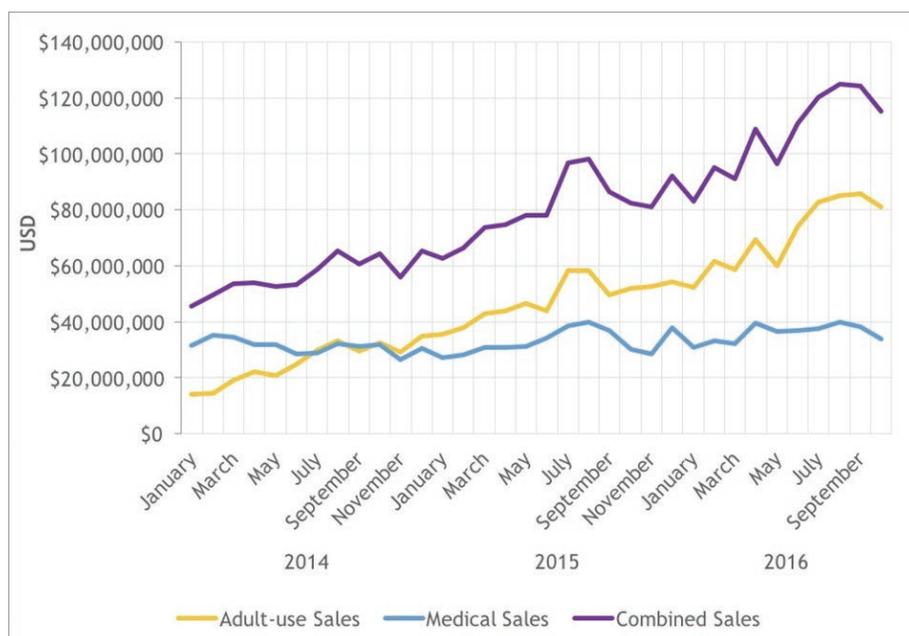
39 Kolwey, N. "A Budding Opportunity: Energy efficiency best practices for cannabis grow operations" (2017) *Southwest Energy Efficiency Project* <http://www.swenergy.org/data/sites/1/media/documents/publications/documents/A%20Budding%20Opportunity%20%20Energy%20efficiency%20best%20practices%20for%20cannabis%20grow%20operations.pdf>

40 "Colorado Water Plan: Chapter 5 Water Demands"(2016) *Colorado Department of Natural Resources, Colorado Water Conservation Board*, <https://www.colorado.gov/pacific/cowaterplan/plan>

41 Hartman, Humphreys, Amend & Burack, "MED 2017 Annual Update *Colorado Department of Revenue* https://www.colorado.gov/pacific/sites/default/files/2016%20MED%20Annual%20Report_Final.pdf Accessed October 5th, 2017

42 Kaskey, J. (2017) "As Pot Prices Plunge, Growers Scramble to Cut Their Costs" *Denver Post, Bloomberg News*, <http://www.denverpost.com/2017/01/21/marijuana-prices-plunge-growers-scramble/>

Figure 6. Colorado Legal Marijuana Sales, January 2014- September 2016



Once the market hits the point of saturation, if it has not already, cultivation facilities and store fronts will have to focus on brand and product differentiation in order to maintain market share.⁴³ An overly-saturated market runs the risk of price-wars (when companies consistently lower prices to undercut their competition), which may currently be in effect, and can start to run a significant amount of suppliers out of the sector.⁴⁴

In Colorado, the market is concentrated in four counties, so cultivations can look to expand to different locations in an effort to tap into new customers. In the four counties where the industry is saturated, it is important for cultivations to focus on cutting superfluous costs where they can, like in their energy and water expenses, and reinvesting those dollars into differentiating their businesses.

Local Government Impacts

Under state law, local governments are permitted to regulate both medical and retail marijuana businesses. Even though the state does not limit the number of medical or adult use marijuana licenses, many localities have chosen to do so. Only 108 of Colorado’s 320 local governments (34%) currently allow retail or medical marijuana facilities and storefronts.⁴⁵ Of those 108, many restrict the number of facilities through mechanisms such as license caps. Some localities, such as Boulder County, have implemented environmental requirements on the marijuana industry. In the home rule state of Colorado, where municipalities and counties have the right to self-governance, local jurisdictions will continue to have significant power in determining and creatively manipulating the marijuana industry’s activity in their areas of purview.

43 Stringfellow, A. “How to Succeed in an Over-Saturated Market” (2017) <https://www.americanexpress.com/us/small-business/openforum/articles/how-to-succeed-in-an-over-saturated-market/>

44 “Market Saturation” (2017) *Investopedia*, <https://www.investopedia.com/terms/m/marketsaturation.asp>

45 Brohl, Humphreys, Kammerzell & Burack, “MED 2016 Annual Report” *Colorado Department of Revenue, MED*, https://www.colorado.gov/pacific/sites/default/files/2016%20MED%20Annual%20Report_Final_1.pdf

License Caps

In the past few years, Denver, Pueblo, and El Paso, the three counties with the most cultivation facilities, have passed local ordinances that would prohibit new cultivation facility licenses in their jurisdictions. These prohibitions are as follows.

- ▶ The City and County of Denver passed an ordinance in April of 2016 to place a cap limiting the number of cultivations to the 311 distinct locations that currently exist. If a license were to go out of business or lose their license, another marijuana business will be allowed to apply and claim that license opportunity.⁴⁶
- ▶ In December of 2016, the Pueblo County Commissioners revisited and affirmed a proposed extension of a moratorium on the licensing of new medical and retail storefronts. This proposal specifically prohibited new retail marijuana cultivation facility applications for businesses that do not have an existing cultivation facility or storefront in Pueblo County until January 1st, 2019. Individuals with a retail marijuana cultivation facility outside of the county will be permitted to change location and move their business into Pueblo.⁴⁷
- ▶ In May 2017, after a yearlong moratorium on the issuance of new medical marijuana licenses, Colorado Springs will now also permanently cap the number of licensed marijuana business at 212 locations. Note that the medical market is essentially all of El Paso County's marijuana cultivation market. Existing business may continue to operate and can change the location of their operation as long as the entire grow moves to the same address, but the surrender or expiration of an existing license does not permit replacement of that license unless one business is sold to another party.

Currently, many jurisdictions are worried about allowing and supporting an overly saturated marijuana market, and the consequences for local communities when it declines. Though this market brings jobs and decent pay to these cities, once the market starts to pick winners, many of the economic benefits will slowly shrink. Therefore, these cities' license caps are an effort to control the market in their areas of oversight. That being said, this does provide the opportunity for other less popular local jurisdictions to benefit from the growth of this market by encouraging cultivations and marijuana businesses to license in their jurisdictions.

Environmental Provisions

Some local governments have taken the opportunity to introduce sustainability requirements for marijuana cultivation facilities. We chose to examine the sustainability requirements of Denver, Pueblo, and Boulder (El Paso has no energy or water conservation requirements) as these four localities cultivate 63% of Colorado's marijuana and therefore have both the largest concentration of energy and water consumption as well as the largest potential for energy and water conservation.

46 "City-wide Cap on Retail Marijuana Licenses; annual open application process" City of Denver, Ord. No. 291-16, & 2, 4-25-16

47 Stein, N. "Pueblo County to Continue Collecting Tax While City Prepares for Retail Pot" *Colorado Springs Independent* (2017) <https://www.csindy.com/coloradosprings/pueblo-county-to-continue-collecting-tax-while-city-prepares-for-retail-pot/Content?oid=4275137>

While the City and County of Denver do not have regulations related to energy or water consumption at licensed marijuana businesses, Denver's Department of Environmental Health (DEH) is working with businesses to encourage voluntary actions to reduce environmental impact. In 2016, DEH assembled the Cannabis Sustainability Work Group, a stakeholder group whose members include industry leaders, local government representatives, and consultants. The work group promotes sustainability through the development and distribution of best management practices and promotes knowledge sharing between the marijuana industry, community, and energy and sustainability experts. The annual Cannabis Sustainability Symposium was held in 2016 and 2017 as a result of the work group.



In Pueblo County, occupancy classification changes (when a business moves) require that the new facility adheres to the 2015 International Energy Conservation Code, a code that has established minimum regulations for energy-efficient buildings using prescriptive and performance related provisions. This requirement pertains to any office space and some ancillary parts of the cultivation operation, but does not include the actual cultivation areas.

Boulder County requires medical and retail marijuana cultivators to either offset their electricity use with renewable energy or pay a 2.16 cent charge per kWh of energy consumed. The County reinvests funds from this charge to achieve sustainability goals through both carbon offset projects, such as the development of renewable energy projects, and education initiatives to encourage best energy-use practices in marijuana cultivation. The Boulder County Energy Impact Offset Fund ensures that the burden is borne by the industry instead of by the general public. A number of jurisdictions have expressed interest in creating a similar strategy.

INDUSTRY HEALTH CONCLUSIONS

As wholesale prices of marijuana continue to decline and new suppliers continue to enter the market (Colorado licensed retail cultivation facilities increased by 13% during 2017 alone)⁴⁸ suppliers will have to be more cautious about how they spend revenues and which markets to enter in order to stay profitable. By reducing unnecessary energy and water expenses, cultivations can cut costs to invest in strategic marketing and branding efforts.

Additionally, because the Colorado marijuana industry is largely dependent on the actions of city and county-level officials, local governments will continue to have significant power in determining the market's direction in their areas of purview. As we are seeing with the Denver Cannabis Sustainability Work Group and the Boulder County Energy Impact Offset Fund, some local governments are taking tangible steps toward achieving sustainability goals, but there are still immense opportunities and barriers that localities should continue to consider.

48 Colorado Department of Revenue, MED, (2016), *MED Licensed Medical Marijuana Centers & MED Licensed Retail Marijuana Centers* [Data Sets] <https://www.colorado.gov/pacific/enforcement/med-licensed-facilities>

Improving Efficiencies Within the Industry

As the license caps and environmental standards enforced by local governments start to impact the direction of the market, it is important to recognize the opportunities within the industry for cultivators to improve their energy and water efficiencies in order to remain competitive.



Despite marijuana's classification as a Schedule I drug by the Federal Drug Enforcement Agency, its legal standing in Colorado has paved the way to operate in a retail capacity.⁴⁹ With this visibility and under the protection of state law, marijuana cultivators have more opportunities to monitor energy use, initiate meaningful conversations with energy providers, and openly work towards more efficient practices. Improving the energy and water efficiencies of marijuana cultivation can yield quick, significant, and sustained energy and financial savings. Some energy efficiency opportunities and tools are detailed below.

Monitoring

Monitoring is the first step to lowering a cultivation's energy costs. To understand the opportunities for energy savings in a cultivation, a cultivator must understand what pieces of equipment are driving what energy usages, and therefore where the cultivation is operating inefficiently. These sources of inefficiency are the opportunities for cost savings.

As a starting point, cultivators can monitor their building energy consumption data. Energy consumption data can include electricity, natural gas, and other energy sources and can be collected through past bills or their accounts with their utility suppliers. For the data to be useful, it must cover the most recent year that full data is available so that operations can understand seasonal changes in energy consumption.⁵⁰

After energy consumption data has been collected, some important metrics to track include:⁵¹

- ▶ Grams/watt
- ▶ Grams/kWh
- ▶ Grams/square-foot
- ▶ Micromole/square-foot
- ▶ kWh/square-foot

For more precise data points, cultivators can track electricity and water consumption per piece of equipment and per unit of product to determine how specific equipment changes can impact their energy consumption.

⁴⁹ Schedule of Controlled Substances: Maintaining Marijuana in Schedule I of the Controlled Substances Act. *U.S. Department of Justice, Drug Enforcement Agency (DEA)*

⁵⁰ "How-to Guide for Medical and Recreational Marijuana Business License Energy Reporting and Carbon Offset Requirements" (2016) *The City of Boulder* https://www-static.bouldercolorado.gov/docs/How_to_Guide_for_Boulder_MJ_JAN_2016_EV_UPDATED_3-1-201604211333.pdf

⁵¹ "Cannabis Environmental Best Management Practices Guide" (2017) *Denver Environmental Health* <https://www.denvergov.org/content/dam/denvergov/Portals/771/documents/EQ/MJ%20Sustainability/Draft%20Cannabis%20Environmental%20BMP%20Guide.pdf>

Once cultivators start tracking and more importantly sharing their data publicly, the marijuana industry will be better prepared to standardize best practices for energy efficiency.

Energy Audit

An energy audit is a useful tool for assessing an operation's energy consumption. Energy audits consist of a site visit, an analysis of the building, a report on audit findings, and suggestions for energy efficient upgrades. Depending on the utility provider or contractor, audits may be free or cost a small fee. Per Xcel, implementing these relatively minor recommendations can save business owners up to 15% on their energy bills.⁵²

Colorado Marijuana Energy Efficiency Calculator

A cost-benefit analysis tool called the Colorado Marijuana Energy Efficiency Calculator, was developed as a part of this study and available documentation is provided in Appendix B. With this tool, cultivators can assess their location, lighting, and climate control equipment and determine how different product choices can impact their energy consumption and bottom line.

Equipment Changes

Having efficient equipment is key to reducing wasted energy in a cultivator's operation. The two most energy-intensive equipment pieces, lighting and climate control, are detailed below.

LIGHTING FIXTURES

In 2014, Utah State University conducted a study to identify the most cost-effective fixtures for supplemental lighting in greenhouses. Although this study was not specific to marijuana cultivation, it still provides helpful insight. To evaluate cost-effectiveness, Utah State University measured two components of each fixture: the lights' conversion efficiency of electricity to photosynthetic photons and the lights' Photosynthetic Photon Flux Density (the amount of light that is delivered to your plant and hereinafter referred to as PPF).⁵³

The study determined the two most efficient LED lights and the two most efficient double-ended high pressure sodium (HPS) fixtures had equal and best efficiencies, which were dramatically better than the HPS fixtures that were in common practice at the time of writing. It also concluded that fluorescent fixtures were least efficient of the four main types of lights tested (LED, HPS, ceramic metal halide, and fluorescent). Although the five-year cost of light is 2.3 times higher for LED fixtures than for HPS fixtures, LEDs can provide precision delivery of photons which means LEDs to have the potential be a more cost-effective option for supplemental greenhouse lighting. Unsurprisingly, the lowest lighting system costs were realized when efficient fixtures were coupled with operations designed to maximize plant photon capture.⁵³

This study did not include reduced cooling and dehumidification costs associated with LEDs nor the bulb replacement costs associated with High Intensity Discharge lamps (HIDs). As manufacturers work to improve technologies, the LED cost per photon will likely decrease, and LED suitability for marijuana cultivation will continue to improve.

52 "Programs and Rebates" (2016) *Xcel Energy* https://www.xcelenergy.com/programs_and_rebates

53 Nelson & Bugabee, "Economic Analysis of Greenhouse Lighting: Light Emitting Diodes vs. High Intensity Discharge Fixtures" (2014) *PLoS ONE*. <https://doi.org/10.1371/journal.pone.0099010>



CLIMATE CONTROL

The primary task of a climate control system is to remove the heat produced by lights to maintain an optimal environment for the plants. Importantly, climate design depends on many factors including facility size, layout, growing methodology, lighting system design, watering schedule, and local climate. Climate control includes cooling, dehumidification, air movement, ventilation, and CO₂ control.

One step cultivators can take in order to save energy is strategic usage of dehumidifiers in concert with HVAC systems. Dehumidifiers help HVAC equipment run more efficiently since an air conditioning system is more effective at controlling temperature when humidity is managed. Additionally, a cultivator shouldn't place their dehumidifier next to the AC unit, as the cold dry air the AC is pushing out limits the dehumidifier's capability to pull moisture from the rest of the cultivation space.⁵⁴

A good dehumidification system can also reduce a cultivation's usage of their HVAC equipment. At night, when the lights go off in the grow space, temperatures tend to drop, increasing the relative humidity. Although cooling isn't required at these times, dehumidification is. By using a dehumidifier instead of an air conditioning system, cultivations can remove the excess moisture without additional temperature control and therefore save on energy costs.⁵⁵

There are design adjustments being tested in the market as well. For example, some cultivations are experimenting by placing cooling equipment closer to the plants where it is needed, instead of at the top of the room so that energy is not wasted cooling the top of the building. More research is needed in this area.

One of the most common mistakes cultivations make is the failure to invest in regular equipment maintenance to ensure operation at peak efficiency. This simple step can help cultivators increase the lifetime of their equipment and avoid unnecessary and costly equipment replacements.⁵⁶

54 "Efficiency Through Humidity Control" (2018) *Cannabis Business Times* <http://www.cannabisbusinesstimes.com/article/efficiency-humidity-control/>

55 "Efficiency Through Humidity Control" (2018) *Cannabis Business Times* <http://www.cannabisbusinesstimes.com/article/efficiency-humidity-control/>

56 "Cannabis Environmental Best Management Practices Guide" (2017) *Denver Environmental Health Cannabis Sustainability Group* <https://www.denvergov.org/content/dam/denvergov/Portals/771/documents/EQ/MJ%20Sustainability/Best%20Practices%20Management%20Guide%20web%20-%20final.pdf>

Incentives

In this report, incentives are in three categories: rebates, demand response programs, and rates.

REBATES

Rebates are monetary incentives offered by local utilities to encourage residential, commercial, and industrial customers to invest in energy efficient equipment such as lighting, HVAC, and motors by helping reduce upfront costs.

An analysis from 2012 determined that lighting and climate control account for 94% of the total energy intensity (kW/h/kg yield) required to grow and process a marijuana crop indoors. The term lighting includes lamps and all auxiliary equipment such as ballasts, light fixtures, and mechanized lamp rails. Climate control refers to ventilation, dehumidification, air conditioning, and heating.⁵⁷ Because lighting and climate control are the most energy intensive pieces of equipment, net energy use will be most impacted by implementing efficiency measures in one or both areas.

Many energy in Colorado providers offer equipment rebates (see Table 16). If a local utility does not offer rebates, it is still beneficial for customers to contact their utility about desired products so the energy provider can measure and compare demand for future offerings.

DEMAND RESPONSE

Demand response (DR) involves paying electricity customers to temporarily reduce their energy consumption during moments of stress on the grid (e.g. during peak demand hours or during emergencies such as power plant failure). Such programs and incentives are commonly employed by utilities and system operators as a sustainable alternative to maintaining balance between supply and demand. Participating in DR services encourages cultivators to reduce energy consumption during peak demand to generate costs savings and reduce their carbon footprint.⁵⁸

Xcel Energy offers the Peak Partner Awards program to any customer that is willing and able to shed 25 kW or more on call (called events) in the summer months (June through September) during peak hours (between 2 p.m. and 6 p.m.). The customer commits to the level of capacity they are willing to reduce (which is decided on a monthly basis) for which they are awarded \$2/kW per month for that commitment. If an event is called, the customer is also eligible for an additional credit of \$0.70/kWh throughout the duration of the event⁵⁹.

Demand-response aggregators, such as Sympower and EnerNOC, have developed cloud-based platforms that connect energy assets – such as lighting and climate control to a management control system. The connected appliances are powered up or down when available, for short periods, to provide electricity-balancing services without affecting their functionality.

A typical cultivator earns around \$30,000 annually for helping to balance the grid, typically by reducing their lighting for less than one hour a week.⁶⁰

57 Mills, E., (2012) "The Carbon Footprint of Indoor Cannabis Production" *Energy Policy* 46 (2012) 58-67

58 "Demand Response" *ENERGY.GOV* <https://energy.gov/oe/services/technology-development/smart-grid/demand-response>

59 "CO Peak Partner Rewards Program" *Xcel Energy* <https://www.xcelenergy.com/staticfiles/xcel-responsive/Programs%20and%20Rebates/Business/CO-Peak-Partner-Rewards-info-sheet.pdf>

60 Harel, L., Market Analyst at Sympower, personal communication, April - May 2016

Rates

TIME-OF-USE RATES

Some utilities offer time-of-use rates to commercial customers (see Table 16), and though they don't reduce energy consumption, they do reduce energy costs and balance system load. Time of use rates charge customers based on the time of day that the energy was used. During peak hours (usually 12-6pm on the weekdays) rates are higher than at any other time. Therefore, setting a grower's lighting schedule to use electricity during the evening and early morning, instead of in the afternoon, will cut energy costs. Interested parties should consult with their local utility for more information.

STAGGERING LIGHT CYCLES

Nearly all the cultivations examined in this report exhibit a cyclical pattern of energy consumption that follows the on and off lighting periods. When a cultivation has multiple separate grow rooms, staggering light cycles can provide an opportunity to reduce the peak energy demand for that facility for that day.

To demonstrate the impacts of staggering lights cycles, take a hypothetical cultivation that has four grow rooms that each operate for 18 hours a day with a lighting demand of 25 kW each. If all four rooms operate their lights during the same 18 hours, the peak demand would be 100 kW for 18 hours each day. If the rooms' lighting was staggered as follows, only three rooms at any one time would have lights on for a demand of 75 kW:

- ▶ Room One's lights operated from 0-18 (i.e. midnight until 6 pm),
- ▶ Room Two's lights operated from 6-24 (i.e. 6 am until midnight),
- ▶ Room Three's lights operated from 12-6 (i.e. noon until 6 am the following day), and
- ▶ Room Four's lights operated from 18-12 (i.e. 6 pm until noon the following day),

Some utilities apply demand charges for commercial and industrial customers. This means a utility must have a fixed charge based on the highest peak demand demanded by a customer during a pay period. Though this technique can reduce costs, it will not reduce consumption.

When comparing the data provided by Boulder County's Energy Impact Offset Funds for two of the sites, Site 5 (Figure 7) has more leveled consumption than the other sites (such as site 6 shown in Figure 8), because this cultivation is already staggering its light cycles. Site 5 is a good example of how peaks and valleys in electricity demand can be flattened utilizing this strategy.

Figure 7. Site 5 Daily Electricity Consumption by Day

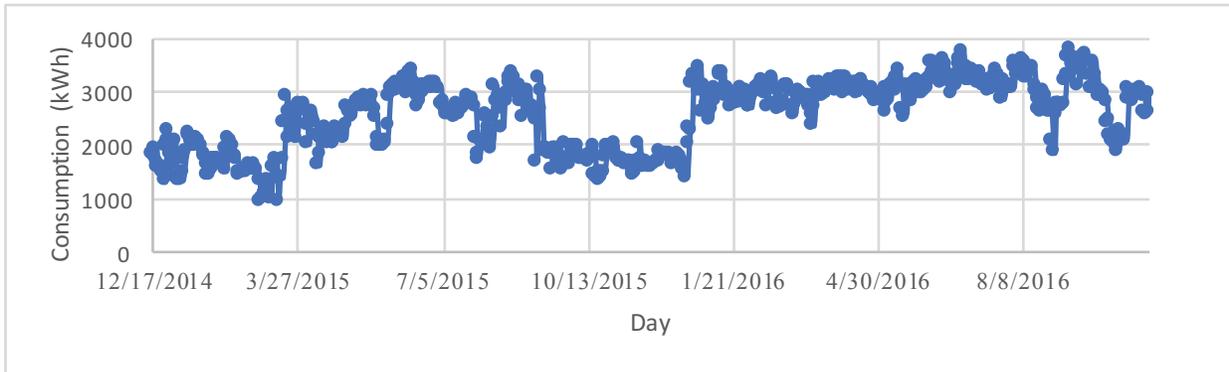
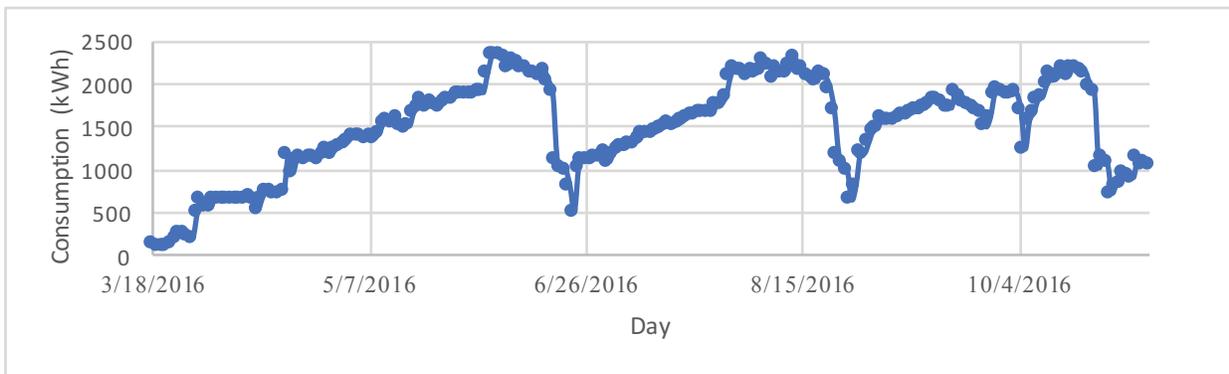


Figure 8. Site 6 Daily Electricity Consumption by Day



Net Metering

Net metering regulations are applicable to residential, commercial, and industrial customers that generate more electricity (typically sourced from renewable resources) on site than that customer consumes. All generation will be credited to a customer's bill and any net excess generation in a given month is applied as a kWh credit on the customer's next bill⁶¹. All electric service providers, except for those servicing less than 5,000 customers, must offer net metering benefits.

Although a complete energy offset from onsite generation is unlikely for most indoor and greenhouse cultivations, there are still partial cost reductions that onsite generation and net metering can offer.

Programs

GREEN POWER PROGRAM

Green power programs allow customers to purchase blocks of electricity from renewable resources at a premium price. Prices, generation resources (such as wind or solar), and opt-in and -out requirements vary by utility. While these programs do not reduce overall energy use or lead to better energy efficiency, they do provide an opportunity for businesses to invest in renewable energy.

61 NC Clean Energy Technology Center, DSIRE, Net Metering: Program Overview, Available: <http://programs.dsireusa.org/system/program/detail/271> Accessed August 7th, 2017

ENERGY STAR

At the Federal level, the EPA's Energy STAR program does not service marijuana cultivators specifically, however, it offers a Portfolio Manager® tool that provides business owners with a reliable way to track and benchmark energy and water use.

Table 16 provides high-level information on utility incentives and programs in the four counties that produce 75% of state's marijuana (Denver, El Paso, Pueblo, and Boulder). *It is important for all energy consumers to contact their energy providers prior to investigating and purchasing resources for any large-scale renovations or retrofit.*

Table 16. Utility Offerings at a Glance, Retail Providers in the Four Largest Marijuana Producing Counties (Denver, Pueblo, El Paso, Boulder produce over 75% of Colorado's marijuana) All of programs refer to those directed at commercial and industrial customers.

Utility	Equipment Rebates	Net Metering	Interruptible Service (Demand Response)	Time of Use	Energy Audit	Green Power Programs
Black Hills Energy	X	X	X		X	X
City of Fountain		X		X		
City of Longmont	X	X			X	X
Colorado Springs Utilities	X	X		X	X	
Mountain View Electric Assoc.	X	X				X
Poudre Valley Rural Electric Assoc.	X	X		X		X
San Isabel Electric Assoc.	X	X		X		
Southeast Colorado Power Association	X	X			X	X
Town of Lyons		X				
United Power	X	X		X		X
Xcel Energy	X	X	X		X	X

When cultivators engage with their local utilities, not only do they learn to take advantage of existing utility programs, but they also provide utilities with meaningful feedback about the needs of cultivations within the utility's territory. This information can help shape beneficial programs and rebates for cultivators in the future.



Improving Water Efficiency

Watering marijuana crop varies by the strain, the growth stage of the plant, and the cultivator's equipment. Technology, methodology, and preference vary from cultivator to cultivator and will be highly influenced by the infrastructure and climate in which the plants are grown.

Water Audit

Improving irrigation efficiency can reduce production costs and environmental impacts. A water audit measures the water used, as well as an assessment of effluent and wastewater quantity and quality. Irrigation methods and equipment, including filtration equipment, should be assessed along with any water efficiency measures and recycling processes that are already in place. Combined with production data, this assessment will determine the quantity of water used per piece of equipment and therefore the efficiency of the irrigation system. With this information, a cultivator can get detailed recommendations for water efficiency improvements. An analysis of the operation's water supply chain can also identify potential risks or environmental impacts, such as sourcing water from scarce or polluted regions.

Water Filtration

It is important to have clean and uncontaminated water to cultivate marijuana on-site. Water treatment can address issues such as:

- ▶ **Byproducts formed from delivery to the site and during treatment**
- ▶ **Contaminant intrusions from distribution line breaks**
- ▶ **Corrosion of the distribution system**
- ▶ **Other products from unknown sources in facility plumbing**

Water-treatment methods utilized by marijuana cultivators include reverse osmosis, carbon filtering, sedimentation tanks, and more. Reverse osmosis is a popular water treatment method that forces water through a fine membrane to remove dissolved minerals. In this process, many dissolved minerals in the water cannot pass through the membrane and are flushed away as waste. As a result, reverse osmosis produces a significant amount of wastewater; some efficient models advertise a 1:1 ratio (producing

one liter of usable water for every liter of wastewater)⁶², however many systems flush three to twenty liters of wastewater for every liter of treated, usable water.⁶³ By choosing alternative water treatment methods, marijuana producers can decrease the water consumption of their facility.

There are also some grow operations choosing not to filter their water and have found their cycles to be just as productive when using this unfiltered water. Cultivations that use water directly from the water provider reduce their facilities' energy use, water use, and costs. It is important for any grow operation that is considering taking this route to conduct a water quality and mineral content analysis before proceeding.

Irrigation Equipment

Although it sounds simple, many cultivators need to avoid over-irrigation. Not only does it use more water than necessary, but it additionally results in nutrient rich run-off. For cultivators, over-irrigation is usually a result of hand watering. By utilizing irrigation systems that water the plants automatically or that monitor the water content, cultivators can greatly improve their water efficiency.

DRIP IRRIGATION

Drip irrigation conserves water by releasing it exactly where it is needed and by keeping other areas around and in between the plants dry. These systems supply plants with drips of water via a thin tubing and small valves that only release drops of water at a time. Some of these systems will automatically water as the soil dries due to the natural suction triggering the opening of the tube. When the soil is sufficiently moist, the system naturally stops watering.



TENSIOMETERS

A tensiometer is a relatively inexpensive device used for measuring soil water tension and soil water conditions at a plant's roots. Tensiometer readings are easily interpreted and can be incorporated into automated irrigation systems. Automated sensor-based irrigation maintains a desired soil water range in the root zone that is optimal for plant growth. Observation of plant health and system maintenance is required.⁶⁴



62 "10 Best Reverse Osmosis Filter Systems & Reviews + Guide 2017)" (2017) *Reverse Osmosis Reviews*, <http://www.ro-system.org/>

63 "Reverse Osmosis Water Treatment" *Alberta Agriculture and Forestry*, (2002) [http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/agdex5432](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex5432)

64 Muñoz-Carpena, M., and Dukes, M. Nutrient Management of Vegetable and Row Crops handbook (SP500): Automatic Irrigation Based on Soil Moisture for Vegetable Crops. University of Florida IFSA Extension. 2015. Available: <http://edis.ifas.ufl.edu/ae354>



Time of Application

For outdoor and greenhouse cultivators, watering during cooler temperatures (early morning or in the later evening) is preferable as evaporation rates are slower. There are differences of opinion in the cultivation community as to whether it is preferable to water in the early mornings or at night for optimal soil health and plant growth.

Rain Delay

For cultivators that use automatic-irrigation systems outdoors, when rain is expected, these cultivators can set up a rain delay that will prevent the controller from watering while the delay is active. The rain delay stops all programs and protects plants from unnecessary irrigation.

IMPROVING EFFICIENCIES WITHIN THE INDUSTRY CONCLUSIONS

While there is still research that needs to be conducted in order to further energy efficiency in the cannabis market, there are many opportunities within a cultivation that cultivators can take advantage of immediately to improve efficiencies and cut costs. For example, by simply staggering the light cycle, a cultivator can reduce stresses on the grid and lower their electricity bill by reducing their demand charges.

Many utilities offer rebates and programs targeted at helping the industrial and commercial sectors. By talking to the local electric utility, cultivators will not only learn about and take advantage of existing programs, but will also be providing utilities with meaningful feedback about the needs of cultivations within their territories.

As local governments potentially start to mandate more environmentally friendly practices and set caps on licenses, cultivations that have more efficient operations will have lower costs and more stability during changing policy environments.

Barriers to Energy and Water Efficiency

FEDERAL BANKING RESTRAINTS

A primary barrier to getting greater penetration of more energy efficient technologies in the marijuana cultivation market is the inability for the industry to obtain financing due to federal banking restrictions. Although it is much more cost effective to install efficient lighting and water equipment in the design phase rather than in a retrofit, many cultivators simply do not have the money upfront. Access to financing would help cultivators obtain more efficient technologies when constructing and designing their cultivations.

OBSTACLES TO SCIENTIFIC RESEARCH

Unlike other agricultural crops, there has been a paucity of public funding for marijuana research. Publicly funded research is needed to determine and share how to best optimize production in a variety of cultivation settings. Existing industry practices on energy and water use have emerged primarily based on information sharing between cultivators. Increased public funding for scientific research would allow for the development of innovative technologies and methodologies specific to marijuana cultivation optimization, contributing to the growth and development of a sustainable marijuana industry.

INTERAGENCY COLLABORATION

For the research and data that is collected on this industry, there are many sharing restrictions. Multiple agencies have access to important marijuana industry data, but the ability to share this information between agencies is limited due to privacy concerns. It is critical that governmental agencies work collaboratively to advance science, research, and solutions for resource efficiency.

DESIRE FOR EFFICIENCY BUT LACK OF KNOWLEDGE/SKILLS

Alex Cooley, co-founder of Solstice and a National Marijuana Industry Association Board Member, stated during a California Public Utilities Commission policy and planning workshop that “the majority of cultivators in Washington care about energy efficiency, but their behaviors are inconsistent with environmental stewardship. Why? Because there is a steep learning curve for cultivators, and many cultivators are not aware that there are gaps in their knowledge, much less where to go for information.”⁶⁵ There is a need for strategic outreach to cultivators to educate the market on technologies, methodologies and incentives that increase efficiency without decreasing yield.

LOCAL PERMITTING

Colorado’s legislation allows for local control in permitting. Local land use decisions predominantly determine the method of cultivation, and in some cases marijuana cultivation is prohibited outdoors or in greenhouses. Local permitting officials have tremendous power to allow for facilities with decreased resource needs.

⁶⁵ Mulqueen, A., Lee, R., Zafar, M/ Energy Impacts of marijuana Cultivation: Workshop Report and Staff Recommendations. California Public Utilities Commission and Policy and Planning Division. April 2017

LED STIGMA

Ten years ago, when LED lights emerged on the market for marijuana cultivation, many cultivators experienced decreased yields due to insufficient wavelength spectrum. This has some cultivators reluctant to adopt LED lighting today, however there have been significant advances in LED technology over the past few years. Some cultivators continue to report decreased yields, while others report higher THC concentrations.⁶⁶ As technology improves, more cultivators experience success with LEDs, and as more information becomes available to the market, confidence in LED technologies will improve and adoption rates should increase within the marijuana community.



Recommendations

► Continued Scientific Research

Further research must be conducted in a variety of settings to determine optimal equipment and methodologies that increase yields while decreasing resource use, particularly energy and water. Once there is scientific data to determine best practices, informational materials should be developed and distributed to cultivators. This information should also be utilized to help inform changes to the building and energy codes.

► Update and Expand Colorado Marijuana Energy Efficiency Calculator

By including new technologies and expanding the Colorado Marijuana Energy Efficiency Calculator that was created for this report, cultivators can remain up to date on how different technologies impact their energy consumption and expected yield.

► Local Government

CEO should monitor the actions of specific local governments to understand how their laws may promote or stifle potential cultivation.

Because of the constraints of some local governments, it may be beneficial for the CEO to engage with local jurisdictions to share information on the energy intensity of different marijuana cultivation methods, and to discuss the intricacies of balancing public safety, aesthetics, and climate policy when considering permitting and zoning requirements.

⁶⁶ Mulqueen, A., Lee, R., Zafar, M/ Energy Impacts of marijuana Cultivation: Workshop Report and Staff Recommendations. California Public Utilities Commission and Policy and Planning Division. April 2017. Personal communication with marijuana Cultivators.

► **Building and Energy Code Updates**

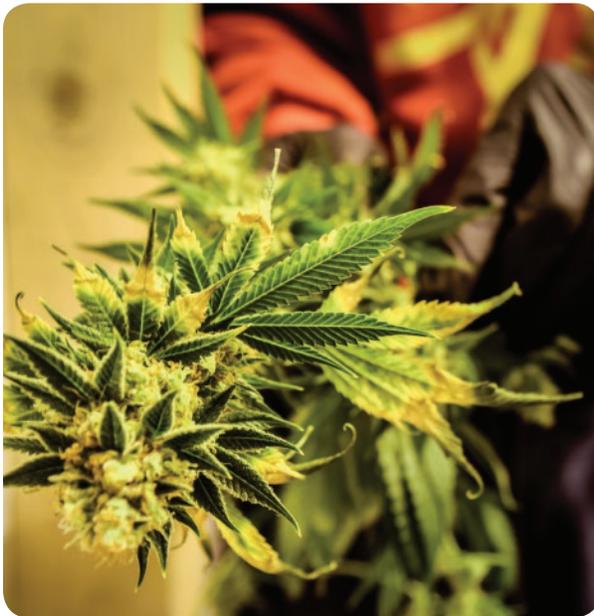
Marijuana cultivators have expressed concern that building codes are not always conducive to marijuana cultivation. It would be beneficial for the CEO to have a focused stakeholder group that included cultivators and engineers to develop provisions for consideration that would help local jurisdictions update the building and electricity codes specifically for marijuana cultivation.

► **Inter-agency Collaboration**

We recommend that governmental agencies find ways to facilitate further exchange of information in the name of scientific advancement, while continuing to protect the sensitivity and security of individual organizations and their data.

► **Educating Customers**

Consumers want to be able to make quick decisions with trusted information. ENERGY STAR is a voluntary energy efficiency certification program that brands energy efficient products with an ENERGY STAR logo to help consumers make easy and educated choices. There are a few marijuana-specific certifications that provide an eco-label to highlight products that are cultivated using the principles of organic agriculture such as DEM Pure, EnviroCann, Clean Green, Americans for Safe Access, and Certified Kind. The Cannabis Conservancy, contributor to this report, provides a Sustainability Certification to marijuana cultivators that adhere to the Seven Pillars of Sustainable Cannabis Production to assure that products are not only free of harmful chemical inputs, but are also energy and water efficient. By encouraging these types of programs, the CEO can help provide consumers with third party assurances regarding resource use and encourage demand for sustainably grown marijuana products.



Conclusion

Due to the fact that our estimates are only for dried flower product and do not take into account other marijuana products that are not only available in the market but are growing increasingly more popular, we chose to focus on the higher estimates from our analyses to try to more accurately describe the market. In conclusion, Colorado’s marijuana cultivation industry could potentially be consuming about 2% of Colorado’s annual electric generation (as of the year 2016). This large demand in a new and competitive industry is an opportunity to promote energy efficiency as a cost saving opportunity.

As for water consumption, compared to the energy impacts, our estimated water consumption of the marijuana cultivation industry in Colorado (523 AF) is a much smaller portion Colorado’s annual water consumption (less than a half a percent). Our report aims to encourage marijuana cultivations to be a leader in water efficiency and not simply reactive market participant as Colorado’s population, economy and their strains on Colorado’s water resources continue to grow.

Energy Consumption Estimates for Dried Flower Product			
Year	Low (000 MWh)	Medium (000 MWh)	High (000 MWh)
2014	325	600	928
2015	338	637	995
2016	355	700	1,115

Water Consumption Estimates for Dried Flower Product			
Year	Low (Acre-feet)	Medium (Acre-feet)	High (Acre-feet)
2014	153	281	435
2015	158	299	467
2016	167	328	523

Consuming an estimated two percent of Colorado’s energy generation is no small feat for a growing industrial sector. As this industry continues to grow, there are many opportunities for local and state governing bodies to reduce the industry’s potentially inefficient use of resources while also keeping the market healthy. With the declining price of wholesale marijuana, the market appears ready for cost saving methods. Ensuring cultivators have easy access and reliable information will be critical to achieving this.

As has been shown in this report, marijuana dispersion and growth is deeply impacted by the policies and regulations that are adopted by the state, its counties, and each of its home rule municipalities. Because of the history of marijuana legalization and how different localities have adopted different marijuana policy, most marijuana production and energy consumption has been concentrated in four counties, Denver, El Paso, Boulder, and Pueblo. Whether cultivators venture outside or stay within these populous counties, localities should consider how to craft good policies and programs and partnerships that will create the desired marijuana markets within their jurisdictions.

Additionally, there are opportunities within the market for cultivators to take advantage of costs savings almost immediately, including staggering their light cycles and HVAC system maintenance. Importantly, installing efficient equipment in the first place or replacing old equipment (particularly lights and climate control pieces) will be the biggest driver for reducing energy costs. As local governments potentially start to mandate environmental operations and limit competition within the market, cultivations that have more efficient operations will have lower costs and less risk, making them much more likely to remain competitive.



2%

Consuming two percent of Colorado's electric generation is no small measure for a growing industrial sector.

Our report aims to encourage marijuana cultivators to be leaders in water efficiency as Colorado's population, economy and demand on water resources continue to grow.

Case Studies

Introduction

For this report, three case studies were conducted on cultivation operations to collect energy and water use data to create a baseline for Colorado's marijuana industry and to provide information on the industry's energy and water use to the marijuana cultivation market. The Cannabis Conservancy (TCC) issued an open call to indoor, outdoor, and greenhouse cultivators through the Cannabase wholesale network and the National Cannabis Industry Association. The choice to participate anonymously or publicly was at the discretion of the participant. Participants were required to allow the installation of meters and sub-meters in their operation and to attend an individualized participant energy workshop which included: document reviews, interviews, and a grow system analysis.

THREE COLORADO CULTIVATORS AGREED TO PARTICIPATE IN THIS STUDY:

- **The Clinic**, an indoor facility;
- **Midwest Ranch**, a greenhouse; and
- **Pot Zero**, an outdoor farm.

These cultivators spent hours answering questions and providing data for this report; they participated for the betterment of the industry and did not receive remuneration. Specifically, these facilities provided historical energy data, historical water use data, production data, operational data, equipment specifications and allowed interval smart meters to be installed on their premises.

Power Takeoff provided the energy smart meters, the associated equipment, the real-time performance platform, and installation and use support. Thermal Energy System Specialists (TESS) provided energy and analysis support and assistance.



The Clinic: Cultivating Better Lives — An Indoor Cultivation Facility

The Clinic Organizational Overview

Founded in 2009 by Max Cohen and now operational in three states, The Clinic is one of the largest marijuana companies in the United States. The Clinic is committed to the health, safety, and well-being of their employees and the communities they serve. Renowned for the quality of its marijuana products, The Clinic has won more national industry awards than any other marijuana company in the state. In Colorado, The Clinic owns ten retail dispensaries, seven cultivation facilities, and three infused products and processing facilities.

The Clinic agreed to participate in this study because they had a desire to improve their sustainability and needed the data to identify opportunities for improvement.



Image 1. One of the Clinic's Dispensaries⁶⁷

⁶⁷ Photo provided by The Clinic

Led by Josh Malman, Grow Operations Manager, The Clinic has experimented with various new technologies and high efficiency lights in both vegetative and flower growth stages. Through their own research and development, they have concluded that the LED lights in the flowering phase have resulted in lower yields when measured by the traditional industry metric of pounds per light, but have found comparable or better results using the metric of grams per kWh. In the vegetative grow rooms, the LED technology has not only reduced power demand (due to the lower wattage lights with less cooling requirements), but for some strains has also increased growth rates.⁶⁸ The reduction in growing weeks alone has made The Clinic convert all vegetative grow rooms to LED lights. But due to the costs of having to replace each HID light with two LEDs, The Clinic decided to not replace the lights in the flowering room. To conserve energy during the flowering stage, The Clinic replaced their dated, single-ended HPS lights with the more photon-efficient Gavita DE 1000W HPS lights.

In addition to energy conservation, The Clinic has taken steps toward sustainable water use and waste management. They have installed a drip irrigation system in their flowering room, which allows them to fine-tune their water consumption and minimize runoff. They have also started to capture and reuse the condensate from their HVAC units to water their plants therefore reducing their water usage. In addition, all their organic waste is diverted to an anaerobic digester through a local waste management company.

The Clinic strives to be a trusted guide to not only their patients and customers, but to the entire marijuana industry. While they continue to look into national opportunities for expansion, Colorado will always remain a primary focus.

The Clinic Operational Overview

Location: Denver

Cultivation type: indoor

Building description: converted warehouse

Facility size: 25,000 square feet

Canopy size: 4,292 square feet

Primary water source: Denver Water

Secondary water source: n/a

Primary energy source: Xcel Energy

Secondary energy source: n/a

Primary heating source: natural gas

Secondary heating source: n/a

Cooling technology: rooftop units



⁶⁸ Malman, J., personal communication, 2017

The Clinic Methodology

Typical of many Denver cultivations, The Clinic grows marijuana in a retrofitted warehouse. Due to the building's pre-existing infrastructure and their multiple expansions, power connections and energy panels are scattered throughout The Clinic's occupied units. After consulting with The Clinic's Grow Operations Manager, the best location for the meters were identified to collect as much relevant energy data with as few meters as possible. Data was collected for four months from mid-September 2016 until mid-January 2017 for all panels. Table 17 details the equipment on each panel.

The Clinic's utility bills were separated by warehouse unit. Unit F corresponds with the 2,800 ft² flower room and Unit E includes the 2,000 ft² vegetative room and four 400 ft² flower rooms. These flower rooms were not separately metered during the study. The data for each unit contained 18 months of energy consumption (July 2015 - December 2016) and 13 months of water consumption (July 2015 - July 2016).

The Grow Operations Manager provided an analysis of the METRC harvest data to identify average yields per plant.

Table 17. The Clinic Metering Detail

Meter Location	Panel Name	Equipment
Vegetative	A3	<ul style="list-style-type: none"> • 12 – EcoPlus Oscillating Fans 12" • 4 – Dayton Oscillating Fans 20" • 2 – Dri Eaz Dehumidifiers • 18 – EcoPlus Submersible Water Recirculating pumps • 3 – Illumitex Power Harvest Tech 10S (LED) • 1 – Illumitex NeoSol DS (LED)
Vegetative	B3	<ul style="list-style-type: none"> • 49 – BML Spydr 600 • 1 – 2-Bulb Induction Light • 1 – Illumitex NeoSol DS
Vegetative	B4	<ul style="list-style-type: none"> • 18 – Illumitex NeoSol DS • 3 – BML Spydr 600
Flowering	GA	<ul style="list-style-type: none"> • 23 – Gavita 1000W DE
Flowering	GB	<ul style="list-style-type: none"> • 23 – Gavita 1000W DE
Flowering	GC	<ul style="list-style-type: none"> • 23 – Gavita 1000W DE
Flowering	GD	<ul style="list-style-type: none"> • 40 – Gavita 1000W DE
Flowering	RTU 1	<ul style="list-style-type: none"> • Carrier 10-ton RTU w/ Humidi-MiZer
Flowering	RTU 2	<ul style="list-style-type: none"> • Carrier 10-ton RTU w/ Humidi-MiZer
Flowering	RTU 3	<ul style="list-style-type: none"> • Carrier 10-ton RTU w/ Humidi-MiZer
Flowering	RTU 4	<ul style="list-style-type: none"> • Carrier 10-ton RTU w/ Humidi-MiZer

The Clinic Cultivation Overview

For The Clinic, a complete grow cycle (from cutting to harvest) lasts an average of 112 days, with an average of 10 days in clone, 39 days in vegetative (veg), and 63 days in flower. All of the lighting is controlled by automatic timers that are specified to each stage of the plant's growth cycle. Temperature and CO₂ (when used) are regulated by a series of sensors.

The Clinic begins their grow cycle by taking cuttings from mother plants and rooting them in EZ cloners. These clones grow under T-5 lights for 24 hours per day before being transplanted and moved into the veg room.

One room houses all of The Clinic's vegging plants. Plants mature in the veg room for four to seven weeks depending on the strain and typically receive eighteen hours of light per day from 4 am to 10 pm.

These plants are watered three times a week through ebb and flow sub-irrigation with each plant receiving roughly .15 gal per watering. When the plants are of adequate size, they are transplanted into 5-gallon pots and are hand watered two to four times a week, with each plant receiving between .5-.75 gals per watering.

When the plants are ready to begin flowering, they are moved into one of five flowering rooms to mature for about nine weeks. The main flower room holds 860 plants while the four smaller rooms hold around 900 plants combined. The main flowering room uses double-ended HPS (high pressure sodium) lights while two of the smaller rooms use LEDs (light-emitting diodes). The two other additional flower rooms use a mix of older model HPS lights.

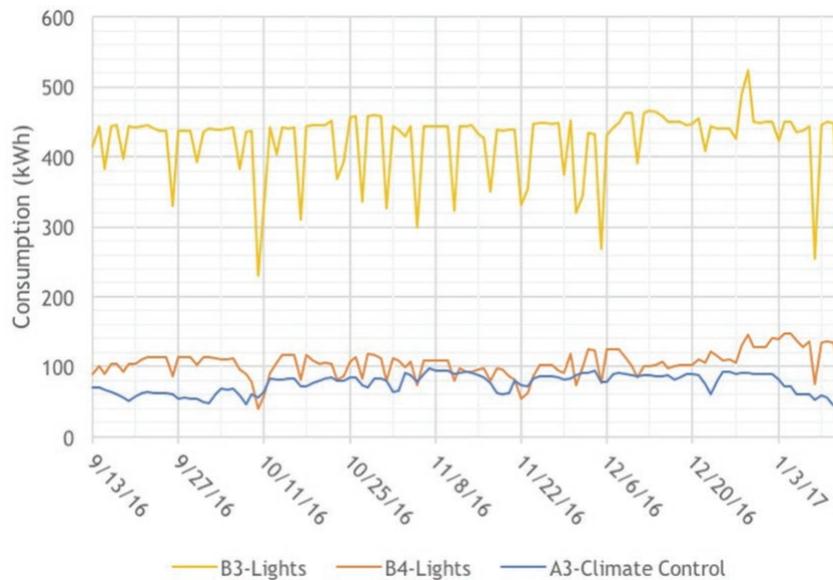
Additionally, the main flowering room has been retrofitted with rolling benches that roll three feet in either direction to maximize planting space under the lights and to eliminate the need for permanent walkways. When flowering, the lights are on for 12 hours per day from 8 am - 8 pm. Irrigation in all flowering rooms is done via drip irrigation that runs two to four times a day for a target amount of .66-.75 gal/pot/day.

The Clinic Energy Observations

This section will assess The Clinic's past and current cultivation style and provide insight into indoor grow operations in Colorado. The metered data was studied at daily, 1-hour and 15-minute intervals. For the daily data, both the total daily consumption and the daily peak demand were analyzed.

The daily energy consumptions for the three panels monitored in the veg room are shown in Figure 9. The climate control (A3) panel is quite variable, which is expected because of the mix of equipment it powers. The main fluctuations observed were an increase in consumption in early October and then a decrease in consumption beginning in early 2017. The daily peak demand data follows a similar trend suggesting that the changes in consumption are due to more equipment operating simultaneously or equipment operating at less efficient conditions. The increase seen in October is likely related to a transfer of equipment as they prepared to change the lights in the main flower room and no explanation could be identified for the January decrease.

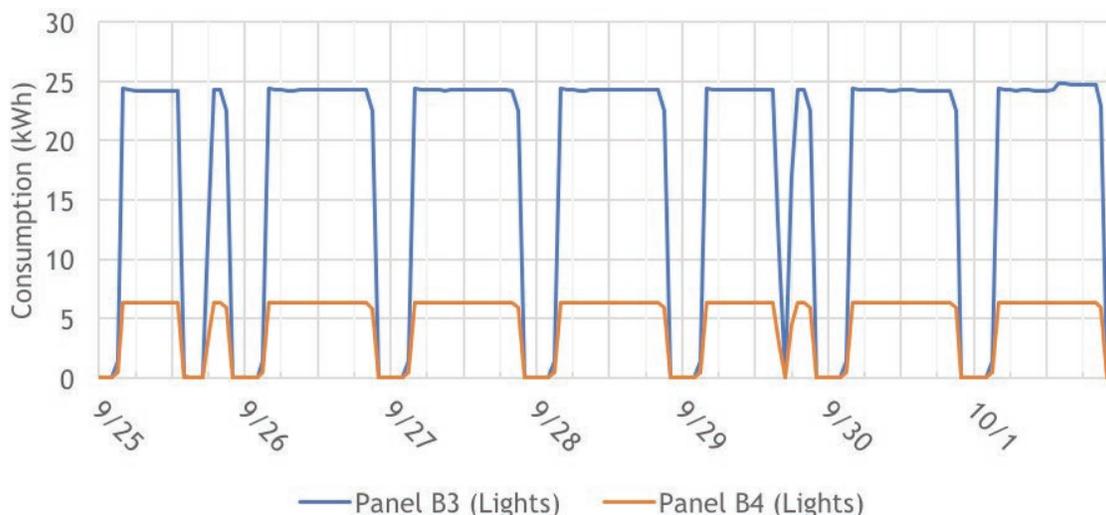
Figure 9. The Clinic Vegetative Room Daily Energy Consumption, September 13, 2016 – January 3, 2017



The daily consumption plot for Panel B3, which contains only lights, shows very consistent off and on periods that is expected with a lighting system that operates on a controlled schedule. Since Panel B4 also includes only lights, we would expect to see data like panel B3; however, the daily energy use shows inconsistent on and off periods with varying levels of consumption. This variability is a result of changes to the lighting, since the behavior is repeated in the daily peak demand and was confirmed by the Grow Operations Manager.

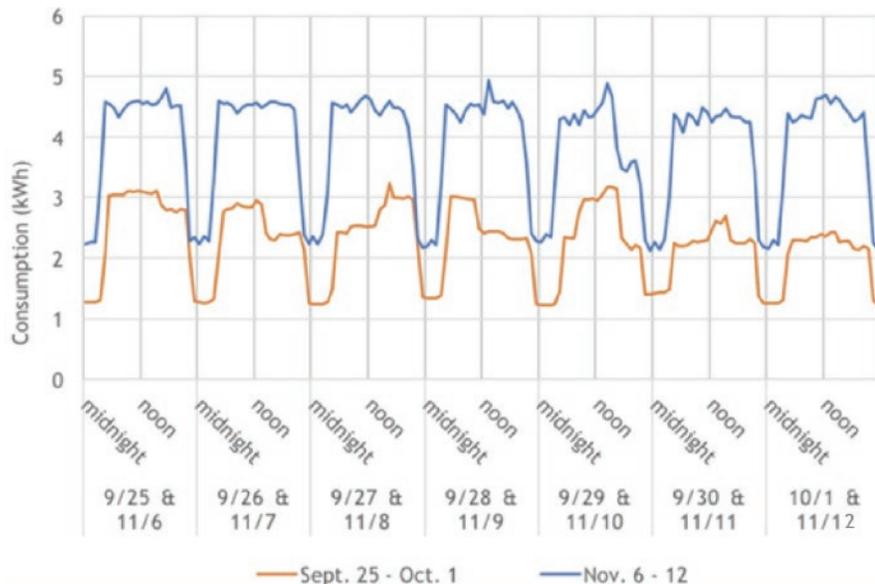
Figure 10 shows one week of panels B3 and B4 that was sampled and measured in 1-hr intervals. As expected, the lighting consumption shows very regular periods of consumption when the lights are on and off. This pattern matches the stated 18 hours per day that the lights are on. There are two inconsistencies during this week where the lights were turned off not on their scheduled times.

Figure 10. The Clinic Vegetative Room Panel A4, 15-Minute Energy Consumption, September 25–October 1 and November 6 – 12



Consumption data for Panel A3 in the vegetative room are shown in Figure 11. This panel captures the consumption of 16 oscillating fans, two dehumidifiers, 18 water recirculating pumps, and three lights. When lights are on, they generate a lot of excess heat that needs to be pulled out of the room to keep the plants healthy. Because the dehumidifier is the largest source of energy consumption on this panel, it shows a pattern of energy consumption that mimics the lights. This equipment’s energy consumption is equivalent to 10% of the lighting consumption.

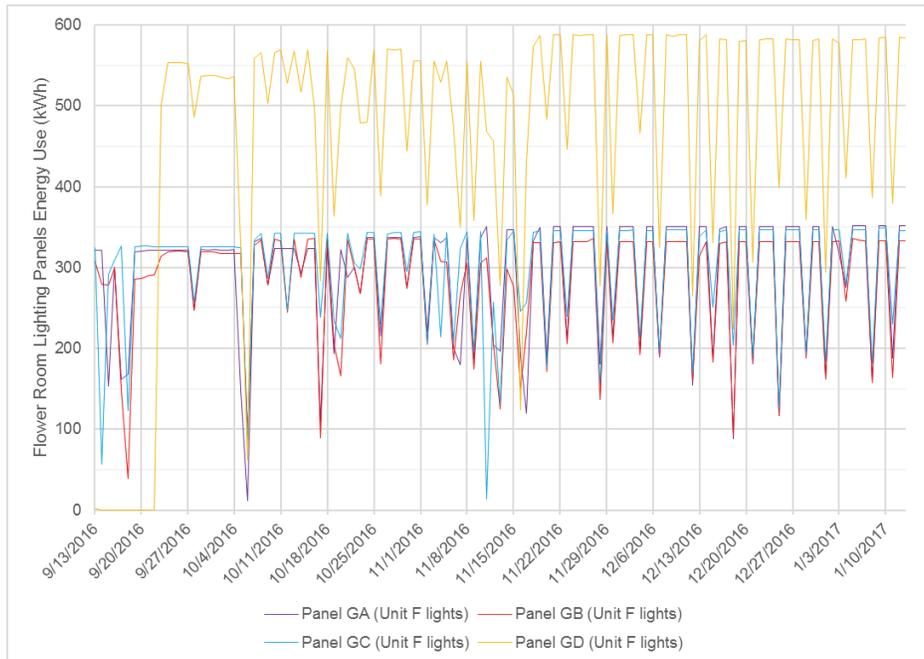
Figure 11. The Clinic Vegetative Room Hourly Energy Consumption, September 26th – October 1st, 2016



Four panels of 109 thousand watt DE HPS lights were monitored in the main flowering room. (figure 12) All four panels show the expected consumption pattern for a lighting system, but there are three distinctive periods of different consumption levels. The first and lowest occurs during September and continues into the middle of October. The consumption then increases through the beginning of November and increases again in mid-November where it remains at the higher consumption level. The same pattern can be seen in the daily peak demand meaning that the lights are consuming more power rather than just running for longer hours. No explanation could be uncovered for the first change in power consumption, but the second increase in power was due to a change in ballasts to correct the voltage from 270 V to 208 V.

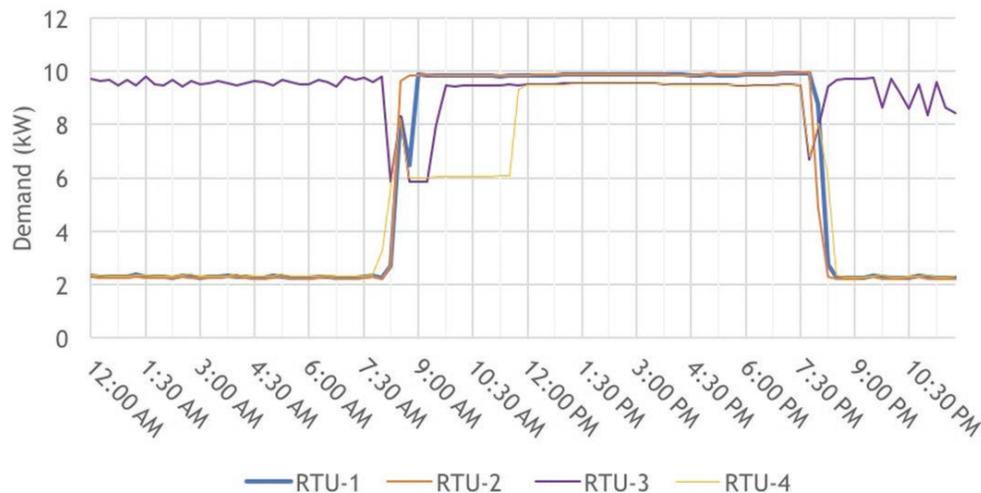


Figure 12. The Clinic Flower Room Lighting Panels, Daily Energy Consumption, September 13, 2016 – January 13, 2017



The climate control for the main flower room is performed by four 10-ton rooftop units that provide both temperature and humidity control. Each unit was metered on its own panel (RTU-1, RTU-2, RTU-3, and RTU-4). Since the equipment is for climate control, the average daily temperature for Englewood, CO was compared and there was no correlation between energy consumption and outdoor conditions, meaning the internal heat gains are the main drivers of climate control equipment (See underlying data in Appendix A). This is confirmed when noting that the energy consumption for RTU-1, RTU-2, and RTU-4 follow the same consumption pattern as the lighting.

Figure 13. The Clinic Flower Room Energy Demand Data, November 9, 2016



During December, RTU-1, RTU-2, and RTU-3 showed an increase in consumption. This could be explained by the room needing more dehumidification since December was the first month the room was back at full capacity after the lighting change.

It is also interesting to note that RTU-3 never turned off. There are several possibilities for this consumption difference compared to the other units. This unit provides dehumidification for the entire room, the control system may not be set up correctly, or the equipment is malfunctioning. We do not have the operational strategy for this equipment so we cannot state why the consumption is different. But this also highlights the importance of measuring the performance of the equipment to ensure it is aligning with a cultivator's operational strategy.

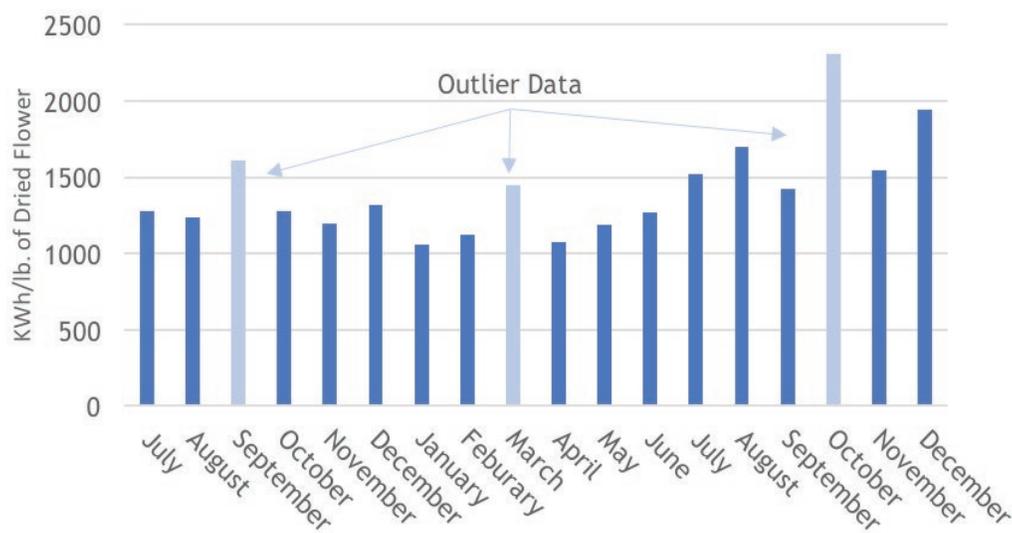
These figures demonstrate how energy consumption (and thus demand) in a grow operation is exponentially dependent on the types of lights used and time of day it is consumed. Using more efficient lights can reduce climate control needs, while staggering light cycles can help reduce demand at any given point during a day.

Production Compared to Energy Consumption

For our production analysis, we focused on dried flower yield because that is the primary product that The Clinic produces (trim and shake are considered usable byproducts). In October, The Clinic changed the lighting in the main flower room from single ended HPS fixtures to HPS lights that are industry-leading in energy efficiency, allowing us the opportunity to compare metrics between the lighting configurations.

Historical data was used to determine the operation's estimated monthly kWh/lb. of dried flower and is visualized in Figure 14. The monthly energy consumption was taken from previous utility bills and the monthly harvest yields were determined from The Clinic's data by applying the average plant yield to the number of plants harvested that month. The months of September, March, and October are shaded to denote outliers in the data.

Figure 14. The Clinic Monthly Electricity Consumption per Production, July 2015 – December 2016

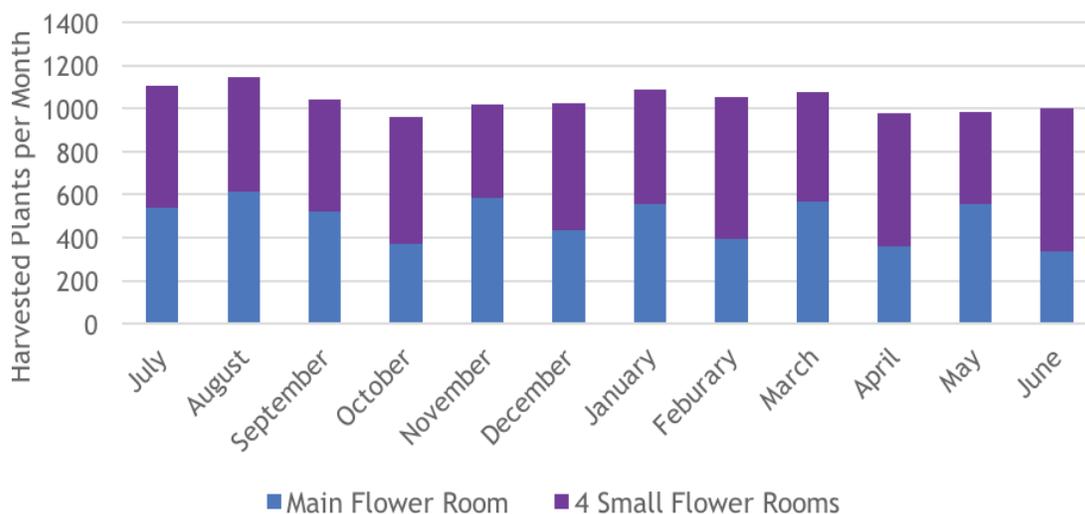


September and March had unexplained utility bills for Unit F that were 57% higher than the surrounding months. After accounting for the outliers by substituting the average of the two surrounding months, the average monthly production efficiency metrics for the year July 2015–June 2016 (data with The Clinic’s past lighting configuration) were:

- ▶ 1,201.8 kWh/lb.
- ▶ 0.095 g/kWh
- ▶ 113.9 kWh/plant

Figure 15 shows the plant harvest breakdown by flower room each month. From this figure, one can see the four smaller flower rooms have a more consistent production pattern while the main flower room alternates higher months with lower months. While the energy consumption from the monthly utility bills does show a minor cyclical pattern, it does not seem to correlate to the number of plants harvested.

Figure 15. The Clinic Flower Room, Plants Harvested per Month, July 2015 – July 2016



For the new configuration, because of the installation of new lights, The Clinic only harvested 53 plants from that room for the month of October, skewing the data for that month. Therefore, for the production metrics of the new configuration, the average of the two October-surrounding months were used in place of the outlier data. Based on observations of the first harvests from the main flower room’s new lighting configuration, each plant is producing an average of 225 g (7.94 oz.) of dried usable product with 49-53% being flower. This leads to an average dried flower yield of 115 g (4.06 oz.) per plant. This is a 267% increase in dried flower yields over the previous lighting setup which averaged 92 g (3.25 oz.) of dried usable product and 43 g (1.52 oz.) of dried flower per plant.

Energy Analysis

To determine the current energy consumption, baseline metering data collected for the four months between September 12, 2016 and January 12, 2017 were analyzed.

VEGETATIVE ROOM

The room used for all of The Clinic's vegetating plants is 1,965 ft² and has a plant capacity of 1,870 plants with a canopy space of 1,152 ft². Though the lighting system is constantly changing, the latest lighting configuration has a total wattage of 33,380 W giving the room an average of 28.9 W/ft² of canopy.

To estimate the vegetative room's annual energy consumption, the daily energy consumption was determined from data collected over the 123-day monitoring period and then extrapolated for a full year. For the 123-day period, the metered equipment in the vegetative room, which included the lights, fans, and dehumidification units, consumed 74.3 MWh with a daily average of 604.3 kWh. Since the meters were not able to capture the two 10-ton A/C units in use, the data collected from similar units (RTU-1, RTU-2) in the flower room were added for a more complete representation; in reality, the HVAC consumption rate will be slightly higher in the vegetative room as the units currently in use are older and less efficient.

To estimate the annual demand, the 123-day total energy consumption was divided by 123 to get a per-day usage, and then multiplied by 365 to get annual consumption, totaling 328.9 MWh for the veg room for the year.

Energy use by piece of equipment is in Table 18. Lighting contributed to 58.6% of the veg room's total energy consumption, HVAC contributed 32.8%, and fans and dehumidification were 8.6%. These numbers are not completely accurate as some lights were on the fan and dehumidifier panel.

Table 18. Vegetative Room Daily Average and Annual Energy Consumption by Equipment

Equipment	Daily Consumption Average	Annual Consumption
Lights	528.23 kWh	192.8 MWh
Oscillating Fans, Pumps, Dehumidifiers	76.09 kWh	27.78 MWh
AC Unit (RTU-1)	149.73 kWh	54.65 MWh
AC Unit (RTU-2)	145.89 kWh	53.25 MWh

MAIN FLOWER ROOM

The main flower room is 2,830 ft² and holds 865 plants with an average canopy space of 1,540 ft². The room has a demand of 109,000 kW of lighting equal to a consumption of 70.8 kWh/ft². The total estimated main flower room's annual energy consumption with the new HPS lighting configuration is 735.69 MWh per year.

Table 19. Flower Room Daily Average and Annual Energy Consumption by Equipment

Equipment	Daily Energy Consumption	Annual Consumption
100 Double Ended HPS Lights	1,335.70 kWh	487.53 MWh
RTU-1	149.73 kWh	(Combined RTUs) 235.47 MWh
RTU-2	145.9 kWh	
RTU-3	204.32 kWh	
RTU-4	145.18 kWh	
Oscillating & HAF Fans		12.69 MWh

To estimate the main flower room’s current energy consumption, the same process that was used for the vegetative room current energy consumption is used, resulting in the main flower room’s annual energy consumption with the new HPS lighting configuration at 735.69 MWh per year. Daily and annual energy use by equipment can be found in Table 19.

The old flower room consisted of 70 single- ended HPS lights, 27 LEDs, four older-model RTUs, and a few standalone dehumidifiers. Analyzing the historical data from July 2015 to June 2016 revealed the main flower room’s old configuration annual energy consumption to be 518.8 MWh. Since the months of September 2015 and March 2016 were outliers, the average of the surrounding two months for each outlier were used.

Grow Cycle

To compare the new and old lighting configurations in the main flower room for The Clinic, we are going to compare the energy used for the grow cycles.

For the clone stage, only the lighting could be estimated with the available data. The clone room uses 10 T-5 lights running 24 hours/day that annually consume 20.7 MWh.

Since the veg and clone rooms grow all the plants that eventually feed into all five flower rooms, 50% of the veg and clone rooms’ energy consumption is allocated to the main flower room, because it holds 50% of the flowering plants. By combining these totals, (10.35 MWh/year for clone and 164.45 MWh/year for veg) the estimated annual energy consumption for the entire grow cycle when only considering the main flowering room for the flower stage is 910.5 MWh/year.

The main flower room’s old set up consumed 518.8 MWh/year for an annual total consumption through the entire grow cycle of 693.6 MWh/year. This equates to a production efficiency of 1,253.5 kWh/lb. of dried flower, 0.36 g of dried flower/kWh, and 118.8 kWh/plant.

The current configuration (which began in September 2016) has 109 Double-ended HPS lights and four newer-model RTUs running humidi- MiZers. When comparing the two operations, the new configuration uses an average of 19.7% more energy due to the increased number of lights and the lights’ higher power.

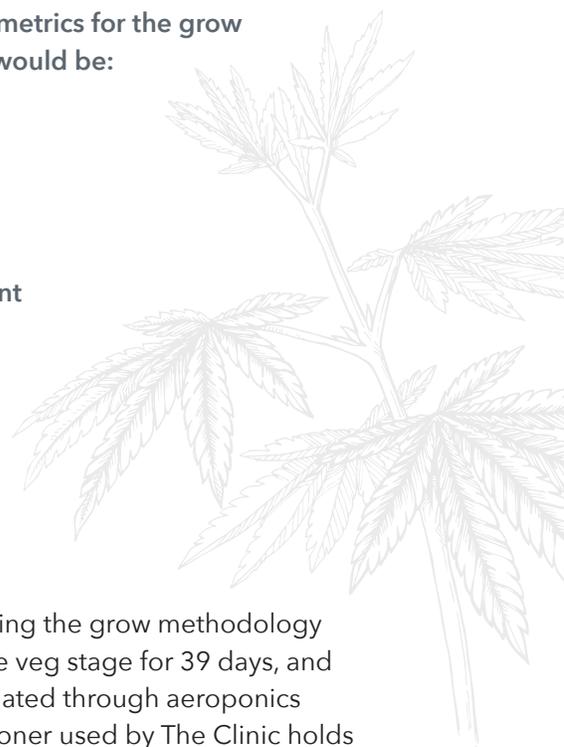
If the preliminary observation of an increased average yield per plant of 115 g of dried flower continues with the new lights, the switch to double-ended HPS lights will have resulted in a 270% increase in flower production and a 240% increase in total dried useable material with only a 19.7% increase in energy consumption. In addition, under the new lights, plants are growing larger, requiring fewer plants for greater yields. At the time of this study, The Clinic was experimenting with placing five plants under each light instead of the previous nine, with the goal of decreasing the overall number of plants while increasing each plant's size and yield. With an average of 5.8 cycles per year, this would lower the harvested number of plants from 5,837 a year to 3,161 a year.

Using the plant counts from July 2015-June 2016, the production metrics for the grow cycle using the flower room that was monitored during this study would be:

- ▶ 1,645.6 kWh/lb. of dried flower
- ▶ 0.28 g of dried flower/kWh
- ▶ 156.0 kWh/plant

At the release of this report, The Clinic has reduced their plant count to 5 plants under each light making the production efficiency:

- ▶ 1,136.1 kWh/ lb. of dried flower
- ▶ 0.40 g of dried flower/kWh
- ▶ 288.0 kWh/ plant



The Clinic Water Analysis

The water consumption per plant and yield was estimated by first analyzing the grow methodology used by The Clinic. An average plant is in the clone stage for 10 days, the veg stage for 39 days, and the flowering stage for 63 days. During the clone stage, cuttings are irrigated through aeroponics (growing plants in an air or mist environment) in an EZ Cloner. The EZ Cloner used by The Clinic holds 20 gals of water and 128 clones. The exact amount of water used per plant over the ten-day period was not measured. However, since the water loss in this type of system is minimal and mainly due to evapotranspiration, we conservatively estimated clone stage water usage at 0.1 gal/plant.

During the average 39-day vegetative stage, plants are watered differently as they grow. When first transplanted and moved into the veg room, plants are watered three times a week with about .15 gal per watering by sub-irrigation via an ebb and flow process. As the plants mature, they are hand watered twice a week with a target of a half-gallon per watering. Prior to moving to the flowering room, irrigation is increased to four times a week with an estimated volume of 0.75 gallon per watering. To estimate the total irrigation in the veg stage, we divided the process into three equal parts of 13 days to account for each watering method, creating the equation:

$$(0.15 \text{ gal} \times 6 \text{ watering events}) + (0.5 \text{ gal} \times 4 \text{ watering events}) + (0.75 \text{ gal} \times 8 \text{ watering events}) = 8.9 \text{ gal}$$

In the flowering stage, drip irrigation is used to water the plants two to four times a day for a total amount of 0.66-0.75 gal/day. The average plant will get 44.42 gal of water during the flowering stage.

For the entire grow cycle each plant is watered with approximately 53.32 gal, which equates to 1.2 gal/g of dried flower and 563.5 gal/lb. of dried flower.

During the study, The Clinic's office provided water consumption figures in the form of past water bills. Upon further inquiry, it was discovered that the water bills The Clinic receives are not from a water meter but are estimations of their share of the entire complex's water usage. This is not an uncommon practice in Denver. An analysis based on The Clinic's production was conducted based on this water bill data.

From the water bills for Units E and F, the annual irrigations from July 2015 to June 2016 were 648,780 gal and 324,390 gal respectively. This equates to an average water efficiency of 0.55 g of dried product/gal and an average water consumption rate of 822.6 gal/lb. of dried usable product. These water consumption results are 69% higher than the growing method analysis. This very large discrepancy should serve as a reminder to cultivators to understand where the data comes from when doing assessments of their operations.

The Clinic Conclusions

The smart meters provided rich data on the energy consumption and demand for two units and multiple plant growth stages in The Clinic's grow facility. Lighting, as to be expected for both units, had regular and cyclical operational patterns which forced the rest of the equipment (most of which are focused on reducing the heat produced by the lights) to follow a similar pattern of consumption.

The installation of higher efficiency double-ended HPS lights in the main flower room resulted in an almost 20% increase in energy consumption. However, production metrics in this new configuration showed a 270% increase of yield from 43 g of dried usable product per plant to 115 g. These results highlight the role production plays in increasing energy efficiency.

Additionally, this new configuration allowed The Clinic to reduce their plant count from 5,837 plants per year to 3,161 plants. The Clinic is now getting higher yields from fewer plants with this equipment change and is saving on labor, nutrients, and other material costs.

The barriers to collecting and effectively analyzing detailed data are shared among many cultivations and demonstrate the importance of considering resource efficiency early in the facility-design and construction process.

Midwest Ranch: Quality Practices = Outstanding Products – A Greenhouse Cultivation Facility

Midwest Ranch Organizational Overview

Midwest Ranch is a family-run recreational wholesale fulfillment company located in Boone, Colorado near Pueblo. Established in 2014, they now sell statewide to dispensaries and concentrate producers. At Midwest Ranch, they value safety, a family atmosphere, and a solid product; one that is pharmaceutical grade and environmentally friendly. Their overall aim is to produce a large variety of consistently high-quality flower and trim.



Image 2. Midwest Ranch Sign

To achieve the quality and consistency their customers have come to expect, Midwest's grow system focuses on automation and a well-trained agricultural team. The cultivation system is designed to be fully automated including light, humidity, temperature, and strain specific nutrient mixes.

Jeff and Jenn Ayotte entered the marijuana industry looking for a new challenge. Jeff designed Midwest's system and oversees the management of the company, while Jenn runs the agricultural side of the business. When designing the system, Jeff relied on his experience creating high performance operations in the food, beverage, and pharmaceutical industries by incorporating good manufacturing practices that focus on automation and staff training to minimize contamination and infestations.

Midwest prides itself on its energy and water efficiency. Due to its location in Colorado's desert region, energy efficiency and water conservation principles were designed into the grow system. This started with the decision to grow in a greenhouse to take advantage of the sunny location. Additionally, the building utilizes multiple layers of insulation to minimize the effect of the variable outdoor temperatures that range from below freezing to more than a hundred degrees Fahrenheit.

To operate the facilities efficiently, Midwest Ranch has installed industrial quality, high performance equipment which needed supportive infrastructure, requiring the business to bring 3-phase power to the site as well as lay 2,800 ft. of high pressure gas lines. As an indeterminate utility customer, they paid for the full cost of these upgrades, but these upfront costs are expected to be mitigated by lower utility bills.

Midwest Ranch Operational Overview

Location: Boone, CO

Cultivation type: greenhouse (flower),
indoor (propagation/vegetative)

Building description: modified
greenhouse, insulated warehouse

Facility size: ~29,000 sq. ft.

Canopy size: ~23,925 sq. ft.

Primary water source: purchased water

Secondary water source: well water

Primary energy source: Black Hills Utility

Secondary energy source: n/a

Primary heating source: natural gas

Secondary heating source: n/a

Employees: 25

Cooling technology: customized
evaporative cooler

The Midwest Ranch cultivation facility is comprised of two main buildings: a warehouse and a greenhouse. The warehouse is a 6,400 ft² two-story building that includes offices, convertible workspaces, drying rooms, curing rooms, and two cultivation rooms. The building envelope was designed for Pueblo's desert climate and is comprised of a standing seam metal shell with three layers of insulation (R11 reflective bubble material, 2" closed cell foam, R19 fiberglass) in between. The propagation room is 2,365 ft² and houses the mothers (original strains of marijuana that are never brought to flower) and approximately half the vegetative plants destined for the greenhouse. Clones are propagated in a separate room measuring 252 ft².

The 20,000 ft² greenhouse is actually two identical 10,000 ft² spaces adjoined lengthwise and used exclusively for the flowering stage. The greenhouse is a modified NEXUS structure with four 5,000 ft² peaks, two per side. The sides of the greenhouse are well insulated by sandwiching a 6" air gap with R11 Reflective Bubble material which is then encased in 26-gauge standing seam metal. The rooftop panels are 85% diffusing Soft Solar panels and light deprivation is achieved using a triple layer, reflective topped curtain with an R-Factor of 10.

There are two rooms attached to the greenhouse. The 1,288 ft² South room houses the equipment to run the facility (water purification, HVAC, automated system controls) and the 2,385 ft² North room is used as an additional indoor vegetative grow room.



Midwest Ranch Study Methodology

Two smart meters, one in the greenhouse and one in the warehouse, were installed at Midwest Ranch from September 2016 to early January 2017. In the production room, electricity usage was monitored for 123 days. The meter in the greenhouse monitored only 84 days of electricity usage. The time discrepancy is due to meter uplink issues stemming from the remoteness of the site.



Image 3. Smart Meter

Photo taken by Jacob Policzer

Both meters monitored the entire building where they were located. The greenhouse included lights, fans, A/C, pumps, compressors, and other various equipment. The meter on the warehouse included the cultivation rooms and office space.

Access to the cultivation areas was limited to maintain the integrity of those areas. Information for this study was collected through interviews and documentation provided by Midwest Ranch. This included utility bills and METRC reports, though many of the documents were incomplete and could not be used for a more thorough analysis.

Minute interval data from the Argus controller for November and December was provided for both sides of the greenhouse and the growing room in the warehouse building. This data was intended to be used to identify detailed equipment consumption figures; however, Midwest Ranch also uses a Siemens PLC to control equipment and without the operational settings for both systems, too many unexplainable inconsistencies arose to use the data in this report.

Midwest Ranch Cultivation Overview

At Midwest Ranch, the clone room contains six 4 x 8 ft. beds with two T-5 light fixtures each, for a total of 12 lights in the room that operate on a 24-hour schedule. The room does not have a separate HVAC system and instead utilizes the building's air conditioner for climate control. There are three horizontal air flow (HAF) fans in the room for air circulation and heating is provided by nine heating mats positioned on top of the grow tables. Clones are transplanted into Jiffy plugs and hand watered as needed.

The propagation room uses two 5-ton Carrier A/C units with economizers and condensing units to enhance the A/C units' operational efficiency. These units are programmed to shut off at 52 degrees Fahrenheit and air is circulated by fifteen HAF fans. The forty to fifty mother plants are arranged on one 6x20 ft. single stack bed under thirteen T-5 lights while the vegetative plants are arranged on twenty-seven 4 X 8 ft. beds with two T-5 lights per bed. Each bed for the vegetative plants averages 32 plants for a total capacity of around 864 vegetative plants.

Prior to entering the vegetative stage, plants are transplanted into 5-gallon pots and are exposed to light for 20 hours/day between 8pm and 4pm. Watering is automated via a drip irrigation system using ½ gal/hour emitters. During the study period, watering was done on an as needed basis as Midwest was still fine tuning their schedule.

The North room attached to the greenhouse has a similar set-up to the warehouse's propagation room. Vegetative plants are arranged on twenty-six 4 x 8 ft. tables with two T-5 lights per table. Each table averages 32 plants for an average total capacity of 832 plants. For HVAC, the room uses two 3-ton Carrier ductless split units, a 24" damper controlled exhaust fan, and fifteen HAF fans. Heat, when needed, is provided from a 6,000 BTU Natural Gas Resonator and Hot Dawg Furnace, which is located in the room but actually primarily services the greenhouse. The room also contains an assortment of equipment such as control panels and pumps which are detailed in Appendix A.

The South room attached to the greenhouse contains the water filtration system, an additional 3-ton Carrier ductless split unit, and a Hot Dawg Furnace for the greenhouse.

As previously mentioned the greenhouse is 20,000 ft² divided into two identical 10,000 ft² sections. For supplemental lighting, the greenhouse uses 392 Gavita 1000 W Double-ended HPS lights, giving the greenhouse a lighting intensity of 19.6 W/ft². These lights are arranged in 12 rows of 18 lights with each light spaced 7 ½ ft. apart. The lighting system demands 15.58 W/ft². For control purposes, the lights are setup in an alternating quadrant format with each quadrant containing 98 lights. The lights are controlled by a Siemens PLC unit linked to an Argus system with sensors throughout the room that measure the Photosynthetic Photon Flux Density (PPFD). When the levels are below a certain threshold, a quadrant of lights is turned on every five minutes until the desired PPFD is reached.

The greenhouse lights are designed to have a 20-minute delay before turning on to account for short lived cloud cover. Additionally, a light deprivation system is used to provide the necessary dark hours required to induce flowering. The lights can be activated from

7am-7pm during the summer months and 5am-5pm in the winter months. This setup increases the energy efficiency of the greenhouse by maintaining a consistent light intensity with a minimal number of lights.

Cooling of the greenhouse is done through a custom designed industrial water wall with cool air specifications. Air is circulated by 33 V-Flow fans and an array of exhaust fans. Each of the four greenhouse peaks contains one 24" exhaust fan and four 48" exhaust fans. Supplemental CO₂ is provided by run lines in each table emitting 2.5 minute bursts every 15 minutes with a target threshold of 1,400 parts-per-million (ppm).

The greenhouse utilizes custom designed rolling tables to maximize space and can hold over 5,100 plants but only operated at around half capacity (around 2,500 plants) during this study. Irrigation is done through a drip irrigation system. Each plant pot has two ½-gal/min emitters and the system runs for either 14 minutes twice a day or 34 minutes once a day depending on the stage of growth. During the last week in flower, each plant is flushed with two gallons of water every other day. Water is sourced from a mix of well and purchased water.

The greenhouse has two storage tanks (5,000- and 2,500- gallons respectively) plus a 7 ½ acre-foot pond onsite. Because Midwest is a marijuana cultivation located in the Arkansas Basin, they are required to purchase fully consumable water rights. Midwest Ranch buys approximately five acre-feet of water from the Arkansas Groundwater Users Association annually. Due to the high costs of water, the system was designed with water efficiency in mind and the manager estimates they recycle 80% of their water runoff, mainly by reclaiming it through a series of floor drains in the greenhouse and in the vegetative rooms. The facility uses a state of the art reverse osmosis system to purify all incoming and recycled water.

Midwest Ranch Cultivation Analysis

PRODUCTION ANALYSIS

Midwest Ranch averages a 16.5-week grow cycle. The length of time a plant spends in each growth phase can vary dramatically depending on the strain, of which Midwest Ranch cultivates over 75 types. On average, plants spend 12-14 days in clone, 4-5 weeks in the vegetative stage and 8-12 weeks flowering.

From the METRC data provided, Midwest Ranch harvested 8,055 plants in 2016. During the study period, 126-195 plants were harvested each week and increased to around 300 plants each week in 2017. From June to August 2016, 1,535 plants of 36 different strains were harvested with a per plant yield ranging from 35.3 to 417.7 grams of dried flower. The average per plant yield during this time was 221.5 grams of dried flower. Extrapolating from the average plant yield, the 2016 total production was 3,933.5 lbs. of dried flower.

ENERGY ANALYSIS

The daily electricity consumption for the greenhouse and production house is shown in Figure 16. The greenhouse shows a steadily increasing consumption of electricity throughout the study. This is to be expected as the days become increasingly short and cold going into winter, requiring an increase in the use of lights.

Unfortunately, the Argus data only provided insight into when the equipment was on or off and not the quantity of equipment it controlled. Due to the amount of differing equipment operating in the greenhouse, an analysis of the interval increases in peak demand showed no consistency, though it did point to the possibility the HPS lights were 750 W rather than 1000 W as stated by the grow. The plot line from the production house (orange line in Figure 16) shows a consistent daily energy use with a slight decrease occurring in mid-November when the lights went from a 24-hour cycle to a 20-hour cycle. This change is indicated by the arrow.

Figure 16. Midwest Ranch Greenhouse and Production House Daily Electricity Consumption, September 16, 2016 – January 16, 2017

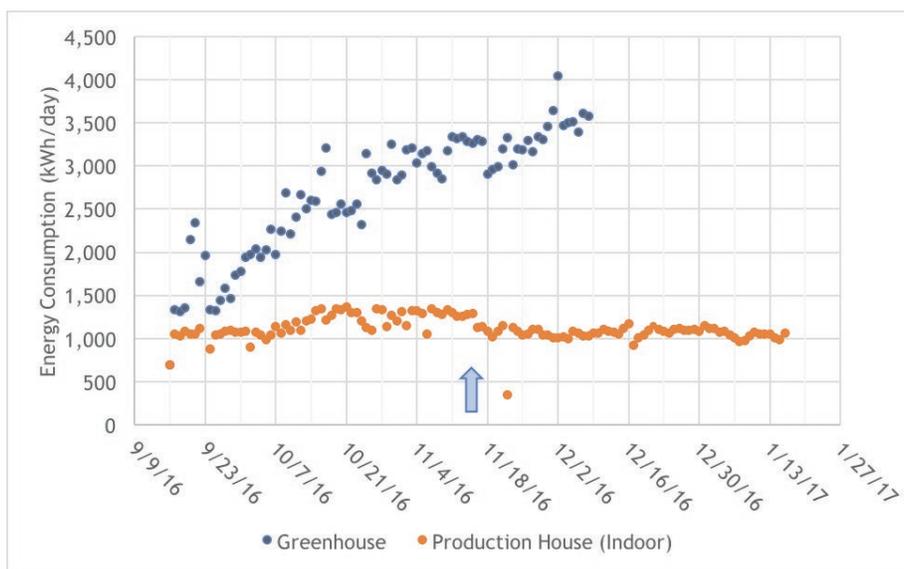
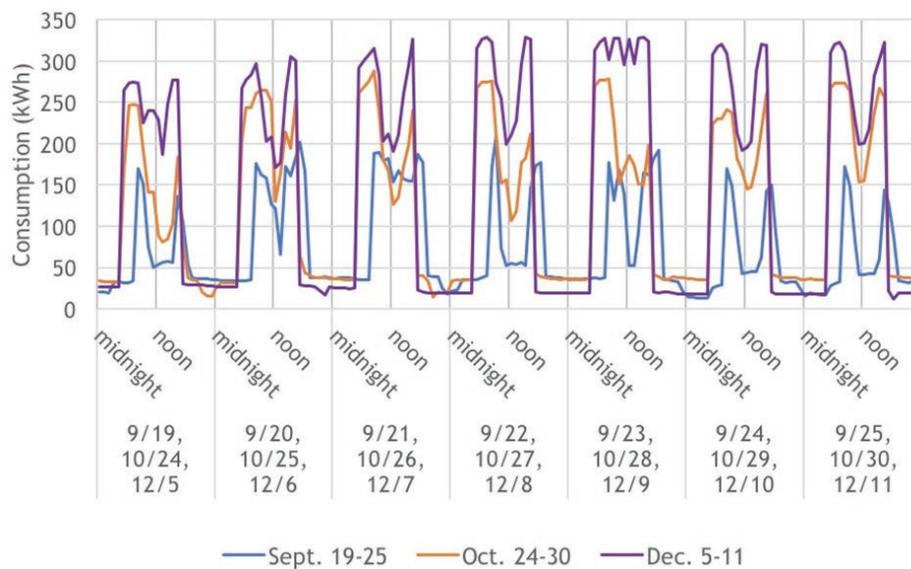




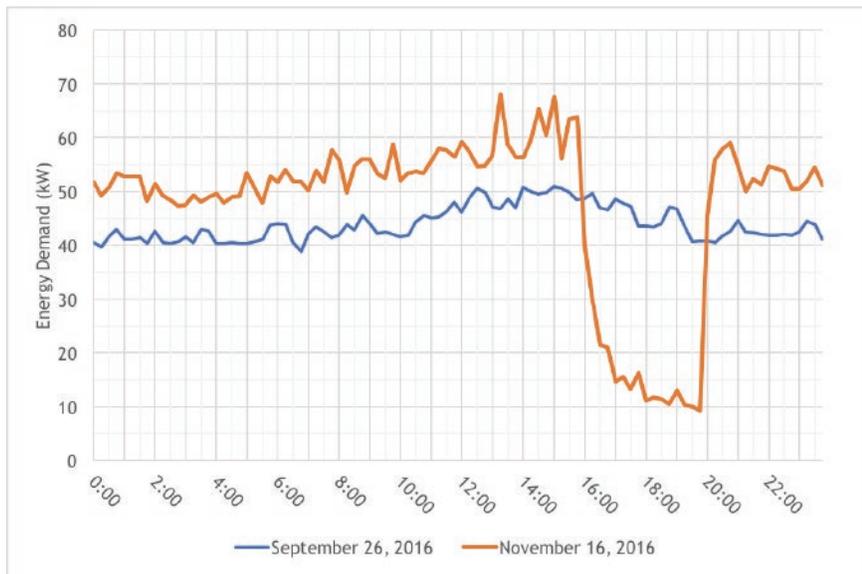
Figure 17 shows the hourly energy consumption of three separate weeks in the greenhouse; September 19th-25th, October 24th-30th, and December 5th-11th. To achieve a 12-hour light period, lights were used during the early morning and late afternoon, which can be identified when the observing the energy spikes of each day. The midday drops in energy usage are from the lights turning off because of adequate levels of sunlight. As shown in Figure 17, the energy consumption each week gets significantly higher. The direct cause of this is not known, but two possible explanations are that more lights were being used as the operation expanded or more HVAC equipment was on due to colder weather, though heating is reportedly done with natural gas.

Figure 17. Midwest Ranch Greenhouse Hourly Electricity Consumption Data, September 19-25, October 24-30, December 5-11, 2016



During the study, the warehouse consumed a relatively stable amount of energy. When the study started, the vegetative room operated on a 24-hour light cycle which, in November, changed to a 20-hour light cycle. Figure 18 illustrates that change. This small change saved an average of 42.9 kWh per day. This figure is derived from the consumption differences between 9/25-10/1 and 11/17-11/23. These weeks were chosen because they each had seven days with no significant unexplained inconsistencies.

Figure 18. Midwest Ranch Production House Electricity Demand Data, September 21 and November 9, 2016



To determine the estimated total energy consumption of Midwest Ranch, the metering data collected from both sites were analyzed to find the average daily energy consumption which was then used to find the estimated yearly total. The warehouse data was doubled to account for the additional vegetative production room attached to the greenhouse, which was not monitored.

During the monitoring period, the greenhouse used 225.7 MWh and the warehouse, including the production rooms, consumed 95.1 MWh. The production house did not record a measurement on September 23rd so the average of September 22nd and 24th was used in its place. The average daily energy consumption was 2,687.1 kWh and 1,112.5 kWh for the greenhouse and warehouse respectively. The estimated annual energy consumption for the greenhouse is 983.48 MWh/year.

Since the study only monitored during the fall and beginning of winter, this extrapolated number does not consider any changes in consumption that will occur during colder and warmer months. In consideration for the temperature range of this area, this has the potential to be significant. The estimated annual energy consumption of the warehouse is 407.16 MWh; therefore, the estimated annual total energy consumption for both vegetative production rooms is 814.36 MWh/year. By combining the vegetative and flowering consumption, Midwest Ranch’s estimated annual energy consumption for all cultivation is 1,797.83 MWh/year. It is important for future studies to capture the seasonal changes in energy consumption that greenhouses will inevitably have.

By comparing the estimated annual energy use with the estimated annual production, Midwest Ranch’s production efficiency is found. These results are as follows;

- ▶ 457.1 kWh/lb. of dried flower
- ▶ 223.2 kWh/plant
- ▶ 99 g of dried flower/kWh

The production numbers were taken from last year's data when the operation was not functioning at full capacity and therefore not performing as efficiently as designed. If operating at full capacity, Midwest Ranch would have a greater efficiency. At full capacity, Midwest Ranch should harvest an estimated 15,600 plants annually yielding 7,617.86 lbs. With these numbers, the energy efficiency becomes:

- ▶ 236.2 kWh/lb. of dried flower
- ▶ 115.2 kWh/plant
- ▶ 1.9 g of dried flower/kWh

The drastic change in energy per production further demonstrates the importance that production quantities have in achieving efficiencies and the importance.

WATER ANALYSIS

Due to a lack of complete data from utility bills, on monthly plant counts, and on production values, an estimate of the water usage per plant was conducted by analyzing the grow system. Depending on the strain, plants are in the clone phase for 12-14 days, the vegetative phase for 4-5 weeks, and the flowering stage for 8-12 weeks. For this analysis, we used 13 days in clone, 32 days in vegetative, and 70 days in flower.

During the clone stage, plants are watered on average once a week in the first week and twice a week in the second week. The amount of water used each time was not available so we assumed 1/3 of a gal per watering for a total of 1 gal consumed during the clone stage.

In the vegetative stage, plants are watered via drip irrigation approximately once every four days for 2 hours. The ½ gal/hour emitters that Midwest uses consumed 1 gal of water for each watering which totals an estimated water consumption of 8 gals during the vegetative phase. Midwest has less frequent watering at this stage compared to other cultivations because their clones are transplanted into 5-gallon pots containing a peat moss heavy mix, meaning that the water drains slowly out the pot which directs more water to the plant over time with less water.

In the flowering stage, plants are watered with a ½ gal each day via drip irrigation for a duration of either two 14-minute intervals or one 34-minute interval. The average water consumption during the flower stage is 35 gals.

On average, each plant consumes 44 gal of water during its growing cycle, which equates to 0.2 gal/g of dried flower based on average plant yield of 221.5 g.

Midwest Ranch Conclusions

The monitored consumption for Midwest Ranch included whole-building electricity consumption for two separate buildings: a greenhouse and warehouse. The monitored equipment for both buildings included lighting, HVAC, climate control equipment, and other miscellaneous equipment. Due to lack of detailed data, it is not possible to draw cemented conclusions about what is happening at the facility.

Pot Zero: Zero Carbon Footprint, Zero Chemicals — A Biodynamic Farm

Pot Zero Organizational Overview

Pot Zero is a biodynamic farm located in the mountains of Eagle County. Their marijuana cultivation takes place outdoors at 8,200 ft. elevation and only uses electricity provided by a hydroelectric turbine. Pot Zero strives to be the leading environmentally conscious marijuana cultivation in Colorado.

Rob and Linda Trotter have owned their property for 24 years and established Pot Zero in 2015. Together they manage all aspects of Pot Zero, with Rob overseeing more of

the agricultural aspects and Linda handling operations. Rob Trotter is the owner of Trotter Real Estate and has been involved in brokerage and development for 26 years. Linda Trotter is the CEO: (Chief Everything Officer) and a musician. She does the bookkeeping, manages the household, assists Rob who is blind, and is the mother of three children.

The name Pot Zero is derived from their commitment to sustainable, biodynamic farming practices, and their use of only natural products. Pot Zero is the only known zero carbon footprint cultivation in Colorado. The entire process is founded on biodynamic principles, as they utilize only composted animal waste from their cattle herd for nutrients. Their agricultural inputs include only three elements: soil, compost, and vinegar.

The location provides rich mountain loam topsoil, a pristine 12,500 ft. mountain water source, and intense ultraviolet light due to the elevation. They are very passionate about having the “cleanest and greenest and most sustainable operation in Colorado”. They chose to participate in this study to showcase their zero-carbon footprint and zero synthetic cultivation model. They are a great model for sustainable marijuana production and in the future, they plan to produce their own branded products that emphasize their clean, green, and sustainable operation.

Pot Zero’s two-acre marijuana field is surrounded by a high fence and a surveillance system to provide required security. All power is produced by their own hydroelectric turbine, which powers the security system, water pump, and newly installed LED lights in their workshop. The rest of the energy is



Image 4. Pot Zero

Pot Zero Operational Overview

Location: Eagle County, CO

Cultivation type: outdoor

Building description: n/a

Facility size: 2 acres

Canopy size: 1.3 acres

Primary water source: private well

Secondary water source: rain

Primary energy source: hydroelectric turbine

Secondary energy source: sun (direct energy to plants, not solar cell converted)

Primary heating source: wood pellet heater

Secondary heating source: n/a

Employees: 2

Months of production: 5 months

provided by the sun. The curing and storage facility is a simple shed with attached shipping containers and is heated by a pellet heater using beetle kill wood. For the 2016 growing season, they installed a drip irrigation system to minimize labor and conserve water resources.

Pot Zero only has one growing season, compared to the 4-5 growing cycles for indoor and greenhouse cultivations. In 2016, they began with slightly less than 6,000 plants. Approximately 500 males were destroyed and several hundred more plants were lost throughout the season. They had approximately 5,100 plants at the end of the growing season, but around 2,000 struggled due to an August frost. Their total yield for 2016 was 102 lbs. of high quality flower and 887 lbs. of lesser quality buds and trim. In 2015, they harvested 1,188 lbs. of total plant product from approximately 3,600 plants with the entire harvest going to oil production as they were still learning the industry and the necessary trimming skills.

Image 5. An Early Frost for Pot Zero



Pot Zero Case Study Methodology

At Pot Zero, one smart meter was installed on the electrical panel located in the onsite shed. To monitor the whole panel, water pump, security system, and a miscellaneous circuit use for temporary equipment, 0.75" split core CT-plugs of 10 amps and 100 amps were used. Because this was the second season growing for Pot Zero, the Trotters were still building out the site and trying new methods of harvesting and processing. Therefore, not all equipment was directly monitored during the study. The meter was installed September 10th, 2016 and used Wi-Fi connectivity, as there is no cellular service on the site.

Pot Zero Cultivation Overview

Being an outdoor grow facility, Pot Zero only uses electricity to power a small water pump, some LED lights, fans that are used temporarily during the harvest and processing periods, and a security system. The security system consists of twenty-six cameras, two DVR recorders, and an array of motion and beam detectors.

Data was collected from early September until mid-January. The harvesting and processing of the crop occurred from the last week of September through the first week of November. At that point, the facility went dormant for the winter months.

Pot Zero has one harvest season that lasts five months each year. For the 2016 growing season, they started germinating seeds in rapid rooter plugs (plugs made up of propagation seed starting roots) on May 1st. After a few weeks, they moved the seedlings into 3.5" pots to continue to grow and harden. On June 15th, when the plants were 6" tall, they began transplanting the plants into the ground. Each stock was spaced three feet apart.

Irrigation is provided through a drip irrigation system that uses 12,000 1 gal/hr. emitters attached to ¾-in tubing. The field is divided into five zones with each zone being watered about twice a week depending on the rain and size of the plants. The plants were in the ground from June 15-September 26 for a total of 105 days. During that time, there were 21 days with rain.

Pot Zero Cultivation Analysis

ENERGY ANALYSIS

The consumption data for the entire study period is shown in Figure 19 with a daily breakdown by source in Figure 20. The consumption rates for "Equipment 2" in Figure 20 were not directly monitored, but sourced by deducting all the sub-metered data from the main panel data.

Three distinct phases of energy consumption can be seen in Figures 19 and 20. The first phase in September shows the last weeks of cultivation when only the water pump and security system are in use. The second phase from mid-September to early November is when the harvesting and processing takes place. There is a substantial increase in energy consumption during the harvesting and processing period compared to the cultivation period due to the use of more equipment, such as lights and fans. The final phase starting in early November and lasting until the end of the study period shows a steady decline in energy use as the site transitions to the fallow period between grow cycles.

Figure 19. Pot Zero Total Daily Electricity Consumption, September 10, 2016 – January 14, 2017

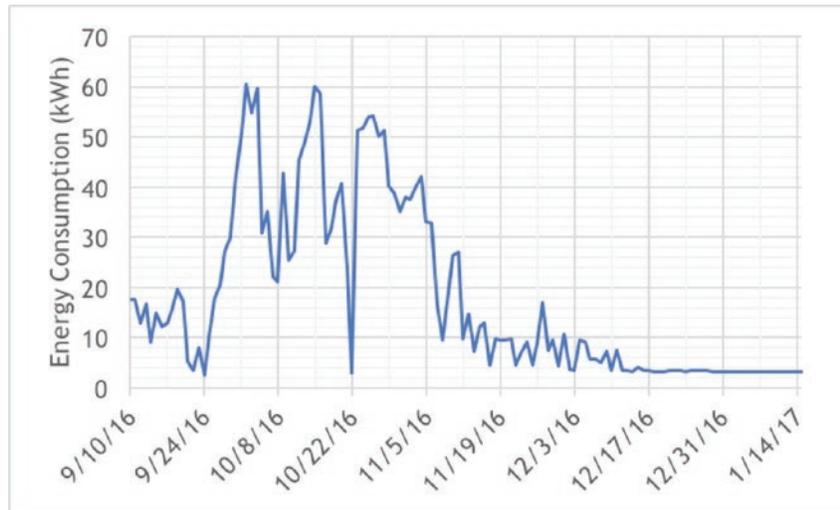
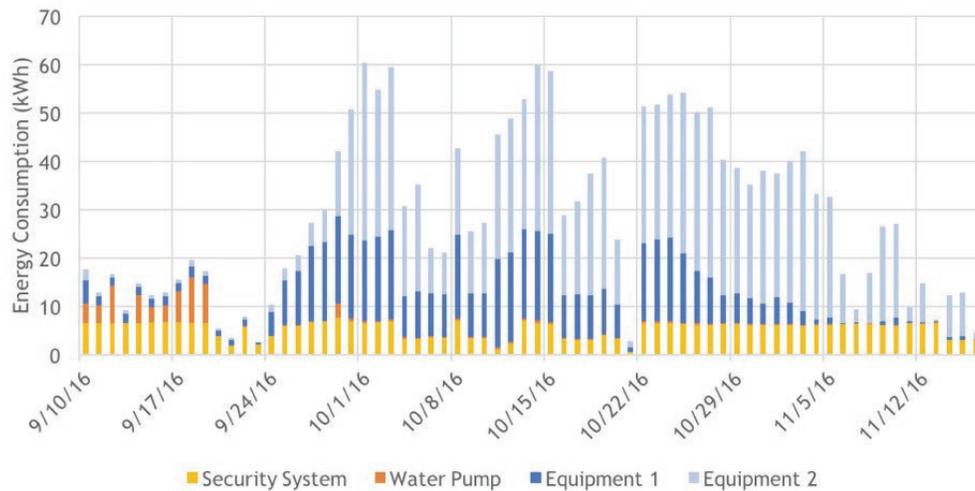


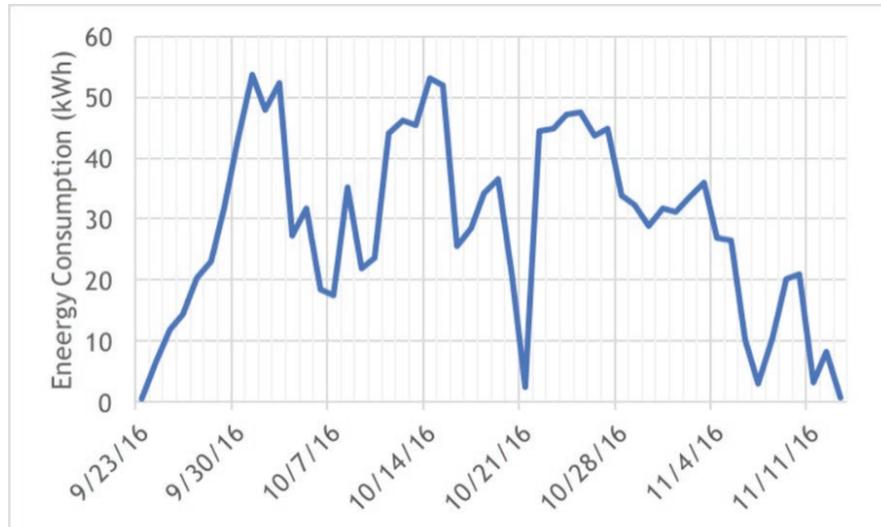
Figure 20. Pot Zero Total Daily Electricity Consumption by Source, September 10 – November 16, 2016



The water pump’s hourly energy consumption for the week of September 12th-18th is shown in Figure 21. The pump data shows sporadic electricity usage during six of the days with a peak consumption around 1.6 kWh. This pattern continues until mid-September when the growing season ends and the pump is no longer in use. Since this is an outdoor grow facility, the end of the pump operation marks the end of the growing season.

The facility equipment monitored during the study is shown in Figure 23 for the period when harvesting and processing is occurring. Though the exact type and quantity of equipment being run on this circuit is unknown, the observed peak demand shows a similar peaks and valleys as the consumption, meaning that the consumption is likely due to higher power draws for the equipment and not because of increased run-time for the same equipment. This would suggest that the fans that were used to dry the harvest are on this circuit.

Figure 23. Pot Zero, Facility Equipment Daily Electricity Consumption, September 23 – November 14, 2016



The energy data gathered during the study can be split into three separate time periods: cultivation, harvesting/processing, and fallow. To calculate Pot Zero’s production metrics, only the cultivation period was examined to make the results comparable to the other case studies in this report.

Starting with cultivation, Pot Zero’s 2016 growing season was 149 days. However, this study only monitored cultivation for 17 days from September 10th to the 26th. Because some harvesting equipment started to come online on the 24th, for our cultivation energy analysis, we only examined the equipment data for the 14-day period of September 10th to the 23rd. To analyze the equipment in use during cultivation, we combined the data from the monitored equipment circuit, Equipment 1, along with the unmonitored equipment, Equipment 2 (Figure 14). This resulted in an average daily consumption of 2.7 kWh/day for all equipment over the 14-day period, which lead to an estimated total energy consumption for all cultivation equipment to be 399 kWh.

When looking at the security system during cultivation, the average daily energy rate was 5.6 kWh/day. This was derived from the metered 95 kWh consumed during the 17 days that cultivation occurred, which lead to the security system’s estimated total energy use as 832.8 kWh during cultivation.

As for the water pump, during the first 44 days prior to being transplanted, the plants were hand-watered. Therefore, for the 149 days of cultivation, the water pump was only used to power the drip-irrigation system for the 105 days the plants were in the field. Additionally, the water pump was only utilized 80% of the field days due to rain. To calculate the total energy use of the water pump, the energy consumption for the 11 days between September 10th and September 20th were averaged

to find the daily rate. This period was chosen because the pump had a utilization rate that matched the 80% of the entire growing season. This revealed the water pump’s average daily energy rate as 4.7 kWh/day and an estimated total of 489.3 kWh for the in-ground cultivation period. To account for the phantom load of the water pump during the first 44 days of the growing season, the average daily energy consumption of the pump was calculated from the 106-day period between October 1 and January 15. During this period the water pump averaged .1 kWh/day for an estimated total consumption 5.8 kWh for the first 44 days of the season.

For the 149-day growing season, Pot Zero used 1,726.9 kWh of electricity and harvested 887 lbs. of usable product and 102 lbs. of flower. Therefore, their cultivation production energy efficiency equates to:

- ▶ 16.9 kWh/lb. of dried flower
- ▶ 1.75 kWh/lb. of total usable product
- ▶ 0.34 kWh/harvested plant

Table 20. Pot Zero 2016 Electricity Consumption

Phase	Date	Daily Average (kWh)	Total Energy Use (kWh)	Equipment Breakdown
Dormant	Jan. 1 – April Nov. 10 – Dec. 31	5.8	1,007.8	65% Security System 34% Misc. Equipment 1% Water Pump
Cultivation	May 1 – Sept. 26	11.6	1,726.9	66% Security System 34% Water Pump
Harvesting/ Processing	Sept. 27 – Nov. 9	38.2	1,681.1	85% Misc. Equipment 14% Security System 1% Water Pump
Total	Jan. 1 – Dec. 31		4,415.8	

During the harvest and processing period from September 27th to November 9th, the cultivation consumed 1,681.1 kWh for an average of 38.2 kWh/day. The equipment used in harvesting and processing accounted for 85% of the energy usage, accounting for 1,433.5 kWh. The security system used 14% of the overall energy with a consumption of 234.7 kWh, and the pump accounted for 1% with 12.8 kWh.

During the study, the site entered its dormant season on November 10; however, the site continued to be monitored for an additional 67 days until January 15. During that time 390.3 kWh were consumed for an average daily consumption of 5.8 kWh. The security system accounted for 65% of the energy consumption, the various onsite equipment for 34%, and the water pump accounted for the remaining 1%. In 2016, the site remained dormant from January 1st to April 30th and from November 10th to December 31st, resulting in a dormant period energy consumption of 1,095.3 kWh.

WATER ANALYSIS

According to Pot Zero, during the 149-day growing season, 957,000 gal of water were used for the 5,100 plants that survived the entire season. This equates to 187.6 gal per plant and 967.6 gal per lb. of useable dried product (flower and trim). Resulting in a production efficiency of 2.1 gal/g of total usable product and 0.05g of dried flower/gal. There is such a low rate of dried flower per gallon because Pot Zero grows primarily for the concentrate market (meaning you do not need high quality flower product) and the flower yielded this year was considered bonus. These figures overestimate the gal/plant and gal/lb. figures as they do not consider the 500 male plants that were removed during the season or the lower yield from the 2,000 plants affected by the summer frost. Due to the nature of outdoor growing, every year will average a different production rate.

Image 6. Pot Zero Drip Irrigation System



Pot Zero Conclusions

As Pot Zero is an outdoor grow with a goal of being a net-zero energy facility, the overall electricity consumption for the site is rather minimal, using less than 5,000 kWh per year growing on over an acre of land. With such a small energy footprint, the energy savings opportunities are few. Pot Zero demonstrates that you can successfully grow marijuana in a high-altitude location with a short growing season. Pot Zero is the model for how to utilize a low-energy cultivation model to reduce the energy impact of marijuana cultivation on the grid.

Anonymous Indoor Facility in Denver

In addition to the case studies conducted during this study, this report received independent consumption data from an anonymous grow in Denver. Details of these data can be found below.

A predominant facility in Colorado provided data for this study but chose to remain anonymous. All this information was self-reported and was not able to be verified by The Cannabis Conservancy (TCC). From this source, we have the cultivation’s monthly energy and water consumption figures and their production in dried weight of flower for the year of 2015. The monthly electricity and water consumptions are shown in Figures 24 and 25. The monthly electricity consumption shows a cycle of lower consumption in the spring and fall which are typically times when less heating or cooling would be necessary. The annual energy usage was 851 MWh and the annual water usage is 124,440 gallons.

Figure 24. Anonymous Denver Indoor Facility Monthly Energy Consumption (2015)

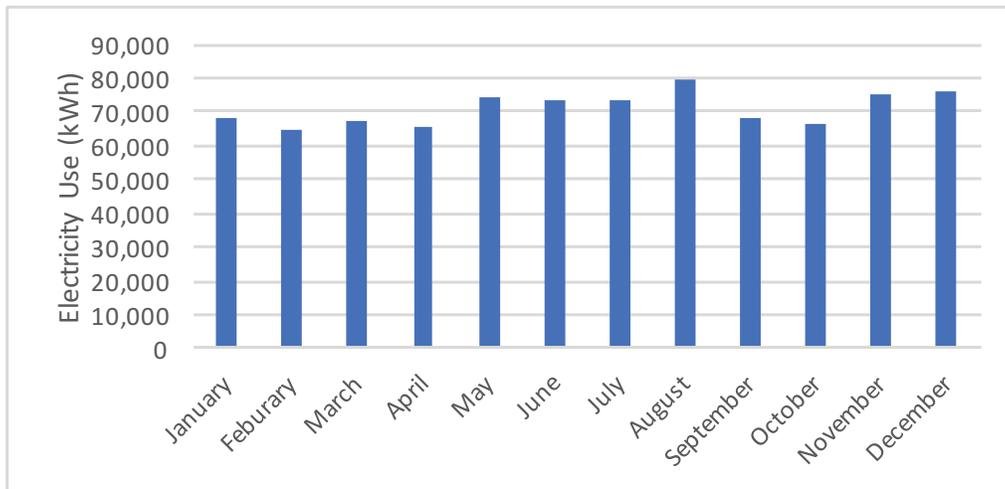
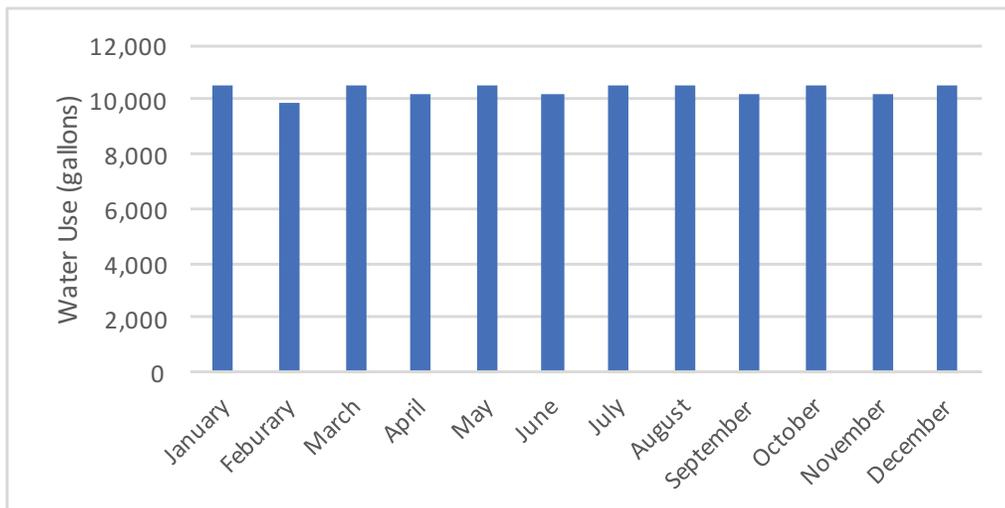


Figure 25. Anonymous Denver Indoor Facility Monthly Water Consumption (2015)



The annual production was 678 lbs. of dried flower and the monthly production numbers were estimated by dividing the annual production by twelve. The capacity of the facility is 300 plants in the vegetative phase with thirty day cycles that occur ten to twelve times a year. When flowering, the capacity is 250 plants that have sixty to seventy day cycles five times a year. There is no information as to whether the cycles are consecutive or overlapping. If flowers are harvested in five cycles per year, then the production rate would be 0.54 lb. per plant. The annual consumption metrics are 1,256 kWh/lb. of dried flower 184 gallons/lb. of dried flower. The monthly electricity and water consumption is shown in Figures 26 and 27.

Figure 26. Anonymous Denver Indoor Facility Monthly Electricity Consumption per Product (2015)

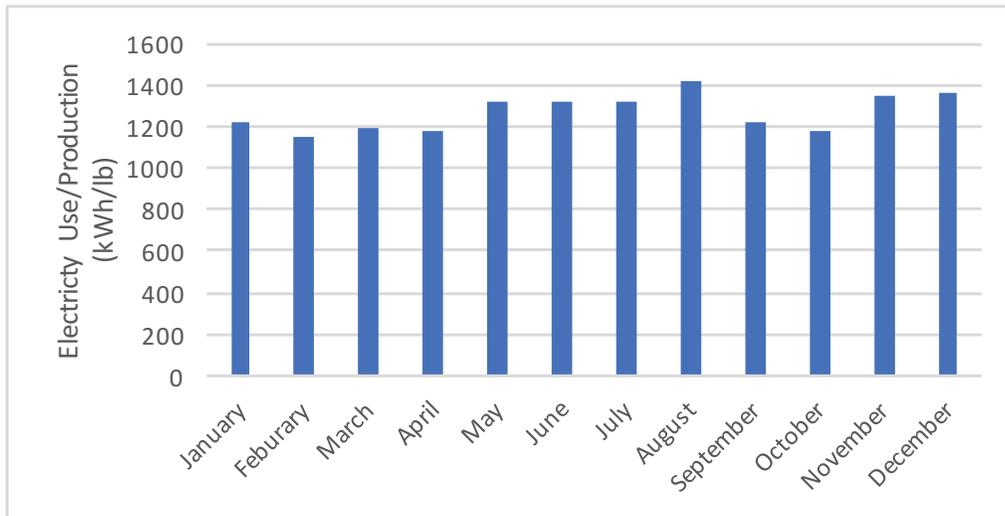
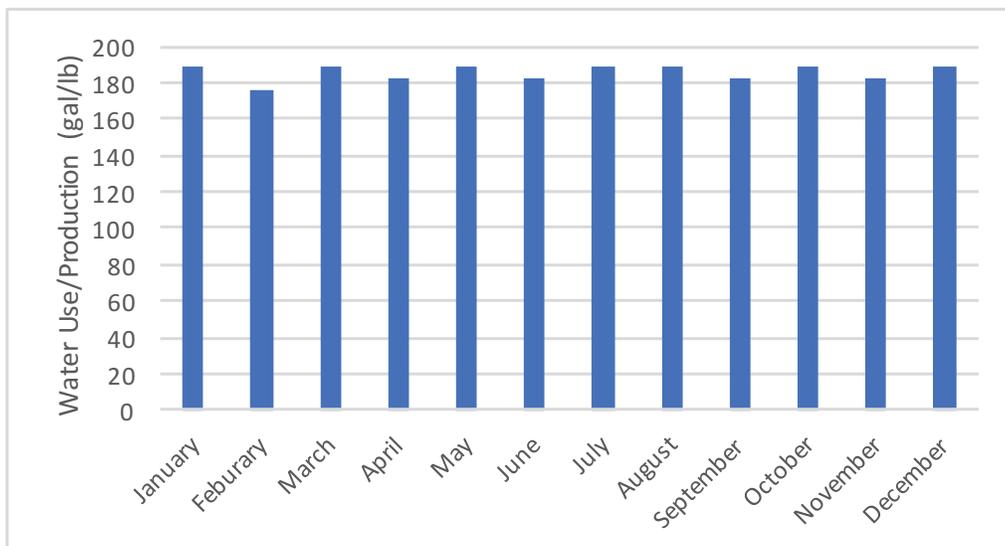


Figure 27. Anonymous Denver Indoor Facility Monthly Water Consumption per Product (2015)



Case Study Results

The three case studies included a large indoor cultivation facility, a greenhouse operation, and a near net-zero outdoor farm. The case studies provide us with a picture of how models of production, cultivation, and resource consumption vary greatly between marijuana production facilities in Colorado (Table 21). As expected, indoor cultivations use the most energy to produce marijuana, followed by greenhouses, and then outdoor cultivations. While lighting technology is consistently improving its efficiency, there is no substitute for natural sunlight. Additionally, as inefficient lights produce unnecessary heat, consistent climate control is required to maintain a healthy environment for the plants. Cultivators should consider greenhouse or outdoor cultivations if they have the opportunity to do so.

Table 21. Cultivation Efficiencies

Source	Type of Facility	Production Rate (lb. of flower/plant)	Electricity Consumption Rate (kWh/lb. of flower)	Electricity Consumption Rate (kWh/plant)	Water Consumption Rate (gal/lb. of flower)
Anonymous	Indoor	0.54	1,256	n/a	184
The Clinic (Historical)	Indoor	0.095	1,202	113.9	564
The Clinic (Current)	Indoor	0.4	1,136	288	564
Midwest Ranch	Greenhouse	0.49	236	115 (66.5 at full capacity)	91
Pot Zero	Outdoor	0.02	1.75*	.34	968*

As wholesale marijuana prices continue to decline, cultivators need to explore efficient and effective opportunities to cut costs to remain profitable. Since lighting alone can be 20% of a cultivation's operational costs, making changes to energy and water consumption strategies and equipment can be simple and impactful ways to save money.

Lighting alone
can be
20%
of a cultivation's
operational costs

Appendix A

Table 22. The Clinic Capacity, Methodology, and Equipment Overview.

Room	Plant Phase	Canopy Space (ft ²)	Capacity (# of plants)	Cycle Duration (weeks)	Cycles Per Year	Lighting # in () indicates quantity	Climate Control
Prop	Mothers and Propagation	32	64 mothers 1,280 clones	2.5	21	<ul style="list-style-type: none"> Mothers: Bar T5 (8) Clones: Bar T5 (4-6) 	<ul style="list-style-type: none"> 2-ton Mini Split, QuietSide (1) 2-ton Roll Away Kwik Kool (1) 18" Oscillating Fan, Airking (2)
Veg	Vegetative	1,152	1,296	4-7	7-13	<ul style="list-style-type: none"> 330W BML LED Spydr 600 (75) 330W Illumitex LED, NeoSol DS (20) 400W Induction, iGrow, Veg Bulb (1) 660W W Illumitex LED, Harvest Pro 10 (3) 	<ul style="list-style-type: none"> 10-ton, York RTU (2) Dehumidifier, Dri Eaz 3500i (2) 12" Oscillating Fan, Ecoplus (12) 20" Oscillating Fan, Dayton (4)
E1	Flower	448	296	9	5.8	<ul style="list-style-type: none"> 660W BML LED Spydr 1200 (22) 660W BML LED Spydr Xplus (6) 	<ul style="list-style-type: none"> 10-ton, York RTU (1) Dehumidifier, Dri Eaz 3500i (1) 12" Oscillating Fan, Ecoplus (6) 16" Oscillating Fan, Airking (1)
E2	Flower	384	216	9	5.8	<ul style="list-style-type: none"> 1000W Air Cooled, Sunlight Supply XXX 8" (24) 1000W Magnestic ballast, Harvest Pro (24) 	<ul style="list-style-type: none"> 10-ton, York RTU (1) Dehumidifier, Dri Eaz 3500i (1) 12" Oscillating Fan, Ecoplus (4) 16" Oscillating Fan, Airking (1)
E3	Flower	384	216	9	5.8	<ul style="list-style-type: none"> 660W BML LED Spydr 1200 (12) 660W W Illumitex LED, NeoSol DS (15) 660W W Illumitex LED, Harvest Pro 10 (3) 	<ul style="list-style-type: none"> 10-ton, York RTU (1) Dehumidifier, Dri Eaz 3500i (1) 12" Oscillating Fan, Ecoplus (3) 16" Oscillating Fan, Airking (1)
E4	Flower	352	198	9	5.8	<ul style="list-style-type: none"> 1000W Air Cooled, Sunlight Supply XXX 8" (24) 1000W Magnestic ballast, Harvest Pro (24) 	<ul style="list-style-type: none"> 10-ton, York RTU (1) Dehumidifier, Dri Eaz 3500i (1) 12" Oscillating Fan, Ecoplus (3)
F	Flower	1,540	865	9	5.8	<ul style="list-style-type: none"> Gavita DE 1000 EL, DE Phillips Bulb (109) 	<ul style="list-style-type: none"> 10-ton, Carrier RTU with Humidi-Mizer (4) 350mm HAF Fan, Dramm (4) 16" Oscillating Fan, Ecoplus (2) 20" Oscillating Fan, Dayton (4)
B	Breeding	265	200	n/a	n/a	<ul style="list-style-type: none"> TS Fluorescent 4 Bar (10) 400W iGrow (14) 330W Spydr 600 LED (2) 	<ul style="list-style-type: none"> 7.5-ton, York RTU (1) 2.5-ton Split, QuietSide (1) 12" Oscillating Fan, Ecoplus (2)

The Clinic's Climate Control Versus Average Daily Temperature

To investigate what impacts temperature could have on a cultivation's energy load, we looked at The Clinic's climate control equipment RTU 1, RTU 2, RTU4 (RTU 3 was not examined because it never turned off). The consumption versus the average daily temperature for Englewood, CO (where The Clinic is located) is plotted in Figures 28-30. As shown, there is no indication of a correlation between outdoor conditions and the consumption.

Figure 28. The Clinic Flower Room RTU-1, Daily energy Consumption Versus Average Daily Temperature, September 13, 2016-January 13, 2017

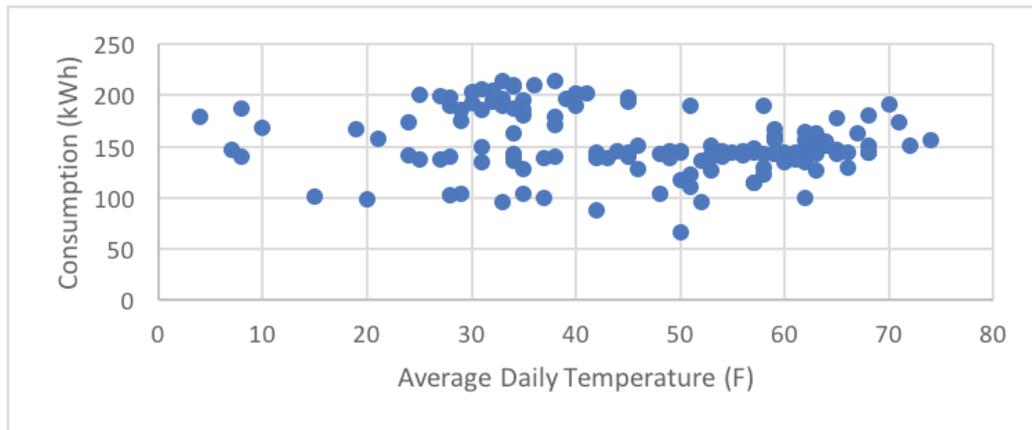


Figure 29. The Clinic Flower Room RTU-2, Daily energy Consumption Versus Average Daily Temperature, September 13, 2016-January 13, 2017

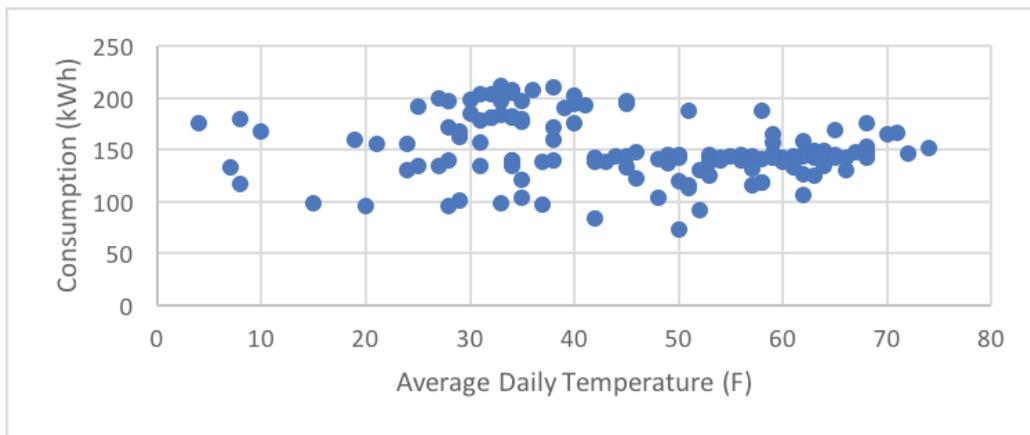
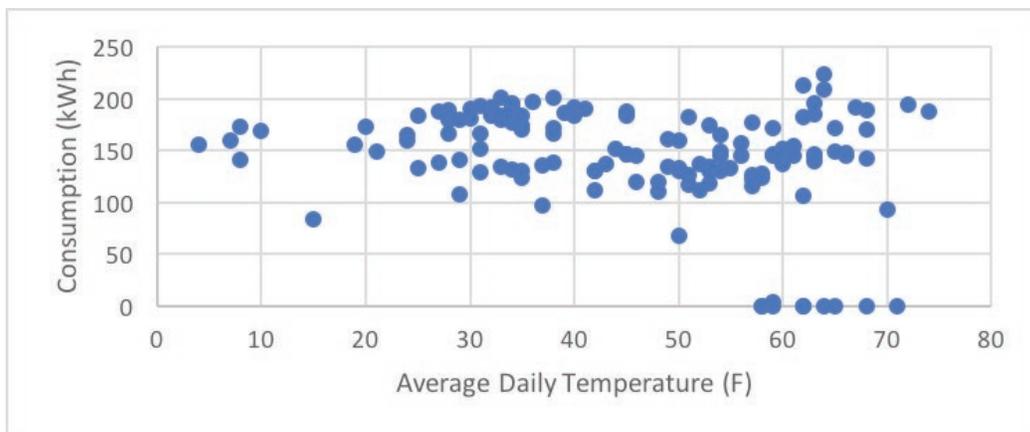


Figure 30. The Clinic Flower Room RTU-4, Daily energy Consumption Versus Average Daily Temperature, September 13, 2016-January 13, 2017



Midwest Ranch

Table 23. Equipment at Midwest Ranch

Location	Purpose	Equipment	Qty	Additional Information
Main Building				
	Office			
		Computers	5	
		T-5 Lights	23	
		Monitor	2	
		TV	3	27", 32", 55"
		A/C unit	1	5-ton, Carter
	Receiving Area			
		T-5 Lights	9	
		Lamps	6	
		Ceiling Fans	2	
		Space Heater	1	
	Production House (Veg)			
		T-5 Lights	54	
			13	For Mothers
		HAF Fans	15	70W, 120V, 60 Hz, 3-speed
		Furnace	2	5,000 BTU Carrier w/condensing unit and economizer
	Clone Propagation			
		T-5 Lights	12	
		Heating Maps	9	
		HAF Fans	3	
	Drying and Curing			
		Furnace	2	5,000 BTU Carrier w/ economizer (Natural Gas)
Greenhouse				
	Flower			
		HPS Lights	392	Gavita 1000W/750W DE
		V-Flow Fans	33	
		Motor	4	3 ¼ Horsepower
		24" Exhaust Fan	4	
		48" Exhaust Fan	16	
		Water Pump	4	¾ HP
		Motor	4	1 ½ HP
		CO2 Tank	1	8,000 gallon (14 ton bulk) tank, with cooling unit & compressor
		Refrigeration Unit	1	
North	Veg. Propagation			
		T-5 Lights	52	
		HAF Fans	15	
		A/C unit	2	3-ton Ductless Split, Carrier (A/C only)
		24" Exhaust Fan	1	Damper Controlled
		Natural Gas Resonator	1	6,000 BTU
		Furnace	1	Hot Dawg
		Water Pump	1	¾ HP
		¼ HP Pump	2	
		1 HP Pump	2	
		Argus Skid	1	
		Lighting Control Panel	1	
		Argus Control Panel	1	
South	Equipment Room			
		A/C unit	1	3-ton Ductless Split, Carrier (A/C only)
		Furnace	1	Hot Dawg Resonator
		Water Pump	1	¾ HP
		½ HP Pump	2	
		1 HP Pump	2	
		Reverse Osmosis System	1	2 HP Pump
		Compressor	1	¾ HP

Appendix B – Colorado Marijuana Energy Efficiency Calculator Documentation

About

The Colorado Marijuana Energy Efficiency Calculator is a spreadsheet that evaluates equipment and climate in order to output energy savings. The HVAC Inputs and Lighting Inputs tabs allow for the input of the existing equipment and the proposed equipment for the facility to be specified. The Results tab displays the savings calculated based on the proposed changes. This spreadsheet can be found on the Colorado Energy Office's website.

HVAC Inputs

NAME: Enter a descriptive name for the analysis

NEAREST CLIMATE LOCATION: The dropdown box gives the options of multiple cities in Colorado. Select the city which is closest in climate to your grow location. Note that this may not be the closest geographically.

DESIGN HEATING TEMPERATURE, OUTSIDE: This is the outdoor temperature that was used to determine the size of the heating equipment needed for your facility. If you do not know this value, look for a note next to the input box will give you guidance based on your selected climate location.

BALANCE POINT DURING HEATING SEASON: This is the outdoor temperature when heating would not be necessary to maintain the indoor set point. This value is typically between 55-65 degrees F, but can be lower if the building is well insulated (or poorly insulated) and has higher than normal internal.

APPROXIMATE OPERATING HOURS, HEATING EQUIPMENT: This value will be automatically calculated based on the climate location, the design heating temperature, and the balance point temperature. If you know the heating operating hours for your facility you can adjust the design heating temperature and the balance point to better reflect your operation.

DESIGN COOLING TEMPERATURE, OUTSIDE: This is the outdoor temperature that was used to determine the size of the cooling equipment needed for your facility. If you do not know this value the note next to the box will give you guidance based on the selected climate location.

BALANCE POINT DURING COOLING SEASON: This is the outdoor temperature when cooling would not be necessary to maintain the indoor set point. This value is typically between 55-65 degrees F, but can be higher if the building is well insulated or has lower than normal internal gains or lower if the building is poorly insulated.

APPROXIMATE OPERATING HOURS, COOLING EQUIPMENT: This value will be automatically calculated based on the climate location, the design cooling temperature and the balance point temperature. If you know the cooling operating hours for your facility you can adjust the design cooling temperature and the balance point to better reflect your operation.

AVERAGE COSTS OVER PAST HEATING SEASON: Enter the average prices that you pay for electricity and natural gas during the heating season.

AVERAGE COSTS OVER PAST COOLING SEASON: Enter the average price that you pay for electricity during the cooling season.

EXISTING HVAC EQUIPMENT INVENTORY: Enter the equipment currently installed at your facility for heating, cooling, dehumidifying and ventilation the building. For each category of equipment, you can select an equipment type from the dropdown box and then enter the number this equipment that you own. Additionally, add the capacity of one of the individual units of this type.

The capacity of the equipment can be determined from the HVAC design done for the building. If you do not have access to these documents for your facility you can determine the capacity of the equipment by looking at the name plate on the piece of equipment. Typically, this is the plate on the equipment that shows the model number. The units of efficiency change based on the equipment being referenced.

Enter the efficiency of the equipment. There are default values based on what is typical for that piece of equipment (if you cannot determine the efficiency of the equipment). Again, the units for the efficiency change is based on the type of equipment selected. There are spaces where the manufacturer, model number, and year installed can be entered. These values are for your informational purposes and are not used in the analysis.

For the humidity control in the facility, there are three control options: stand-alone dehumidifiers, cooling equipment (humidity sensors installed in the facility that provide a control signal to the cooling equipment), and no humidity control (while there is cooling equipment that influences the humidity in the facility, there are not any humidity sensors providing control signals to the cooling equipment). The choice of humidity control is made using the radio buttons.

PROPOSED HVAC EQUIPMENT INVENTORY: Enter the equipment switches that you want to analyze. Any equipment that is staying in the facility should be entered in both the existing and proposed section.



Lighting Inputs

The analysis name and the electricity costs for the heating and cooling season are automatically transferred from the HVAC Inputs tab.

Choose whether cooling savings (due to the reduced cooling load of high-efficiency lighting) should be calculated. *Note –The calculation will likely be somewhat optimistic in the amount of cooling usage reduction due to the lighting usage.

EXISTING LIGHTING EQUIPMENT INVENTORY: For the lighting systems currently installed in your facility, select the fixture type from the drop-down menu and enter the quantity of this type of fixture installed. The wattage of the lighting will be estimated based on the selected type of fixture and the wattage used in the analysis is displayed.

For each fixture type, enter the operational schedule for those fixtures in hours per day, days per week, and weeks per year. The annual run hours for the lighting system will be displayed based on these choices, you can adjust your usage pattern to better match the annual run hours if you have the required data.

Outside of the input boxes, you can enter whether automated controls are used, the location of the lights and any other notes. These are for informational purposes and are not used in the analysis.

PROPOSED LIGHTING EQUIPMENT INVENTORY: Enter the lighting systems that will be installed in the facility. Any lighting systems that are staying in the facility should be entered in both the existing and proposed section.



Results

The third tab displays the results of the analysis.

At the top of the sheet are the results for the HVAC system analysis. First there is a summary of the heating, cooling, ventilation, and dehumidification capacities of the existing and proposed equipment. The difference between the existing and proposed capacities is displayed and the percentage change is calculated. For the analysis to have any validity, the capacities should not be substantially different.

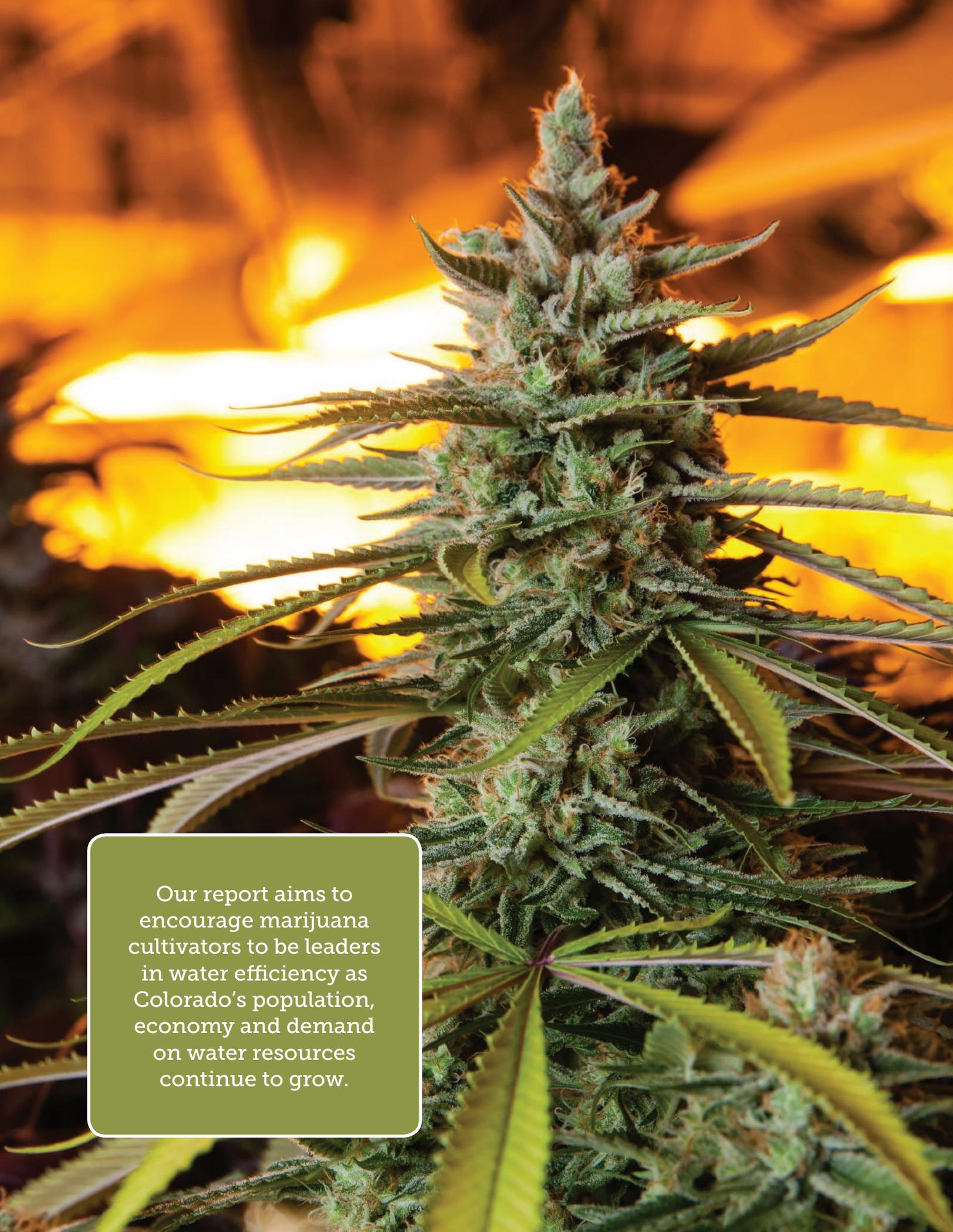
Then the calculated energy and cost savings between the existing and proposed HVAC equipment is displayed. Again, this is broken down between the four different categories: heating, cooling, ventilation and dehumidification. First, is the estimated energy usage of the existing equipment (for the heating equipment, this includes both electricity and natural gas). Then the estimated energy usage of the proposed equipment is shown. The difference is computed and the cost savings are calculated based on the energy costs entered on the HVAC input sheet. At the far left, the totals across all four categories, as well as the grand total of energy cost savings, is shown. Below the HVAC results, the lighting savings calculations are displayed. Again, the first couple of rows summarize the installed and proposed kW for the lighting systems.

Unlike the HVAC analysis, since different types of lights draw different amounts of power, we do not expect that these numbers will necessarily be close to each other. The estimated peak power consumption is shown with the assumption that all the lights would be on at the same time. Then the estimated energy consumption of the existing and proposed lighting system is shown along with the estimated annual energy savings due to the changes in the lighting system.

If you selected to compute any savings in the cooling energy due to changes in lighting technology, this amount will be shown on this spreadsheet.

The estimated total energy and cost savings are shown at the bottom of the column.





Our report aims to encourage marijuana cultivators to be leaders in water efficiency as Colorado's population, economy and demand on water resources continue to grow.

